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DEPARTMENT OF THE ARMY TECHNICAL MANUAL

POWER UNIT

PE–220–C

DEPARTMENT OF THE ARMY • DECEMBER 1949

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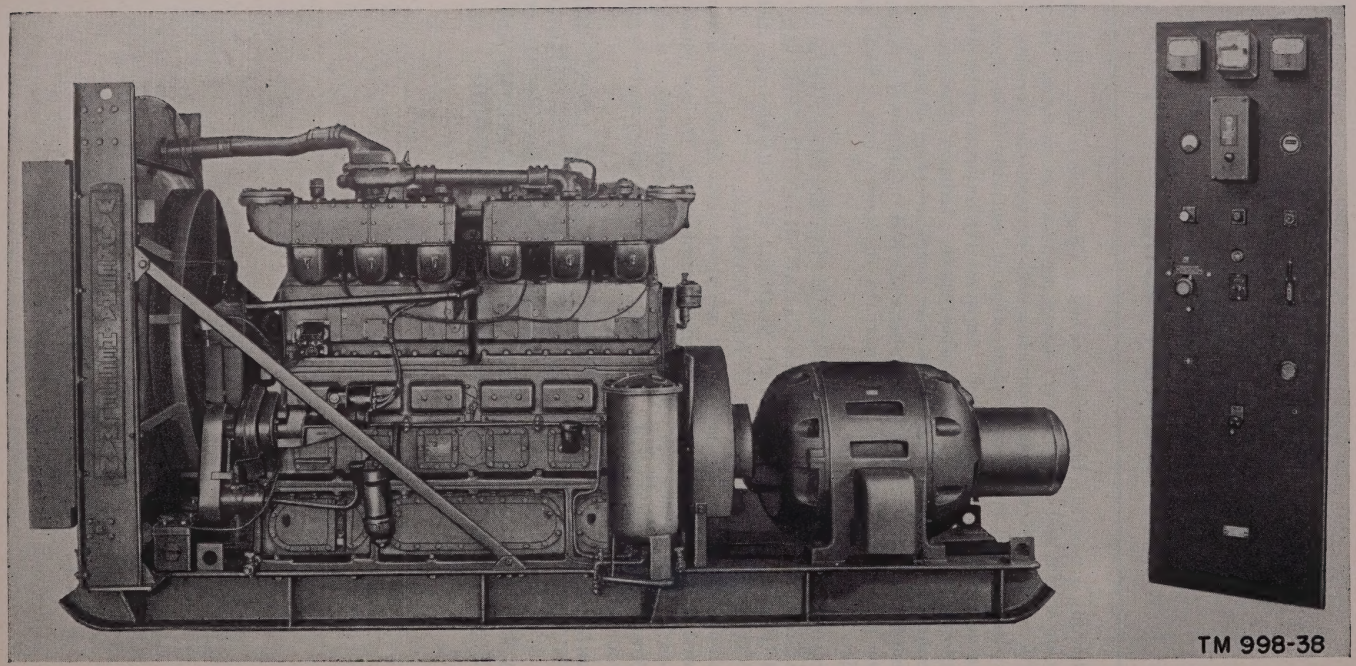
SAFETY NOTICE

This unit generates a high voltage which is dangerous to life. The operator must be careful and observe every safety regulation at all times. Keep clear of all live parts. Never make connection while the unit is in operation. Severe and possibly fatal shocks may be experienced, especially if the power unit is operating on wet or damp ground. Adequate ventilation must be provided, if the power unit is operated in a confined space. Exhaust gases produced are poisonous, and excessive inhalations may result in severe sickness or death. Do not service power unit with gasoline while it is running or if a radio transmitter is operating in close proximity to the power unit. Avoid spilling gasoline on a hot engine.

Caution: ALWAYS MAINTAIN THE PROPER OIL LEVELS IN THE CRANKCASE AND IN THE AIR CLEANER OF THE ENGINE, AND LUBRICATE THE ENGINE AT PROPER INTERVALS AS RECOMMENDED IN THIS INSTRUCTION MANUAL.

Guards and shields: All moving or operating parts have been adequately guarded or shielded to provide maximum protection. Do not remove any guards, shields, screens, etc., to perform service or maintenance work while the power unit is in operation. To do so, removes the safety features provided for your protection.

Caution: TOOLS, OILCAN, BOLTS, AND OTHER LOOSE OBJECTS MUST NOT BE PERMITTED TO LIE ON, OR NEAR THE GENERATOR SET WHERE THEY MIGHT FALL INTO THE GENERATOR OR BE DRAWN INTO THE ROTATING PARTS BY MAGNETIC ATTRACTION, CAUSING SEVERE DAMAGE TO THE WINDING.



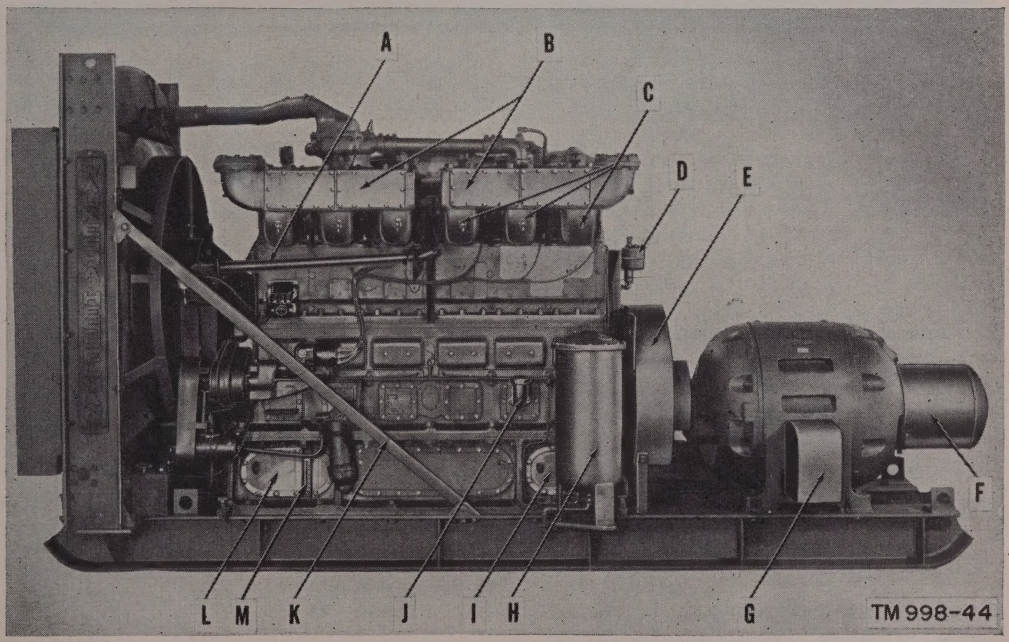
Power Unit PE–220–C.

CHAPTER 1
INTRODUCTION

Section I. DESCRIPTION OF POWER UNIT PE–220–C

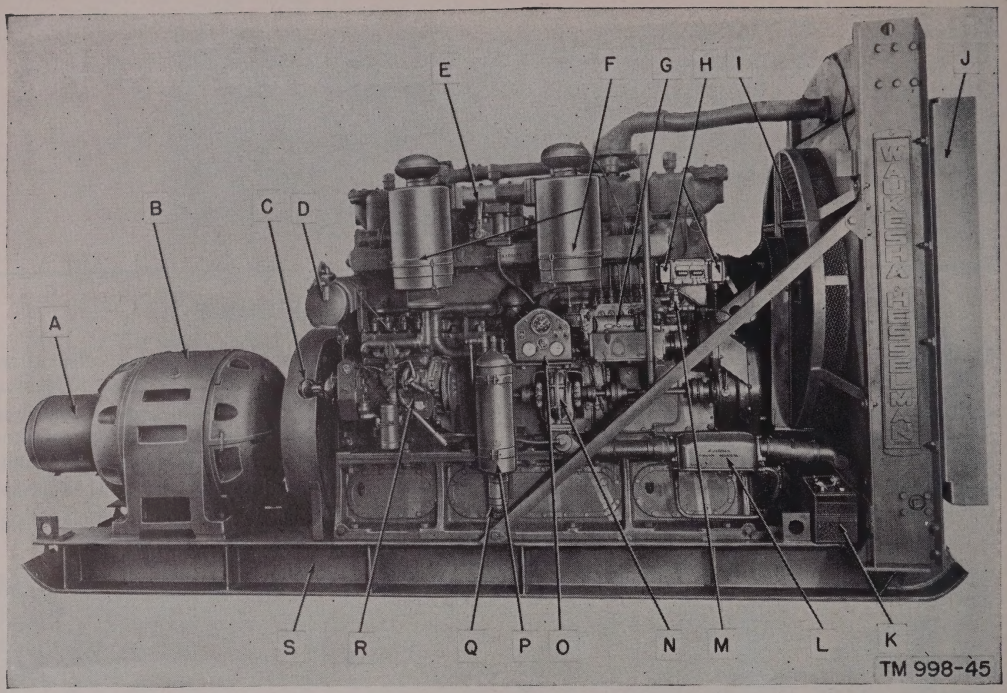
1. General

Power Unit PE–220–C is an oil-engine-driven, electric power plant designed to furnish a 240-v (volt), 3-phase, 60-cy (cycle), ac (alternating current). The equipment contains a 6-cylinder, spark-ignition, oil engine directly connected, through a flexible coupling, to an alternator with a direct-driven, shunt-wound exciter. The alternator is rated at 100 kw (kilowatts), 125 kva (kilovolt-amperes). A control panel containing the necessary switchgear is provided for generator control. Except for the control panel, the complete unit is mounted on a welded steel skid-base with provision for bolting to a concrete foundation.



A. Governor linkage.
B. Exhaust manifolds.
C. Spark exhaust inspection cocks (6).
D. Priming pump and tank.
E. Coupling guard.
F. Exciter.
G. Alternator terminal box.
H. Lubricating oil purifier.
I. Rear oil compartment door.
J. Crankcase oil filler.
K. Radiator brace.
L. Front oil compartment door.
M. Oil temperature gage.

Figure 1. Power Unit PE–220–C, left side.



A. Exciter.
B. Alternator.
C. Bendix drive.
D. Cranking engine gasoline tank.
E. Oil engine throttle.
F. Air cleaners (2).
G. Fuel injection pump.
H. Safety switch.
I. Fan guard.
J. Radiator air duct adapter.
K. Batteries (one to each side).
L. Lubricating oil cooler.
M. Shut-down solenoid valve.
N. Circulating water pump.
O. Oil engine instrument panel.
P. Fuel oil clarifier.
Q. Primary fuel oil filter
R. Cranking engine.
S. Skid-base.

Figure 2. Power Unit PE–220–C, right side.

2. Table of Major Assemblies

a. Weights and Dimensions of Major Components.

Component	Number required	Dimensions (inches)			Weight (pounds)
		Height	Length	Width	
Bare unit, including		107	193	63	18, 670
Engine	1	85	109⅛	60¾	13, 300
Generator	1	33⅝	63⅞	43	3, 435
Control panel	1	90	27⅜ deep	28	
Batteries, 6 v (volt)	2	9⅞₂	12¹¹⁄₁₆	7¹⁄₁₆	34

b. Tool Kit. The tool kit provided with Power Unit PE–220–C consists of the following tools:

1 special injector pump wrench (B–6751 LRHU).
1 special injector pump wrench (B–6752 LRHU).
1 spark plug wrench.
1 spark plug wrench handle.
1 injector nozzle wrench.
1 starting rope assembly.
1 open end wrench (7/8″ x 25/32″).
1 short box wrench.
1 box wrench (15/16″ x 1″).
1 combination open end and box wrench (9/16″ x 9/16″).
1 combination open end and box wrench (1/2″ x 1/2″).
1 combination open end and box wrench (5/8″ x 5/8″).
1 combination open end and box wrench (7/16″ x 7/16″).
1 combination open end and box wrench (3/4″ x 3/4″).
1 water pump pliers.
1 general pliers.
1 drive socket wrench (7/8″ — 12 point — 1/2″ drive).
1 drive socket wrench (15/16″ — 12 point — 1/2″ drive).
1 drive socket wrench (1″ — 12 point — 1/2″ drive).
1 drive socket wrench (1 1/8″ — 12 point — 3/4″ drive).
1 drive socket wrench (1 1/4″ — 12 point — 3/4″ drive).
1 drive socket wrench (1 5/8″ — 12 point — 3/4″ drive).
1 drive socket handle (15″ lg — 1/2″ drive).
1 slide bar (18″ lg — 3/4″ drive).
1 ratchet handle (18″ lg — 3/4″ drive).
1 drive extension (16″ lg — 3/4″ drive).
1 screw driver (1/4″ x 4″).
1 box wrench (1 3/8″ x 1 1/4″).
1 box wrench (1 5/16″ x 1 3/8″).
1 socket drive, square key stock (3/4″ x 5″).
1 socket wrench (1 7/8″).
1 feeler gage.
1 engine and generator coupling Allen setscrew wrench.
1 barring-over rod (1 1/4″ diam x 24″ lg).

c. Spare Parts for Exhaust System.

1 flexible exhaust hose.
1 Std blk steel coupling, 6″.
6 connecting rod bearings.
4 connecting rod bearing shims.
1 cylinder sleeve.
12 cylinder sleeve packing rings.
6 valve springs, inner.
6 valve springs, outer.
2 valve spring retainer nuts.
2 valve spring retainers, exhaust.
2 valve spring retainers, intake.
4 connecting rod bolts.
4 connecting rod bolt nuts.
1 magneto coupling adjusting ring.
1 magneto coupling.
2 magneto coupling cap screws.
1 magneto drive shaft oil seal.
1 surge dampener spring seat.
1 governor spring.
2 governor rod end pins.
2 butterfly shaft ball bearings.
1 oil pressure gage.
3 fan belts.
1 injection pump drive shaft (driver).
1 injection pump coupling intermediate disk.
6 piston pin locks.
2 rocker arm adjusting screws.
1 rocker arm cover breather cap.
2 valve tappets.
1 magneto and water pump shaft oil seal.
10 water pump packings.
1 seamless blk steel pipe, 4″, bent to 90°, threaded one end (58″ lg).
1 seamless blk steel pipe, 4″, bent to 23°, welded to 6″ ID by 16″ lg threaded nipple with one 6″ pipe cap and one 6″ std blk steel coupling attached.
1 asbestos rope packing (1″ diam 47″ lg).
1 steel exhaust pipe packing ring (4 9/16″ ID x 6 1/4″ OD by 1/4″ thk).
1 length blk iron pipe (6″ ID, threaded both ends, 120″ lg).
2 elbows (90°) (6″ std).
2 pipe nipples (6″ x 6″ std).
2 screwed flanges (6″ std).
2 durabala plain exhaust gaskets (6″ ID by 8 3/4″ OD).
1 nipple cut at 45° (6″ ID, threaded one end).
16 square head bolt (3/4″–10 by 3 1/2″ lg (for flanges)).
4 hexagonal head bolts (3/4″–10 by 15″ lg (for muffler supports)).
20 hexagonal nuts (3/4″–10, for flanges and supports).

20 lockwashers (¾″ for flanges and supports).

d. Spare Parts for Oil Machine.

1 complete gasket set.
2 exhaust valves.
1 intake valve.
4 crankshaft main bearings, front and center.
8 crankshaft main bearings, intermediate.
2 crankshaft main bearings, rear.
4 crankshaft main bearing shims, front and center.
8 crankshaft main bearing shims, intermediate.
4 crankshaft main bearing shims, rear.
24 piston rings, compression.
6 piston rings, oil.
6 (1 set) fuel injection pump tubing (from No. 1 to No. 6 cylinders).
1 fuel injector assembly.
2 fuel injector bushings.
5 fuel oil line tube end connection copper washers.
18 spark plugs (Defiance No. 149–9 reworked).
10 Deterg-O-Fill packages oil purifier filter element.
5 fuel oil clarifier elements (Briggs).
1 primary fuel oil filter assembly.
2 magneto breaker points (stationary).
2 magneto breaker arms and points (movable).

e. Spare Parts for Cranking Engine.

2 exhaust valves.
1 intake valve.
1 gasket set.
2 connecting rod bearings.
2 valve springs.
2 valve spring retainers.
2 pairs valve-spring tapers (valve keys).
1 valve lifter assembly.
4 piston pin retainer rings.
4 spark plugs ((Champion) J–9 14 mm (millimeter)).

f. Spare Parts for Generator.

4 alternator brushes.
4 exciter brushes.

g. Spare Parts for Switchboard.

10 cartridge fuses (6 amp (ampere) 250 v).

3. Description of Major Components

a. Engine (figs. 1 and 2). The engine is a six-cylinder, four-stroke cycle, liquid-cooled, spark-ignition, oil engine. It develops 225 horsepower at a governed speed of 900 rpm (revolutions per minute). (For engine specifications, see par. 4.) The complete engine is composed of the basic engine with its components, operating accessories, and system assemblies. The system assemblies consist of a gasoline cranking engine, priming system, spark-ignition system, oil-fuel-injection system, cooling system, pressure-lubrication system, air-intake system, exhaust system, frequency-control system, and a safety-control system.

(1) *Basic engine.* The oil engine is a vertical, stationary type with base-type oil pan, having a cylinder bore of 8½ inches, piston stroke of 8½ inches, and piston displacement of 2,894 cubic inches.

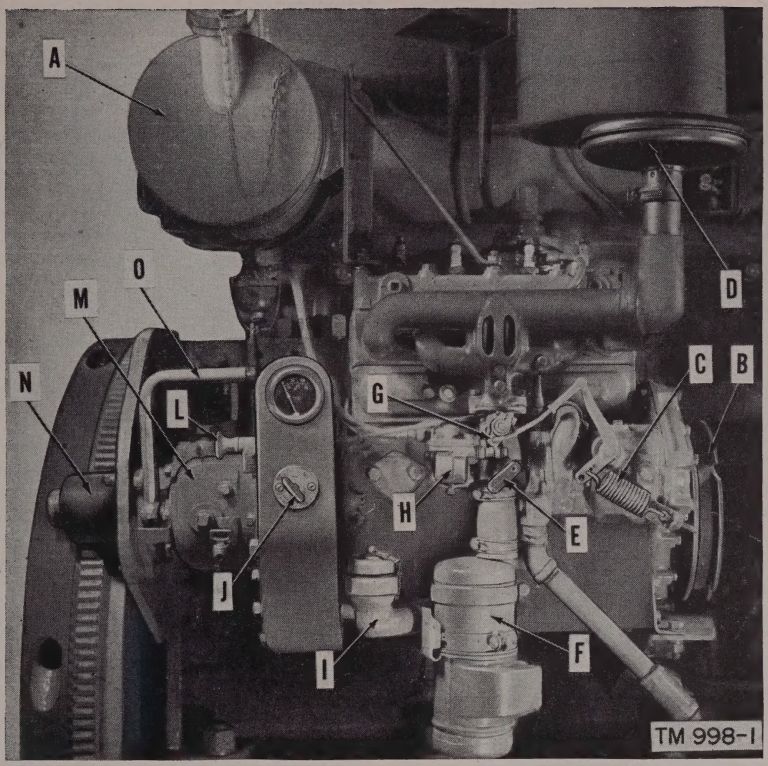
(2) *Cranking engine* (fig. 3). An independent, four-cylinder, gasoline engine, with a 2½-inch bore and 3⅛-inch stroke, is mounted on the right side of the engine, to provide for cranking the oil engine. The gasoline cranking engine is complete with its own magneto ignition, forced-feed lubrication, water-circulating pump, governor, carburetor, sediment-bowl strainer, and 2-gallon gasoline tank. The cooling system, which is thermostatically controlled, is connected to the water jacket of the main engine. A lubricating oil pressure gage and an ignition switch are mounted on the cranking unit. The cranking engine operates at a governed speed of 2,000 rpm.

(3) *Cooling system.* The cooling system consists of an independently mounted radiator, an outward draft fan, a positive, centrifugal-type circulating pump (N, fig. 2), four thermostats, and a dial-type water-temperature thermometer. The cooling system capacity is 65 gallons.

(4) *Exhaust system.* The exhaust system is composed of two-water-cooled, cast-iron exhaust manifolds (B, fig. 1), a silencer, a flexible metal hose, and piping.

(5) *Ignition system.* Ignition is provided by a high-spark-energy magneto (M, fig. 16), an impulse coupling, 18-millimeter spark plugs, and cables. The magneto is equipped with a conventional distributor and breaker mechanism.

(6) *Fuel system.* The fuel-injection system consists of a fuel delivery pump, a primary filter (Q, fig. 2), a fuel oil clarifier (P, fig. 2), an injection pump with



A. Gasoline tank.
B. Starting pulley.
C. Governor spring.
D. Silencer.
E. Choke.
F. Air cleaner.
G. Throttle.
H. Carburetor.
I. Oil filler.
J. Ignition switch.
K. Oil pressure gage.
L. Throttle control knob.
M. Clutch and transmission housing.
N. Bendix drive.
O. Clutch lever.

Figure 3. Cranking engine.

vacuum control (G, fig. 2), an injection nozzle for each cylinder, a 200-gallon fuel-oil tank, and necessary piping.

(7) *Priming system.* A gasoline priming pump and tank are mounted over the engine flywheel. The priming pump sprays gasoline into the oil engine to facilitate starting.

(8) *Engine speed control system.* Engine speed is controlled by a built-in, centrifugal-type governor (Q, fig. 16), a governor solenoid (P, fig. 16), and a butterfly valve in the intake manifold. A manually operated throttle control lever (E, fig. 2) is also provided.

(9) *Air-intake system.* Air to support combustion is drawn into the combustion chambers through the intake manifold mounted on the right side of the engine. Two air cleaners (F, fig. 2), mounted on the right side of the engine in front of the intake manifold, filter the air drawn into the combustion chambers.

(10) *Lubrication system.* The lubrication system consists of a positive, gear-type pump mounted on the outside of the engine, an automatic, spring-loaded relief valve, an oil screen or strainer, an oil cooler (L, fig. 2), an oil filter (G, fig. 16), an oil purifier (D, fig. 16), and a bayonet-type gage (I, fig. 16).

(11) *Engine instrument panel* (fig. 17). A small instrument panel for the main engine is installed on the cranking engine side of the unit. The following devices are installed on this instrument panel:

water-temperature gage (G), lubricating oil-pressure gage (F), fuel oil-pressure gage (E), manifold-vacuum gage (A), two red and one green jewel lights (B, C, and D), a single-pole, single-throw toggle switch (H), and identifying plates.

(12) *Safety controls.* The following safety devices are provided: a high-water-temperature switch, a low-lubricating-oil-pressure switch (H, fig. 2), an alarm horn, and one green and two red jewel lights. The green light remains lit during safe operation of the engine. In case either of the safety devices (high-water-temperature and low-oil-pressure switches) is operated, the related red light lights and the alarm horn sounds. The toggle switch on the engine instrument panel is provided for turning off the horn, and may be used, in an emergency, for stopping the engine.

b. Generator.

(1) *Alternator.* The alternator is an 8-pole, 60-cycle, 3-phase, 3-wire unit that produces 240 volts, at the engine-driven speed of 900 rpm. It is rated at 100-kw, 125-kva, 80 percent power factor, 300-amperes output. Designed for continuous operation, it will carry a load at 156.25 kva, 80 percent power factor, for 2 hours with a temperature rise not exceeding 40° C. The frame is of open, self-ventilated construction. Tropical insulation is provided. Damper windings (amortisseur windings, fig. 58) are provided to prevent *hunting* (variation from synchronous speed) when units are used in parallel operation (par. 8).

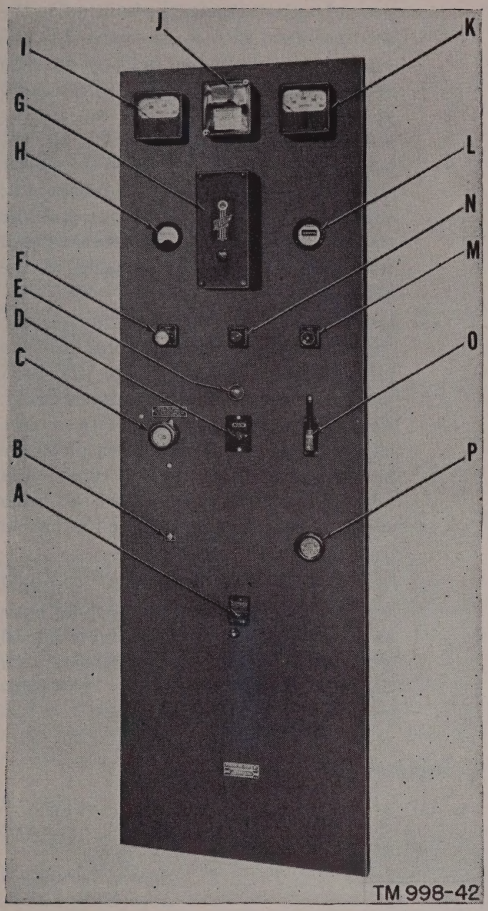
(2) *Exciter.* The exciter is shunt wound, rated at 3 kw-125 volts, and is provided with tropical insulation. It is mounted to one end of the alternator and is direct-driven.

c. Coupling. The alternator is coupled to the engine through a flexible coupling, the flange half of which is bolted to the engine flywheel. The hub half is pressed on and keyed to the alternator shaft. Steel pins in the hub half engage rubber-bushed bronze bearings in the flange half of the coupling. The resiliency of the rubber bushings provides the flexible feature.

d. Steel Base. The engine and alternator are mounted on a welded steel skidbase with five ⅞-inch holes drilled in each side piece to allow for bolting to a concrete foundation. Ten metal-capped cork vibration dampers and bushings are also provided, so that the unit can be mounted with the cork dampers between the concrete foundation and the steel base.

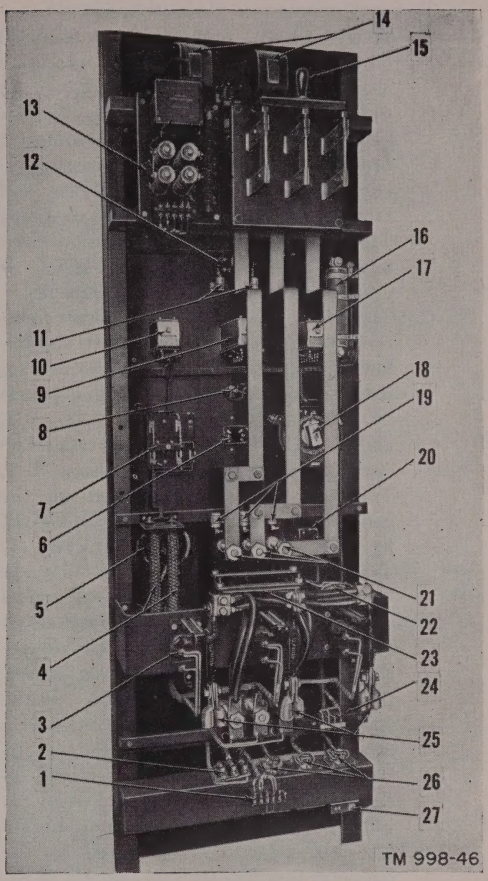
e. Switchboard (figs. 4 and 5). The switchboard and the circuit breaker, inclosed in the switchboard, are both mounted on a base separate from the engine and the alternator unit. The switchboard is of the free-standing, dead-front type, and is electrically connected to the alternator by multiple conductor cables. Two wall braces of 1¼-inch black enameled pipe, complete with wall flanges and panel brackets, are furnished with each panel. The assembled brace, when installed, locates the front of the panel 75 inches from the supporting wall. A 6-inch by 1⅞-inch floor sill is also furnished with each panel. Provision is made for bolting the switchboard to a foundation, if desired. The switchboard contains the following equipment:

1 line ammeter (K, fig. 4), 5 amperes with 0–400 scale.
1 line voltmeter (I, fig. 4), 0–300 scale.
1 total hour meter (H, fig. 4), 115 volts, 60 cycles.
1 frequency meter (L, fig. 4), 58–62 cycles.
1 voltmeter switch (F, fig. 4).
1 ammeter switch (M, fig. 4).
1 voltage regulator (G, fig. 4).
1 voltage regulator transfer switch (N, fig. 4).
1 reverse power relay (J, fig. 4).
3 current transformers (3, fig. 5), ratio 400/5.
3 potential transformers (26, fig. 5), 230/115 volts, 50 va (volt-amperes).
1 frequency control transformer.
1 synchronizing receptacle and lamp (E, fig. 4).
1 alternator field switch (O, fig. 4), 2 pole, single throw, 60 amperes, 250 volts.
1 alternator field discharge resistor (4, fig. 5).
1 air circuit breaker (A, fig. 4), 400 amperes, 600 volts, 3 poles, with 2 auxiliary switches and 240-volt, a-c shunt trip coil.
1 disconnect switch (15, fig. 5), 400 amperes, 500 volts, 3 poles, single throw, nonfusible.
1 governor control rheostat (P, fig. 4).
1 exciter field rheostat (C, fig. 4).
1 four-point terminal block for small wire connections.
1 set ¼-inch x 1½-inch copper bus between circuit breaker and disconnect switch.
5 capacitors, 0.1 mf (microfarad), 500 volts, dc (direct current).



A. Circuit breaker handle.
B. Rectifier ON-OFF switch.
C. Exciter field rheostat.
D. Synchronizing lamp switch.
E. Synchronizing lamp.
F. Voltmeter switch.
G. Voltage regulator.
H. Total hour meter.
I. Voltmeter.
J. Reverse power relay.
K. Ammeter.
L. Frequency meter.
M. Ammeter switch.
N. Voltage regulator transfer switch.
O. Alternator field switch.
P. Governor control rheostat.

Figure 4. Switchboard, front view.



1. 5-point terminal block.
2. 3-pole fuse block.
3. Current transformers (3).
4. Alternator field discharge resistor.
5. Governor control rheostat.
6. Synchronizing lamp switch.
7. Alternator field switch.
8. Synchronizing lamp socket.
9. Voltage regulator transfer switch.
10. Ammeter switch.
11. 0.1 mf capacitors (2).
12. Voltage adjusting rheostat.
13. Voltage regulator damping transformer and rectifier unit.
14. Reactors for reverse power relay (2).
15. Knife switch.
16. External resistor for voltage regulator.
17. Voltmeter switch.
18. Exciter field rheostat.
19. 0.1 mf capacitors (3).
20. Rectifier on-off switch.
21. Top circuit breaker connections.
22. Selenium rectifier.
23. Governor control circuit transformer.
24. 4-point terminal block.
25. Lugs for generator connections.
26. Potential transformers.
27. Grounding stud.

Figure 5. Switchboard, rear view.

f. Radio Suppression Components.

(1) *General.* Radio suppression is essential on a power unit that supplies current to electronic devices which are affected by radio interference. Interference may be caused by sparking of commutator brushes, radiation of r-f (radio-frequency) currents from static discharges, and vibration of relay and regulator contacts. The location of radio-suppression components on Power Unit PE–220–C is described in the following paragraphs.

(2) *Capacitors.* Capacitors bypassing r-f currents to ground are mounted in the following places: Five capacitors are mounted on the exciter terminal panels at terminals GF–1, GF–2, A–2, A–1, and F–1 (M, fig. 13). Three capacitors (bypassing the alternator leads, T–1, T–2, and T–3) are mounted on the generator terminal board (A, C, and E, fig. 13). Three capacitors (19, fig. 5) are mounted on a bracket at the top terminals of the circuit breaker. Two capacitors (11, fig. 5) are mounted at terminals RR–2 and RR–1 of the voltage adjusting rheostat. The above capacitors are all 0.1 mf, 500 volts, dc. In the 12-volt engine circuit, a 0.25 mf and a 0.1 mf capacitor are connected to the BAT and GEN terminals, respectively, of the voltage regulator, an 0.1 mf capacitor to the battery charging generator, and an 0.25 mf capacitor is mounted on the ammeter terminal stud on the rear of the engine instrument panel.

(3) *Shielding.* Tinned copper braid-covered #14 wire is used on the engine between the STOP-RUN switch and the battery charging ammeter; between the ammeter and the voltage regulator; between the voltage regulator and the battery charging generator; between the STOP-RUN switch and the water temperature switch; between the water temperature switch and the oil pressure switch; between the oil pressure switch and the solenoid fuel valve; and between the oil pressure switch and the green pilot light. Both ends of tinned copper braid are carefully grounded on all these wires.

(4) *Bonding.* By connecting heavy tinned copper braid from floating metal to solid ground, any static charges built up on the floating metal surface are shunted to the ground instead of being radiated out into space to be picked up by sensitive radio or other electronic equipment in the vicinity. Such bond straps (G, fig. 13) are used between the foot of the power generator and the base of the power unit, the battery charging generator and the frame, the starting engine transmission case, and the flywheel housing of the large engine.

(5) *Ignition systems, oil and cranking engines.* The high tension ignition cables from the megnetos on both engines to the spark plugs are encased in copper-tinned braid. Each magneto is covered with a cast aluminum shield, and all spark plugs are inclosed in shielded cans. A 10,000-ohm resistor suppressor, mounted at each spark plug cable, suppresses r-f radiation from the cables.

(6) *Unit assembly.* Special IET (internal and external toothed) lockwashers have been used in the unit assembly in all cases where paint would interfere with the grounding of r-f currents. See paragraph 106 for further details.

4. Table of Specifications

a. Oil Engine.

Engine	Waukesha (6LRHU)
Type cylinder head	valve in head.
Spark plugs	Defiance No. 149–9—reworked by I. D. E.
Fuel tank capacity	200 gal.
Fuel consumption (gal per bhp hr)	55 at 900 rpm.
No. of cylinders	6.
Bore (cylinder)	8½″.
Piston displacement	2,894″.
Piston stroke	8½″.
Compression ratio	5.6 to 1.
Engine speed	900 rpm.
Type of cooling	water.
Horsepower	225 at 900 rpm.
Lubrication	forced feed.
Air cleaner (2)	Oil bath (Vortox No. GA–110).
Oil purifier	Honan Crane.
Fuel oil clarifier	Briggs.
Ignition	magneto.
Lubricating oil capacity	37 gal.
Governor	gear-driven, fly-weight.
Battery (2)	152 amp-hr, 6-v ea.

b. Cranking Engine.

Engine (gasoline)	Waukesha (ICKU).
Type cylinder head	"L".
Spark plugs	Champion, J–9—14 mm.
Fuel tank capacity	2 gal.
No. of cylinders	4.
Bore	2½".
Stroke	3⅛".
Piston displacement	61".
Compression ratio	5.7 to 1.
Engine speed	2,000 rpm.
Type of cooling	water.
Horsepower	10.0.
Lubrication	forced feed.
Air cleaner	Oil bath, Vortox No. 3630–D.
Ignition	magneto.
Governor	gear-driven flyweight.

c. Generator.

Model	General Electric, type AT1, frame 964.
Rating	100 kw, 240 v.
Power factor	80%.
Generator speed	900 rpm.
Exciter	General Electric, type BF, frame 823.
Exciter speed	900 rpm.
Generator drive	Flexible coupling.
Exciter drive	direct.

5. Performance Data Chart

Approximate load	Volts	Amperes	Cycles	Exciter volts
¼	246	58. 7	61. 0	59
½	244	123. 5	60. 6	62
¾	242	179	60. 3	65
Full	240	241	60. 0	70

Section II. APPLICATION

6. Normal Use of Power Unit PE–220–C

Power Unit PE–220–C is primarily intended as a source of power for United States Airways Communications System installations. This equipment is also used as a power supply for Signal Corps fixed plant communication equipment requiring power within the rated capacity of the unit.

7. Other Uses

Power Unit PE–220–C may be used for any purpose where power within the rated capacity of the unit is required. Other applications may include supplying power for motor-driven tools, compressors, pumps, and for lighting purposes.

8. Parallel Operation

Power Units PE–220–C may be operated in parallel with each other, or in parallel with Power Units PE–200–A and PE–200–B when power requirements are in excess of 100 kw. Detailed information on parallel operation is given in paragraph 27.

Section III. ASSEMBLY AND INSTALLATION

9. Uncrating and Preliminary Care

a. General. Power Unit PE–220–C is packed in four crates. Crate No. 1 contains the engine coupled to the alternator and exciter, batteries (mounted and dry), fuel tank, exhaust fittings, spare parts, and tools. Crate No. 2 contains the radiator, with frame attached, and muffler. Crate No. 3 contains the electrolyte for the two storage batteries. Crate No. 4 contains the alternator control panel, with fittings for attaching to an adjacent wall or to another panel, and a clear glass synchronizing lamp. Two copies of the complete packing list, in waterproof envelopes, are tacked to the outside of each crate, and one is tacked to the inside. When uncrating, be careful to avoid damaging the equipment. As each crate is unpacked, check the contents immediately against the packing list.

b. Crate No. 1 (fig. 6).

(1) *Metal strapping.* Pry off the steel straps which hold the top panel to the side panels of the crate.

(2) *Cover.* Lift off the cover.

(3) *Front and back panels.* Remove each end panel of the crate, as a unit, by prying it away from the side panels.

(4) *Fuel tank.* Lift out the fuel tank and remove the braces which hold the tank in place.

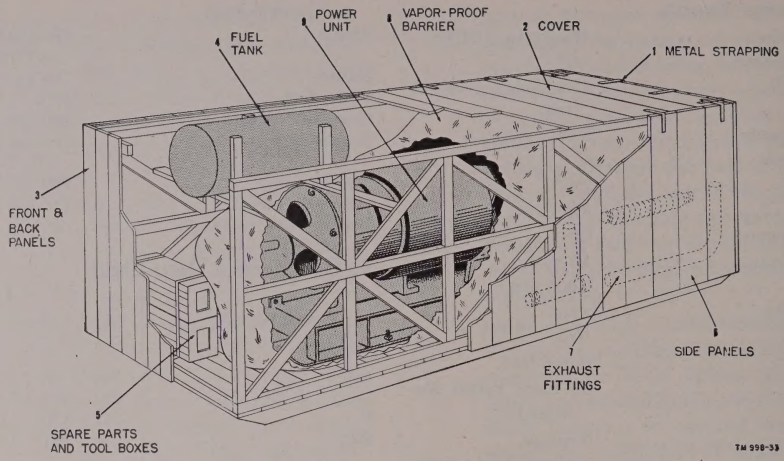


Figure 6. Unpacking crate No. 1.

(5) *Spare parts and tool boxes.* Remove the strapping that holds the spare parts and tool boxes to the floor of the crate. Lift out the boxes.

Note. Spare parts shipped with this unit have been carefully processed and wrapped to protect them against corrosion and damage. Each package is clearly labeled and should not be opened until the parts are to be used.

(6) *Side panels.* Pull the side panels outward to pry the sides away from the braces. Pull them out and down, and pry loose from the wooden base.

(7) *Exhaust fittings.* Remove the straps that hold the exhaust fittings to the side panels of the crate. Remove the fittings.

(8) *Vaporproof barrier.* Cut the vaporproof barrier inclosing the power unit along the seam and along the edges of the base.

(9) *Power unit.* Remove the nuts from the mounting bolts that hold the unit to the wooden base.

c. CRATE NO. 2 (fig. 7).

(1) *Metal strapping.* Pry off the steel straps which hold the top panel to the sides of the crate.

(2) *Top panel.* Lift off the top panel.

(3) *Muffler.* Lift out the muffler.

(4) *Front and back panels.* Remove the end panels of the crate by prying each panel away from the side panels..

(5) *Side panels.* Pull the side panels outward to pry the sides away from the braces. Pull them out and down, and pry loose from the wooden base.

(6) *Radiator.* The radiator can now be removed from the crate base.

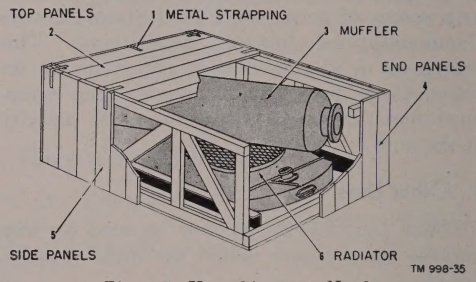


Figure 7. Unpacking crate No. 2.

d. CRATE NO. 3 (fig. 8).

(1) *Metal straps.* Remove the metal straps from the wooden crate.

(2) *Cover boards.* Remove the cover boards that are nailed to the sides of the crate.

(3) *Fiberboard containers.* Lift out the three fiberboard containers. These contain glass jars, filled with electrolyte, which are protected by cellulose pads. Use extreme care in handling.

e. CRATE NO. 4 (fig. 9).

(1) *Metal straps.* Pry off the steel straps that hold the top of crate to the sides.

(2) *Coverboards.* Remove the nails that hold the boards in place and lift off each board individually.

Note. The cover cannot be removed as an assembly.

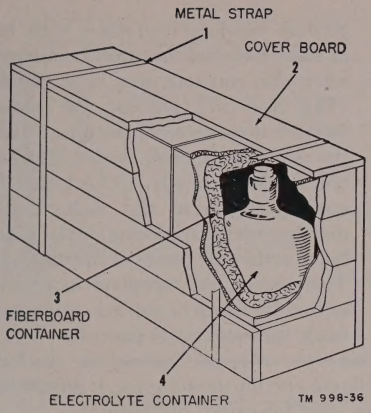


Figure 8. Unpacking crate No. 3.

(3) *Vaporproof barrier.* Cut the vaporproof barrier at the seam.

(4) *Switchboard.* Lift the switchboard out of the crate.

(5) *End panels.* Remove each end panel of the crate as an assembly by prying away from the side panels.

(6) *Synchronizing lamps.* Remove the straps that hold the corrugated container in which the synchronizing lamps are packed. Remove container.

(7) *Side panels.* Pull the side panels outward to pry the side away from the braces. Pull them out and down, and pry loose from the wooden base.

(8) *Pipe fittings.* Remove strapping that holds the pipe fitting to the bottom of the crate and lift out the fittings.

f. Equipment Checks. Check the equipment against the packing list immediately after uncrating, to determine if the unit is complete in all its parts, both components and accessories.

10. Installation

a. Locating Unit. Power Unit PE–220–C is normally installed within a building. As the equipment has no unit housing, some form of shelter must be provided. It is imperative that a foundation be provided that is heavy and solid enough to support the weight of the unit and maintain alinement between the engine and generator. Locate the unit as close to the electrical center of the load as practicable. This will hold line losses to a minimum and afford better voltage control at the remote ends of the lines. Provide ample ventilation within the room, building, or shelter and locate the unit with its radiator facing an opening through which the hot air from the cooling fan can be forced out. Be sure to allow about 3 feet of space on all sides of the unit to provide access for servicing the equipment. Before proceeding with the installation, prepare a floor plan. The electrical control panel is provided with wall braces which necessitate setting this equipment 75 inches from a supporting wall. If it is expected that additional units will be installed for parallel operation, make provision for them when planning the installation. Figure 64 illustrates a typical installation showing location of remote fuel tank, exhaust, and correct ventilation.

b. Foundation. The following equipment is supplied to install the unit on a concrete founda-

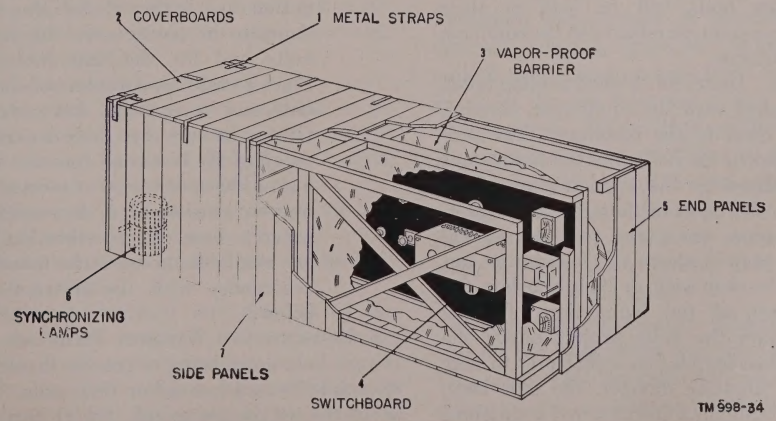


Figure 9. Unpacking crate No. 4.

tion: 10 holding bolts, with a 20-inch straight shank with a 3¾-inch right angle bend at one end to prevent turning in the concrete foundation; ten 15¼-inch lengths of 1½-inch standard, unthreaded pipe, to be placed over the bolts before the cement is poured; 10 metal-capped-cork-vibration dampers and bushings, to be placed between the foundation and the steel base. Five ⅞-inch holes are drilled in each side piece of the steel skid-base for the holding bolts.

(1) *Construction* (fig. 10). The construction and the thickness of the foundation are regulated by the condition and type of the soil where the unit is to be installed. If the soil is firm, provide a foundation at least 3 feet thick. If the soil has poor bearing properties, make the foundation at least 46 inches thick, with a sub-base 2 feet thick, extending at least 2 feet beyond the edge of the foundation on all sides.

(*a*) *Template.* Construct a wooden template to hold the foundation bolts in their proper location while the concrete is being poured. The template may be fabricated from the base of the shipping case, or from the wooden skids to which the unit is bolted for shipment. Nail crosspieces to the skids so that the pattern of the bolt holes conforms to the foundation plan. The crosspieces must be long enough to support the template over the edges of the excavation. Place the template over the excavation so that the foundation bolts will be held in their proper position relative to the complete foundation.

(*b*) *Bolts.* Insert the 20-inch holding bolts, supplied with the equipment, through the holes in the template. The projection of the bolts into the template is regulated by the 1½-inch pipe. Support the bolts so that the top edge of the pipe, when used as a sleeve, will not project above the foundation but will be even with, or slightly below, the surface of the foundation. In this position the bolts project above the finished foundation sufficiently to take the vibration damper, the unit base, the bushing, a locknut, and a standard nut. Center each bolt in the pieces of pipe by blocking it in place with rags or some material that may be removed after the concrete has been poured. (The rags will prevent the cement mixture from entering the pipe.) Level the template, making certain that each bolt hangs vertically. Check that the spacing between the bolt centers matches with the spacing of the ⅞-inch holes in the side pieces of the unit base. Then fasten the template in position so that it cannot be shifted accidentally while the concrete is poured.

(2) *Concrete.* Mix the concrete for the foundation and for the sub-base, if one is used, in the following proportions: 1 part cement by weight, 2 parts coarse sand, and 3 parts gravel or crushed stone. Add only sufficient water to produce a workable mixture. The quantity of water to be used depends upon the amount of moisture in the other ingredients, but no more than 6½ to 7 gallons should be used for each 94-pound bag of cement. The sand should be free of all organic matter. Tamp the concrete thoroughly while pouring, and work it carefully around the foundation bolts to prevent their shifting from the proper position. Level off the top of the concrete, and then allow it to set thoroughly before removing the template. Keep the top damp for at least 10 days to insure proper curing.

(3) *Placing the unit.* After the cement foundation has hardened, set the vibration dampers in position on the hold-down bolts and lift the unit into position. Place a washer and nut on each hold-down bolt and turn them down moderately tight. Be sure that there is even tension on all of the bolts and that the skid-base has not been distorted or twisted through uneven tension or a depression in the concrete base. If no vibration dampers are available, prepare the foundation in accordance with the instructions in *c* below.

c. Installation Without Dampers. Obtain 16-inch hold-down bolts, or run the threads on the 20-inch bolts up 4 inches fron their ends. Proceed as instructed in paragraph 10*b*(1) through (3). Build a wooden form not less than 1 inch high

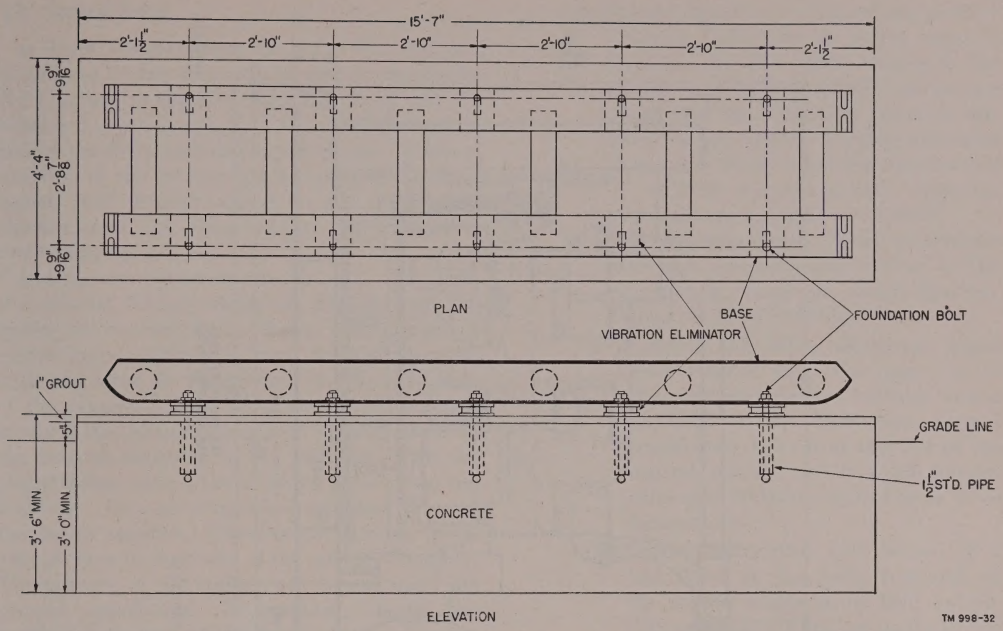


Figure 10. Foundation drawing.

around the concrete block. Prepare a mixture of 1 part cement, 1 part sharp sand, and only enough water to make a thick, easily workable liquid. Pour this mixture into the wooden form after the unit has been lowered into place over the hold-down bolts. Use a stick, and push or tamp the mixture under the skid-base. Allow the cement mixture to set thoroughly and then level the unit by means of steel wedges or shims. Place a washer and nut on each bolt and turn them moderately tight. After the cement has thoroughly hardened, remove the wooden form.

d. Installing Radiator and Fan.

(1) After the unit has been installed on its foundation, bolt the fan to the fan-drive pulley by means of the six bolts, nuts, and lockwashers provided.

(2) Adjust the fan belts by means of the fan-belt adjusting screw.

(3) Remove the fan guard from the back of the radiator.

(4) Raise the radiator into position on the end of the skid-base and secure it with the fastenings provided.

(5) Set the two radiator support braces in position and fasten them with the bolts provided.

(6) Place the two halves of the fan guard in position with the division between the two halves vertical. Bolt the two halves of the guard together and secure the guard brackets to the radiator frame.

(7) Install the coolant inlet and outlet connections and tighten the hose clamps securely.

e. Installation of Fuel Tank. Install the 200-gallon fuel-oil tank in accordance with the diagram shown in figure 64. When locating the fuel-oil tank, consideration must be given to the length of the fuel inlet and return lines provided with the unit. These lines are 20 feet in length. Do not sink the bottom of the fuel tank more than 8 feet below the level of the connection to the fuel-oil filter on the unit. Provide a check valve in the fuel line, near the tank, to prevent back drain when the unit is shut down. Be sure to provide an air vent for the tank.

f. Removal of Seals. Examine the entire unit for any seals which may have to be removed. These are usually provided for such openings as the exhaust outlet, air intakes, breathers, etc. Remove any seals that are found.

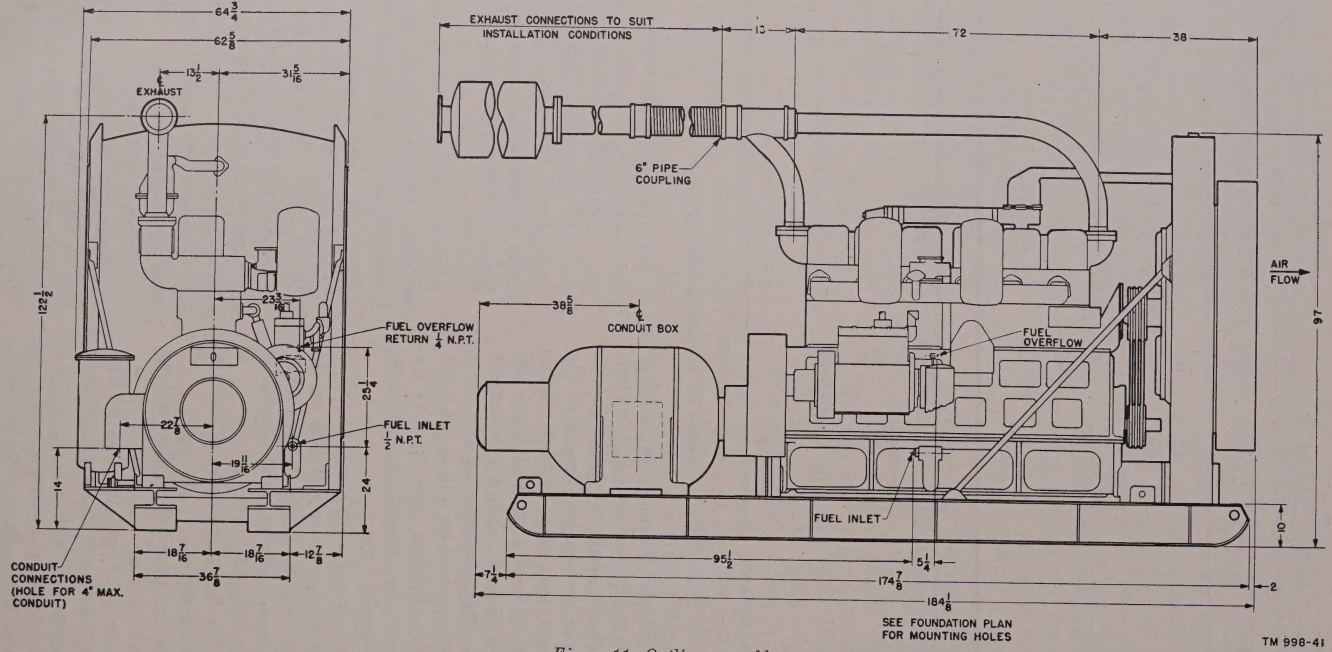


Figure 11. Outline assembly.

11. Connections

a. Fuel Connections (fig. 11). Connect one end of the 20-foot fuel-oil inlet line to the ½-inch NPT fitting on the first-stage fuel filter, and the other end to the ½-inch NPT fitting on the bottom end of the 200-gallon-fuel-supply tank. Connect one end of the 20-foot fuel overflow line to the ¼-inch NPT fitting located on top of the fuel clarifier, and the other end to the 200-gallon fuel supply tank.

b. Exhaust Connections (fig. 11). Assemble the exhaust fittings which are packed with the power unit in crate No. 1. Remove the upper half of the flange connections from the exhaust manifolds and screw the flanges onto the threaded ends of the exhaust fittings. Determine the direction in which the exhaust line is to be run and assemble the exhaust assembly to the manifolds with the outlet facing toward the intended outlet from the building. Be sure to install the gaskets between the flange sections. Connect the flexible metal exhaust hose to the outlet of the exhaust assembly. The position of the muffler will depend upon the general installation. If practical, install the muffler on the end of the flexible hose and carry the exhaust pipe from the muffler to the outside of the building. Be sure to provide adequate support for the muffler and exhaust line and adequate insulation where the exhaust pipe passes through walls or partitions. Protect the outside end of the exhaust line so that rain or other forms of moisture will not enter it. Make certain that all joints and connections in the exhaust line are gas tight.

c. Duct Connections. The radiator is equipped with a metal frame to which a duct of canvas, or other material, may be attached to direct the hot air from the engine to the atmosphere. If a duct is used for this purpose, provision must be made for the entry of air into the engine room to replace the air which is forced out through the duct by the fan. If a metal duct is used, install a short section of flexible material, such as canvas, between the frame on the radiator and the metal duct. The frame is drilled to facilitate the installation of such equipment. (Duct material is not provided as part of the unit.)

d. Electrical Connections (figs. 12, 13, and 14).

(1) *Battery connections.* Connect the positive terminal of one battery to the negative terminal of the other. Connect the remaining positive terminal to the ground strap, and the remaining negative terminal to the battery charging generator ammeter. Positive terminals are marked +, or POS, or painted red. Negative terminals are marked −, or NEG.

(2) *Generator connections.* Make connections from the alternator and exciter to the switchboard, using the solder lugs provided. Proceed as follows:

(*a*) Connect the three alternator phase leads marked T–1, T–2, and T–3 to the correspondingly marked lower terminals of the instrument current transformer located at the rear of the control panel. Use two 350,000-circular mils cables for each of these three connections.

(*b*) Connect alternator field wires GF–1 and GF–2 to the lower terminals of the 2-pole, single-throw field switch. The terminals are marked on the wiring diagram (fig. 12) with the same identification letters.

(*c*) The negative exciter armature lead is permanently connected to one field terminal on the exciter terminal panel. Run wire A–1 from this connection to the upper terminal A–1 of the 2-pole field switch.

(*d*) Connect exciter lead A–2 to the other upper terminal A–2 of the 2-pole field switch.

(*e*) Connect exciter lead F–1 to the stud on the 2-pole field switch which is connected to the field rheostat.

Caution: Do not use acid core solder or acid as a flux when making these connections.

(*f*) If the cables from the generator to the control panel are run in pipe or other rigid conduit, use a section of flexible conduit adjacent to the alternator and exciter to absorb any vibration.

(3) *Engine to switchboard connections* (fig. 14). Run two #12 cables from the switchboard

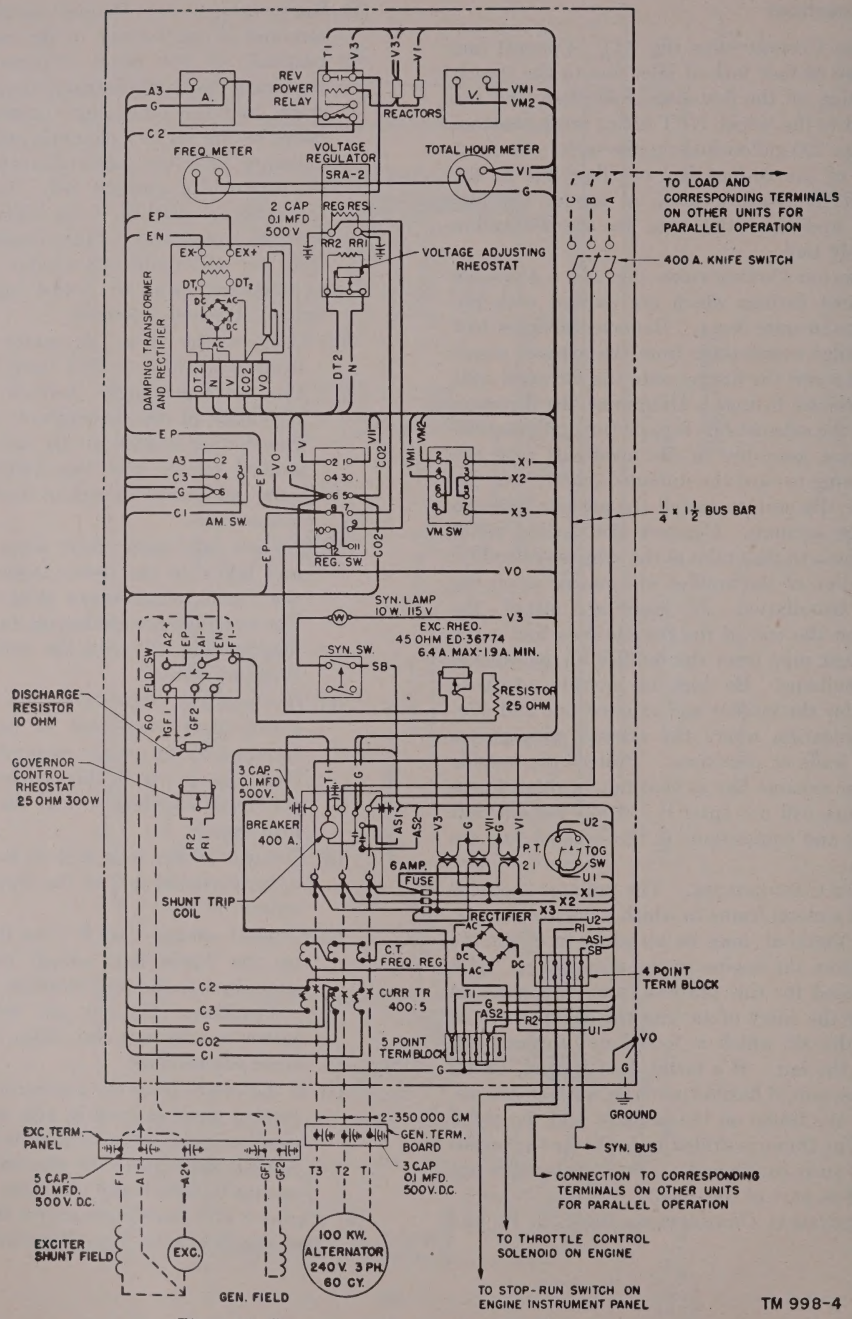
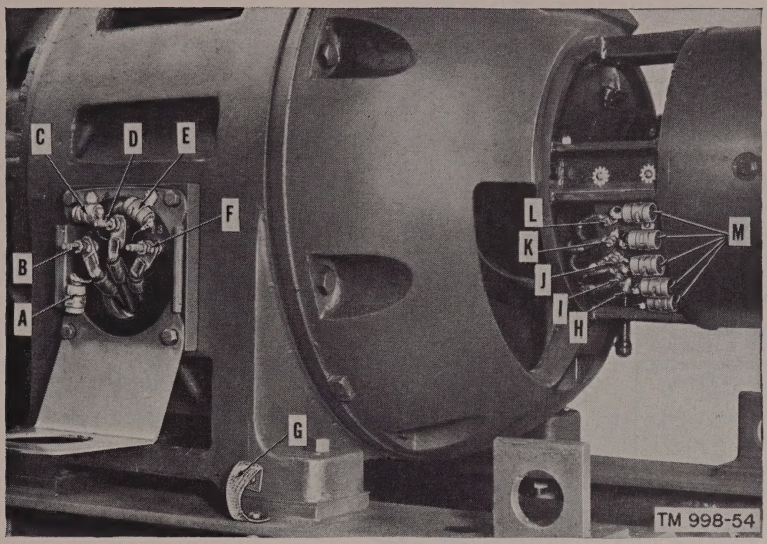


Figure 12. Generator-to-control panel wiring diagram.



A. 0.1-mf capacitor.
B. Terminal T–1.
C. 0.1-mf capacitor.
D. Terminal T–2.
E. 0.1-mf capacitor.
F. Terminal T–3.
G. Bonding strap.
H. Exciter terminal GF–1.
I. Exciter terminal GF–2.
J. Exciter terminal A–2.
K. Exciter terminal A–1.
L. Exciter terminal F–1.
M. 0.1 mf-capacitors.

Figure 13. Alternator and exciter, cover removed.

to the studs on the engine instrument panel in the following manner:

(*a*) Connect terminal R–1 on the switchboard to the solenoid terminal marked R–1 on instrument panel (fig. 12).

(*b*) Connect terminal U–2 on the switchboard to the safety-switch terminal marked U–2 on the instrument panel.

(4) *Load connections.* Connect the load cables to the top terminals of the 400-ampere knife switch (15, fig. 5) mounted on the rear of the switchboard panel.

(5) *Ground connections.* Connect the frame of the generating unit and the switchboard to a low-resistance ground, such as a pipe or rod driven into moist ground. The ground cable should be large enough so that it will *not fuse* under a sustained short circuit between line and ground. Use a ground cable at least equal in size to the largest connection between the alternator and switchboard. The ground connection should be as short as conditions permit and located to minimize radiation of r-f waves.

12. Connections for Parallel Operation

When two or more units are to be operated in parallel, install connecting cables between the switchboards of the units. Connect corresponding points of the terminals of the output knife switches on all switchboards. Using copper wire no smaller than #12, connect terminals marked SB and AS–1 on the 4-point terminal block (fig. 12) to all correspondingly marked terminals of all units to be operated in parallel. Ground frames of each board to a common ground.

13. Preparation for Movement

a. When equipment is to be moved, stop the unit as instructed in paragraph 25. After the unit is stopped, perform the adjustments and checks (except for adding fuel and oil) as described in paragraph 38. Drain the fuel system and cooling system of both the oil and the cranking engines; empty and clean the oil-bath air cleaners. Disconnect all power cables, control cables, and fuel connections. See that they are in satisfactory condition, and coil and tie them securely. See that all unit coverings are in place and secure.

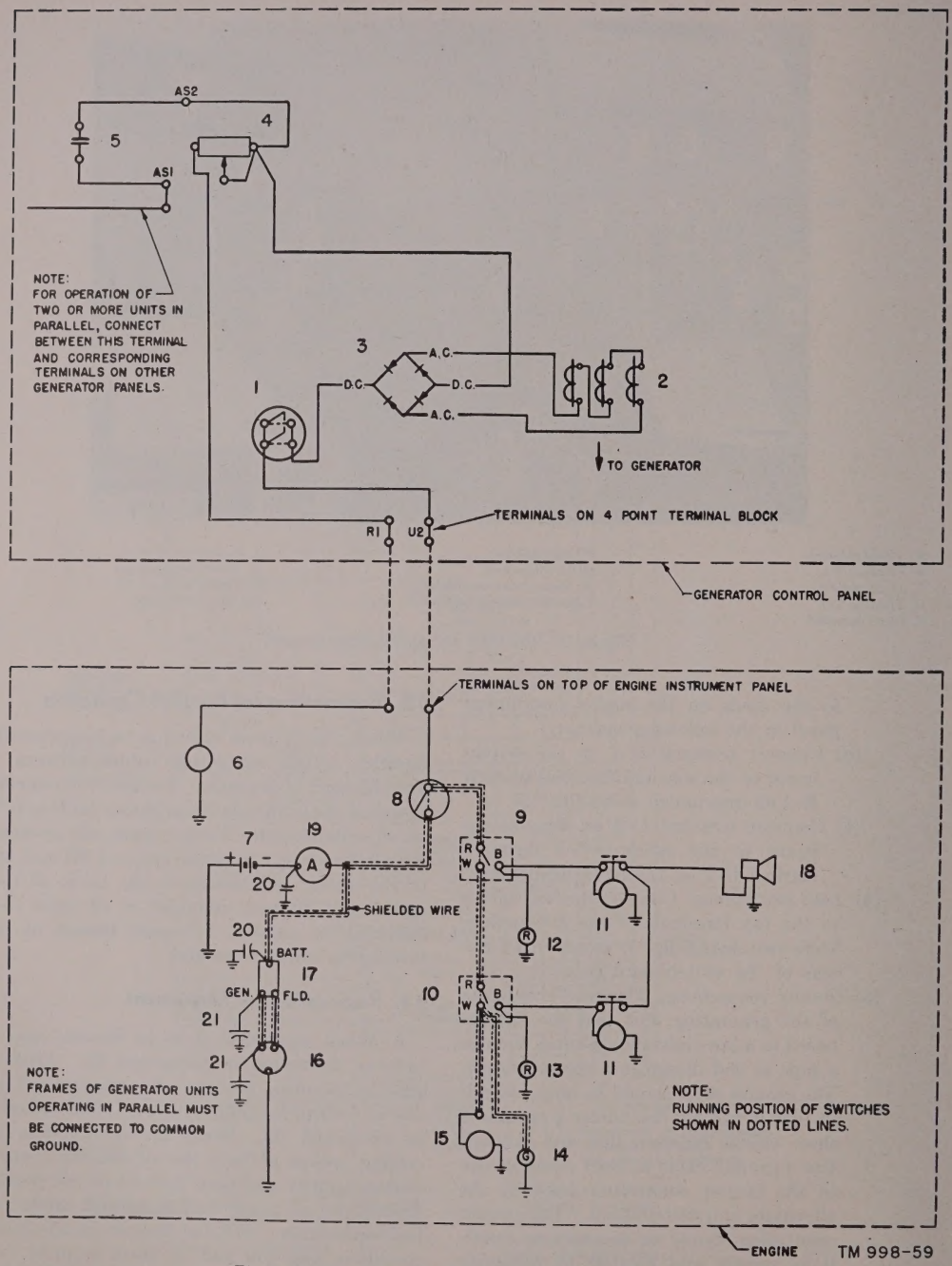


Figure 14. Engine safety and frequency control wiring diagram.

1. DPST toggle switch.
2. 3-phase current transformer.
3. Selenium rectifier.
4. Governor control rheostat.
5. Auxiliary switch on circuit breaker.
6. Throttle control solenoid.
7. Control battery.
8. RUN-STOP switch.
9. Water temperature switch.
10. Oil pressure switch.
11. Single pole relays.
12. Water temperature (WATER) light (red).
13. Oil pressure (OIL) light (red).
14. RUN light (green).
15. Solenoid fuel valve.
16. Battery charging generator.
17. Battery charging regulator and cut-out.
18. Alarm horn.
19. Ammeter.
20. Radio suppression capacitors.
21. Radio suppression capacitors.

Figure 14. Engine safety and frequency control wiring diagram—Continued.

b. If the unit is to be moved only a short distance and returned to service immediately, do not drain the unit, but perform all the adjustments and checks after stopping.

c. If the unit is to be moved a considerable distance or is likely to be out of service for several days, proceed as directed in paragraph 14.

14. Repacking Instructions

If the power unit is not to be used for 30 days or more, or is to be transported to a remote point, prepare the unit as follows:

a. Empty the fuel tank. Refill with a 10-gallon mixture of 50 percent high-grade light lubricating oil and 50 percent kerosene. Run the engine on this mixture for 30 minutes to insure filling the fuel system with this flushing compound. Leave the flushing compound in the fuel system to prevent rust, and protect the pump and nozzles during the lay-up period.

b. Drain the lubricating oil from the injection pump, and fill with new oil

c. Drain the cooling system.

d. Clean and put new oil in the two air cleaners on the oil engine and also in the one on the starting engine.

e. Clean the lubricating oil pump intake screen.

f. Drain the sediment out of the lubricating oil filter located below the magneto.

g. Do not drain the lubricating oil purifier or the fuel oil clarifier.

h. Remove the spark plugs and turn the engine over by hand until the piston of one of the cylinders is at the bottom of its stroke. Spray at least 1 ounce of oil, lubricating, preservative, medium (PL-Medium) into the cylinder through the spark plug hole. Repeat this operation for each cylinder. When the preservative oil (PL-Medium) has been sprayed into each cylinder, turn the engine over several times by hand to distribute the oil thoroughly. Treat the cranking engine in the same manner but use a proportionately smaller quantity of oil. If the unit is to be out of service for 90 days or more, repeat this process each 90 days.

i. If the exhaust system has been dismantled, cover the manifold opening carefully. If it has not been dismantled, cover the exhaust pipe opening to prevent moisture from entering the manifold. Cover the starting engine silencer opening.

j. Remove the storage batteries. Check each cell for charged condition. If batteries do not show a high specific gravity reading, charge them. If the unit is to be stored less than 60 days, electrolyte may be left in the batteries. After 60 days, check their condition and recharge, if necessary. If storage period is to be longer than 60 days, drain the electrolyte out of the batteries, and flush each cell with clean water. Preserve electrolyte in glass or crockery containers. *Do not use metal containers to store electrolyte.* If electrolyte is not drained for the 60-day period, store the batteries in a place where the temperature is above 32° F. Drained batteries may be stored at any temperature. For complete information on storage of lead-acid type storage batteries, refer to paragraph 73*b* of TM 9–2857.

k. Turn down the water pump grease cups and oil the alternator bearings.

l. Clean or wash the exterior of the engine thoroughly.

m. Apply a complete but thin coating of Compound, rust preventive, light (CL) to all exposed unpainted parts, such as threads and nuts, etc. Use a brush to apply the compound, being careful not to wet any rubber parts or any windings on the alternator or exciter.

n. Cover the alternator and exciter with a tarpaulin, or other material, to keep dust and moisture out. Remove the synchronizing lamps from the control panel and wrap them separately in paper. Place them inside the control panel. Cover the control panel with tarpaulin or other dustproof material.

o. Attach a red tag to the engine indicating that lubricating oil and water have been drained out.

p. Service the fuel system of the cranking engine in accordance with the following instructions:

(1) Decomposed and partially decomposed gasoline forms a gummy compound which settles in fuel lines, fuel tanks, carburetors, and other parts of the fuel system. This gum, when carried into the engine, acts as a binder for other products of combustion and causes sticking valves and excessive carbon formation. The use of Compound, gum preventive will aid in preventing the formation of gum deposits in the fuel system of gasoline engines. This compound is a preventive measure only and will not remove deposits already formed. When the equipment is being prepared for storage, inspect and clean the following parts:

(*a*) Fuel pump: valves and screens.

(*b*) Carburetor: screens, venturi, choke and throttle valves, float chamber, and float valve.

(*c*) Fuel lines, fuel filter, fuel tank, and other screens in the fuel system.

(2) Gum can be removed from the above parts with benzol, acetone, alcohol, or a mixture of these solvents. It may be necessary to remove dried gum by scraping, brushing, or other mechanical means before washing them in the solvent. After thoroughly cleaning and reassembling the equipment, fill the fuel tank with fresh gasoline to which one, 4-ounce container of gum preventive compound has been added. Operate the engine for a minimum of 5 minutes and then thoroughly drain the fuel system. All gasoline must be removed from the carburetor, fuel pump, fuel tank, and fuel lines. The necessary materials for gum proofing are as follows:

(*a*) Compound, Gum Preventive—4-ounce containers—Fed. stock No. 51–C–1587–225.

(*b*) Benzol, Technical—1-gallon containers—Fed. stock No. 51–B–450.

(*c*) Acetone, Grade B—1-gallon containers—Fed. stock No. 50–A–227.

(*d*) Alcohol, Denatured—1-quart containers—Fed. stock No. 52–A–100.

q. Restore the unit to service as follows:

(1) Remove coverings from the alternator, exciter, and control panel. Replace the synchronizing lamps in their sockets.

(2) Dry out alternator and exciter.

(3) Check all wiring circuits for correct, tight connections.

(4) Examine all hose in the cooling system and replace any that has deteriorated.

(5) Fill the cooling system and check for leaks.

(6) Flush the crankcases of both engines with kerosene and fill them with the required amount of lubricating oil (OE) of the correct grade.

(7) Fill the cranking engine gasoline tank.

(8) Check the oil in the injection pump. Refill if necessary.

(9) Remove all coverings from the exhaust pipe openings, etc.

(10) Install the batteries, charge them if necessary.

(11) Remove the spark plugs and pour a mixture of one-half gasoline and one-half oil (OE 10) in each cylinder of both engines. Use approximately 6 tablespoonfuls for the oil engine, and 1 spoonful for each cylinder of the cranking engine. Leave all spark plugs out. Crank the starting engine over several times to blow the oil mixture out of the spark plug openings.

(12) Replace the spark plugs and start the cranking engine. After it is operating smoothly, engage the clutch and let the cranking engine turn the oil engine over for a few minutes to blow out the oil mixture. Hold the fuel injection pump lever in a horizontal position (toward the generator) during this operation.

(13) Replace the spark plugs in the oil engine. Start the unit as described in paragraph 18. Hold the engine speed down manually by means of the governor valve until it starts to warm up. Do not let it run at governed speed immediately.

Section IV. PREOPERATION PROCEDURES

15. Checking and Charging Storage Batteries

a. Checking Batteries and Electrolyte. The two 6-volt storage batteries are shipped dry-charged. The electrolyte is shipped in separate containers. Dry-charged batteries require electrolyte with a specific gravity of 1.275; uncharged batteries use electrolyte with a specific gravity of 1.345 (at 80° F.). Check the label on the electrolyte bottle to make certain that the proper strength electrolyte has been supplied. Fill the batteries as follows:

b. Putting Dry-Charged Batteries Into Service.

(1) Unscrew the filler plugs and remove the sealing disks located on top of the filling holes or under the caps. Discard the disks.

(2) Fill each cell to a depth of three-eighths inch to one-half inch above the tops of the separators with electrolyte. Make certain that both the solution and the battery are at a temperature above 60° F. but not above 100° F.

(3) Let the batteries stand for 1 hour. Add more electrolyte if the level has fallen below the initial filling.

(4) Replace the plugs and wipe any spilled electrolyte from the top of the battery. Coat the battery terminals and clamps with Grease, general purpose No. 2 (WB2) after the batteries have been installed.

(5) The charged batteries are now ready for service. However, full battery capacity is not yet available. If the specific gravity of the electrolyte has dropped below 1.265, the battery will not become fully charged until after several hours of operation of the unit.

(6) If an external charging source is available, an initial charge should be given to the batteries before connecting them to the unit. Charge the batteries at 8 amperes until the batteries are fully charged (all cells gassing and bubbling freely and the specific gravity stops rising), after which they may be connected to the unit. While the batteries are on charge, specific gravity readings should be taken at ½-hour intervals and recorded. The batteries should be charged until four successive readings show no change in specific gravity. The specific gravity of a fully charged battery is approximately 1.285 corrected to 80° F.

c. General Precautions in Battery Charging.

(1) When charging a battery from an external source, do not allow the battery electrolyte temperature to exceed 110° F. Control the temperature by reducing or interrupting the charging current. In a locality where the daytime ambient temperature is 110° F. or above, charge the batteries at night if possible. The battery charging current should not exceed 8 amperes. At the end of the charge, adjust the electrolyte level to the proper height (three-eighths inch to one-half inch above the separators) by the addition of distilled water followed by a ½-hour of mixing charge.

(2) All hydrometer (gravity) readings given are based on a normal electrolyte temperature of 80° F. Fill dry-charged batteries with electrolyte of 1.275 specific gravity; fill new batteries that have not been charged with electrolyte of 1.345 specific gravity. A fully charged battery, in good condition, should show a gravity reading of 1.285, while a discharged battery will show a reading of 1.130. When testing battery electrolyte, place a battery thermometer in the cell and note the temperature. Make corrections of the hydrometer readings in accordance with the following table:

Temperature of electrolyte	*Add to reading*	*Temperature of electrolyte*	*Subtract from reading*
160° F.	0.032	70° F.	0.004
150° F.	0.028	60° F.	0.008
140° F.	0.024	50° F.	0.012
130° F.	0.020	40° F.	0.016
120° F.	0.016	30° F.	0.020
110° F.	0.012	20° F.	0.024
100° F.	0.008	10° F.	0.028
90° F.	0.004	0° F.	0.032
80° F.	0.000		

(3) In cold climates with temperatures below 80° F., correct by subtracting from the observed reading 0.003 for each 10° F. below 80° F. to obtain the true reading.

(4) Battery temperatures above 110° F. will cause deterioration and failure, and should be avoided. Low temperatures (below freezing) reduce battery efficiency and are harmful. If the unit is to stand idle for several hours in cold climates, remove the batteries to a warm place. Best all-around battery performance will be obtained at temperatures from 70° to 80° F.

d. Preparing Electrolyte. Prepare battery strength electrolyte by adding 1 part (by volume) of concentrated sulphuric acid (1.835 sp. gr.) to 2.8 parts of distilled water. Pour the acid very slowly into the water and stir constantly while mixing. *Never add water to the acid.* Use either glass or earthern ware containers, *never metal.* The above proportions will result in a solution of 1.275 which is proper for temperate climates. For tropical climates, add 1 part of acid to 3.4 parts of distilled water.

16. Preparation for Use

When the unit is shipped from the factory, all the oil is drained from the crankcases of both the oil and cranking engines, the air cleaners, and the fuel injection system. All water is drained from the cooling systems of both engines. The storage batteries are charged and dry. Before starting to operate the unit, inspect it thoroughly to see that it is complete and in working order. Check all fuel, oil, water, and wire connections to see that they are secure and properly assembled. Tighten all loose screws, nuts, or bolts. Bar the engine over several times to determine that all parts are free and that the fan clears the radiator and guard. *Do not prime* the engine with gasoline prior to this operation; starting is *not* advisable until the freedom of moving parts has been determined.

17. Servicing Unit

a. Lubrication.

(1) Lubricate the entire power unit. Follow the lubrication instructions (sec. II, ch. 3) as a guide. Fill the oil engine crankcase through the filler (J, fig. 1) with the proper grade oil (OE) for the expected ambient temperature.

(2) Remove the cover from the lubricating oil purifier and fill the perforated metal basket (N, fig. 23) with filter material which is packed in individual packages and is included with the spare parts for the main engine. Carefully reassemble the purifier unit and replace the cover.

(3) The combined lubricating oil capacity of the main engine lubricating oil reservoir and purifier is 37 gallons. Remove the bayonet oil gage on the side of the main engine crankcase and recheck the oil level after the engine has been operated for a short time. Add oil to correct the lubricating oil level if necessary.

(4) Remove the lubricating oil filler cap (C, fig. 20) on the fuel oil injection pump and pour in one-half pint of the same grade of lubricating oil as used in the engine crankcase. Check the oil level by means of the bayonet gage (F, fig. 20). The oil level should be up to the line on this gage.

(5) Remove the oil bowls from the air cleaners on both the main engine and cranking engine, make sure that the wire mesh element is free from all foreign matter, and fill the oil bowls, up to the indicator mark, with the same grade of oil as used in the engine crankcase. About 2 quarts will be required for the air cleaners on the main engine.

b. Fuel.

(1) Disconnect the fuel oil line at the inlet of the primary fuel oil filter (E, fig. 43). Use a thoroughly clean container and pour clean fuel oil into the open connection until it overflows. Fill the fuel oil clarifier (P, fig. 2) in a like manner. *Do not* pour fuel oil into the fuel system at any point where it will reach the injection pump before passing through the filters. Use every possible precaution to prevent any foreign matter from getting into the fuel system.

(2) Pour 2 gallons of gasoline into the gasoline tank on the cranking engine (D, fig. 2) and also fill the priming tank (D, fig. 1) with gasoline.

Caution: Do not handle gasoline while smoking, near an open flame, or when the engine is running. Keep the container, from which gasoline is being poured, in positive contact with the tank to avoid static discharge.

c. Cooling System. Make certain the drain cocks at the bottom of each cylinder block, at the water pump inlet, and at the bottom of the oil cooler are secure. Also check all hose connections. Remove the radiator cap and fill the cooling system with clean, fresh water or with antifreeze. The capacity of the cooling system is 65 gallons. In temperatures below 32° F., protect the cooling system with antifreeze in accordance with table I below. If antifreeze is not available, drain the cooling system every time the unit is shut down. Whenever antifreeze is added, make certain that the antifreeze used is the same as that already in the cooling system.

Table I. Quantities of Antifreeze Solutions

Pure methyl wood alcohol (gal.)	Denatured wood alcohol (gal.)	Ethylene glycol (gal.)	Radiator glycerine (gal.)	Freezes at degrees	
				F.	C.
8. 45	11. 05	10. 40	24. 05	20	−7
13	16. 90	16. 25	35. 75	10	−12
17. 55	22. 10	21. 45	45. 50	0	−18
20. 80	26	25. 35	52. 65	−10	−23
24. 05	29. 90	28. 60	59. 80	−20	−29
26	34. 45	31. 20	65	−30	−35

d. Generator Control Panel. Check the following on the control panel:

(1) Knife-disconnect switch at rear of panel should be open.
(2) See that circuit-breaker handle is down.
(3) Field-switch indicator should point to OFF.
(4) Exciter-field rheostat should be turned to extreme clockwise position.
(5) Regulator transfer switch should be turned to REGULATOR position.
(6) Voltage-adjusting rheostat on regulator should be midway between extremes of travel.
(7) For the first operation only, remove the glass cover on the reverse-current relay, turn the time-delay index lever to No. 5, and remove the paper blocking from the back of the indicator relay.

CHAPTER 2
OPERATING INSTRUCTIONS

Section I. OPERATION

18. Starting

a. GENERAL.

(1) Fill the gasoline priming tank (1, fig. 15).

(2) Pick up any loose tools or bars which may be laying on, or around, the unit.

(3) Remove obstructions from the radiator which might prevent the free passage of air and thus reduce cooling efficiency.

b. CRANKING ENGINE.

(1) Turn the ignition switch key (J, fig. 3) on the cranking engine to ON position.

(2) Insert the knot of the starting cord in one of the notches of the starting pulley and wind the cord around the pulley several times. Close the choke (E, fig. 3) and give the starting cord a vigorous pull. Open the choke as soon as the engine starts.

Caution: Do not wrap the starting cord around the hand when cranking the engine.

(3) After the cranking engine has run for a few seconds, set the throttle control (L, fig. 3) so that the engine is running slightly above idling speed. Then pull the clutch lever (O, fig. 3) toward the operator until a click is heard. This should be approximately half-way between a vertical and horizontal position.

c. MAIN ENGINE.

(1) Open the priming tank valve (7, fig. 15) by turning counterclockwise.

(2) Open the vent (8, fig. 15) on the fuel clarifier.

(3) Reset the throttle (L, fig. 3) on the cranking engine to the wide-open position, and run the engine at full speed. Then pull the starting clutch all the way down to the clutch lever stop (horizontal position). The main engine will now start to turn over.

(4) Using the hand priming pump lever (10, fig. 15), pump 3 strokes of gasoline into the oil engine. Continue to use the pump to keep the oil engine running on gasoline. Hold the fuel lever (11, fig. 15) on the injection pump toward the generator, and keep the engine running on gasoline until fuel flows freely from the fuel clarifier overflow (fig. 24). Then open the injection pump bleeder valve (H, fig. 20) and continue cranking until fuel flows freely from the overflow tube.

(5) Check the main engine throttle (E, fig. 2) to see that it is in straight down position.

(6) Release the fuel lever (11, fig. 15). The engine will now fire on oil and come up to running speed. The governor will automatically take over the speed control.

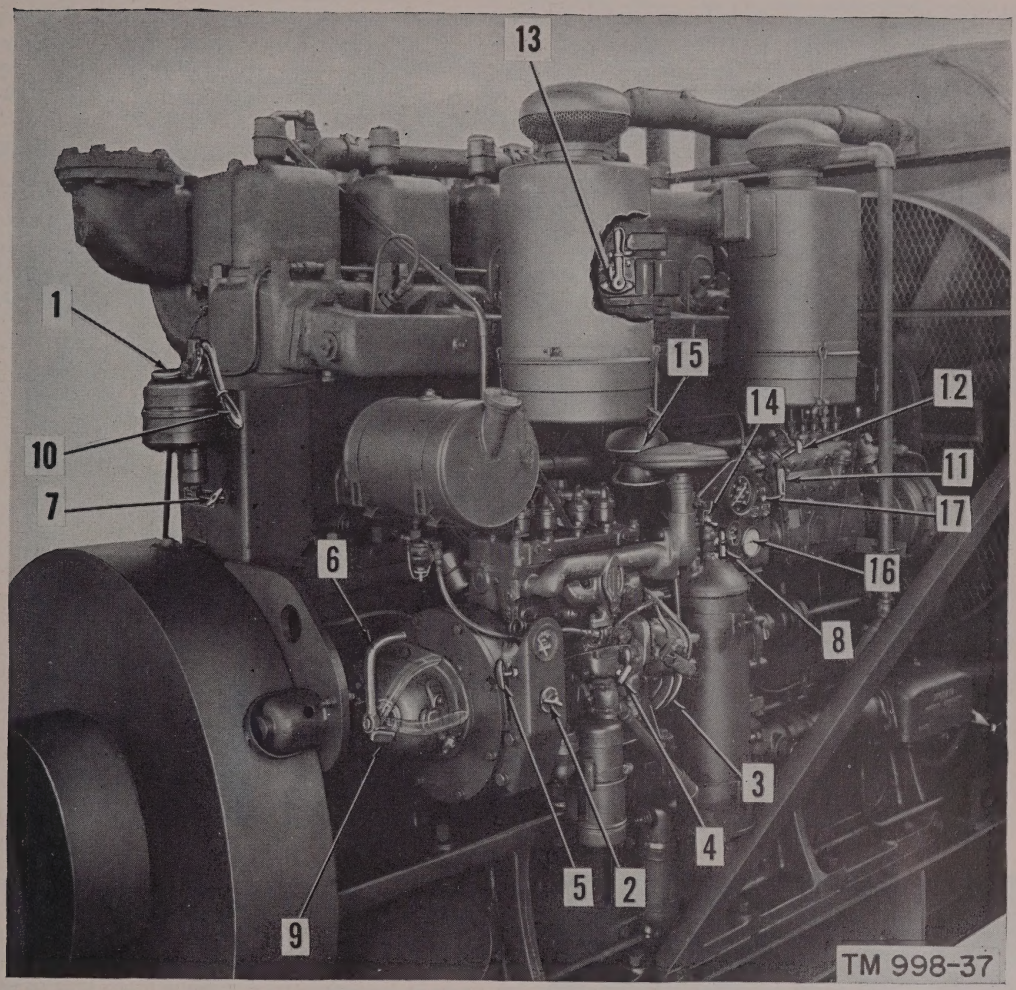
(7) Keep the engine running by priming with gasoline until the engine runs smoothly.

(8) Shut off the gasoline priming valve (7, fig. 15) by turning the handle clockwise.

(9) When the engine starts, the starting clutch will automatically disengage. Slow the cranking engine down to idling speed, and turn the ignition switch off.

(10) Snap the toggle switch (H, fig. 17) on the main engine instrument panel to RUN position. This switch controls the safety system only.

Note. The alarm horn will sound until the lubricating oil pressure gage (F, fig. 17) indicates a minimum of 10 pounds. The green jewel light (B, fig. 17) on the instrument panel will then light.

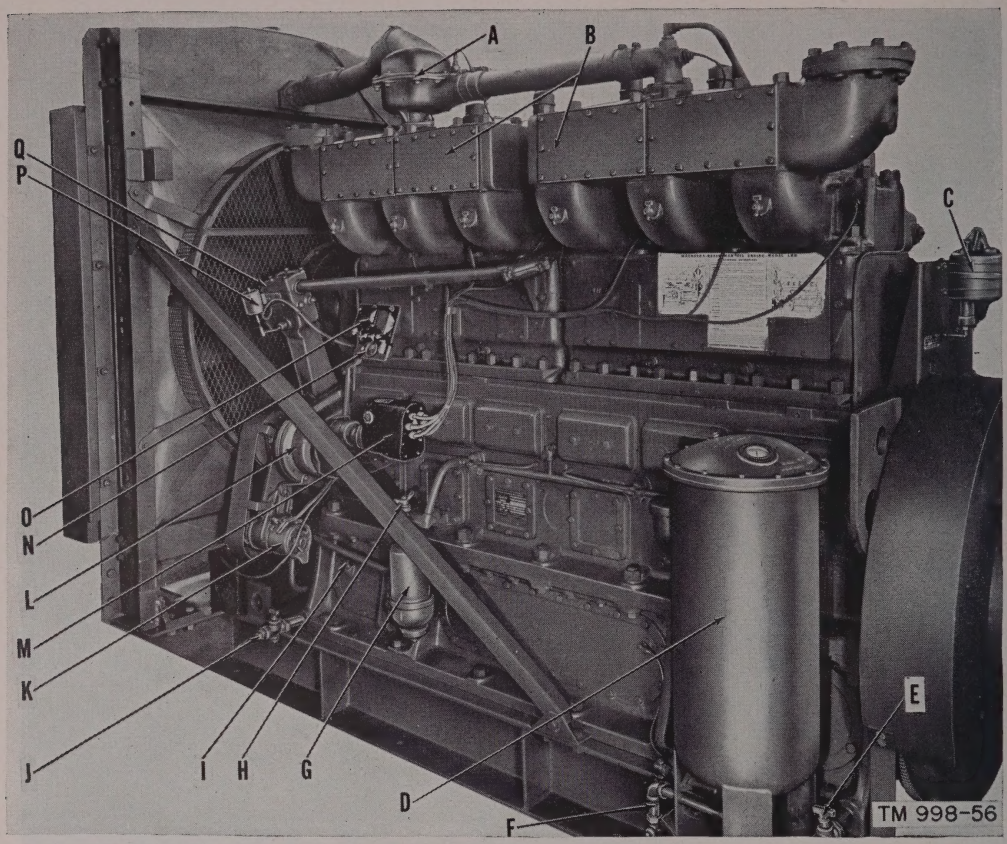


1. Gasoline priming tank filler.
2. Key ignition switch, cranking engine.
3. Pulley recess for cranking rope.
4. Cranking engine choke.
5. Cranking engine throttle control.
6. Clutch lever.
7. Priming tank valve.
8. Fuel oil clarifier vent.
9. Clutch lever stop.
10. Hand priming pump handle.
11. Injection pump lever.
12. Injection pump bleeder valve.
13. Oil engine throttle.
14. Safety system toggle switch.
15. Alarm horn.
16. Lubricating oil pressure gage.
17. Run light.

Figure 15. Starting controls.

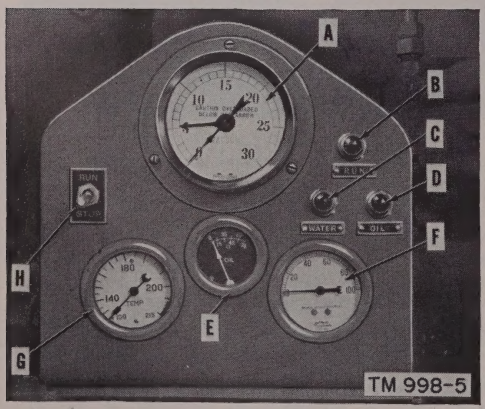
19. Adjustments and Checks after Starting (figs. 16 and 17)

As soon as the engine is operating smoothly, check the lubricating oil pressure gage (E, fig. 17). Reading should be 40 pounds. Check the water-temperature gage (G, fig. 17). Temperature should range from 170° to 190° F. The green light (B, fig. 17) on the instrument panel should be lit. The battery-charging ammeter (N, fig. 16) should show a slight positive charge. The engine should be operating smoothly and quietly, with a clear exhaust. The vacuum gage (A, fig. 17) should show a depression of between 19 and 21 inches (482.6 mm and 533.4 mm) of mercury with the engine thoroughly warmed and idling at a fair speed.



A. Thermostat housing.
B. Exhaust manifolds.
C. Priming tank.
D. Lubricating oil purifier.
E. Rear engine oil drain.
F. Lubricating oil purifier drain valve.
G. Primary lubricating oil filter.
H. Handle, primary lubricating oil filter.
I. Engine oil level bayonet gage.
J. Engine oil drain.
K. Battery charging generator.
L. Timing gear train housing.
M. Magneto.
N. Battery charging ammeter.
O. Battery charging voltage regulator.
P. Governor solenoid.
Q. Governor.

Figure 16. Engine close-up, left side.



A. Vacuum gage.
B. Running light.
C. High water temperature red light.
D. Low oil pressure red light.
E. Fuel oil pressure gage.
F. Lubricating oil pressure gage.
G. Water temperature gage.
H. Toggle switch.

Figure 17. Engine instrument panel.

20. Adjustments During Initial Operation

The automatic voltage regulator (G, fig. 4) and the regulating resistance become effective when the voltage regulator switch (N, fig. 4) is in the REGULATOR position and the exciter field rheostat (C, fig. 4) is in or near the *resistance-all-out* position (rotated clockwise). A voltage adjusting rheostat is provided in the regulating coil circuit so that the voltage regulator can be set to hold the

desired alternator output. The knob of this rheostat is located on the front cover of the voltage regulator (G, fig. 4). Raise the alternator voltage by turning the knob clockwise, and lower it by turning the knob counterclockwise.

21. Applying Load

a. After the unit has reached operating temperature, apply the load. Make certain that the disconnect switch, on the rear of the control panel, and the circuit breaker are open. Proceed as follows:

(1) With the voltage regulator transfer switch (N, fig. 4) in the REGULATOR position, turn exciter field rheostat to its extreme clockwise (resistance-all-out) position.
(2) Turn voltmeter and ammeter switches (F and M, fig. 4) to the phase position.
(3) Close the field switch (O, fig. 4).
(4) Adjust the voltage to approximately 245 volts by using the voltage adjusting rheostat on the voltage regulator (Q, fig. 4).
(5) Turn the rectifier ON-OFF switch (B, fig. 4) to ON position.
(6) Adjust the frequency to 69.5 cycles by means of governor control rheostat (P, fig. 4).
(7) Close the knife switch (15, fig. 5) at the rear of panel.
(8) Close the circuit breaker (A, fig. 4).
(9) Check the ammeter (K, fig. 4) to see if the load is within the rated capacity of unit.

b. After the load is applied, the voltage will drop 5 volts or less. If it rises, see trouble-shooting chart (par. 62) for causes and remedies. Readjust the governor control rheostat (P, fig. 4) at full load so that the frequency is 60 cycles.

22. Overload Protection

The air circuit breaker on the switchboard is equipped with a thermal overload device, a magnetic short circuit trip, a shunt trip, and an auxiliary switch in series with the shunt trip. The overload thermal device is a metallic strip which changes shape with temperature changes. This causes the circuit breaker mechanism to operate and open the circuits when currents are higher than normal. The device also acts as an inverse time delay device and prevents unnecessary interruptions on momentary overloads, without altering the protection afforded in the event of short circuits or sustained overloads. If the breaker trips on overload, a few minutes must be allowed for the thermal element to cool off and reset before the breaker can be reengaged.

23. Operation in Arctic Climates

a. Shelter. If the unit is to be operated in below-freezing weather, the unit should be inclosed within a shelter. During shut-down periods when the unit is located in an unheated shelter or out in the open, cover the entire unit with a tarpaulin to retain as much engine heat as possible.

b. Cooling System. When the temperature drops to 32° F. or below, water may freeze in the cooling system. To eliminate this hazard, drain the cooling system at the end of each operating period, or fill the cooling system with antifreeze (par. 17*c*). Check the entire cooling system frequently for leaks, hose deterioration, etc.

c. Fuel System. Moisture condensing in the fuel tanks and various parts of the fuel system will result in the formation of ice crystals which may cause serious damage to the injection pump, filters, and fuel lines. Make certain that all fuel used and all fuel containers are free from condensation and water, and keep all lids and caps on tight. Fill the fuel tanks at the end of each operating period and drain the fuel filters frequently. These precautions cannot be overemphasized.

d. Batteries. Extremely low temperatures may reduce the power output of storage batteries as much as 50 percent. When operating in extremely low temperatures, remove the batteries when the unit is not operating and store them in a moderately warm place. Keep the batteries fully charged. The specific gravity of the electrolyte in each cell must not be below 1.275 at any time. Do not attempt to use a battery that has been exposed to temperatures below —10° F. without first warming it to a moderate temperature. A fully charged battery, with electrolyte having a specific gravity of 1.275, will not freeze in temperatures as low as —40° F. A partially charged battery, however, will freeze at much higher temperature. Never add water to a battery in freezing temperatures unless the battery is

to undergo a charge immediately. Check the specific gravity and level of the electrolyte frequently.

e. Spark Plugs. If the spark plugs do not operate properly, remove the plugs, dry them with heat, and then wipe clean. Check spark plug gap before reinstalling (par. 86).

f. Lubricating System. If the unit is to stand overnight in freezing temperatures, it is advisable to drain the crankcase oil and then store the oil in a warm shelter. Fill the crankcase just before starting the unit.

g. Starting the Unit. To start the unit in low temperatures, keep the fuel injector lever (K, fig. 20) on the injection pump in the full stop position. Prime the engine with gasoline and follow the customary starting procedure (par. 18). After a few seconds operation on gasoline, restore the fuel lever to the vertical position, and the engine will begin to function on fuel oil. Prime slowly with gasoline until the engine operates smoothly and the exhaust clears.

24. Operation in High Temperatures

a. Lubrication. Lubricate the power unit with the correct grades of lubricant for the expected temperatures.

b. Batteries. Battery electrolyte evaporates rapidly and battery charge dissipates in extremely hot weather. In very dry, hot climates, check the electrolyte level and the specific gravity daily. Keep the batteries fully charged. If a battery is allowed to remain in a discharged condition, sulphation will take place and the plates will eventually buckle.

c. Fuel System. Fill the fuel tanks at the end of each operating day. This will prevent moisture condensation within the tank during cool evenings.

d. Cooling System. High temperature will cause the loss of cooling water and as a result the unit will overheat. To minimize these effects, check the water level in the radiator frequently. Replace the radiator cap tightly. Check the fan belts for their condition and tension. Keep the radiator and radiator core free of obstructions that will prevent circulation of air through the radiator. Clean and flush the cooling system frequently.

25. Stopping

a. Removing the Load. To remove the load, push the circuit breaker handle (A, fig. 4) down to the OFF position.

b. Stopping the Unit. After removing the load, set main engine throttle (13, fig. 15) at idling position and allow engine to run 1 to 2 minutes to cool. Push the fuel injection lever (11, fig. 15) to the extreme left (towards the generator) as far as it will go. This shuts off the fuel supply. Hold the lever in the extreme left position until the engine stops. Snap toggle switch (14, fig. 15) on engine instrument panel from RUN to STOP position. (This switch is merely intended to cut off the safety alarm horn and should not be used to stop the unit.) Never stop the unit by turning off the ignition.

26. Operation of Stand-by Units

Stand-by and spare units should be started and run at regular intervals to make sure they will be ready when they are needed. Each unit should be run under normal or equivalent load long enough to bring the unit up to operating temperature.

27. Conditions for Parallel Operation

a. General. For satisfactory operation of engine-driven a-c generators in parallel, the following conditions must exist:

(1) The driving engines and their governors should have similar speed regulation characteristics.

(2) The generators should have similar voltage regulation characteristics.

(3) The generators should have approximately the same waveform.

(4) The generator frequencies should be the same.

(5) The phase sequence of the generators should be the same.

Caution: If an alternator operating in parallel is shut down, the switchboard does not become electrically dead. The load terminals on the air circuit breaker and the wires from these points to the synchronizing switch are alive so long as the second generator remains in operation.

(6) The phase voltage relationship of the generators should be the same.

(7) The generators should develop the same terminal voltage.

Note. Condition (1) is determined by the design of the engine and the construction and setting of the governor. Governors of sets designed for parallel operation are factory-

adjusted and must not be adjusted unless absolutely necessary. Conditions (2), (3), and (4) are determined by the design, construction and number of poles, and rpm of the generator. Condition (5) is obtained by connecting the generator leads properly as described in paragraph 11*d*. Conditions (6) and (7) are obtained with the use of synchronizing lamps (E, fig. 4). It is essential that voltage regulators be used in order to maintain a constant voltage under varying loads.

b. Phasing Out. Power units furnished with control panels having synchronizing lamps are factory adjusted to develop proper phase sequence if the generator and switchboard terminals are connected in accordance with the terminal markings. When it is necessary to test generators for proper phase sequence, proceed as follows: Connect lamps of the proper voltage between the generator side and the line side of each pole of the generator switch, with the switch in the open position; then run the generators at about synchronous speed. If all the lamps do not become bright or dark at the same time, interchange any two of the connections from the generator to the switch.

c. Synchronizing. Before connecting two alternators in parallel, exactly the same frequencies and voltages must be established on each unit. To parallel a second unit with one carrying the load, close the synchronizing switch on the first unit. Start the second unit and adjust the voltage to exactly the same voltage of the first unit. Then close the synchronizing switch of the incoming (second) unit. The synchronizing lamps will flash on and off. Reduce the engine speed of the incoming unit until the lamps flash on and off slowly, every 1 or 2 seconds. After speed adjustments have been made, it may take a few seconds until the lamp fluctuations slow up. Close the circuit breaker while the lamp is dark.

Caution: Severe voltage disturbances will result if the breaker is closed while the lamps are lighted.

d. Load Distribution. When operating in parallel, each unit should carry an equal part of the load. This is indicated by equal ammeter readings; both ammeter switches should be in the same position when taking reading. Check for proper load sharing by taking the readings on the vacuum control gages on the engine instrument panels. The unit with the higher vacuum reading carries the smaller part of the load. Adjust the frequency control rheostat on the control panel until the load is equally divided. Once equal load distribution is established, voltage adjustments must be made simultaneously to avoid wattless current.

e. Eliminating Wattless Current. After the load has been equally divided, check for wattless (circulating) current between the two units. Flow of wattless current is indicated when the sum of the two ammeter readings is higher than the total current taken by the load. This current is caused by a difference between the terminal (generated) voltage of alternator No. 1 and alternator No. 2.

To eliminate wattless current, adjust the excitation in the following manner: Turn the voltage adjusting rheostat on the voltage regulator of one unit, first clockwise, then counterclockwise. One movement or the other should decrease the ammeter readings. Continue until the lowest reading is obtained, then repeat the process for the second unit.

f. Adjustment. Once the proper load distribution between the two units is established, little or no adjustment of load distribution should be required whenever the load is increased or decreased. However, any frequency or voltage adjustments should be made simultaneously on both units to avoid circulating current. Equal division of wattless current (reactive kva) will be maintained by the cross-current compensating feature of the voltage regulator.

g. Removing a Generator from the Line. To remove a generator operating in parallel from the line, throttle the engine so as to reduce the load on the generator. When the ammeter readings have dropped approximately three-quarters, open the circuit breaker.

h. Reverse Power Relay (J, fig. 4). The reverse power relay, which operates in a manner similar to a wattmeter, insures that each unit operating in parallel with one or more units delivers approximately its share of the load. If one unit ceases to deliver power, and instead takes power from another unit, the reverse power relay will operate when such power taken exceeds approximately 20 kw and will trip the circuit breaker through the shunt trip. A certain amount of time is necessary before the breaker is tripped, because during the adjustments for paralleling, a variation in division of load may not be avoided. However, if this variation exceeds approximately 20 kw, the relay will operate to trip the circuit breaker.

Section II. EQUIPMENT PERFORMANCE CHECKLIST

28. Use of Checklist

Refer to the equipment performance checklist when preparing the unit for operation, when starting it, while operating it, and when stopping it. Items listed in the *Item* column are those points on the unit to be checked during each step. *Action or condition* is the operation necessary, or the condition that should exist, for proper operation. Normal indications are those conditions that will exist if all equipment is operating normally. Corrective measures are the actions that must be taken in the event that an abnormal condition is indicated. Whenever a normal indication is not shown, refer to the column headed *Corrective measure* and follow instructions in that column.

29. Equipment Performance Checklist

	Item No.	Item	Action or condition	Normal indication	Corrective measure
	Oil engine				
	1	Crankcase	Check bayonet oil gage	Full	Add oil.
	2	Radiator	Check coolant level	Full to 2" from top	Add water or antifreeze.
	3	Injection pump	Check oil level	Full	Add oil.
	4	Air cleaners	Check oil reservoir	Oil up to marked line	Do.
	5	Fuel tank	Check connections to fuel tank.	Connections secure	Tighten.
			Check fuel in tank	Fuel supply ample for expected operating time.	Add fuel.
P					
R					
E	6	Batteries	Check electrolyte level	Electrolyte ½" from top	Add distilled water.
P	7	Priming tank	Check gasoline level	Full	Add gasoline.
A					
R	*Cranking engine*				
A					
T					
O	8	Crankcase	Check bayonet oil gage	do	Add oil.
R	9	Gasoline tank	Check gasoline level	do	Add gasoline.
Y	10	Air cleaner	Check oil reservoir	Oil up to marked line	Add oil.
	Control panel				
	11	Knife disconnect switch	Check to see that it is open	Knife blades not engaged	Open switch.
	12	Circuit breaker	do	Handle is down	Pull handle down.
	13	Field switch indicator	Check indicator	Indicator points to OFF	Pull field switch to OFF position.
	14	Exciter field rheostat	Check to see that it is turned to extreme right.	At extreme right	Turn counterclockwise to extreme right.
	15	Voltage regulator transfer switch.	See that it is in REGULATOR position.	In REGULATOR position.	Place in indicated position.
	16	Voltage adjusting rheostat knob on regulator.	Turn to MID position	In MID position	Place in MID position.
	17	Reverse current relay (initial start only).	Check setting	Points are open and indicator set at 5.	Set movable arm at 5.

	Item No.	Item	Action or condition	Normal indication	Corrective measure
	18	Ignition switch, gasoline engine.	Snap to ON position	In ON position	
	19	Starter rope, cranking engine.	Wind around pulley and pull quickly.	Engine cranks	If engine does not start, repeat.
	20	Throttle, gasoline engine.	Set throttle so engine idles.	Engine idles	
S	21	Starting clutch	Pull clutch lever half way until a click is heard.	Not apparent	
T	22	Priming tank valve	Turn counterclockwise to open.	do	
A	23	Vent on fuel clarifier	Open vent	do	
R	24	Throttle, gasoline engine.	Set throttle in wide open	Engine picks up speed	
T	25	Starting clutch lever	Pull clutch lever to clutch stop.	Oil engine starts turning	Check adjustment of clutch.
I	26	Priming pump	Pump 3 strokes of gasoline into oil engine.	Oil engine starts firing on gasoline.	Inspect nozzle.
N	27	Fuel lever, injection pump.	Hold down toward generator in horizontal position.	Fuel supply shut off. Keep engine running on gasoline until fuel flows from vent on fuel clarifier.	Fuel lever must be held in horizontal position.
G	28	Injection pump bleeder valve.	Open valve	Keep open until fuel flows from overflow tube freely.	Inspect for clogging.
	29	Main engine throttle	Should be in straight down position.	Lever in straight down position.	Place in position indicated.
	30	Fuel lever, injection pump.	Release lever	Lever returns to vertical position. Engine starts firing on oil and comes up to speed. Governor takes over control.	If lever does not return to vertical position push it to position indicated.
	31	Priming pump	Continue pumping gasoline.	Pump gasoline until exhaust clears and engine runs smoothly.	
	32	Gasoline priming valve	Turn clockwise to shut off.	Engine runs on fuel oil	
	33	Clutch	Clutch automatically disengages.	Clutch handle in vertical position.	
	34	Throttle, cranking engine.	Set throttle in idling position.	Gasoline engine idles	
	35	Cranking engine ignition switch.	Snap to OFF position	Starting engine stops	
	36	Toggle switch, instrument panel.	Snap to RUN position	Horn sounds until lubricating oil pressure comes up to 10 lbs.	If pressure does not come up to 10 lbs. quickly, shut down and check.

	Item No.	Item	Action or condition	Normal indication	Corrective measure
DURING OPERATION	37	Lubricating oil pressure gage.	Check gage	Steady at 40 lb., engine hot.	If no indication, stop engine and check oil supply and lubricating system.
	38	Water temperature gage.	do	Between 170°–190° F. (depending on ambient temperature).	If abnormal indication stop engine and check, coolant supply and cooling system.
	39	Green jewel light	Check whether lighted	Should be lit	If light is not lit, and both red lights are off, check lamp. If either red light is on, green light will not be lit.
	40	Red jewel light	do	Should not be lit	If either light is lit, stop unit immediately. Check lubricating oil system or cooling water system, according to the nameplate under the lighted lamp.
	41	Vacuum gage	Check gage	Manifold depression should read from 19 to 21″ of mercury.	Check fuel ratio.
	42	Battery-charging ammeter.	Check meter	Should register slight positive change.	Check electric system, voltage-control relay and generator.
	43	Exciter field rheostat	Turn to resistance-all-out by turning knob clockwise.	To extreme left	
	44	Voltmeter switch	Turn to phase position	Set at phase position	Reset from OFF position.
	45	Ammeter switch	Turn to phase position	do	Apply load.
	46	Field switch	Close field switch	Closed handle up	
	47	Voltage regulator	Adjust voltage to 250 v by using voltage-adjusting rheostat on regulator.	Midway of travel	Check exciter field rheostat position and voltage regulator on-off switch.
	48	Governor control rheostat.	Adjust rheostat	Frequency meter should read 60 cy.	Raise or lower engine speed.
APPLYING LOAD	49	Toggle switch on control panel.	Check to see that it is closed.	Closed	Close switch.
	50	Knife disconnect switch	Close switch	do	
	51	Air circuit breaker	Close breaker. Pull handle up.	do	
	52	Ammeter	Check reading	300 amp	Reduce load to rated capacity.
	53	Voltmeter	Observe for operation	Voltage steady	If voltmeter swings, check for open circuit or wrong polarity of exciter.
	54	Vacuum gage	Check gage	Manifold depression of not less than 1½″.	

	Item No.	Item	Action or condition	Normal indication	Corrective measure
S	55	Circuit breaker	Push circuit breaker handle to OFF position.	Voltage rises. Amperage drops to 0.	
T					
O	56	Main engine throttle	Set in idling position		
P	57	Fuel injection pump lever.	Push to extreme left	Hold in this position until engine stops.	
P					
I	58	Toggle switch on control panel.	Snap from RUN to STOP		
N					
G					

CHAPTER 3

MAINTENANCE INSTRUCTIONS

Section I. OPERATOR'S PREVENTIVE MAINTENANCE TECHNIQUES

30. Meaning of Preventive Maintenance

To understand PM (preventive maintenance), it is necessary to distinguish between it and trouble shooting and repair. The primary function of PM is to prevent major break-downs and the consequent necessity for repair. The primary function of trouble shooting and repair is to locate and correct existing faults and defects. The importance of PM cannot be overemphasized.

31. Purpose of Operator's Maintenance

a. To insure mechanical efficiency, it is necessary to inspect the equipment systematically before operation, while at halt (during stand-by periods), and after operation. The operator must be constantly alert for any indications of faulty operation so that defects may be detected and corrected before they result in serious damage or failure. Certain scheduled maintenance services will be performed each day before operating the unit, during at-halt or stand-by periods, and at the end of each day's run, immediately after stopping the unit.

b. Be sure that each unit is provided with a properly filled out WD Form 48. Operators should be trained to perform the maintenance operations listed on this form and treated in this manual.

c. The items listed on WD Form 48 are discussed in detail in this manual to provide specific procedures for accomplishment of the inspections and services. These services are arranged to facilitate inspection and to insure that the unit will receive a thorough check.

32. Preventive Maintenance Services

a. General. These services include the scheduled maintenance services performed by power unit operators and unit mechanics respectively.

b. Unit Operator. Ordinarily the power unit operator will replenish fuel, oil, grease, coolant, and battery liquid. He will perform necessary cleaning operations; tighten loose nuts, bolts, screws, and other fastenings; care for tools and accessories and make such emergency repairs as are within the scope of his ability, tool equipment, and parts available. He will see that all lubrication operations scheduled for daily lubrication are properly and regularly performed. These operations are performed by the operator daily, before operation, at halt (during shut-down periods) and after operation. He will assist the unit mechanic in performing the weekly maintenance on the unit.

c. Unit Mechanic. The unit mechanic will perform the weekly and monthly maintenance operations with the assistance of the unit operator. He will perform all service operations within the scope of his ability, tool equipment, and spare parts available. He will also perform all lubrication operations scheduled for weekly and monthly lubrication and will check that daily lubrication operations have been properly performed by the unit operator.

33. Driver's Trip Ticket and P. M. Service Record

Every operator of an individual power unit or power unit installation will provide himself with WD Form 48 (Driver's Trip Ticket and P. M. Service Record). To adapt this form to power unit operation, the following interpretation of various headings on that form will be necessary: *Time Out* will be interpreted as the start of a period of power unit operation; *Time In* will be understood as the end of that operating period; *Kind of Work* will be interpreted as the equipment

for which the power unit was used as a source of power; the *Speedometer* heading will be ignored and the reading of the *Hour Meter* will be entered under that heading at the beginning and end of the operating period, if such a meter is provided on the unit. If no hour meter is provided, only the total number of hours operated during the operating period will be recorded. No entry will be made under the heading *Trip or Load Record.* Under the heading *Passengers or Weight,* enter the load in amperes during the operating period and under the heading *Speedometer or Hour Meter,* enter the total number of hours for which the load entered was carried by the unit. The *Dispatcher's Signature* will be that of the officer charged with the equipment. All other entries on the front of the form are self-explanatory. On the reverse side of WD Form 48 are listed the Before-operation, During-operation, At-halt, and After-operation services. The power unit operator will line out all operations listed which do not apply to power units and will perform all remaining operations. Upon the completion of each group of operations, the unit operator will place his initials in the space provided. The balance of the back of this form is self-explanatory.

34. Before-operation Service

a. General. This service should never be entirely omitted, even in extreme tactical situations. If thoroughly trained, the operator will go through this service almost automatically so that a few moments will enable him to size up the condition of the unit.

b. Procedures. The Before-operation service consists of inspecting the following items according to procedures described below, and correcting any deficiencies, or reporting them to the proper authority.

(1) *Item 1, tampering and damage.* Check the entire equipment. Look for damage that may have resulted from falling debris, shell fire, sabotage, or extreme weather conditions. Be alert for any indications of tampering. Look for items such as loosened or damaged parts or accessories. Check for cut drive belts, wires, hoses, and fuel or oil pipes. Wipe any moisture, if present, from the spark plugs and ignition system. Where evidence of tampering is discovered, proceed with caution.

(2) *Item 2, fire extinguishers.* Check for security of mounting, corroded nozzles, and closed valves. Make sure extinguishers are fully charged.

(3) *Item 3, fuel, oil, and water.* If the after-operation service (par. 37) was properly performed, this item will consist only of checking to see that the fuel tank is full, the level of the lubricating oil in the engines is correct, and the coolant in the radiator is at the proper level. If the unit is being operated in freezing temperature, see that the coolant is protected against freezing. If the fuel, oil, or coolant level is noticeably low, check for possible leaks in the system. Correct or report any leaks that may be found.

(4) *Item 4, accessories and drives.* Check all accessories such as carburetors, fuel injectors, fuel pumps, fuel and oil filters, magnetos, battery-charging generator, and fan for loose connections or mountings.

(5) *Item 6, leaks, general.* Inspect the fuel, oil, and cooling systems for leaks. Look under the unit for evidence of fuel, oil, or coolant which may have dripped while the unit was out of operation. If any leaks are evident, trace them to their source, and if possible, correct them before operating the unit. If unable to trace or correct any leaks, report them to the proper authority. Pay particular attention to all hose connections, fuel and oil line connections, and to the radiator core. Carefully inspect all gasketed joints and connections for evidence of leakage.

(6) *Item 7, engine warm-up.* Start the cranking engine and allow it to warm up for a few minutes before engaging the starting clutch. Start the oil engine and allow it to warm up for a period of not less than 10 minutes before applying load. A load should never be applied to a cold engine. Note the action of the starting mechanism. Pay particular attention to the cranking speed and to whether or not the starter engages and disengages properly without unusual noise. Observe the oil pressure gage and signal light. If they do not indicate properly within 30 seconds after the

engine is started, stop the engine and correct the trouble or report it to the proper authority.

(7) *Item 8, choke and primer.* While starting the cranking engine, check the operation of the choke. As the engine warms up, reset the choke, as required, to prevent overchoking. If it is necessary to keep the choke partially closed to prevent the engine from stalling, notify the proper authority. Check the primer tank and priming pump on the oil engine to see that the priming pump is operating properly.

(8) *Item, 9, instruments.*

(*a*) *Lubricating oil pressure gage and light indicator.* Check the lubricating oil pressure gage and light indicator (F and D, fig. 17) to see that they function properly. The lubricating oil pressure gage should indicate pressure as soon as the engine is started. The red jewel light should go out as soon as the oil pressure is built up. If these instruments do not indicate properly, stop the engine immediately, investigate and correct the cause or report it to the proper authority. The alarm horn will sound until a 10-pound pressure is indicated on the lubricating-oil-pressure gage.

(*b*) *Battery-charging ammeter.* Observe the battery-charging ammeter. It should indicate a slightly higher charging rate when the unit is first started than will be indicated after a short period of operation. When the engine is operating at normal speed, a slight positive charge should be indicated. Any unusual drop or rise in the charging rate should be investigated immediately. A high-charging rate for an extended period may indicate a faulty battery or charging generator regulator.

(*c*) *Frequency meter.* Observe the frequency meter (L, fig. 4). It should indicate approximately 60 cycles. Deviation should not be more than one-half cycle when load is applied to the unit.

(*d*) *Voltmeter.* Observe the voltmeter (I, fig. 4). This meter should indicate 240 volts.

(*e*) *Water temperature gage.* Observe the engine temperature gage (G, fig. 17). This gage should indicate between 170° and 190° F. when the engine has reached operating temperature. The engine temperature should increase gradually during the warm-up period. Abnormal engine temperature, after a reasonable warm-up period, should be investigated and any existing cause corrected or reported to the proper authority.

(9) *Item 21, tools and equipment.* See that all tools and equipment belonging to the unit are present, properly mounted or stowed, and in serviceable condition.

(10) *Item 22, engine operation.* The oil engine should operate on oil in about 30 seconds after starting in moderate temperatures. In low temperatures, a longer priming period may be required. When the unit is operating satisfactorily on fuel oil, apply a normal load to the unit and note any unsatisfactory operating indications as the load is applied and removed. Pay particular attention to the governor action and investigate any unusual noise or abnormal operating condition.

(11) *Item 23, operator's publications.* The operator must make sure that all publications pertaining to the equipment are in his possession, or with the equipment, and that they are in good condition. These will include such publications as WD Form 48, TM 11–998, etc.

Note. Add the item *Electrical controls*, discussed in (12) below, to WD Form 48.

(12) *Electrical controls.* Note whether the generator's electrical controls operate smoothly and if their operation is followed by proper indications. If there is indication of faulty operation of any switches, buttons, circuit breakers, voltage regulator, or other electrical controls, notify the proper authority. Check indications against the equipment performance check list (par. 29).

35. During-operation Service

a. GENERAL. While the unit is in operation, the operator must watch and listen for any indications of trouble, must check all meters and gages

at frequent intervals, and must be alert to detect any signs of smoke from any part of the unit. He must listen for any foreign sounds such as rattles, knocks, squeals, or hums; must watch for steam from the radiator; and must be alert for odors that might indicate an overheated condition in any part of the equipment.

b. PROCEDURES. The during-operation services start as soon as the unit is placed in operation. They consist only of observance of the general precautions listed above and of items 31 and 32 listed below. All other items listed under the during-operation service on W D Form 48 will be ruled out and omitted.

(1) *Item 31, engine and controls.* The operator must be alert for any deficiencies in engine performance such as lack of usual power, misfiring, unusual noise, indications of overheating, unusual exhaust smoke, and improper response to controls. Note whether the governor functions properly and whether the engine responds properly to governor action.

(2) *Item 32, instruments.* Observe the readings of all instruments frequently during operation to see if they are indicating properly.

(*a*) *Water temperature gage.* See that the engine temperature gage indicates within the normal range (170° to 190° F.) except when operating under conditions of extreme heat or cold. Excessive heat will cause the automatic shut-down and alarm system to function. This is usually an indication of trouble and should be investigated immediately, corrected if possible, or reported to the proper authority.

(*b*) *Lubricating oil pressure gage.* Normally, when the lubricating oil pressure drops below 10 pounds, the automatic safety device will stop the unit. Watch the oil pressure gage and stop the unit immediately if the oil pressure should drop below 10 pounds and the automatic cut-off fails to function. Check the oil level in the engine crankcase and if lack of sufficient oil is not the cause of the trouble, notify the proper authority. Low oil pressure may be an indication of leaks, loose bearings, or a faulty oil pump.

(*c*) *Battery-charging ammeter.* During operation, the battery-charging ammeter should indicate a slight positive reading. A discharge reading may indicate a faulty generator or regulator. Report a discharge reading to the proper authority.

(*d*) *Frequency meter.* See that the frequency meter (L, fig. 4) indicates approximately 60 cycles at all times when the unit is running. Refer to the trouble chart for the possible cause of faulty indication.

(*e*) *Vacuum gage.* The vacuum gage should record a manifold depression of not more than 1¼ inches. If the reading is above 1¼ inches, the engine is not operating at top efficiency and the air-fuel ratio may require adjustment.

36. At-halt or Stop Service

a. GENERAL. The at-halt service should be regarded as minimum battle maintenance and must be performed under all tactical conditions even though the more extensive services may be slighted or omitted.

b. PROCEDURES. This service consists of investigating any deficiencies noted during operation that did not require an immediate shut-down of the unit. It includes correcting any such deficiencies and inspecting the following items. Any further corrections or adjustments indicated as a result of inspection must be attended to before the unit is again started.

(1) *Item 38, fuel, oil, and water.* Check the fuel supply for both the cranking engine and oil engine. Make sure that it is adequate to operate the unit until the next at-halt or stop period. When filling the cranking engine fuel tank, use every possible safety precaution and stop the unit while the tank is being filled. Ground the tank and filling container while pouring in fuel and make sure that no radio transmitter is operating in close proximity. Allow space in the tank or filler neck for expansion and make certain that the vent hole in the filler cap is unobstructed. Be sure that this cap is replaced securely. Check the crankcase oil level in both the cranking engine

and the oil engine and replenish if necessary. Check the lubricating oil level in the fuel injection pump. Remove the radiator cap. Be careful of steam when removing this cap. Replenish the coolant as required. If the engine is excessively hot, allow it to idle without load for a short period to cool it off before adding coolant. Add coolant very slowly while the engine is running without load. Do not fill the radiator to overflowing but leave sufficient space for expansion of the coolant. If the unit is being operated in freezing temperatures, make sure that there is ample protection against freezing.

(2) *Item 39, temperature.* Feel all accessible bearing housings to see if they are abnormally hot. If any bearing housing is too hot to grasp with the bare hand, the bearing may be improperly lubricated, damaged, or improperly adjusted. Report all such conditions to the proper authority.

(3) *Item 46, leaks, general.* Check the entire unit for any signs of leaks. Observe all fuel, oil, and cooling-system connections; gasketed joints; fuel and oil filters; fuel and oil pumps; and the radiator core. Correct or report any leaks detected.

(4) *Item 47, accessories and belts.* Check the fan, water pumps, fuel pump, fuel and oil filters, air cleaners, carburetor, magnetos, oil and fuel lines, priming pump, and other equipment and accessories to see that they are secure. Inspect the fan belts to see that they are properly adjusted and in good condition. If the fan belts are found unsatisfactory or in need of adjustment, notify the proper authority. Operators will adjust belts only in an emergency.

(5) *Item 48, air cleaners.* If the unit is being operated in extremely dusty or sandy locations, inspect the air cleaners and all breathers. If found in need of service, service them in accordance with the lubricating instructions.

37. After-operation and Weekly Service

a. General. When performing the after-operation service, the operator should rectify any irregularities noticed during the operation of the unit in the before-operation, during-operation, and at-halt services. Any lubrication of the equipment should be performed as soon as the unit is stopped, so that, if draining the crankcase is necessary, the oil will not have settled, but will be in a free-flowing condition. The after-operation service should serve to reduce the before-operation service to an absolute minimum. The after-operation service will be performed by the unit operator preceeding any weekly service which will be performed by the unit mechanic. The operator will assist the unit mechanic in the performance of any scheduled weekly PM services. The weekly PM will consist of the appropriate items listed on WD, AGO Form 464.

b. Procedures. The after-operation service consists of inspecting the following items according to the procedure described below and of correcting or reporting any deficiencies noted.

(1) *Fuel, oil, and water.*

(*a*) Check the coolant level and replenish if necessary. If the unit is being operated in freezing temperatures, make sure that antifreeze protection is ample for the lowest expected temperature. Check the level of the lubricating oil in both the cranking engine and the oil engine, and add any required amount in accordance with the lubrication instructions. Fill the fuel oil tank with the correct grade of fuel oil and fill the gasoline tank for the cranking engine. Be sure to ground the filling container and gasoline tank while pouring gasoline into the tank.

Caution: Make sure that there is no open flame in close proximity and that no radio transmitter is operating nearby while the gasoline tank is being filled.

If an unusual amount of fuel, oil, or coolant is required, check the unit carefully for leaks, and correct or report any that may be found.

(*b*) When operating in freezing temperatures, make a hydrometer test of the coolant and add the necessary amount of antifreeze at the time of the weekly PM service. Protect the cooling system for the lowest expected temperature.

(2) *Item 55, engine operation.* Apply and remove a normal load while the unit is operating and note any tendency to miss or backfire, any unusual noise or vibration that might indicate worn parts, loose mountings, incorrect fuel mixture, or faulty ignition. Observe the action of the governor and check whether the engine responds properly to governor action. Correct or report any unsatisfactory engine operating condition.

(3) *Item 56, instruments.* Inspect all instruments to see that they are securely mounted, properly and securely connected, and not damaged. Correct or report any unsatisfactory condition.

(4) *Item 62, battery and voltmeter.*

(*a*) *Daily.* Check the batteries to see that they are clean, secure, and not leaking. See that the vent caps are in place and that the vent holes are not obstructed. With the unit operating, check the battery-charging voltmeter to see that it indicates a normal rate of charge.

(*b*) *Weekly.* When the weekly PM service is performed, clean the outside of the batteries. Remove the battery connections from the terminal posts; clean both the terminals and the posts. Replace the terminals on the posts and tighten them securely. Apply a light coating of grease to the terminals. Check and tighten the battery hold-downs, if necessary. Remove the vent caps, test the specific gravity of the electrolyte, check the level of the electrolyte and add distilled water as needed to correct the level. Always test the specific gravity before adding water. If the unit is being operated in freezing temperatures, never add water to the batteries unless the unit is to be operated, or the batteries placed on charge, immediately.

(5) *Item 63, accessories and belts.*

(*a*) *Daily.* Check all accessories such as the battery-charging generator, battery-charging regulator, battery-charging ammeter, fan, water pumps, and fan belts for loose connections, loose mountings, and unsatisfactory condition. Check the adjustment of the fan belts. Fan belts should deflect three-fourths of an inch to 1 inch when depressed midway between the pulleys. Report any loose or unserviceable belts to the proper authority. Correct or report any other unsatisfactory condition.

(*b*) *Weekly.* When the weekly PM service is performed, tighten or adjust any loose connections, linkage, or accessory mountings. Adjust all belts in need of adjustment and check the alinement of all belt pulleys. Examine all belts for fraying, wear, cracking, or the presence of oil. Belt adjustment should be performed only by the unit mechanic.

(6) *Item 64, electrical wiring.*

(*a*) *Daily.* Check all wiring and wire connections to see that they are in good condition and securely connected. Tighten any loose connection.

(*b*) *Weekly.* When the weekly PM service is performed, make a thorough check of all wiring on the unit proper and on the control panel. Inspect for faulty or damaged insulation, loose terminals on the wire or cable ends, and dirty or loose connections. Inspect all remote control and power connection cables and repair or report any unsatisfactory condition found.

(7) *Item 65, air cleaner and breathers.* Inspect the oil-bath air cleaners to see that the oil in the reservoir is clean and up to the proper level. Refer to the lubricating instructions (sec. II, this ch.) and, if servicing is indicated, service the item in accordance with the lubrication instructions. Inspect all breather caps and see that they are in satisfactory condition to deliver clean air. If these caps are dirty, clean them in Solvent, dry-cleaning (SD); if they are provided with a filter element, service them in accordance with the lubricating instructions. Service the lubricating oil filters in accordance with the lubricating instructions, and drain and refill the base of the fuel injection pump.

(8) *Item 66, fuel filters.* Refer to the lubricating instructions and service the fuel filters in accordance with the instructions given. On the cranking engine, remove

the glass sediment bowl and screen and clean them thoroughly. If a considerable amount of foreign matter is noted, drain the gasoline tank and refill with clean fuel. On the oil engine, open the drain cocks on the fuel oil purifier and primary fuel oil filter, and drain off any water that may be present. If an abnormal amount of water or foreign matter is noted, report this fact to the proper authority.

(9) *Item 67, engine controls.* Check for worn or disconnected linkage. Correct or report any unsatisfactory engine control linkage noted during operation.

(10) *Item 73, leaks, general.* Check the entire engine and its accessories for any traces of leakage. This should include all cooling-system connections, fuel lines, oil lines, and fuel- and oil-line connections. Inspect all flanged and gasketed joints and connections. If any leakage is detected, make necessary repairs or report to the proper authority.

(11) *Item 83, lubricate as needed.* Lubricate the unit in accordance with the lubricating instructions in section II, this chapter. Check for loose, broken, or missing lubrication fittings and replace or report any that are noted.

(12) *Item 84, clean engine and vehicle.*

(*a*) *Daily.* Wipe off the entire unit with a clean cloth. Be sure to remove all excess oil and grease. See that all air passages are free from obstructions.

(*b*) *Weekly.* When the weekly PM service is performed, clean all control linkage and control joints. Blow any dust and dirt from the generator, and blow dust and dirt from between the tubes of the radiator. Clean greasy surfaces with solvent (SD). Be sure that no solvent gets into the bearings, fuel tanks, generator windings, or engine crankcase.

(13) *Item 85, tools and equipment.* See that all tools are present and properly stowed or mounted. After the weekly PM service is performed, clean all tools thoroughly and see that they are in good condition. Inspect all accessories, remote control cables, power cables, and remote fuel lines. Report any missing or unserviceable items to the proper authority.

Note. Add items listed and discussed in (14) through (17) below to WD Form 48.

(14) *Electrical controls.* Check the operation of all switches, buttons, circuit breaker, rheostats, voltage regulator, and other electrical controls. Inspect all controls for tightness of mounting, condition of wiring, and cleanliness. Tighten all loose screws, bolts, and terminal connections. Remove all dust and dirt from the control mechanism and control boxes.

(15) *Power connections.* Inspect the alternator and exciter cables for secure connections. Check all leads and load cables and cable connections to see that they are in good condition. Tighten any loose connections or mountings and clean terminals if they are corroded or dirty. Replace or report any unsatisfactory cables.

(16) *Generator and exciter.* When the weekly PM service is performed, clean the commutator and slip rings with a piece of canvas or other suitable lint-free material. Inspect the condition of all brushes.

(17) *Safety and alarm system.* Check the operation of the safety and alarm system at the start of each day's operation.

Section II. LUBRICATION

38. Lubricants

a. General. Instructions contained in this section are essential and must be complied with fully to insure satisfactory operation of the equipment. Lubrication is an essential part of PM, and determines to a great degree the serviceability of parts and assemblies. It is extremely important that the lubricants and lubricant containers be kept clean and free from foreign matter, and that each lubricating point be well cleaned before lubricant is applied. In the field, it may not be always possible to supply the complete assortment of lubricants required. In such cases, it is necessary to make the best use of those that are available, subject to inspection by the officer concerned, and in consultation with all responsible personnel.

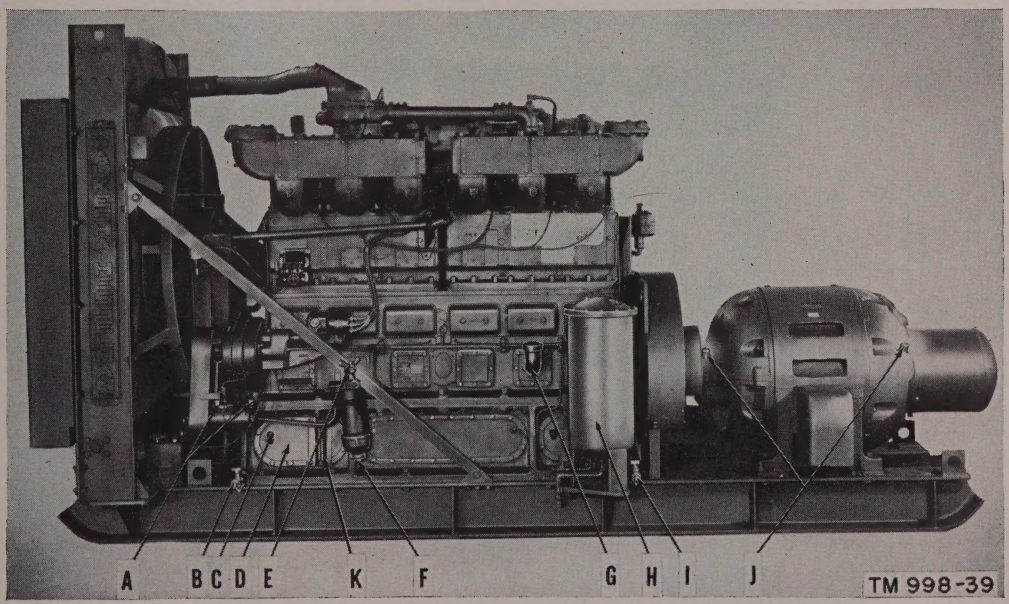
b. Approved Lubricants. The following table lists the lubricants necessary to lubricate Power Unit PE–220–C:

Symbol	Standard nomenclature
OE	Oil, engine.
LO	Oil, lubricating, light.
CG–0	Grease, general purpose No. 0.
CG–1	Grease, general purpose No. 1.
WB2	Grease, general purpose No. 2.
WP	Grease, water pump.
PL–Special	Oil, lubricating, preservative, special.
PL–Medium	Oil, lubricating, preservative, medium.
DA or DX	Oil, fuel, Diesel.
CL	Compound, rust preventive, light.
SD	Solvent, dry-cleaning.

c. Crankcase Lubricant. The following table lists the proper grade of crankcase lubricant to use under specific air temperatures and oil operating temperatures. To determine the correct grade, fill the crankcase the first time with the oil listed for the expected air temperature. After the engine is hot, check the temperature of the oil by means of the oil temperature gage on the side of the crankcase. Keep a record of this reading. When the crankcase oil is changed, refill with the grade oil listed for the oil operating temperature reading previously obtained. Again, measure the oil temperature in a hot engine, and check with the data listed under oil operating temperature. If a different grade of oil is indicated, make the correction the next time the crankcase oil is changed.

Expected air temperatures	OE SAE No.	Oil operating temperatures	OE SAE No.
70°–90° F	SAE 50	200°–220° F*	SAE 50
30°–70° F	SAE 30	160°–200° F	SAE 30
Below 30° F	SAE 10	140°–160° F*	SAE 10

*220° F. and 140° F. are the operating limits for the lubricating oil. Any temperature above or below these limits are considered unsafe for proper engine operation and lubrication. If the oil temperature drops below 140° F., provision for raising the engine temperature should be made, such as covering part of the radiator or removing the oil cooler.



A. Generator oil cups.
B. Engine oil drain.
C. Lubricating oil gage.
D. Oil compartment door.
E. Primary lubricating oil filter handle.
F. Primary lubricating oil filter drain.
G. Engine oil filler.
H. Lubricating oil filter.
I. Engine oil drain.
J. Generator sleeve bearing oil wells.
K. Oil temperature gage.

Figure 18. Lubrication points, left side of unit.

39. Lubrication Charts for Power Unit PE–220–C

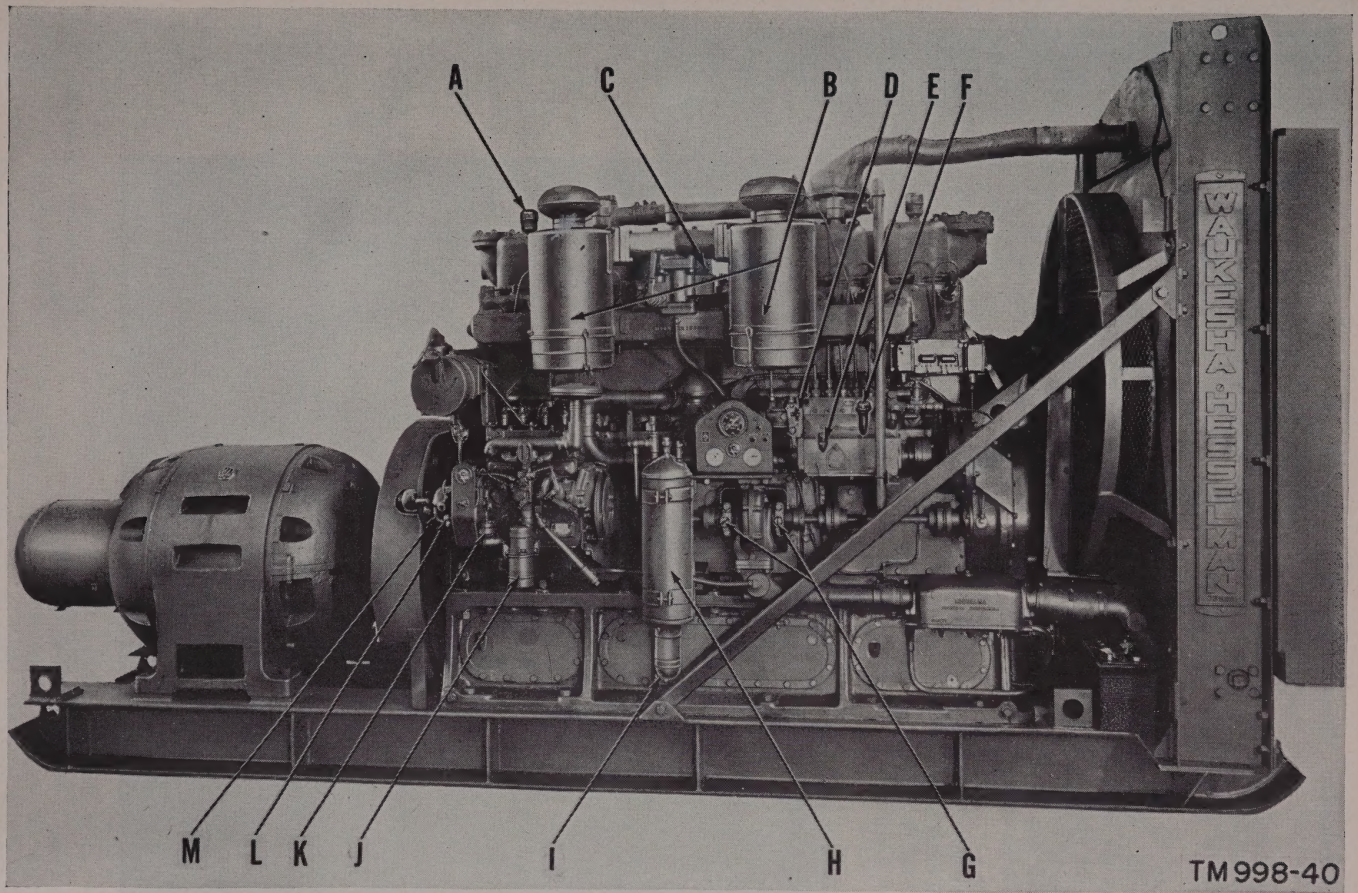
The following charts are keyed to figures 18 and 19. Lubrication points on the left side of the engine are shown in figure 18. Points to be lubricated on the right side of the engine are shown in figure 19.

a. Lubrication Points, Left Side of Engine (fig. 18).

Fig. ref.	Operating hours	Lubricant	Lubrication points
A	1,040	OE 10	Generator oil cups. Fill.
B	320	OE	Engine oil drain. Drain crankcase and refill with specified grade of lubricant.
C	8	OE	Lubricating oil gage. Check lubricating oil supply. Refill at (G) if necessary.
D	320	----------	Oil compartment door. Remove and clean oil pump screen.
E	8	----------	Primary lubricating oil filter. Turn handle 2 full turns daily.
F	320	----------	Primary lubricating oil filter drain. Drain when changing crankcase oil.
G	8	OE	Engine oil filler. Add oil if need is indicated at (C) above.
H	1,040	----------	Lubricating oil filter. Replace element.
I	320	OE	Engine oil drain. Drain crankcase and refill with specified grade of lubricant.
J	1,500	OE	Generator sleeve bearing oil wells. Remove caps and add lubricant.

b. Lubrication Points, Right Side of Unit (fig. 19).

Fig. ref.	Operating hours	Lubricant	Lubrication points
A	24	OE	Breathers. Clean and lubricate sparingly.
B	24	OE	Air cleaners. Empty lower compartments, clean and refill.
C	480	OE 10	Governor linkage oil cup. Fill.
D	104	LO	Vacuum control oil cup. Add 5 drops.
E	8	OE	Injection pump oil level gage. Check oil level. Refill if necessary.
F	104	OE	Injection pump oil filler. Drain pump and refill.
G	24	WP	Water pump grease cups. Turn one full turn daily. When cups have been turned all the way down, refill with grease (WP).
H	1,500	----------	Fuel oil clarifier. Change cartridge. If fuel oil pressure, as indicated on fuel oil pressure gage, drops to 10 pounds, change cartridge before regularly scheduled.
I	320	OE	Primary fuel oil filter. Drain shell and wash element.
J	24	OE	Cranking engine air cleaner. Examine cleaner for dirt. When oil is dirty, clean and refill.
K	320	OE	Cranking engine oil filler and gage. Check contents. Add oil if necessary.
L	320	OE 10	Starter clutch case oil level cock. Check level. Refill if necessary.
M	720	OE 10	Starter clutch case oil filler. Refill.



A. Breathers (6).
B. Air cleaners.
C. Governor linkage oil cup.
D. Vacuum control oil cup.
E. Injection pump oil level gage.
F. Injection pump oil filler.
G. Water pump grease cups.
H. Fuel oil clarifier.
I. Primary fuel oil filter.
J. Cranking engine air cleaner.
K. Cranking engine oil filler and gage.
L. Starter clutch case oil level cock.
M. Starter clutch case oil filler.

Figure 19. Lubricating points, right side of engine.

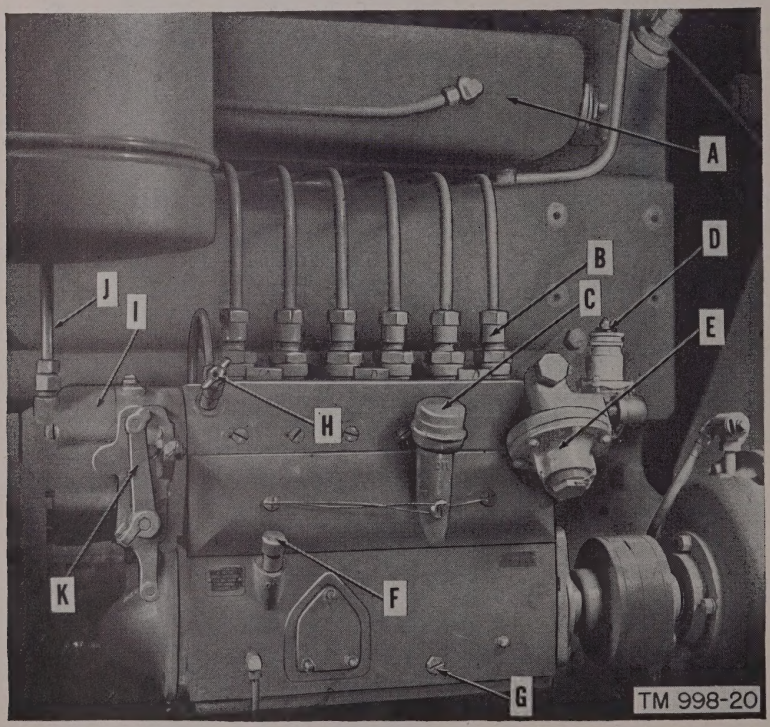
40. Specific Lubrication Procedures, Oil Engine

a. Crankcase Level. Check the level of the lubricating oil as follows:

(1) Unscrew the wingnut top of the bayonet gage.
(2) Withdraw the bayonet gage and wipe it clean with a clean cloth.
(3) Reinsert the bayonet gage until the bottom of the wingnut touches the top of the threaded sleeve.
(4) Withdraw the bayonet gage again and check the level of the oil indicated on the bayonet.
(5) Add sufficient oil to bring the level up to the full mark on the bayonet gage.
(6) Replace the bayonet gage; then screw the wingnut down tight.

b. Fuel Injection Pump (fig. 20). The space in the base of the fuel injection pump forms an oil reservoir for lubricating the cams, roller tappets, and bearings. To fill, remove the bayonet oil gage, and pour oil into the opening until it reaches the full level of the bayonet gage.

c. Primary Stage Lub ricating Oil Filter. The primary lubricating oil filter (fig. 21) is located on the exhaust manifold side of the engine. It is an edge-type filter requiring no change of filter element or other part. Turn the handle 2 turns daily to clean any sediment that may have collected in the filtering element. The sediment drops into the lower section of the casting which is fitted with a plug. Remove the plug to drain out the residue each time the crankcase oil is changed.



A. Intake manifold.
B. Metering pumps.
C. Lubricating oil filler and cap.
D. Solenoid valve.
E. Surge valve.
F. Bayonet gage.
G. Injection pump drain.
H. Vent valve.
I. Vacuum control.
J. Vacuum pipe from intake manifold.
K. Fuel lever.

Figure 20. Fuel injection pump.

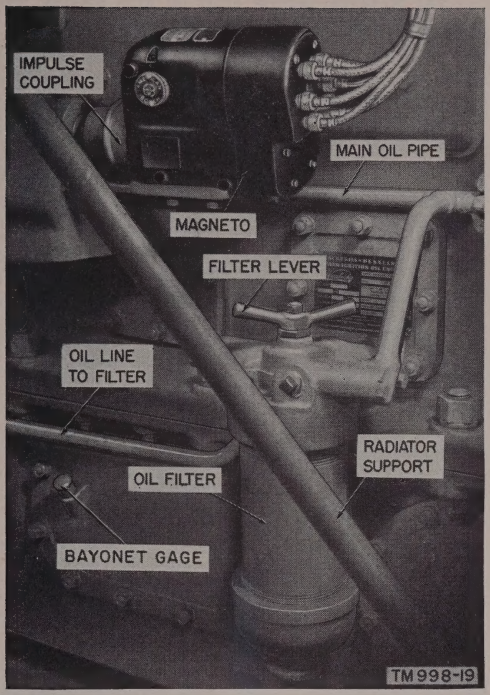


Figure 21. Primary lubricating oil filter.

d. Water Pump (fig. 22). Give the grease cups 1 turn a day under normal operating conditions. When cups have been turned all the way down, refill with grease (WP).

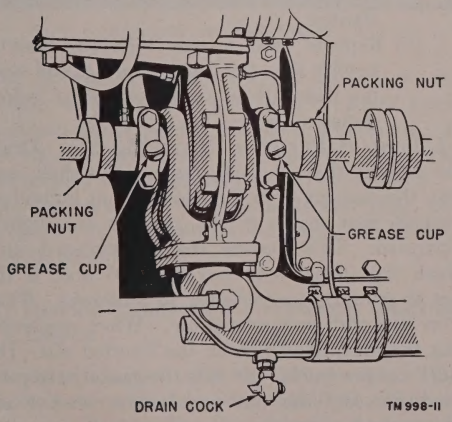


Figure 22. Water pump.

e. Air Cleaners. Change the lubricating oil in the 2 air cleaners every 24 hours. Remove the oil cup assembly. Add oil to the level marked on the air cleaner. To clean, see paragraph 93*b*.

f. Fuel Pump, Vacuum Control Cylinder and Housing. Remove the screw cap on the vacuum control cylinder. Squirt 1 or 2 tablespoonfuls of oil (LO) into the cylinder. Remove the cap on the end of the vacuum control housing and apply a few drops of the same oil on the piston stem. Replace the cap on the vacuum control housing, then the cap on the control cylinder. Screw the cap on tightly to prevent entrance of dirt into the mechanism.

g. Crankcase Drain. Every 320 hours, after the engine has reached operating temperature, shut the unit down and immediately open the four drains at the corners of the crankcase and allow the crankcase oil to drain. Catch all drained oil in containers. Keep the drains open for a few minutes to allow as much oil as possible to drain back into the crankcase. Close the drains when the oil stops flowing, and refill with the correct oil for temperature conditions. Run the engine for 30 minutes, and then check the level on the bayonet gage again. If it is not up to the full mark, add sufficient oil to bring it up to the mark. The flat base of the oil pan is baffled so that it may take a few minutes for the oil to reach its final level. Always allow sufficient time for the oil to fill the sump. The first time the crankcase is filled, 37 gallons will be required, 30 gallons for the oil pan and 7 for the lubricating oil purifier. Subsequent filling requires 30 gallons for the crankcase and only 4 for the purifier.

h. Oil Pump Screen. Clean the oil pump screen every time the crankcase oil is drained. Reach through the hand hole in the side of the base and remove the screen and baffles as a unit. Place screen and baffles in solvent (SD) long enough to allow the carbon to soften. Scrape the carbon off with a putty knife; be careful not to damage the screen. Replace the screen and baffles.

i. Cooling Fan. Remove the screw plug in the fan hub between the fan blades and the belt pulley. Fill the hub with grease (WB 2).

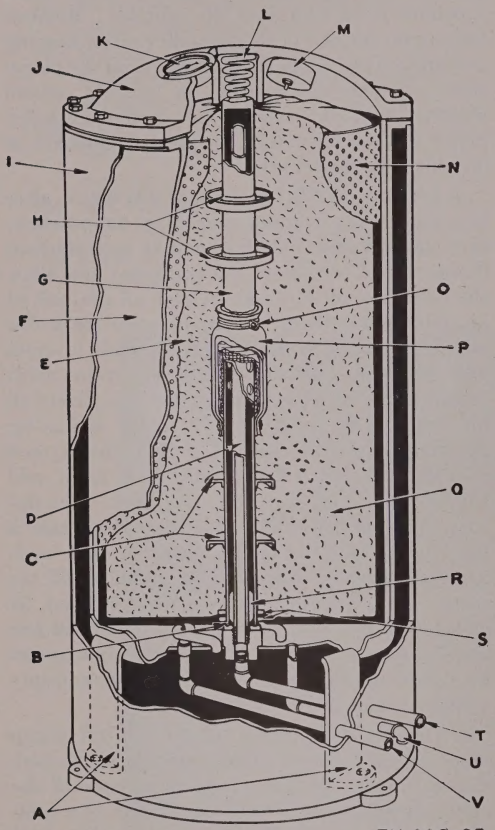
j. Lubricating Oil Purifier (fig. 23). To change the filter element in the lubricating oil purifier, proceed as follows:

(1) Open the valve on the drain pipe (U) and drain sufficient oil from the purifier to

bring the level of the oil below the top of the purifier body.

(2) Remove the lid (J) and lift out the center tube (G) and the perforated basket (N).

(3) Remove the center tube (G) and centering ring from the basket and clean with fuel oil or wipe with a clean cloth.



A. Mounting feet.
B. Asbestos gasket.
C. Baffles.
D. Center outlet pipe.
E. Filter element.
F. Steel body.
G. Center tube.
H. Baffles.
I. Outside jacket.
J. Lid.
K. Thermometer.
L. Pressure spring.
M. Pressure gage.
N. Perforated basket.
O. Felt clamp.
P. Felt.
Q. Filter element.
R. Guide.
S. Nuts to hold tube in bag.
T. Outlet pipe.
U. Drain.
V. Inlet pipe.

Figure 23. Lubricating oil purifier.

(4) Replace center tube in the basket by fastening with the lower locknut (S), allowing the lid of the tube to extend slightly below the nut to insure a perfect seat on the lower gasket.

(5) Place cork in bottom of center tube to prevent dirt from entering.

(6) Make certain heavy asbestos gasket (B) is in place in bottom around center outlet pipe (D).

(7) Be sure guide over asbestos gasket is in place.

(8) Fill basket with filter element to top of center tube.

(9) Remove the cork from the bottom of the center tube. Place the perforated basket back in the purifier. Be sure the center tube slips down over the guide to seat firmly on the asbestos gasket.

(10) Replace the lid, making certain that the pressure spring (L) rests on the center tube.

(11) Add the same amount of lubricating oil to the purifier as was originally drained off.

k. Fuel Oil Clarifier. The fuel oil clarifier (fig. 24) is located slightly to the left and below the engine instrument panel. Replace the element every 1,500 hours, or when it becomes impossible to maintain fuel oil pressure at 10 pounds or over. Proceed as follows:

(1) Check to make certain that the condition is not caused by leaking connections or broken lines.

(2) Remove the holding nut, and drop the element out through the bottom of the clarifier.

(3) Replace with a new element, making certain that the gasket, spring, and sealing plate are in same position as before disassembly.

l. Primary Fuel Oil Filter (fig. 24). Drain the case at the pet cock, remove the shell, and take the element from the head so that individual washers that make up the element are slightly separated. This loosens the accumulated dirt. Wash the elements in solvent (SD) and, if the dirt is gummy, use a brush to loosen it. Then blow dry with compressed air. When reassembling the unit, hand-tighten the knurled nut—DO NOT use a wrench. Be sure the gasket is in good condition and the nut and copper washer are drawn tight to prevent air and oil leaks.



Figure 24. Fuel oil clarifier.

m. Magneto. The magneto bearings are packed with sufficient oil to give 2,500 hours operation under normal operating conditions. If the magneto is overhauled, however, follow the instructions in paragraph 84 for lubrication.

n. Oil Cleaner. Disassemble and clean the oil cleaner every 6 months, following the instructions in paragraph 75.

41. Specific Lubrication Procedures, Cranking Engine

a. Air Cleaner. Fill the air cleaner to the marked point with the same grade of oil as is used in the crankcase. The time for changing the oil in the air cleaner is dependent upon the time the cranking engine is in operation. Examine the filter every 2 or 3 days, and replace the oil when the filter is dirty and the oil is in poor condition.

b. Crankcase Level. Check the oil level in the crankcase weekly by removing the bayonet gage, wiping it clean, reinserting it in the oil pan, and noting the oil level on the gage. Add sufficient oil (OE 10) to bring the level up to the full mark.

c. Crankcase Drain. When checking the oil level, inspect the sample that clings to the gage. If it appears dirty or thin, drain the crankcase and refill with 3 quarts of oil (OE 10).

d. Transmission. To add oil to the transmission case, remove the squarehead pipe plug located in the middle of the transmission housing just above the oil level pet cock. Open the oil level pet cock. Add one-half pint light cylinder oil (OE 10), making certain oil level is below the pet cock opening.

e. Magneto. When the magneto is serviced, apply 3 or 4 drops of oil (OE 50) to the cam wick and 1 drop to the breaker bar bearings. Do not get oil on the breaker points or allow oil to flow over the interior of the magneto.

42. Lubrication under Special Climatic Conditions

a. Severe Operating Conditions. Under severe operating conditions, or over prolonged periods of operation in surrounding high temperatures, be sure to reduce the time intervals between lubrication periods for the unit. Under desert conditions take precautions to prevent sand and dust from blowing around the unit, either during operation or when idle. Be careful to keep dirt, sand, and other foreign matter from filtering into lubricated parts. Cover the equipment when not in use. Thorough cleanliness is imperative. Instead of adding new lubricants at regular intervals, clean and lubricate all moving parts whenever practicable. If possible, inspect and clean the equipment daily. Inspect the air filters and similar protective devices every day and clean them whenever necessary. Refer to TB SIG 69 (Lubrication of Ground Signal Equipment).

b. Cold Weather Instructions. Special precautions are necessary to prevent poor performance or total operational failure of equipment in subzero temperatures. Most signal equipment can be used in winter if difficulties common in low temperatures are anticipated and precautions taken to

prevent them. In cold weather, lubricants become stiff, cause drag and also cause moving parts to stick. Refer to section II of chapter 3 for detailed lubrication instructions. Also refer to paragraph 23.

43. Records and Reports

a. Records. A complete record of lubrication must be kept for each power unit in Preventive Maintenance Roster (WD, AGO Form 460), adapted as explained in paragraph 45.

b. Reports. If lubrication instructions are closely followed and proper lubricant used, and if satisfactory results are not obtained, make a report to the signal officer responsible for the maintenance of the material.

Section III. UNIT MECHANIC'S PREVENTIVE MAINTENANCE TECHNIQUES

44. Scope

a. Preventive Maintenance Services. Regular schedules, maintenance, inspections, and services are PM functions of the using arms. They are the responsibility of commanders of operating organizations. An efficient control system is an essential aid in determining when power units are due for periodic maintenance services either because of time elapsed, or hours operated.

b. Frequency. The frequency of the PM services performed by unit mechanics (or other designated maintenance personnel) outlined herein is considered a minimum requirement for normal operation of Power Unit PE–220–C. Under unusual operating conditions, such as extreme temperatures, or dusty or sandy terrain, it may be necessary to perform certain maintenance services more frequently.

c. Operator's Participation. The operators should be present and should assist unit mechanics while periodic weekly and monthly PM services are performed. Ordinarily, the operator should present the power unit for a scheduled PM service in a reasonably clean condition; that is, it should be dry and should not be caked with mud or grease to such an extent that inspection and servicing will be seriously hampered. However, the unit should not be washed or wiped thoroughly clean, because certain defects, such as cracks, leaks, and loose or shifted parts or assemblies, are more evident if the surfaces are lightly soiled or dusty.

d. Technical Inspections.

(1) These inspections are performed by technically qualified personnel, under direct supervision of technically qualified officers. Technical inspections are made for the following purposes:

(*a*) To determine if a power unit should be continued in service or withdrawn for overhaul or reclamation of component parts.

(*b*) To determine extent of damage and estimated cost of repair for inclusion in report of technical inspection survey and other similar proceedings.

(*c*) To discover causes of difficulties encountered by combat troops with material so that efficiency may be improved.

(2) When a power unit goes to field or base maintenance shop for repair, it will receive a technical inspection to insure that all defects have been corrected before it is returned to the using organization.

(3) Except in a theater of operation, technical inspections will be made whenever power unit accountability is transferred to determine power unit condition.

(4) After a technical inspection, the unit should be restored to a safe operating condition, unless it is scheduled for repair by a higher maintenance unit. Any disassembled parts or assemblies that are found to be damaged during the inspection should be replaced by serviceable parts.

45. Scheduling Services

Schedule services for a month in advance, using WD AGO Form 460, Preventive Maintenance Roster. On the left-hand page write the names of the responsible mechanics, the power units in their care, and the normal operating hours of each unit. Under UNIT SERIAL No., give the number assigned to each power unit by the organization. If no such number is assigned, put the manufacturer's serial number in the last column.

a. On the right-hand page, show in pencil the services which will come due during the month. If a unit operates 8 hours daily, it gets weekly and monthly services at the usual intervals. If the

unit operates 16 hours daily, it gets weekly service every 3 or 4 days, and monthly service every 14 days. If a unit operates 12 hours daily, it gets monthly service every 20 days, and semiannual service every 4 months.

b. When services are actually performed, write over the entries in ink.

c. If a unit is deadlined by accident or for repair by a higher maintenance unit, show this fact on the roster, but do not reschedule.

46. General Procedures

PM services and technical inspections are recorded in detail on WD AGO Form 464 (Work Sheet for Engineer Equipment).

a. At the top of the form, fill in the spaces marked WD No., Hours or Miles (take reading of Total Hour Meter), Date, Organization, Nomenclature, Make, Model, Serial No., and Engine No.

b. The two double columns of blocks are used for recording the completion of the items.

(1) For a technical inspection, use the left-hand blocks under the heading *256 HR, MAINT. OR TECHNICAL INSPECTION.* Rule out the inapplicable words and the right-hand blocks.

(2) For a monthly inspection, use the same right-hand blocks, crossing out the heading and noting *MONTHLY INSPECTION.* Also cross out the left-hand blocks.

(3) For a semiannual inspection, use the left-hand blocks. Cross out the present heading and the right-hand blocks. Label the left-hand blocks *S*, indicating semiannual inspection.

c. An open block opposite an item means that the item is to be inspected and corrected. In each inspection, be sure that the item and its supporting member or connection are in good condition, correctly assembled, secure, and not excessively worn. If an item is found okay, put a check mark (✓) in the box. If an adjustment or repair is needed, put an (X) in the box. If replacement is needed, use (XX). When the adjustment, repair, or replacement is made, circle the mark as follows: Ⓧ or ⓍⓍ.

d. Some of the boxes have letters in them. These letters mean that, besides the usual inspection and correction, one or more of the special services listed below must be performed. When the special services have been performed, circle the letter or letters; for example, Ⓒ Ⓢ.

(1) *C—Clean.* Using solvent (SD), remove oil, grease, or dirt; rinse and dry. Gasoline will not be used as a cleaning fluid at any time.

(2) *T—Tighten.* Use the correct wrench, and do not overtighten. Make sure that locknuts, lockwashers, cotter keys, and locking wires are in place.

(3) *A—Adjust.* Make adjustments as directed in paragraph 47.

(4) *L—Lubricate.* Perform special lubrication as directed in paragraph 47.

(5) *S—Service.* Perform special operation as directed in paragraph 47.

e. On a technical inspection, make only such adjustments, repairs, or replacements, and perform only those special services which are necessary to restore the unit to a safe operating condition. Replace damaged parts after the inspection.

47. Specific Procedures

Following are detailed instruction for the items in the work sheet which apply to this power unit:

a. Check the column marked for the inspection or service which is to be performed. At each place where an item number appears in the column, follow the instructions to the right of the number. Make a general inspection on each item.

b. As the items are completed, mark the work sheet accordingly, and rule out all items not mentioned here, since they do not apply.

Tech. insp.	Semi-annual	Monthly	Instructions
			BEFORE OPERATION SERVICE
1	1	1	Perform the before-operation services (sec. IV) to determine if the power unit is in a satisfactory condition to make the test safely, and that it is adequately supplied with fuel, oil, and coolant.
2	2	2	*Lubrication.* Check the power unit to determine if lubrication is needed. Consult the maintenance roster, or other lubrication records, for the date on which lubrication was last performed. Check these dates against the lubrication instructions, and apply lubricants where necessary. Make a record of all completed jobs to avoid the possibility of overlubrication by uninformed maintenance personnel and plant operators. On any unit where disassembly was necessary for inspection purposes, lubrication must be performed, unless the unit is scheduled for repair. Lubricate in the following manner: Lubricate all points of the power unit in accordance with instruction in section II, chapter 3, current lubrication bulletins, or directives. Use only clean lubricant. Keep all lubricant containers and dispensers covered, except when withdrawing lubricant. Before applying lubricant, clean the lubrication fitting or plug, so that dirt will not enter with the lubricant. If lubrication fittings, flexible lines, vents, or plugs are missing or damaged, replace them immediately. Clean the hole in which the new fitting is to be installed, install the fitting, and lubricate the unit. On all unsealed bushings or joints, apply the lubricant until it appears at the openings. On units such as universal joints, which are provided with lubricant retainer seals, use an appropriate hand-operated grease gun, and do not force the lubricant beyond the seals. Open any clogged lubrication passages until lubricant is properly delivered. When draining oil from the engine, do so immediately after the engine has been operating, and is at operating temperature. Refill to the correct level with specified oil as soon as draining is completed. ***Caution:*** Do not fill to overflowing. Reinstall all drain and filler plugs securely. Make certain all gaskets are in good condition and in place on the reinstalled plugs. Do not apply more than the specified amount of lubricant. Wipe off any excess lubricant that may drip onto rubber parts or the body of the power unit.
3	3	3	*Tools and Equipment.* Check all the standard tools and equipment against the packing list to be sure they are all present. Inspect to be sure that tools are in good condition, clean, and properly stowed or securely mounted. Examine tools which have cutting edges to see that they are sharp.
4	4	4	*Fire Extinguisher.* Examine the fire extinguisher; be sure that it is in good condition, and that it is filled and ready for operation. Clean dirt and corrosion from the nozzle.
5	5	5	*Publications.* See that the following are present in a legible condition: TM 11-998. WD AGO Form 48 (Trip Ticket). WD AGO Form 464 (Work Sheet for Engineer Equipment). WD AGO Form 460 (Preventive Maintenance Roster). WD AGO Form 468 (Unsatisfactory Equipment Report).
6	6	6	*Appearance.* Examine the unit for cleanliness and be sure the paint is in good condition. Pay particular attention to any bright spots in finish that might cause glare or reflection. Inspect markings and identification (including identification plates and mountings) for legibility.

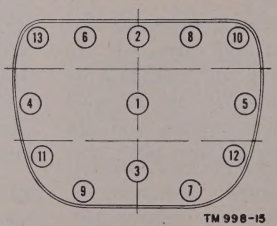
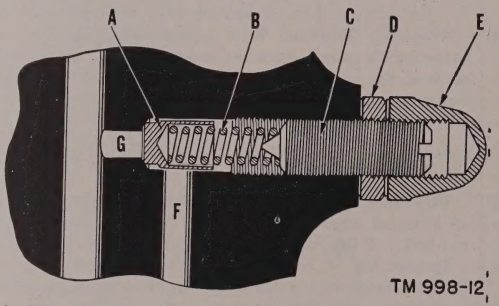


Figure 25. Cylinder head bolt tightening sequence.

Tech. insp.	Semi-annual	Monthly	Instructions
			ENGINE AND ACCESSORIES
11	11	11	*Cylinder Heads, Manifold and Gasket.* Check for cracks, or indications of oil, water, or compression leaks around studs, cap screws, and gaskets.
			Caution: Ordinarily, cylinder heads should not be tightened unless there is a definite indication of looseness or leaks. If tightening is necessary, use a torque-indicating wrench and tighten in the proper sequence (fig. 25). Torque wrench tension should be 3,500 to 3,600 inch-pounds.
			Tighten the hold-down studs in two or three successive stages, starting with the center, and working toward each and alternately. This insures even pressure over the entire surface of the cylinder head and gasket. Check the intake and exhaust manifolds. Be sure that they are in good condition and secure, and that gaskets are in good condition and not leaking. Tighten all manifold assembly, mounting, and exhaust pipe nuts evenly and securely.
12	12	12	*Valve Mechanism.* To test valves, crank the engine. The valves should seat fully and should hold a charge so that the hand crank will bounce back, or *rock* as the engine is turned over. If the engine does not offer added resistance to the crank on the compression stroke, leakage can generally be heard as a hiss. If it comes most distinctly through the intake, the intake valve is leaking; if most distinctly through the exhaust, the exhaust valve is leaking; if through the breather, the leak is past the pistons and rings. Leaks at the spark plugs and injector nozzles can be seen while the engine is running. Leaking valves should be inspected and reground (par. 99).
12	12	------	Remove the valve springs and check the valve stems and the fits in the guides. If wear is excessive, replace the valve and the guide. Otherwise it will be impossible to secure a tight seat by grinding. Notice particularly the exhaust valve guides, and valve stem shoulders. The valve guide should not project into valve gas passage, and the shoulders on the stems should be sharp. The shoulders should be 1/32 to 1/16 inch below the top of the valve guide when the valve is seated. Replace any worn valve guides as directed in paragraph 101.
12	12	12	Examine valve tappet clearances while the engine is hot. Valve tappets, rocker arms, shafts, and springs should appear in good condition, correctly assembled, and secure. Oil should be delivered properly. Make sure valve cover gaskets are in good condition. Test the oil lead to the rocker arm shaft to make sure it is not clogged.
		12	*Adjust.* Release the locknut and adjust the tappet clearances, with the engine cold, to 0.025 to 0.027 inch (intake) and 0.030 to 0.032 inch (exhaust) running clearance. If valves have been ground, add 0.002 inch to these figures for the first 10 hours of operation. Tighten the locknut after clearances have been adjusted.
14	14	14	*Crankcase Breathers.* With engine idling, examine crankcase, valve covers, and timing gear cover for oil leaks. Stop the engine, and, after the oil has drained into the crankcase, see if the oil is at the proper level. Through one of the inspection openings, see if the crankcase oil has formed sludge and coated the interior of the engine or whipped up into a thick froth. If it has, oil changes should be more frequent.
			Note. If an oil change is due, drain the crankcase and refill to the proper level with specified oil. Do not start the engine again until item 15 is completed.
15	15	15	*Oil Filters.* Inspect the primary lubricating oil filter, the continuous lubricating oil purifier, and all external engine lubricating oil lines, to see that they are in good condition, secure, and do not leak. If due, or if condition indicates such action is desired, replace filter elements.
15	15	15	Inspect the oil cooler element for sludge and gum deposits. Clean the oil cooler (par. 75), if such a treatment is due or if inspection reveals excessive dirt and sludge.
16	16	16	*Radiator.* See that the core, shell, mounting, hose, connections, caps, and gaskets are in good condition, securely mounted and connected, correctly assembled, and do not leak. See that the core air passages are not obstructed with dirt, insects, or trash, and that the core fins are not badly bent. Examine the coolant to see if it is so contaminated with rust, oil, or other foreign matter that the cooling system should be drained. If cleaning is necessary, proceed as follows: Drain the radiator by opening the drain cocks on either side of the engine, at the bottom of each series of cylinder blocks, on either side of the radiator, at the water pump inlet, and at the bottom of the oil cooler.
			If ethylene-glycol antifreeze is used, save the drainings for reuse. Clean the cooling system according to current directives, using only specified cleaner. Flush cleaner from the entire cooling system with clean water. Refill radiator with coolant, adding specified inhibitor, unless new

Tech. insp.	Semi-annual	Monthly	Instructions
			ENGINE AND ACCESSORIES—Continued
			antifreeze is used, which contains inhibitor. Do not fill to top; allow room for expansion. If antifreeze is used, determine its protective value and make a record in the space provided on the reverse side of the work sheet. Clean the dirt, insects, and trash from the core by blowing out with compressed air, or with a stream of water.
			Caution. Do not clean the core with steam. Tighten all loose radiator mountings and hose clamps.
17	17	17	*Water Pump, Fan, Shroud.* Check the water pump to see that it is in good condition, is not leaking, and is securely installed. Remove the intake fitting and make sure that the pump rotor is tight on the shaft. Carefully tighten packing gland nut on water pump. Do not overtighten as this will cause scoring of the shaft and leakage. Loosen fan-drive belts, and keep them loose until adjustment is made. Examine fan shaft for end play and loose bearings. Inspect the fan blades to see that they are in good condition and properly secured to the hub. Be sure that the fan guard is in good condition and securely mounted.
18	18	18	*Belts and Pulleys.* Check the three fan belts for evidence of fraying, excessive wear, and deterioration. Be sure that all pulleys and hubs are in good condition, securely mounted, and correctly alined.
	18	18	*Adjust.* Loosen the nut holding the fan belt guide in position, and slide the guide up until the fan belts can be depressed about ¾ inch. Then tighten nut.
19	19	19	*Oil Pump, Pressure Relief Valve.* Check the reading on the oil pressure gage when the engine is hot. If the pressure reads 40 pounds per square inch, the oil pump is operating properly, the automatic oil pressure valve is correctly adjusted, and the entire lubrication system is operating satisfactorily. Pressure below 40 pounds per square inch may be caused by improper adjustment of the pressure valve, dirt in the pressure valve, a clogged intake screen, defects in the oil pump, or a ruptured oil line. Before changing the adjustment on the valve, make sure the crankcase oil is in good condition, clean the oil pump intake screen and the oil relief valve. Check the unit for ruptured oil lines. To adjust the valve, proceed as follows: With engine at operating speed, and running at the governed speed, remove the cap (E, fig. 26), and with a screw driver inserted in the slot of the pressure-adjusting screw (C, fig. 26), turn the screw to raise or lower the oil pressure. If the oil pump is defective, replace it.



A. Cylindrical valve plunger.
B. Pressure control spring.
C. Pressure-adjusting screw.
D. Adjusting screw lock.
E. Protecting cap.
F. Overflow passage to crankcase when A opens.
G. Oil pressure duct from main oil line.

Figure 26. Oil pressure relief valve.

20	20	20	*Governor and Linkage.* See that there are no loose joints in operating rods and links; be sure there are no sticking joints, bent or deformed rods, or dirt or rust accumulation about pivots, shafts, or connections.
			STARTING OR AUXILIARY ENGINE
26	26	26	*Air Cleaner.* Inspect the connections and tubing. Be sure all joints are tight (par. 93).
27	27	27	*Cooling System.* Inspect the connections of the cooling system. Be sure they are tight, properly connected, and securely in place. Replace any parts that are worn or show signs of deterioration.

Tech. insp.	Semi-annual	Monthly	Instructions
			STARTING OR AUXILIARY ENGINE—Continued
28	28	28	*Cylinder Head, Manifold and Gasket.* Check for cracks, or indications of oil, water, or compression leaks around studs, cap screws, and gasket. ***Caution:*** Cylinder heads should not be tightened unless there is evidence of looseness or leaks. If tightening is necessary, use a speed wrench and draw the fastenings fairly tight. Start with the center studs, and work toward the ends, alternately. Examine the combination intake and exhaust manifold; be sure it is secure and in good condition. See that all gaskets are in good condition; be sure they are not leaking. Securely tighten all manifold assembly, mounting, and exhaust pipe nuts.
29	29	29	*Crankcase Breathers.* With engine idling, examine crankcase and valve covers for oil leaks. Stop the engine, and, after oil has drained into the crankcase, see if the oil is at the proper level.
30	30	30	*Valves.* Crank the engine and listen for a hissing noise at the air intake and exhaust outlet. If such noise is heard, valves are leaking and must be reground. Inspect the valve tappet clearances. Tappet clearance dimensions, with engine oil at room temperature, are 0.005 to 0.007 inch intake, and 0.007 to 0.009 inch exhaust. Add 0.002 inch to the dimensions given for the first 10 hours of operation after a regrind job.
31	31	31	*Ignition System.* All high-voltage wiring (spark plug cables) should be in good condition and securely fastened to all support mountings and terminals. See that all insulation and connections are clean. Check the spark plug and magneto as described in paragraphs 84 and 86.
32	32	32	*Fuel Pump, Carburetor, and Governor.* See that the carburetor, choke, governor control linkage, throttle, and governor are in good condition, correctly assembled, and securely installed; that the carburetor does not leak; that the control linkage is not excessively worn; that the choke valve opens fully when it is operated; and that the governor is secure and properly sealed. Inspect the gasoline strainer for dirt. When dirt begins to collect in the bottom of the glass bowl, close the shut-off cock, unscrew the thumbscrew retainer, and remove and clean the glass bowl. When replacing, be sure that the bowl seats properly, and that the gasket has not been damaged.
33	33	33	*Clutch and Transmission.* Start the cranking engine and engage the clutch. The clutch should just begin to engage when the handle has moved about one third of the total travel. If it does not begin to engage at this position, adjust the clutch as described in paragraph 103*d*.
35	35	35	*Magneto or Distributor.* See that the magneto is clean and dry. If the unit is operated under severe conditions, remove the distributor spool, wipe it off, and see that the carbon brushes work freely and have a slight spring tension. Check the contact points and resurface with a fine stone if there is evidence of pitting. Adjust to a maximum opening of 0.014 to 0.016 inch. Lubricate at the same time, applying 3 or 4 drops of OE 50 oil to the cam wick and 1 drop to the breaker-bar bearing. Do not get oil on the breaker points or allow oil to flow over the interior of the magneto.
36	36	36	*Spark Plugs.* Remove and examine the spark plugs. Make sure that their insulators are clean and in good condition. Note any evidence of leakage around the insulators or gaskets.
	36	36	Examine the spark plugs for poor condition, paying particular attention to broken insulators, excessive carbon deposits, and to electrodes which are burned thin. Replace unserviceable plugs. Check the spark plug gap with a feeler gage. Gap should be from 0.025 to 0.030 inch. Report excessive deposits or damaged insulators, as these conditions may indicate incorrect heat range.
		36	*Clean.* Clean the deposits from the electrodes with kerosene, or fuel oil, and a stiff brush. Check the insulators to see if they are cracked.
	36		*Adjust.* Adjust gaps to 0.025 to 0.030 inch. When reinstalling plugs, use new gaskets and be sure not to overtighten them as this may cause distortion and damage.
37	37	37	*Oil Pump and Relief Valve.* Inspect the oil pump screen for cleanliness. If the need for cleaning is indicated by the condition of the screen, remove the oil pan and unscrew the screen assembly from the pump. Put the screen in solvent (SD) and allow it to remain long enough to soften any carbon which may have accumulated. Scrape off carbon with a putty knife. Be careful not to puncture or damage the screen. Observe the reading of the cranking engine oil pressure gage. Hot oil pressure, with engine at operating speed, should be 15 pounds. If pressure is low, and oil supply is adequate, inspect the pressure relief valve for chips or dirt, and the oil pump for a sheared drive pin or key. If the pressure valve requires cleaning, remove the protecting cap, the adjusting screw lock, adjusting screw, pressure contact spring, and the cylindrical valve plunger. Wash all parts in solvent (SD) including the valve seat in the crankcase. Scrape away any hardened carbon. Then reassemble. If, after the oil screen has been cleaned, the pressure valve is checked and cleaned, and the supply of lubricating oil in the crankcase is sufficient, remove the oil pan and take off the back plate of the oil pump. Then crank the engine over. If the pump rotor with the two sliding vanes does not rotate as the engine turns, the pump is defective and must be repaired.

Tech. insp.	Semi-annual	Monthly	Instructions
			STARTING OR AUXILIARY ENGINE—Continued
38	38	38	*Fuel Pumps and Housing.* Service as follows: *Fuel supply pump.* See that the fuel supply pump and lines are in good condition, are secure, and are not leaking. Replace any pump that does not produce proper pressure. If there is evidence of oil leaking around the drive shaft, and if drawing up on the packing nut (on the right side of the pump) does not stop the leak, back off the packing nut, remove the old packing, and replace with new packing, using as much as possible. Do not overpack or packing nut will not start. Tighten the nut sufficiently to stop any oil leakage. *Fuel injection pump.* See that all high-pressure fuel fittings are kept tight and do not leak. Inspect the coupling adjustment of the gear-driven fuel injection pump. If the coupling has slipped, or if any floating member of the coupling shows signs of wear, timing of the fuel injection pump will be seriously affected. If the fuel injection pump does not operate properly, it should be replaced as a unit. *Adjust.* Adjust the timing of the coupling and the fuel pump in the following manner: Rotate the engine until the No. 1 piston is coming up on compression. Continue to crank the engine until the timing pin registers with the FP mark on the flywheel. Do not move the engine from this position during the remainder of the timing adjustments, which are made by moving the pump itself. Rotate the pump and its half of the coupling in the same direction as its driving shaft moves, and bring the timing mark on the coupling hub in line with the indicator point on the end of the pump housing. With the pump in this position, there will be two of the multiple holes in the flange of the driving member of the coupling in alinement with the driven member attached to the pump shaft. Insert the cap screws in these holes and draw them snugly and evenly into place. ***Caution:*** Never break any fuel injection pump connections, or remove the pump without first cleaning with fuel oil. As soon as connections are broken, cover the openings carefully with clean cloths tied in place.
40	40	40	*Filters.* Examine the primary filter, the clarifier, fuel lines, and connections. Be sure that they are secure, in good condition, and are not leaking. If due, or if inspection reveals cleaning or replacement of the filter elements is desired, replace the filter element in the clarifier as directed in paragraph 40*k*, and clean the primary filter as instructed in paragraph 40*l*.
41	41	41	*Air Cleaners.* Inspect the connections to both air cleaners. If they show signs of deterioration, replace them. To eliminate strain on connections, be sure the pipes line up. All joints between the air cleaner and the manifold and cylinders must be tight to secure efficient operation of the unit. All gaskets should be in good condition, and the bolts drawn up tight. Clean and service as instructed in paragraph 93.
42	42	42	*Nozzles and Injectors.* Inspect the fuel injection nozzles for spray pattern and opening pressure To observe the pattern, remove one nozzle at a time and connect it to the fuel line. Run the engine on the remaining cylinders so that the injector being tested sprays into the atmosphere. Check the spray against those shown in figure 27. ***Caution:*** Keep hands and other parts of the body out of the path of the spray when testing. The fuel is ejected with sufficient force to penetrate the flesh. (A) shows the correct pattern; (B) indicates that the balls of the seats of the check valve are worn, the spring is deformed, or dirt is in the valves; (C) indicates the sprays run together, probably due to worn nozzle holes. In (D) dirt in the nozzle holes or canals has caused an uneven spray. If the spray openings of the injectors are clogged, clean them by inserting a thin, hard, brass wire, not larger than #28, or 0.0126 inch (0.317 mm). If the spray pattern does not then conform to the correct pattern (A), the injectors and nozzles must be cleaned (par. 91). If cleaning does not correct the trouble, replace the worn parts, or the entire assembly. Inspect the primer spray nozzle. Be sure that it is not clogged or dirty. Disassemble the nozzle and insert a wire through the openings.
43	43	43	*Tank, Filler Element, Cap and Gasket.* Inspect the fuel oil and gasoline tanks to see that they are in good condition and securely mounted. Examine caps for defective gaskets or plugged vents. See that the filler necks are in good condition, and the caps fit securely. Check fuel lines and fittings. Make sure that they are in good condition, supported securely, and are not leaking.

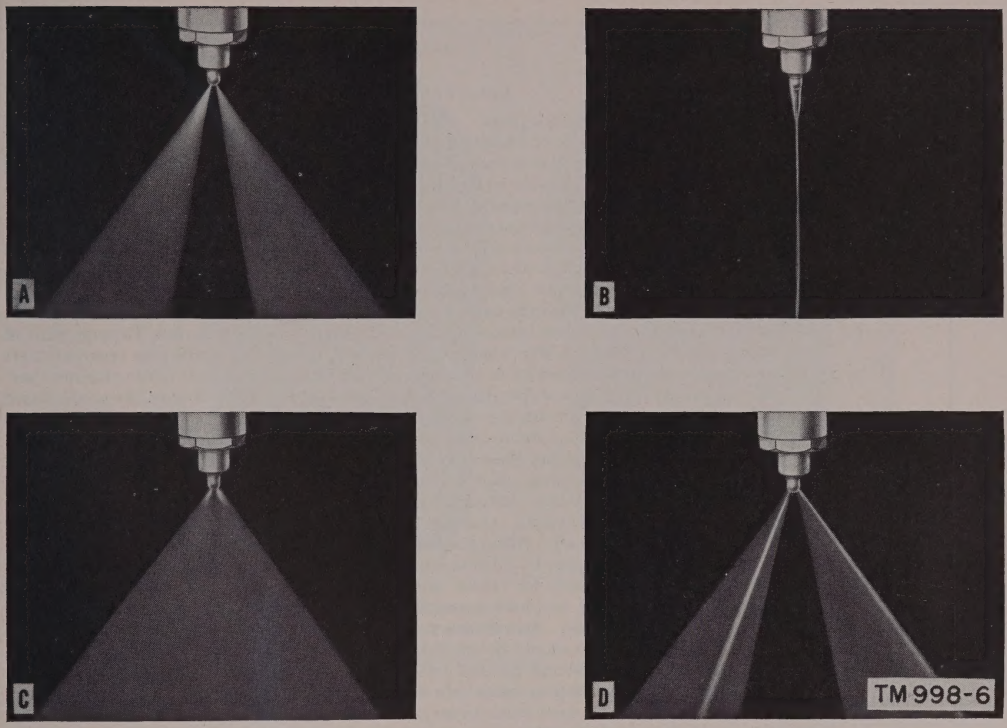
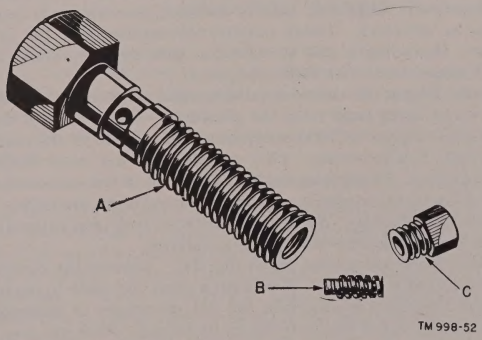


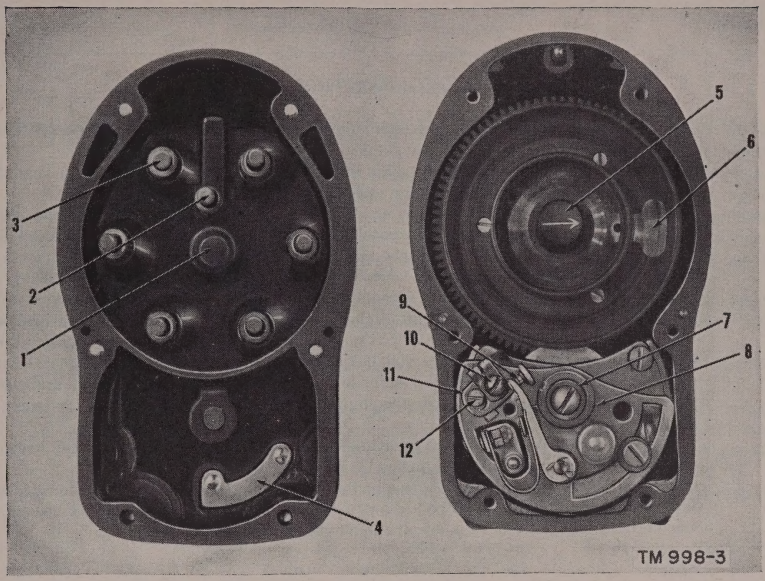
Figure 27. Injector nozzle spray patterns.



A. Hollow cap screw.
B. Brass whirler fitting.
C. Spray tip.

Figure 28. Primer spray nozzle.

Tech. insp.	Semi-annual	Monthly	Instructions
			ELECTRIC SYSTEM
		46	*Spark Plugs.* Check the spark plugs. Make sure that their insulators are clean and in good condition. Note any evidence of leakage around the insulators, or gaskets.
	46	46	Remove the spark plugs, one at a time, and check for condition. Clean and replace each plug before removing those in the other cylinders. Pay particular attention to broken insulators, excessive carbon deposits, and electrodes which are burned thin. Report excessive deposits or damaged insulators, as these conditions may indicate incorrect heat range. *Clean.* After the plugs have been removed, wash them in solvent (SD) and dry. Check the insulators at this time to determine if they are cracked, or have lost their glaze due to harsh cleaning methods (sand blasting, filing, scraping, or grinding). If any of the plugs are defective, replace them with the same kind of plugs as used in the original equipment. Do not replace cleaned plugs until excess fuel has been purged from the cylinders. To purge, shut off the fuel oil by holding the stop lever in OFF position. With one spark plug removed, start and operate the unit on gasoline in the same manner as for operation in arctic climates (par. 23). Run the engine on five cylinders at a moderate speed. This will blow the accumulated fuel out of the combustion chamber through the spark plug opening. After operating for 30 seconds in this manner, stop priming the engine with gasoline. Shut the unit down, and replace the dried spark plug. Repeat these operations for each cylinder. ***Caution:*** The spark plugs used in the oil engine have electrodes that project much further into the combustion chamber, and are much sturdier than conventional plugs used in ordinary gasoline engines. Ordinary gasoline engine plugs will not fire the charge in this engine, and cannot be used. Always replace plugs with new ones identical to those removed.
		46	*Adjust.* Adjust the gaps to 0.018 to 0.020 inch (0.467 to 0.483 mm) with a feeler gage.
47	47	47	*Battery.* Inspect battery case for cracks and leaks. Clean top of battery. Inspect cables, terminals, bolts, posts, straps, and hold-downs for good condition. Test specific gravity and make record on WD AGO Form 464. Specific gravity readings below 1.260 indicate battery should be recharged. Electrolyte level should be one-half inch above the tops of the plates. Bring electrolyte to proper level by adding distilled water. Clean entire battery and carrier. Repaint carrier if corroded. Clean battery cable terminals, terminal bolts and nuts, and battery posts, and grease them lightly. Inspect bolts for serviceability. Carefully tighten terminals and hold-downs to avoid damage to battery.
48	48	48	*Battery-Charging Generator, Voltage Regulator, and Ammeter.* Note if these items are in good condition, securely mounted, and if wiring connections are clean and secure. During operation of the unit, the ammeter should show a positive reading. If it shows a negative reading, batteries may be improperly connected, battery-charging generator may require servicing, or voltage regulator may be defective. Check battery connections (par. 11*d* (1)), and clean and service the generator. If reading is still on discharge side, replace voltage regulator. Clean the charging generator commutator with #000 sandpaper. ***Caution:*** Do not use emery or carborundum cloth on commutator or brushes. Remove the cover band from the generator. Cut a stick of dry wood the width of the commutator; place a piece of #000 sandpaper over the end of the stick and hold it against the commutator while it is revolving. Blow out all dust, and check the height of the mica between the commutator bars. If the mica is above the level of the commutator bars or if the commutator is badly pitted or worn, remove it, and have it turned down in a lathe.
49	49	49	*Distributor or Magneto.* See if the distributor body and external attachments are secure and in good condition. Examine other parts as follows: *Distributor block and breaker points* (fig. 29). Remove the distributor block by backing out the screws which hold it in place. Wipe with a clean, dry cloth to remove all traces of dirt. Polish the brush track with fine crocus cloth (do not use emery or sandpaper). Examine the distributor brush (2) to see that it moves freely in its holder. Blow out any dirt in the distributor opening with dry air. *Breaker box and points.* Remove the breaker box cover plate and wipe with a dry cloth to remove all traces of dust. Examine the breaker points. Be sure that they meet squarely and are free of pits and ridges. Use a fine-grit hone to dress the points. Round the stationary point very slightly to be sure it has no ridge around the edge. Wipe the points with a clean cloth, making sure that all grease and oil has been removed from this part of the mechanism. If the breaker points are badly pitted, replace both points. Replace the capacitor as a defective capacitor is frequently the cause of pitting. Apply a small quantity of PET (Petrolatum) to the fiber lobe of the moving contact arm. Adjust the breaker points 0.012 to 0.016 inch (0.30 to 0.40 mm) gap. Use the feeler gage supplied with the unit to check the gap.



1. Inspection window.
2. High tension distributor brush.
3. Spark plug cable contact brush.
4. Grounding plate.
5. Indicator arrow.
6. Distributor rotor segment
7. Interruptor cam.
8. Cam lubricating felt wick
9. Contact points.
10. Contact bracket fastening screw.
11. Contact bracket
12. Adjusting screw.

Figure 29. Heavy duty magneto, oil engine.

Tech. insp.	Semi-annual	Monthly	Instructions
			ELECTRIC SYSTEM—Continued
50	50	50	*Coil, Wiring, and Switches.* All high-voltage wiring (spark plug cables) should be in good condition and securely fastened to all support mountings and terminals. All insulation and connections should be secure. If insulation has rubbed or burned off of any cable, it will short circuit. Oil saturated cables and dirty cables may cause the engine to miss. Inspect all low-voltage wiring (safety control circuit) on the engine in the same manner. Inspect capacitors for condition and connections.
			Note. Do not tighten wiring connections unless actually loose, as overtightening of terminals will cause damage.
			Check all the items on the switchboard to see that they are clean, dry, in good condition, securely mounted, and see that all electrical connections are secure. See that all fuses are held securely by their clips, and that contacts are clean.
	51		*Voltage Regulator.* Inspect the voltage regulator to be sure that it is securely mounted and in good condition. To test the regulator, start the unit, and, with the unit delivering rated voltage at full load, turn the exciter field rehostat in the resistance-all-in position until the a-c voltage drops about 10 percent. Normal values of a-c voltage can then be controlled by manipulating the exciter field rheostat. To check regulator operation, place the unit on automatic control by turning the exciter field rheostat to resistance-all-out position, and check the voltmeter. If the voltmeter reading is approximately 240 volts, voltage regulator is operating satisfactorily.
52	52	52	*Lights.* Check the instrument panel. Be sure that the green jewel light is lit during operation of the unit.
53	53	53	*Circuit Breaker.* Inspect the circuit breaker to see that it is securely mounted and in good condition.

Tech. insp.	Semi-annual	Monthly	Instructions
			CONTROL SYSTEM
57	57	57	*Gages.* Check the gages on the engine instrument panel during the operation of the engine and observe as follows: *Lubricating oil pressure.* Check oil pressure at frequent intervals. Be sure that the oil-pressure gage is approximately 40 pounds per square inch at governed speed. ***Caution:*** If the gage indicates less than 10 pounds, and the safety switch has not shut the engine down, stop the engine immediately and investigate the cause. (Also check safety switch.) *Water temperature gage.* Check the temperature gage to be sure that it indicates in the normal range. The temperature should increase gradually during the warm-up period, and normally should not exceed 170°–190° F. The temperatures at which the gage hesitates during warm-up period indicate the opening of the four thermostats. Extremely low temperatures, after a reasonable warm-up period, may indicate that one (or more) of the thermostats is stuck open. Temperature above normal may indicate that the thermostat is stuck closed, or that the cooling system is clogged. If the gage indicates the water temperature is higher than 205° F., and the safety switch has not shut the engine down, stop the engine immediately and investigate the cause. (Also check the safety switch.) *Vacuum gage.* With the unit operating at full load the vacuum gage should record a manifold depression of not more than 1¼ inches. *Fuel oil pressure gage.* The reading of the fuel oil pressure gage on the engine instrument panel should read approximately 25 pounds with the engine hot. This gage is connected to the fuel oil clarifier and registers the pressure of the oil going through the clarifier.
58	58	58	*Meters* *Battery-charging ammeter.* Check the reading of the battery-charging ammeter located on the left side of the engine above the magneto. Be sure that it indicates a slight positive charge when the unit is running normally. If the battery is low a high charge should be indicated. The ammeter needle should show only slight fluctuations. *Frequency meter.* The frequency meter is adjusted to operate correctly at its rated voltage. If on checking it is determined the frequency meter is not operating correctly replace the instrument. *Total hour meter.* Check the total hour meter to be sure that it is recording.
71	71	71	*Safety Controls.* The green light on the engine instrument panel should be on and the two red lights should be off.
			GENERATORS
172	172	172	*Armature, Commutator, and Slip Rings.* Check bearing lubrication and lubricate if due, or if inspection reveals lubrication is necessary. Remove the exciter wrap-around cover, and inspect the unit. Remove any accumulation of dirt or grease with solvent (SD). Blow dirt out away from the windings with a medium blast of compressed air. Enamine the brushes. Be sure that the pigtails are securely fastened to the brush holders; that exciter brushes move freely in their holders; and that brushes have good contact surface with collector rings and commutator, along the engine brush face. Adjust spring tension according to brush wear. Generator brushes are designed to have a wearing depth of three-quarter inch. The lever assembly and spring are designed so that, for each ¼-inch of brush wear, correct brush pressure can be maintained by moving the spring arm one notch. If brushes are worn so that correct pressure cannot be maintained by this adjustment, new brushes must be installed. While the unit is operating, check exciter commutation, and sparking of commutator brushes. If the commutator is black or dirty, wipe it with a piece of dry canvas (or other hard, lint-free material) wound around a block of wood held against the commutator as it rotates.

Tech. insp.	Semi-annual	Monthly	Instructions
			GENERATORS—Continued
173	173	173	*Controls, Switchgear, and Wiring.* Check wiring for broken insulation and for tight, properly insulated connections. Check the insulation resistance of the windings of the stator and rotor of both the alternator and exciter with a megger (megohmmeter). The insulation resistance of new machines should not measure less than 1 megohm. Although insulation resistance varies greatly in different machines, regulator measurements of the same machine in the same temperature will reveal any abnormal condition of the insulation, and steps may be taken to remedy it before failure occurs. To determine the insulation resistance of the windings, use the following test procedure: *Alternator stator test.* Open the circuit breaker; connect the megger to a stator lead. This may be done where either stator lead is connected to the switchboard. Connect the other side of the megger to ground. *Alternator rotor test.* Lift the brushes from the slip rings; connect the megger between a slip ring and ground. *Exciter armature and field test.* Open field switch on control panel. Test by connecting the megger to one of the brushes and ground. Check all items on the switchboard to be sure they are clean, dry, secure, and in good condition, and that electric connections are tight. See that all fuses are held securely by their clips.
174	174	174	*Drive Coupling.* Remove cover from exciter and coupling, and check for presence and tightness of all nuts, cap screws, and bolts.

48. Weatherproofing Power Unit PE–220–C.

a. General. Signal Corps equipment, when operated under severe climatic conditions such as prevail in tropical, arctic, and desert regions, requires special treatment and maintenance. Fungus growth, insects, dust, corrosion, salt spray, excessive moisture, and extreme temperatures are harmful to most materials.

b. Tropical Maintenance. A special moistureproofing and fungiproofing treatment has been devised, which if properly applied, provides a reasonable degree of protection. This treatment is explained fully in TB SIG 13 and TB SIG 72.

c. Winter Maintenance. Special precautions necessary to prevent poor performance of total operational failure of equipment in extremely low temperature are fully explained in TB SIG 66.

d. Desert Maintenance. Special precautions necessary to prevent equipment failure in areas subject to extremely high temperatures, low humidity, and excessive sand, and dust are fully explained in TB SIG 75.

e. Lubrication. The effects of extreme cold and heat on materials and lubricants are explained in TB SIG 69. Observe all precautions outlined in TB SIG 69 and pay strict attention to all lubrication orders when operating equipment under conditions of extreme cold or heat.

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CHAPTER 4

REPAIR INSTRUCTIONS

Section I. THEORY OF OPERATION

49. General

The function of the oil engine in Power Unit PE–220–C is to drive the alternator through a flexible coupling attached to the engine flywheel and the alternator rotor shaft. An instrument panel mounted on the engine contains the necessary gages and switches to control the engine output. A separate switchboard is equipped with switches and instruments for controlling the alternator output. The functioning and operation of the complete power unit and its assemblies are described in the following paragraphs.

50. Oil Engine

a. General. The engine in this unit is a spark-ignition type oil engine, operating with certain modification on the usual principles of the four-stroke cycle internal-combustion engine, with intake, compression, power, and exhaust strokes. The air-fuel ratio remains constant within close limits regardless of load. The engine is similar to a gasoline engine, except that the intake charge is air alone and the liquid fuel is metered and injected as in a Diesel engine. The mixture of fuel and air is fired in the combustion chamber by a spark plug.

(1) In order to mix the air and fuel, the intake air, as it enters the cylinder through the ports in the cylinder head, is given a rotary motion which forces it around the vertical axis of the cylinder. This rotary motion, which is approximately five times crankshaft speed, assures sustained turbulence through the intake and compression strokes.

(2) The combustion chamber consists of a deep, bowl-shaped depression in the top of the piston, the bottom of which extends below the level of the upper piston rings. The incoming fuel charge is sprayed into the combustion chamber, where, striking the walls of the combustion chamber, it picks up residual heat which aids in vaporization of the fuel.

(3) Fuel is injected into the combustion chamber by means of the injection pump and spray nozzle when the piston is at the approximate top of its compression stroke. The injection nozzle has two orifices and the nozzle is so positioned that the two jets of fuel from these orifices are sprayed in two directions; one following the direction of turbulence within the combustion chamber, and one counter to it. The turbulence within the combustion chamber thoroughly mixes the fuel and air while the heat created by compression, and that picked up from the walls of the combustion chamber, thoroughly vaporizes the charge so that it may be readily ignited by the spark plug. Air is drawn into the combustion chamber through the intake valve while the piston is moving downward on the intake stroke. This air is drawn in through the intake valve which opens 8° after TDC (top dead center) and closes 40° after BDC (bottom dead center). The ignition spark is timed to occur 12° before TDC and can not be advanced or retarded. The exhaust gases are forced out of the cylinder through the exhaust valve on the exhaust stroke. This valve opens 40° before BDC and closes 10° after TDC. In general, the action in this engine is the same as occurs in a conventional

gasoline engine with the exception that the fuel is injected into the combustion chamber where it is mixed with air instead of being mixed before entering the combustion chamber as in the gasoline engine.

b. Air-Fuel Ratio (figs. 30 and 31). The proper air-fuel ratio is maintained by a vacuum control unit which is encased in a cast aluminum housing, bolted to the rear of the fuel injection pump. A cylinder liner (G, fig. 31) is pressed into the housing and is fitted with a spring loaded piston (K, fig. 31), sliding in the cylinder. The sliding piston has a hollow stem, threaded inside, which passes through a bushed hole in the back wall of the housing so that it travels freely. The space between the back wall and the piston is the vacuum chamber housing the adjusting springs (D and H, fig. 31). This vacuum chamber is connected to the engine side of the butterfly valve in the air intake manifold (E, fig. 31). The space on the other side of the piston is connected by another tube (L, fig. 31) to the atmospheric pressure between the air cleaner and the intake butterfly. A threaded adjusting screw with the end enlarged and counterdrilled to receive the auxiliary stop spring (M) and the operating extension of the injection pump fuel-volume control rod (P) is screwed into and extends through the hollow piston stem. An elongated slot is cut through the sides of the stop-spring housing (R), through which the ends of a pin (N) project. This arrangement provides the free linkage necessary to allow manual fuel control independent of the governor and vacuum, in order to stop the engine. The springs (D and H) which tend to push the piston to the right when fully extended, push the injection pump fuel-volume control rod (P) wide open if there is no vacuum drawing the piston to the left. When the air throttle butterfly closes, the vacuum in the intake manifold increases and draws the piston against the springs, thereby cutting down the fuel supply. Air-fuel ratio is, therefore, controlled by the balance of the spring tension to the intake vacuum. Two springs are required because the air-fuel ratio is set leaner for light loads than for heavy loads. The outer spring (H) regulates the movement of the fuel control piston from full load to 60 percent load; from 60 percent load to no load, control is taken over by the stiff inner spring (D). The vacuum control unit not only maintains the proper air-fuel ratio, but also functions as a speed stabilizer. For example, if the engine should overspeed, the governor weights will close the air throttle. This increases the vacuum, drawing the piston against the spring, moving the fuel metering rack toward the stop position. This decreases the amount of fuel injected, and lowers the engine speed. Conversely, if the engine slows down when idling with the throttle valve in a fixed position, the manifold vacuum decreases, the spring moves toward full load position, more fuel is injected, and the engine picks up speed.

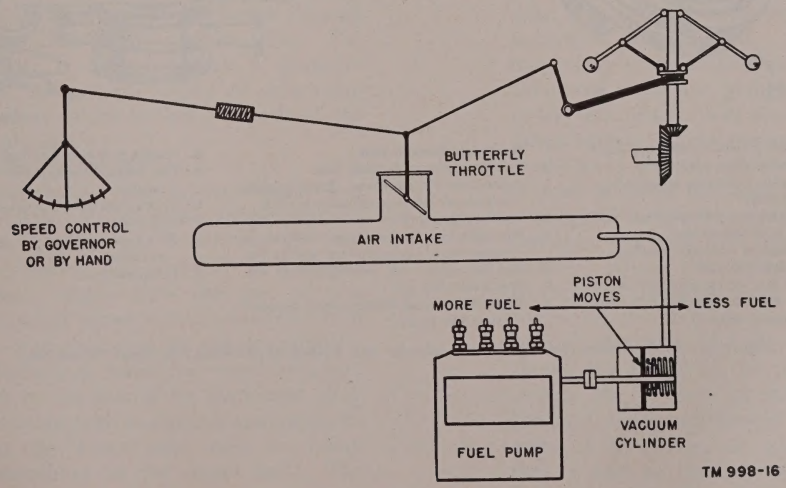
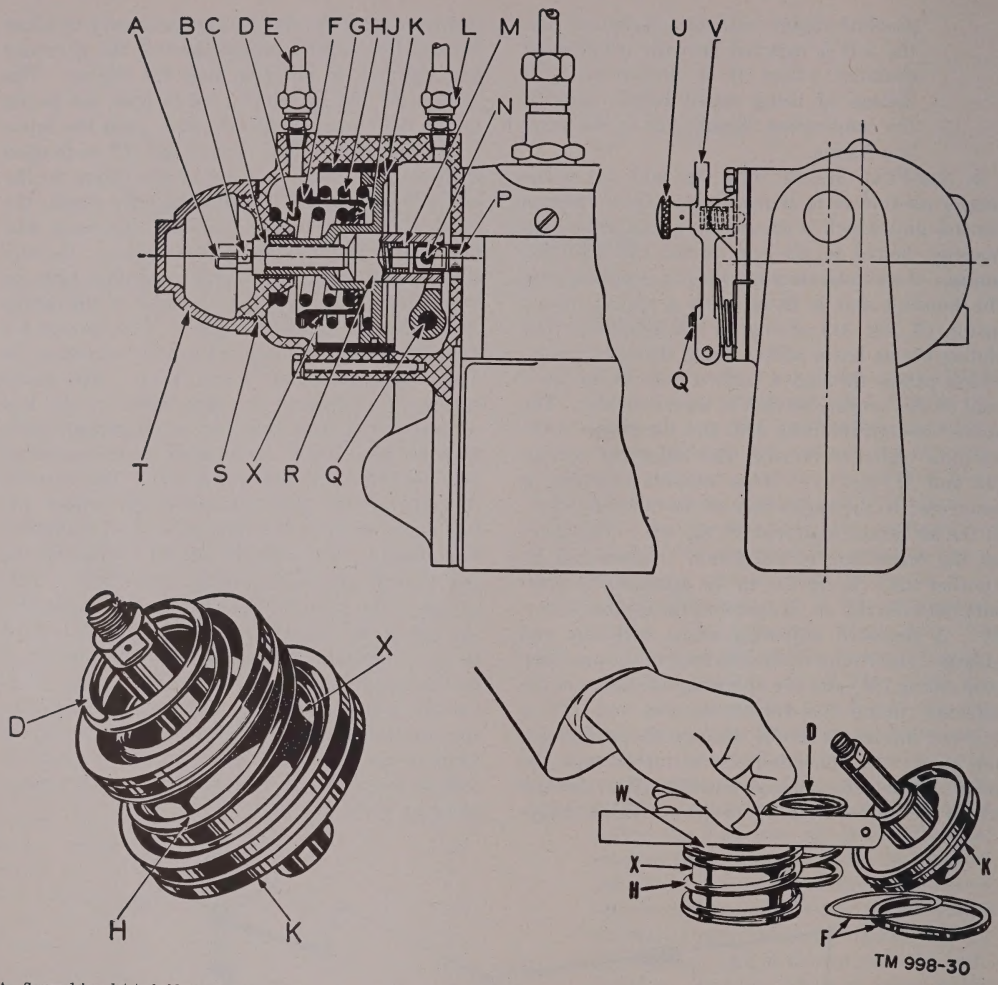


Figure 30. Schematic diagram of vacuum control hook-up.



A. Screw drive slot to hold piston stem insert while adjusting position of piston.
B. Cotter or locknut for locking adjustment.
C. Hollow piston stem.
D. Stiff inner spring for controlling fuel ratio from idling to 60 percent load.
E. Vacuum connection to intake manifold.
F. Shims to regulate *free travel*.
G. Stainless steel liner for vacuum cylinder.
H. Outer spring which controls fuel ratio from 60 percent load to full load.
J. *Free travel* measured here.
K. Vacuum piston with piston ring.
L. Connection to atmosphere. Must be made between air cleaners and throttle valve.
M. Auxiliary stop spring.
N. Pin connecting injection pump fuel volume control rod to vacuum piston mechanism.
P. Injection pump fuel volume control rod.
Q. Stop lever pivot pin.
R. Stop spring housing, enlargement of threaded piston stem insert.
S. Gasket to exclude dirt from mechanism.
T. Cap which is removed for making adjustments.
U. Locking pin to hold stop lever in position.
V. Stop lever.
W. Disk approximately ⅛ inch thick (not furnished).
X. Spring retainer.

Figure 31. Cross-section view of vacuum cylinder and method of checking free travel dimension.

c. Fuel System.

(1) *General.* Fuel oil is drawn from the supply tank, through a primary filter, into the fuel delivery pump, and then to the fuel oil clarifier. From the clarifier, the oil passes through a diaphragm-type surge valve into the sump of the injection pump. The injection pump delivers the correct amount of fuel to the respective nozzles at the proper pressure and the proper time.

(2) *Primary filter.* The primary filter consists of a series of thin disks spaced 0.002 inch apart. Fuel passes from the outside of the element through the fine spaces. All foreign matter coarser than 0.002 inch is removed by the disks.

(3) *Fuel oil clarifier* (fig. 24). Fuel oil is forced into the fuel oil clarifier by the primary fuel pump. Fuel enters the clarifier through the inlet connection and flows down through the clarifier to the cartridge. The cartridge is a block of fuller's earth surrounded by layers of ribbed cellulose. More layers of cellulose and a wire screen line the cartridge. A hollow-center tube passes through the bore of the cartridge. The fuel slowly passes through the cartridge which removes resins, gums, acids, and dirt. The clarified oil then enters the hollow-center stud, flows up through the stud, and discharges out of the clarifier through the outlet connection (fig. 24). The clarifier is equipped with a pressure-relief valve. The outlet of this valve connects to the low-pressure side of the supply line.

(4) *Injection pump* (fig. 20).

(*a*) *Description.* The injection pump is a constant-stroke, cam-actuated, lapped-plunger pump. It meters the fuel accurately, and delivers it at a precise time, under high pressure, to the injection spray nozzles, through which it is injected into the engine cylinders. The pump, which has a self-contained drive, consists of an aluminum alloy housing, with a camshaft compartment in the lower half, and six pump assemblies in the upper half. The camshaft compartment contains a camshaft, turning on ball bearings, supported by the end plates. Felt cushions in the closing plugs in the housing base facilitate lubrication of the cams and roller followers of the tappet assemblies. Directly above these are the plunger and barrel assemblies, control sleeves with toothed segments, plunger return springs, spring seats, and the control rod. The upper half of the housing contains the fuel sump, delivery valve assemblies and gaskets, delivery valve springs, delivery valve holders, and nipple nuts for connection of the discharge fitting.

(*b*) *Operation.* Six individual injection pumps are provided within the injection pump assembly. Each injection pump consists of a barrel and plunger assembly. The plunger has a groove around its circumference which has a circular lower and a helical upper edge. The space thus formed communicates with the top face of the plunger through a vertical slot. Hence, any fuel above the plunger will flow down the vertical slot and fill the helical space. At the lower end of the plunger are two lugs which fit into corresponding slots in the bottom of an outer sleeve fitted around the pump barrel. The upper part of the sleeve is fastened to a gear segment which meshes with a horizontal toothed rack. Any axial movement of the toothed rack rotates the outer sleeve and plunger, relative to the two inlet ports in the stationary pump barrel. At the beginning of the discharge or delivery stroke, the pump plunger is below the inlet ports, permitting the fuel to flow into the pump chamber, vertical slot, and helical groove. When the plunger begins its upward movement, it gradually covers the two inlet ports, preventing further admission of fuel. The continued movement of the plunger increases the pressure of the trapped fuel until the spring force of the check valve is overcome, at which point fuel is sent to the injection nozzle. Before the end of the discharge stroke, however, the helical edge in the

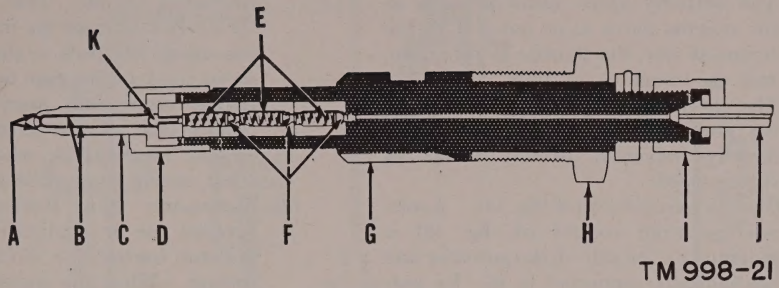
plunger uncovers the inlet port on one side allowing the fuel to flow back to the inlet. This produces an immediate drop in fuel pressure so that the check valve closes sharply, thus stopping further delivery to the injection nozzle. Rotating the pump plunger by means of the toothed rack causes the helical groove to uncover the inlet port sooner, or later, during the stroke of the plunger, thereby controlling the amount of fuel delivery for every throttle position. In this way, the fuel charge is made to suit engine load requirements. The teeth of the gear segment engage corresponding teeth on the control rod. By shifting the control rod, either manually or by a governor, the plunger is rotated in its barrel in either direction. The less the control rod is moved away from its stop position, the less the plunger turns in the barrel, and the sooner the helix opens the bypass port, resulting in a smaller fuel delivery per stroke. The reverse action takes place when the control rod is farthest away from its stop position, resulting in a larger fuel delivery per stroke. For maximum fuel delivery, the control rod is farthest from its stop position and the plunger is turned farthest in its barrel, causing very late opening of the bypass port in the helix. For zero fuel delivery, with the control rod in the stop position, the plunger is rotated in the barrel until its vertical groove registers with the bypass port. In this position, the pressure chamber in the barrel is in constant communication with the sump during the entire mechanical stroke of the plunger. Therefore, no fuel is delivered by the plunger. The external control of the fuel delivery per stroke is accomplished by the control rod, one end of which is connected to the engine governor. When the control rod is in the stop position, the rod must be moved about three-sixteenths inch from its full stop position before fuel delivery starts. After the control rod has moved three-sixteenths inch, the quantity of fuel delivered is proportional to the movement of the control rod.

(5) *Injection nozzles* (fig. 32). The injection nozzle is a simple, open-type injector with three check valves in series, arranged to prevent dribbling from the end of the nozzle tip and to stop combustion pressure from backing up into the pump line. The nozzle tip, which projects into the combustion chamber, is covered, except at its extreme end, by a soft copper bushing. This bushing serves both as a gasket and as a medium for quickly conducting heat from the tip of the walls to the cylinder head. Two spray holes at the end of the nozzle tip force the fuel out in two jets. To keep the spray holes in the same position with respect to the center line of the cylinder, each nozzle tip has a half-round lug on the end where it joins the nozzle body. This lug locates the spray holes in a fixed position with regard to the rest of the assembly. The lug, in turn, is located in a fixed position relative to the combustion chamber by dowels in the cylinder head which fits into a keyway (G) milled along the upper end of the nozzle body. The injector hold-down nut (H), which screws into the cylinder head, is in back of the keyway (G). Following the injector hold-down nut is the fuel connection, consisting of a washer, a nut, and a tapered sleeve.

d. Governor (fig. 33).

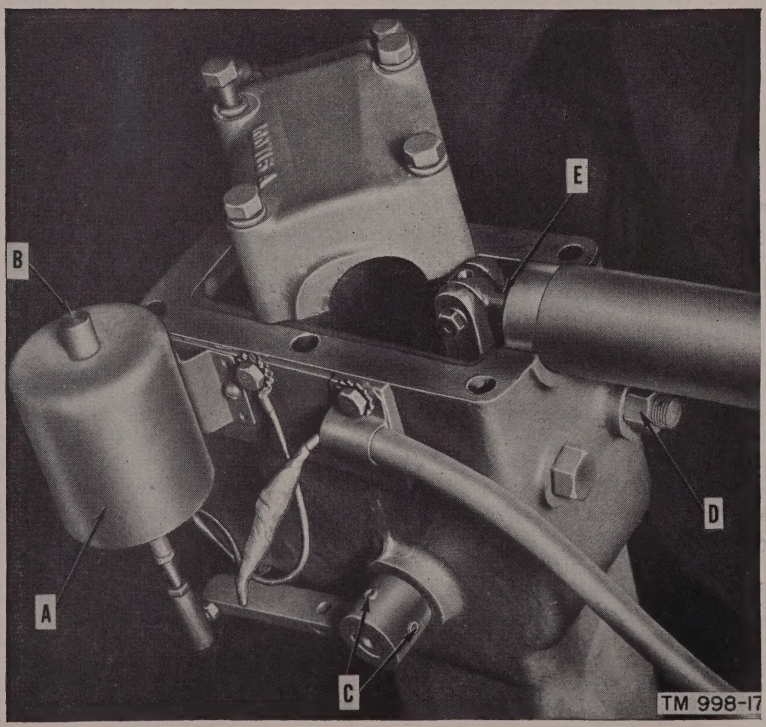
(1) *Purpose.* The purpose of the fly-ball governor is to maintain the speed selected by the operator, irrespective of load variations, within the rated limits of the unit. The governor is set to maintain an engine speed of 900 rpm, but can be adjusted to a limited extent.

(2) *Operation.* A set of revolving weights are pivoted to a driving spider so that they can move outward from the driving shaft as the rate of revolution increases. An adjustable spring opposes this outward movement, so that the amount of movement for each engine speed can be controlled. The moving weights are connected through a lever and linkage to the air throttle butterfly valve (fig. 30).



A. Twin openings in nozzle tip.
B. Twin grooves in nozzle insert feed fuel to tip openings.
C. Stainless steel nozzle tip.
D. Nozzle assembly nut
E. Triple spring check valve.
F. Half ball checks.
G. Keyway slot (locates nozzle in combustion chamber).
H. Nozzle hold-down nut (screws into cylinder head).
I. Fuel line compression nut.
J. Steel fuel line.
K. Insert fang.

Figure 32. Injector nozzle.



A. Solenoid.
B. Solenoid plunger.
C. Setscrew for plunger-holding arm.
D. Bumper spring adjustment.
E. Linkage connecting to butterfly valve.

Figure 33. Governor control.

The butterfly valve opens or closes as the weights move in or out. With the engine at rest, the throttle is wide open, and the weights are fully contracted. The governor is gear-driven by the timing gears so that its speed is always directly responsive to any change in engine speed.

(3) *Governor solenoid control* (fig. 33). A solenoid governor control (A, fig. 33) is mounted on the side of the governor and mechanically connected to it. Its purpose is to obtain closer regulation than the governor alone can provide. It also insures automatic load sharing when the units are operating in parallel, by interconnecting the solenoid control circuits of all units operating in parallel (terminals AS 1 on 8-point terminal blocks). The solenoid coil is energized by the two 6-volt batteries, connected in series with the d-c terminal of a selenium rectifier mounted on the back of the generator control panel. The a-c input to the rectifier is obtained from a three-phase current transformer whose secondary windings are connected to give single-phase output. One primary coil of the current transformer is connected in each of the three phases of the power bus on the control panel. A switch to disconnect the solenoid from operation is located on the front of the generator control panel. Also included in the solenoid circuit is a rheostat which is used to adjust the engine speed manually.

e. Ignition System. The ignition system is similar to that on a conventional, gasoline engine. It consists of high-spark-energy magneto, impulse coupling, extra-long spark plugs, and cables. The principle condition that must be met is the proper coordination and synchronization of the electric ignition and the fuel injection systems. No provision is made for advancing or retarding the spark, as is customary with most spark ignition engines. The spark is set to operate at 12° advance.

f. Cooling System.

(1) *General.* The engine cooling system consists of a blower-type fan, core radiator, four thermostats, and a coolant-circulating pump. The coolant flows from the radiator through the oil cooler to the circulating pump. This pump forces the coolant through the water jackets of the engine and back to the radiator. A water temperature gage mounted on the engine instrument panel records the temperature of the coolant. Normal coolant temperature, when the engine is hot, should be approximately 190° F.

(2) *Thermostats.* Four thermostats located between the first cylinder head and the radiator control the circulation of the coolant. When the engine temperature is below 165° F., the thermostats are closed, and the coolant from the engine jackets is shunted through a bypass line back to the pump. When the thermostats are open, the coolant flows through the radiator, where it is cooled, and then back to the pump. The limited circulation allowed by the thermostats during warm-up permits the engine to reach normal operating temperature quickly and prevents the formation of steam pockets. The thermostats start to open when the coolant temperature reaches 165° F., they open fully when the temperature reaches 190° F.

(3) *Coolant-circulating pump* (fig. 22). The centrifugal coolant pump, which is shaft-driven, is mounted on the intake manifold side of the engine. Stuffing pipes lead from the pump to each stuffing box. In the event of an air leak, coolant flows through these pipes, thus preventing air from entering the pump.

g. Lubricating Oil System (fig. 34).

(1) *General.* The engine is equipped with a full pressure lubricating oil system which distributes lubricating oil through positive channels to all the principal bearings and wearing surfaces. This system, which is entirely automatic, keeps oil circulating positively in these ducts as long as the engine is in operation, and the lubricating oil supply is adequate. When the engine is shut down, surplus oil on the internal parts drains back into the main reservoir. The lubricating oil system consists of a lubricating oil pump, a spring-loaded relief valve, a continuous lubricating oil purifier, and a primary, edge-type filter. Lubricating oil pressure is recorded on the lubricating oil pressure

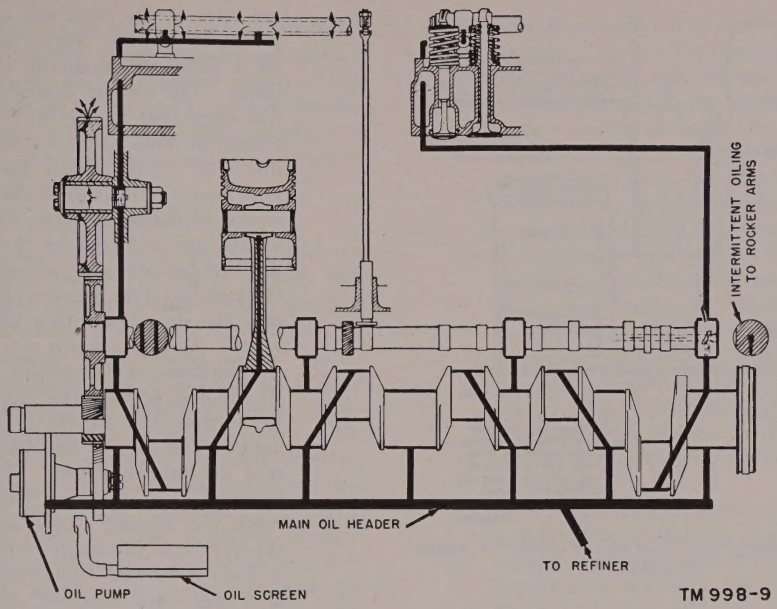


Figure 34. Schematic diagram of lubricating oil system.

gage mounted on the engine instrument panel. Pressure should be 40 pounds when the engine is hot.

(2) *Lubricating oil pump.* The lubricating oil pump is externally mounted on the front of the crankcase. This pump draws oil from the reservoir or sump in the base of the engine through an intake pipe which is provided with a screen to prevent the entrance of dirt or foreign matter. The screen assembly consists of a cup with the screen mounted above the cup opening. An adjustable, spring-loaded oil pressure relief valve is provided to control the pressure of the lubricating oil.

(3) *Lubricating oil purifier* (figs. 35 and 36). The lubricating oil purifier continuously removes dirt and counteracts acidity in the lubricating oil. Oil enters the purifier from the crankcase through the inlet pipe (B, fig. 36). The flow of oil is divided as it enters the body of the purifier, and the oil is forced upward until it completely surrounds the entire purifying mass. The dirty oil passes through the perforated metal basket (N, fig. 23), which acts as a spacer to permit the oil to surround the filtering material, and then into the mass of purifying material, toward the center outlet. As the oil moves toward the outlet, the impurities and acids are removed and retained by the filtering material. To reach the center outlet, the purified oil passes through three layers of dense wool felt and a fine mesh spacer screen surrounding the center tube. The oil then rises to the top of the center pipe and then flows down through the center pipe to the outlet (D, fig. 36).

(4) *Primary lubricating oil filter.* The primary lubricating oil filter is an edge-type, self-cleaning, all-metal filter. The element consists of a stack of flat, wheel-shaped disks mounted on a rotating spindle. The disks are separated by thin metal spacers conforming in shape to the hub and spokes of the disks, but without rims. The degree of filtration is determined by the thickness of the spacer. The stack of disks is closed at one end, the spaces between the disk spokes forming passages within the cartridge which

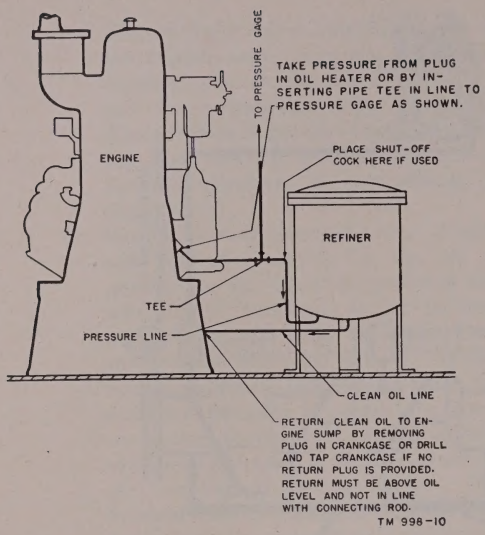
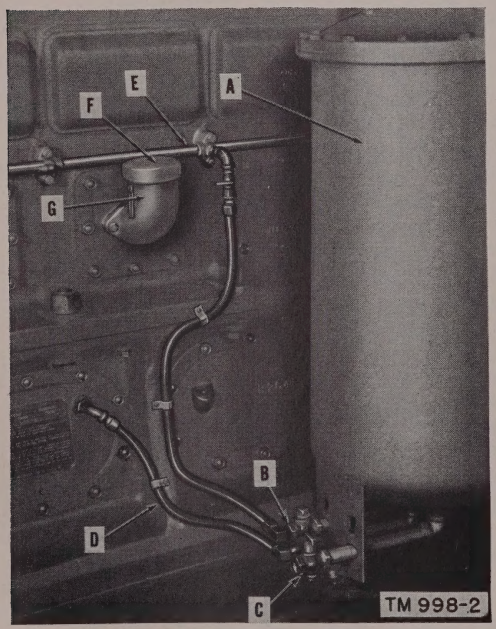


Figure 35. Schematic drawing of lubricating oil purifier installation.



A. Purifier unit.
B. Inlet.
C. Drain.
D. Outlet.
E. Main oil header.
F. Breather cap.
G. Oil filler.

Figure 36. Lubricating oil purifier piping.

are open at the other end of the outlet passage. Cleaner blades are mounted on a fixed rod alongside the stack of disks. The cleaner blades have knife-like edges that extend into the slots between the disks to the inside edge of the disk rim. Each cleaner blade is separated from the next by a spacer. Lubricating oil enters the filter, fills the outer casing, and is forced by the differential pressure between inlet and outlet to flow through the slots between the disks and into the passages within the filter element. All solids which are larger than the thickness of the spacers are retained on the disk edges. The filter is cleaned by turning the handle two full turns daily. This causes the disks to rotate past the cleaner blades. The solids are removed from the disk edges as they reach the cleaner blades and settle to the bottom of the sump. The blades are so located that all solids stopped by the filter disks are removed, whether they adhere to the disk edges or are actually lodged between the disks.

h. Air Cleaners. Each air cleaner consists of two assemblies: the body assembly, which consists of the main filter element, inlet tube, and prefilter, and the oil cup and disk assembly. Two threaded rods provided with wingnuts hold the oil cup to the upper assembly. The rods swing from a band around the body. The lower end of the rods fit into lugs on the oil cup, and the wingnuts, screwed onto the ends of the rods, hold the oil cup in place. Air enters each cleaner through the inlet tube and strikes the oil-covered disk surface. This disk deflects the air outward and upward into the prefilter. The sharp reversal of air flow creates a centrifugal action which draws the heavier, dust-laden particles down until they strike the oil-covered disk. The oil film, which is constantly moving outward on the disk, pushes the heavy dust particles outward and downward over the disk edges into the oil cup. Once normal air flow is established, the oil above the disk is driven outward toward the walls of the cleaner, and part of this oil is whipped up into a spray. Particles of foreign matter are picked up by the globules of oil that constitute this spray and are thus prevented from being drawn into the engine. Some of the oil spray is carried with the air into the outer portions of the prefilter and

the main filter. The main filter, consisting of many fine coil springs, catches the remaining dust particles. As the oil spray carried into the main filter with the air drops back down when the engine is stopped, it washes the dust particles into the oil cup and so assures a continuous washing of the main filter element.

i. Engine Safety Control System.

(1) *General.* The engine safety control system is powered by the two 6-volt batteries. The diagram showing electrical connections is shown in figure 14.

(2) *Operation.* The engine safety system shuts the engine down when the coolant temperature becomes too high or the lubricating oil pressure too low. The following devices are provided for safety control: high-water-temperature and low-oil-pressure switches, one green and two red jewel lights, a solenoid-operated fuel shut-off valve, alarm horn, and toggle switch, together with the necessary gages. As long as the coolant temperature and lubricating oil pressure are normal, the contacts of the safety switches are closed, thus energizing the circuit to the fuel solenoid valve. When the solenoid valve is energized, fuel flows to the injection pump. The green jewel light on the engine instrument panel is lighted, indicating normal unit operation. When the coolant temperature rises above 205° F., or the lubricating oil pressure drops below 10 pounds, the corresponding safety switch opens, breaks the circuit to the fuel solenoid valve, and closes the valve. This shuts off the fuel supply to the injection pump and the unit stops. In the event either switch operates, the green light on the instrument panel is extinguished, the corresponding red light lights, and the alarm horn sounds. A single-pole toggle switch is installed on the instrument panel for the purpose of turning off the horn. In case either device operates, the cause must be removed before the engine can again be started. In the case of high coolant temperature, the safety switch cannot open the solenoid valve until the coolant temperature has dropped below 170° F.

j. Battery Electrical Systems.

(1) *General.* Two 6-volt batteries (K, fig. 2) mounted on the radiator end of the base provide power for the safety and frequency control devices. In addition to the two 6-volt batteries, which are connected in series, a battery-charging generator, a voltage regulator, and a battery-charging ammeter are provided.

(2) *Battery-charging generator.* The battery-charging generator which operates when the engine is running replaces the electric energy taken from the battery. The generator is of the third-brush type, with the third brush connected to the field circuit. This provides control of the generator output by preventing the current output from exceeding its rated maximum.

(3) *Battery-charging regulator and cut-out switch.* The regulator unit consists of a voltage regulator and cut-out switch mounted on the same bracket with the battery-charging ammeter.

(*a*) *Cut-out switch.* The cut-out switch cuts off the battery when the unit is stopped. This prevents the battery from discharging through and damaging the generator when the unit is not operating. This magnetically-operated switch, which connects or disconnects the generator and battery, consists of a solenoid, a stationary contact point, and a moving contact point which is mounted on the armature. The contacts are held open by spring action of the armature when the generator is not operating. The solenoid has two windings: the first, a voltage or shunt winding of many turns of fine wire, and the second, a current winding of a few turns of heavy wire. The same side of the shunt winding is always grounded so that the current always flows through it in one direction, thus creating a magnetic field that tends to close the switch. The current winding works with the shunt winding against the armature spring tension when the generator or engine is operating, pulling down the armature and closing the contacts points, thereby connecting the generator to the battery. When the generator

stops, battery current flows through the solenoid in the opposite direction to that of a generator current. With the magnetic field reversed, this counteracts the effects of the shunt-winding field, and the armature spring tension opens the switch immediately.

(*b*) *Voltage regulator.* The voltage regulator prevents excessive voltage which may harm the battery. The regulator actually is a magnetic switch consisting of two solenoids: a flat armature and a pair of contact points, one contact on the armature, the other stationary above the armature. The voltage regulator cuts-in or shorts-out a fixed resistance in the battery-charging generator field. The generator field circuit is completed through the contacts directly to ground. This permits the generator output to increase to a maximum. As the battery approaches a charged condition, it causes a corresponding voltage increase at the generator, the increase becoming great enough to operate the voltage regulator. When the regulator operates, the voltage is high enough to create a magnetic field sufficiently strong to overcome the armature spring tension. When the points are separated, the generator field circuit current flows through the resistance to ground, resulting in reduced field current and a reduced generator output. As long as the battery remains at full charge, the resistance remains in the generator field circuit. As soon as the battery partially discharges, and its voltage drops below a certain value, the lowered voltage is insufficient to retain the armature in the down position. Spring tension then pulls the armature up, the points close, and the generator delivers normal output.

51. Cranking Engine

a. General (fig. 37). The function of the cranking engine is to crank the oil engine. The cranking engine is a complete four-cylinder, four-stroke cycle, automotive-type gasoline engine provided with a clutch and bendix drive assembly. The functioning of the components and systems of the cranking engine are described below.

b. Cooling System. The cranking engine cooling system is connected to the oil engine cooling system. From the bottom of the oil engine radiator, the coolant is led to the inlet of the main engine coolant pump and, by a smaller line, to the inlet of the cranking engine coolant pump. After the cranking engine has started, and until it reaches normal operating temperature, coolant from the outlet at the top of engine is bypassed directly back to the coolant pump to provide a recirculation that enables it to warm up quickly. When the outlet coolant reaches operating temperature, the bellows of the thermostat begins to open so that only part of the coolant is sent through the bypass. The bellows is fully expanded at 190° F., and the full volume of coolant flows through the outlet pipe. The circulation of coolant in the cranking engine virtually stops when the engine is shut down.

c. Lubricating Oil System. Lubricating oil is drawn from the oil pan by a valve-type pump, mounted at the front end of crankcase and driven from the camshaft gears. The oil is forced through a rifle-drilled header in the crankcase and then through drilled passages to the three bushings supporting the camshaft. A slot is milled in each camshaft journal. This slot acts as a distributing valve and releases the oil, under pressure, through passages to jets which direct the intermittent oil streams into countersunk feed holes drilled in the large end of each connecting rod. A hole drilled in the front end of the crankcase permits oil from the pan to flow into the bottom of the gear compartment. The oil pump gear whips the oil up so that it lubricates the entire gear train. Passages are also drilled in the camshaft which lead oil from the front camshaft bushing to a hole in the idler gear hub. Crankcase oil mist lubricates pistons, cylinders, valve tappets, and main bearings. An oil-pressure gage, mounted on the same panel as the cranking engine ignition switch, indicates the proper operation of the lubricating system. Correct oil pressure is 15 pounds per square inch, when the engine is at normal operating temperature and running at governed speed. At low idling speeds, oil pressure may be as low as 5 pounds. Oil pressure is adjustable from the outside by a pressure relief valve.

d. Fuel System. Gasoline flows from the 2-gallon gasoline tank mounted on the unit through the strainer and bowl and into the carbu-

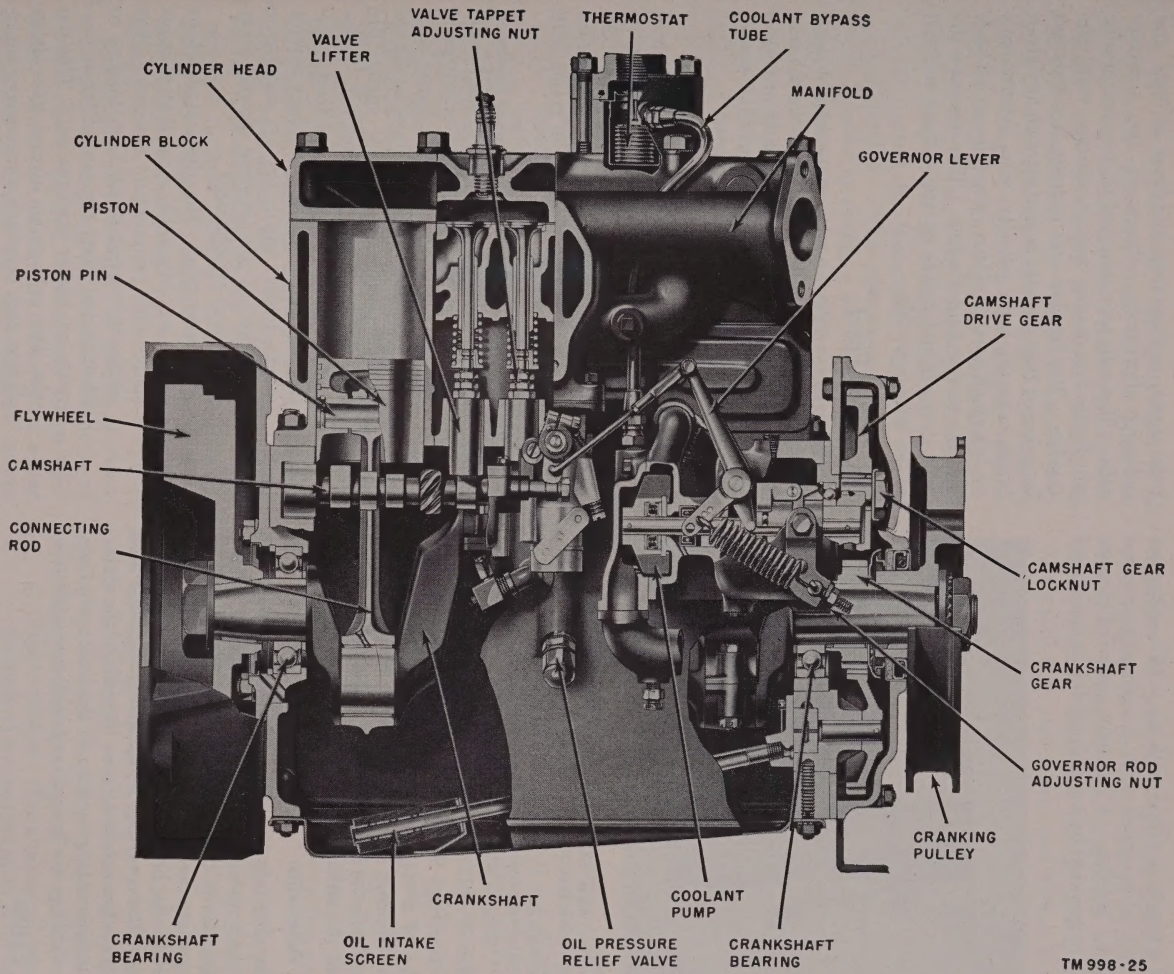
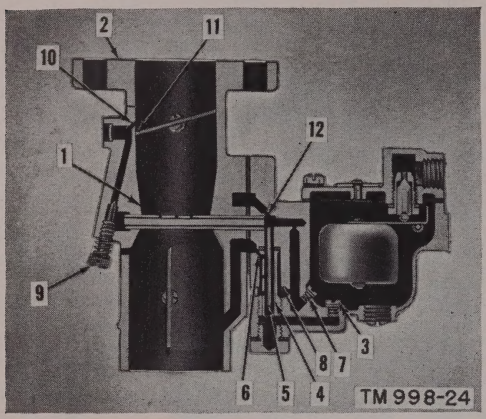


Figure 37. Side sectional view of the cranking engine.

retor where it is mixed with air. The carburetor (fig. 38) is equipped with a manually-operated choke for starting. A manually-operated throttle which is operated by a push-pull device is installed also.



1. Venturi.
2. Mounting flange (venturi size stamped on face).
3. Main jet.
4. Metering well.
5. Metering well calibration.
6. High speed air bleed.
7. Well addition jet.
8. Well reservoir.
9. Idle adjusting needle valve.
10. Idle discharge port.
11. Throttle plate.
12. Metering well air vent.

Figure 38. Sectional view of cranking engine carburetor.

e. Ignition System. The ignition system, consisting of a magneto, cables and spark plugs, is self-energizing. The spark plugs fire in 1–2–4–3 order, with the No. 1 cylinder nearest the radiator end of the unit.

52. Alternator

The alternator consists of a revolving field with slip rings riding against carbon brushes, plus a wound stator. Direct current at 125 volts from the exciter is carried into the revolving field through the brushes and slip rings. The eight poles of the revolving field, cutting magnetic lines of force when revolving past the coils of the stator, set up alternating currents in the stator windings. The windings are brought out in a star connection.

53. Exciter

The exciter consists of a stationary field assembly with 2 main poles, a revolving armature with commutator, and 4 brushes mounted 90° apart. The exciter field forms a magnetic circuit in which residual magnetism remains when the exciter is not in operation. When the unit is started, the armature revolves and carries its 27 coils past the pole pieces, cutting magnetic lines of force and inducing alternating voltages in the armature coils. The coils are connected to the commutator which revolves under, and in contact with, the brushes. The brushes and commutator bars are so arranged that the bars in contact with any given brush have the same polarity, thus generating a dc. A small portion of this current is carried back into the exciter field winding. This increases the field strength and builds up the voltage induced in the armature coils.

54. Control Panel

a. General. The function of the control panel is primarily to distribute and control the alternator output. A secondary function is to provide a manual method of adjusting the governor speed, and thereby the engine operating speed.

b. Circuit Breaker.

(1) *General.* The circuit breaker, which is rated at 600 volts, 400 amperes, is equipped with a thermal overload device, magnetic short-circuit trip, shunt trip, and auxiliary switch in series with the shunt trip.

(2) *Operation.* The circuit breaker is closed manually by lifting the operating handle to ON position. If the breaker is tripped automatically, the handle returns only to the *mid* position, and it must be moved to OFF position in order to engage the latch before it can again be closed. Automatic tripping occurs on overload (thermal overload device), or short circuit (short-circuit trip), or by automatic operation of the reverse power relay (shunt-trip attachment).

(3) *Overcurrent trip.* The thermal overload device is a bimetallic strip that changes shape with temperature changes. This causes the circuit-breaker mechanism to operate and open the circuit when currents are higher than normal. This device also acts as an inverse time delay device and prevents unnecessary interruptions on momentary overloads without altering the protection afforded in the event of short circuits or sustained overloads. If the breaker trips on overload, a few minutes must be allowed for the thermal element to cool off and reset before the breaker can be reengaged.

(4) *Short-circuit trip.* On short circuits of approximately three times breaker rating, instantaneous breaker tripping without time delay is desired. This is accomplished by the short-circuit trip. Current passing through a stationary magnet operates a moving magnet, which in turn trips the circuit breaker.

(5) *Shunt-trip.* The shunt-trip attachment consists of a tripping magnet, tripping armature, energizing coil, and cut-off switch. When the shunt coil is energized by closing a switch at some point away from the breaker assembly, the circuit breaker trips. On this installation, the shunt-trip coil is energized by the closing of the contacts of the reverse power relay described in *c* below. The cut-off or auxiliary switch is in series with the shunt trip; as it opens when the circuit breaker opens, the shunt-trip circuit is also opened. The use of this switch permits a stronger and more positive shunt-trip attachment than would be possible with a coil designed for continuous power.

c. Reverse Power Relay. The reverse power relay operates in a manner similar to a wattmeter. It acts as a safety device for the generator to insure that each unit in parallel is delivering approximately its share of the load. If one unit ceases to deliver power, and instead takes power from another unit, the reverse power relay will operate when such taken power exceeds about 20 kw (kilowatt) and will trip the circuit breaker through the shunt trip. A certain amount of leeway is necessary before the breaker trips, as a variation in load division cannot be avoided during adjustment for parallel operation. However, this variation should not exceed more than 20 kw.

d. Frequency Meter. The frequency meter indicates frequency by the resonant vibration of certain units in a row of accurately tuned steel reeds. When the instrument is connected across the alternator circuit, the electromagnet within the unit imparts impulses which are transmitted to the reeds just as one tuning fork will respond to another having the same period of vibration. The scale of the instrument is marked to correspond with the vibration frequency of the reeds and indicates the number of cps (cycles per second) of ac to which the reeds will respond. Thus, the frequency is indicated. The vibration of each reed extends over a certain range of frequency. Vibration begins at about 2 percent below the exact value to which the reed is tuned, reaches its maximum at exact value, and extends to about 2 percent above that value. Therefore more than one reed is usually in motion, and from the respective lengths of the bands formed by the vibrating reeds across the scale opening, the exact value of the frequency may be read.

e. Switches.

(1) *Ammeter, voltmeter, and voltage regulator switches.* These are all similar in construction and are sustained contact, cam-operated, rotary-type, differing only in the number of contact points and positions. Ammeter and voltmeter switches are provided to enable amperage and voltage readings to be taken in any phase. The voltage regulator switch cuts the regulator in or out of service as desired.

(2) *Power switch.* A 400-ampere, 500-volt, 3-pole, single-throw nonfusible switch is mounted on the back of the panel and operated from that position. Load connections are made to this switch.

(3) *Alternator field switch.* The alternator field switch is mounted on the back of the panel, but operated from the front. It is a 2-pole switch. The handle is equipped with a latch device in the form of a button projecting from the handle that must be depressed to either open or close the switch.

(4) *Synchronizing lamp switch.* This switch, which is used to close the synchronizing lamp circuit in preparation for paralleling two or more power units, is a spring-contact, single-pole, single-throw switch.

(5) *Toggle switch.* A single-throw, double-pole toggle switch is used to open the automatic frequency control circuit.

f. Voltage Regulator.

(1) *Voltage control.* The alternator voltage is determined by its excitation, and this in turn is determined by the amount of resistance in the shunt field of the exciter. When the load fluctuates during normal power-unit operation, the alternator voltage tends to vary considerably, dropping upon increase in load and rising when the load is decreased or removed. To keep

the a-c voltage constant within narrow limits, it is necessary to control the d-c excitation voltage being being fed to the alternator field. Under manual control, it is necessary to adjust the excitation to obtain constant voltage every time a load change occurs. The voltage regulator is used to achieve the same results automatically by varying a regulating resistance which is connected in the shunt-field circuit, in series with the exciter field circuit.

(2) *Voltage regulator operation.* The voltage regulator unit consists of a voltage sensitive control element, a voltage adjusting rheostat, a regulator resistance, and auxiliary equipment including a damping transformer, a damping resistor, a compensating resistor, and a rectifier. The voltage regulator control element consists of an electromagnet with an air gap in the magnetic circuit. Centered in the gap is an iron armature mounted on a spring-supported moving arm. At the upper end of the arm, a driving member (a setscrew with pin of insulating material) controls the position of flat springs of varying length. A silver contact button is located near the free end of each spring. As the armature moves, because of a change in the magnetism of the coil caused by a variation of the alternator voltage, the connected arm causes a various number of the silver buttons to be brought into contact or separated, as the case may be. These silver buttons short-out or cut-in steps of a regulating resistance connected in the exciter field circuit, in series with the exciter field rheostat. The variation of this resistance alters the exciter field current in the same manner as the manually operated rheostat, thus controlling the alternator voltage. When the voltage rises, the magnetizing effect of the regulator coil increases, the pull on the armature increases, and the armature moves in opposition to the pull of the coil spring, thus opening the silver buttons. As the buttons open, resistance in the field circuit increases, and the voltage drops. Conversely, as the voltage drops, the magnetizing effect of the regulator coil decreases, armature pull decreases, and the armature moves toward the pull of the coil springs, thereby closing the silver buttons. The resistance in the field circuit drops, and voltage increases. The action of the voltage regulator is very fast as the maximum travel of the moving arm is very short, thus permitting resistance to be inserted into, or taken out of, the circuit rapidly when operating conditions require such control.

(3) *Damping transformer.* To prevent swinging and to stabilize the regulated voltage, a damping transformer is used which introduces a damping effect into the regulator coil circuit. The damping transformer has a small air gap in the laminated iron magnetic circuit. This transformer has two windings: the first connected in series with the regulator coil, the second connected across the field of the generator. When the regulating action of the regulator causes a change in excitation voltage, there is an induced transfer of energy from one winding to the other of the damping transformer. The energy introduced into the circuit of the regulator coil, electrically damps excessive action of the moving arm. This prevents the moving arm from carrying the change in regulating resistance and the resulting change in excitation too far. The damping transformer has no effect when the regulated voltage is steady and the regulator is in balanced condition, as it operates only when the excitation is changing.

(4) *Rectifier unit.* Since the regulator is a d-c operated device, a full-wave dry-disk rectifier is used to rectify the single-phase, a-c supply to the regulator to a proportional value of d-c energy. The rectified d-c energy is independent of frequency changes, and the a-c regulator is correspondingly free of frequency error caused by small changes in the speed of the a-c machine.

Section II. TEST EQUIPMENT USED IN TROUBLE SHOOTING

55. Test Equipment Used for Power Generator Testing

To test the power generator, use a megger and bridge. Test Set I–48–B (Sig.C stock No.3F4048B. may be used for this purpose.

56. Testing Alternator and Exciter Windings

a. General. High potential tests of 1,500 volts have been made on the alternator and exciter field winding, and other windings have been tested at twice their normal voltage plus 1,000 volts. No failure of insulation resistance is anticipated, but every precaution should be taken to prevent moisture on the windings or any mechanical damage to them during handling of the unit. An injury to any part of the windings may cause a coil to burn out or may cause a short circuit.

b. Resistance Tests. The insulation resistance of the windings of the stator and rotor of both alternator and exciter can be determined with a megger. The insulation of new machines (cold) should not measure less than 1 megohm. The insulation resistance varies greatly in different machines, but regulator measurements on the same machine at the same temperature will detect any abnormal condition of the insulation, and steps may be taken to remedy it before failure occurs. To determine the insulation resistance of the windings, use the following test procedure:

(1) *Alternator stator test.* Open the circuit breaker. Connect the megger to a stator lead, where either stator lead is connected to the switchboard. Connect the other side of the megger to the ground.

(2) *Alternator rotor test.* Lift the brushes from the slip rings. Connect the megger between a slip ring and the ground.

(3) *Exciter armature field test.* Test these together by connecting the megger to one of the brushes and the ground. Before testing, open the field switch on the control panel.

c. Short Circuit and Open Circuit Tests.

(1) Using the megger, check the resistance between lines on the alternator. All three resistances should be equal. If infinite, stator winding is open. If resistances are unequal, shorted turns may exist. Run the machine for 4 hours without load at rated voltage, and check the temperatures. Any spot at excessive temperature on the stator coils will indicate shorted turns. Run the exciter at rated voltage for 4 hours without load, and check temperature. Any spot at excessive temperature on the armature coils will indicate shorted turns. Armature resistance, if low, may indicate shorted turns; if high, it may indicate an open circuit.

(2) Using a bridge, check alternator field resistance. Infinite resistance indicates open circuit. Low resistance indicates shorted turns. Detect shorted turns by passing an ac through the field, and compare the voltage drop across the individual poles, as well as the loss in watts.

(3) Exciter field resistance is also checked with a bridge. The indications have the same significance as indicated in (2) above.

Section III. TROUBLE-SHOOTING PROCEDURES

57. General Trouble-shooting Information

No matter how well equipment is designed and manufactured, faults do occur in service. The repairman must locate and correct these faults as quickly as possible. The material supplied in this manual will aid in the rapid location of such faults. Consult the following data when necessary:

a. Oil engine, cranking engine, generator, and control panel trouble charts (pars. 60, 61, 62, and 63).

b. Control panel wiring diagram (fig. 12).

c. Engine safety control wiring diagram (fig. 14).

d. Theory of operation (sec. I).

e. Illustrations of components, cross-sectional views.

58. Trouble Symptoms

a. General. Most difficulties experienced with mechanical equipment will be evidenced by certain sounds, unusual appearance, or looseness. Power unit operators should learn such symptoms

and be able to detect them when they develop.

b. Visible Symptoms. Visible symptoms include: cracked or broken parts, parts appearing to be out of alinement, or parts appearing to be improperly adjusted; evidence of fuel or lubricating oil leakage, leaks in the cooling system, excessive smoke from the engine exhaust, and smoke from other parts of the equipment.

c. Audible Symptoms.

(1) *Knocks.* A metallic knock usually is an indication of worn or loose parts in some moving part of the equipment. Knocks of this kind may indicate worn connecting-rod bearings, worn piston pins or piston-pin bushings, a loose flywheel or coupling, or worn cylinders or pistons. Other bearings or bushings supporting rotating parts also will produce this type of knock.

(2) *Pings.* A sharp knock or ping usually is an indication of too rapid combustion, or too early firing of the fuel charge. In a gasoline engine, this might be caused by a fuel of too low octane rating, or by a spark advanced too far. It also may be caused by excessive combustion deposits in the combustion chamber.

(3) *Hums or squeaks.* A hum or squeak usually is an indication of lack of lubrication. It also might indicate an overload on a generator or improper seating of generator brushes.

(4) *Rattles.* A rattle usually is an indication of a loose part or parts.

(5) *Hissing.* Hissing sounds usually are an indication of leaks at gaskets; for example, between the cylinder and cylinder head.

59. Sequence of Trouble Shooting

Troubles experienced in power units may be divided into engine troubles, generator troubles, and control panel troubles. The trouble charts which follow indicate various trouble symptoms, with possible causes and suggested remedies. When the nature of the trouble has been determined, check the points under the heading *Possible causes.* Apparent major trouble often may be reduced to minor troubles by checking the items in the prescribed order.

60. Oil Engine Trouble Chart

Trouble	Possible cause	Checks and remedies
1. Failure to start on oil	Controls incorrectly positioned	Check starting instructions (sec. V). Position correctly.
	Fuel supply shut off	Check fuel lines for restrictions.
	Fuel system airbound	Check fuel system for loose pipes, joints. Vent fuel system.
	Inadequate fuel supply	Check fuel supply. Add proper grade fuel if necessary.
	Clogged fuel filters	Inspect filter elements. Replace or clean as necessary (items *k* and *l*, par. 40).
	Fuel pump strainer dirty or clogged	Check strainer and clean if necessary.
	Broken fuel line	Repair fuel line.
	Faulty ignitions	Check and repair or adjust magneto.
2. Engine missing and operating unevenly.	Poor fuel or water in fuel	Check fuel and drain system. Replace fuel if necessary.
	Restricted air intake	Check air cleaners. Service and clean (par. 93).
	Restricted exhaust	Check exhaust system. Remove restrictions.
	Faulty timing of injection pump	Make timing check. Adjust, if necessary (par. 90).
	Injector nozzles dirty or leaking	Check spray patterns to determine condition of nozzles (par. 47, item 42). Clean nozzles (par. 91).
	Leaking valves	Check for leaking valves and adjust (par. 47, item 12).
	Fouled spark plugs	Prime with gasoline while engine is running on fuel oil until missing stops. If it does not stop, shut down engine, clean plug in missing cylinder, or replace.
	Incorrect vacuum	Check vacuum gage. If reading incorrect, adjust air fuel ratio (par. 95).

Trouble	Possible cause	Checks and remedies
2. Engine missing and operating unevenly—Con.	Air in fuel system	Bleed fuel system.
	Water in fuel system	Drain water from filters.
	Valves not seating properly	Check and correct faulty valve condition.
	Sticking of magneto breaker points	Check points for pitting and burning. Clean, or replace points and capacitor if necessary (par. 47, item 49).
	Oil saturated and dirty spark plug cables.	Replace cables, making sure all connections are secure and in good condition.
3. Low power at full load with clean exhaust.	Faulty governor	Check governor. Disassemble and repair (par. 92). If governor is defective, do not attempt adjustment but replace the entire assembly.
	Obstructions in fuel supply system	Check fuel system and filters and remove obstructions. Vent injection pump.
	Spray nozzles clogged	Check spray pattern and clean or replace nozzles (par. 47, item 42).
	Lack of lubrication	Check oil supply. Check lubrication system.
	Clogged fuel system	Check fuel system and correct cause.
	Clogged exhaust	Check exhaust.
	Lack of compression	Check valves, pistons and rings, and cylinders.
4. Low power at full load with dark exhaust.	Fuel mixture too rich	Check air-fuel ratio (par. 95).
	Restrictions in air cleaner	Check cleaner. Clean and service (par. 93).
	Leaky valves	Inspect valves and clearance. Regrind if necessary.
5. Engine smokes	Engine overloaded	Check load specifications and reduce load.
	Poor fuel	Check condition and grade. Drain and change to correct grade.
	Improper lubricant	Check grade and condition. Drain and replace.
	Improper governor adjustment	Check and adjust if necessary.
6. White exhaust smoke	Fouled spark plugs	Prime with gasoline while engine is running on fuel oil until missing stops. If it does not, stop engine, clean spark plug in missing cylinder, or replace it.
	Vacuum too low	Adjust air-fuel ratio (par. 95).
	Leaky suction line or air in fuel. (Indicated by occasional puff of white smoke.)	Check fuel supply line. Vent fuel injection pump.
	Magneto or fuel pump timing off. (Indicated by occasional puff of white smoke.)	Check timing and adjust.
7. Dark exhaust smoke	Fuel mixture too rich	Check air fuel ratio and adjust.
	Air cleaners dirty	Check air cleaners. Clean and service (par. 93).
	Valves leaking	Check valves for signs of pitting or burning. Replace or service valves as necessary (par. 99).
8. Engine knocks	Poor fuel or water in fuel	Check condition. Drain fuel, replace with correct grade.
	Injector nozzles leaking	Check spray patterns. Clean, repair or replace nozzles (par. 47, item 42).
	Faulty timing of injection pump	Check timing and adjust (par. 47, item 38).
	Broken or loose engine parts	Inspect for loose parts. Tighten loose parts and replace broken parts if possible.
	Loose bearings	Check bearings. Repair or adjust (pars. 97 and 98).
	Water in combustion chamber	Check for leaks. Take appropriate action.
	Loose flywheel	Check and tighten flywheel.
	Worn pistons and/or cylinders	Check engine compression. Report to proper authority.
	Engine overheated	Check coolant. Check cooling system for possible stoppage. Check air flow through radiator. Take appropriate action.
	Unit overloaded	Reduce load.

Trouble	Possible cause	Checks and remedies
9. Engine overheats	Insufficient coolant	Check supply. Add water or antifreeze if necessary.
	Restrictions in radiator core	Check core for restrictions. Clean core (par. 47, item 16).
	Fan belt slipping	Check tension. Take up slack if necessary (par. 47, item 18).
	Dirty air cleaners	Check cleaners. Clean and service (par. 93).
	Thermostats blocked	Remove water outlet fitting housing thermostat. Clean and replace.
	Unit overloaded	Reduce load.
	Air flow to radiator obstructed	Remove obstruction.
	Insufficient ventilation in engine room or inclosure.	Provide more ventilation.
	Water pump not operating	Check pump and replace packing if necessary.
	Collapsed hose	Check hose. If collapsed replace with new hose or slip brass ring inside old hose.
	Improper air-fuel ratio	Check air-fuel ratio and adjust (par. 95).
	Leaky valves	Check intake and exhaust valves for signs of pitting and burning. Replace or service valves (par. 99).
	Leaky piston rings	Check rings. Replace if necessary (par. 101).
	Improper spark timing	Check timing. Preignition will result in overheating.
	Low oil pressure	See 11 below.
10. Fuel oil pressure low.	Fuel oil too light or too thin	Use specified grade of fuel oil only.
	Air leaks in intake fuel lines	Tighten joints. Check after tightening.
	Fuel oil filter or clarifier clogged	Clean filters. Replace element. (par. 40, items *k* and *l*).
	Wear in transfer pump	Replace worn parts.
11. Low lubricating oil pressure.	Crankcase oil deteriorated	Check condition. Drain and replace.
	Insufficient lubricant	Check supply. Add oil if necessary.
	Intake strainer screen of oil pump clogged.	Check screen and clean (par. 76).
	Oil line ruptured	Check lines. Replace or repair any broken lines.
	Worn pump	Check pump. Repair or replace.
	Dirt in oil relief valve	Inspect valve and clean if necessary (par. 47, item 19).
	Dirt and sludge in oil cooler element	Inspect and clean cooler (par. 75).
12. Excessive lubricating oil consumption.	Oil leaks	Check connections and gaskets in lubrication system for tightness. Tighten all loose joints or gaskets. Replace leaking gaskets.
	Piston pumps oil	Replace piston rings (par. 101).
	Incorrect grade of lubricant	Drain lubricant. Replace with proper grade.
	Leaky cylinder head gaskets	Tighten the cylinder heads (par. 47, item 11). Replace defective gaskets.
	Worn bearings	Check bearings. Take appropriate action.
13. Dilution of lubricating oil in crankcase.	More fuel oil injected than engine can consume.	Check for free travel of vacuum control springs (par. 95).
	Thermostats not operating properly, and engine temperatures too cold.	Check thermostats. Replace if defective (par. 83). Provide radiator curtain.
	Fuel pump improperly timed	Check timing. Adjust if necessary (par. 47, item 38).
	Tardy magneto timing	Check timing. Adjust (par. 84).
	Engine missing	Check spark plug and clean and adjust or replace (par. 47, item 46).
14. Lack of compression.	Worn pistons rings, pistons, or cylinders.	Check engine compression. Correct or report faulty conditions.
	Valves dirty, pitted, sticking, or improperly adjusted.	Check guides, tappet clearances, and valve seats. Adjust or clean (par. 99).
	Stuck, worn, or broken piston rings	Clean or replace (par. 101).
	Leaky cylinder head gasket	Tighten cylinder heads after replacing gaskets (par. 99).

Trouble	Possible cause	Checks and remedies
15. Lack of power	Air bound injection pump	Vent air from system.
	Carbonized spray nozzles	Clean nozzles (par. 91).
	Leaky or improperly adjusted valves	Adjust valve tappet clearances.
		Grind valves (par. 99).
	Insufficient fuel	Check fuel pumps and filters, as well as fuel supply.
	Air cleaner dirty	Clean and service air cleaners (par 93).
	Insufficient lubrication	Check items in 11 above.
	Incorrect grade lubricant	Change to specified grade.
	Clogged exhaust pipes or muffler	Clean out pipes and tighten joints.
	Stuck piston rings or worn cylinders	Remove rings, clean in solvent, replace worn rings.
		Replace worn cylinders (par. 101).
16. Engine stops	No fuel in tank	Add fuel oil.
	Ice particles in fuel line or filters	Check for ice in fuel oil system.
		Check filters for clogged condition.
		Apply heat to affected part.
	No fuel oil pressure	Check fuel injection pump and fuel supply pump.
	Fuel lines or filters clogged	Check and clean (par. 40, *k* and *l*).
	Defective magneto	Check magneto. Repair or replace faulty parts.
17. Engine alarm sounds.	Low lubricating oil pressure (safety switch operates).	Check items under 11 above.
	High water temperature (safety switch operates).	Check items under 9 above.

61. Cranking Engine Trouble Chart

Trouble	Possible cause	Checks and remedies
1. Failure to start	Gasoline shut-off closed	Open supply cock.
	No gasoline at carburetor	Check supply. Add gasoline.
	Carburetor choked (engine flooded)	Check for bent choke valve stem.
		Replace defective parts.
	No spark	Check and clean plugs, check gap, adjust if necessary.
		Check ignition wiring and breaker points.
		Clean or replace.
	Condensation on spark plugs	Wipe dry.
	Short-circuited ignition switch	Repair or replace.
	Gasoline strainer clogged	Remove bowl and check condition of strainer. Clean strainer.
	Air intake restricted	Clean air cleaner.
	Clogged carburetor	Clean carburetor.
2. Missing and backfiring.	Water in gasoline	Check sediment bowl. Empty bowl and drain tank. Refill.
	Air leaks around intake manifold	Check manifold bolts. Tighten if necessary.
	Valves leaking or sticking	Check valves. Apply lubricating oil to valve stems. Check and adjust tappet clearances.
	Fouled spark plug (or plugs)	Remove, check, clean, and adjust spark plugs.
	Cooling system thermostats stuck open	Check engine temperature and check thermostats.
	Faulty magneto	Check magneto. Adjust or replace faulty parts.
3. Dilution of lubricating oil in crankcase.	Stuck piston rings	Free rings and wash in solvent (SD).
	Low operating temperature or defective thermostat.	Check thermostat and replace if defective.
	Worn pistons and/or cylinders	Check pistons and bore dimensions. Replace parts if worn.

Trouble	Possible cause	Checks and remedies
4. Lubricating oil pressure drops or fluctuates violently under load.	Poor or insufficient lubricant	Check lubricant for condition and quantity. Replace or refill if necessary.
	Lubricant diluted	Check items under 3 above.
	Oil pump screen clogged	Remove screen and clean.
	Oil line to pressure gage disconnected	Check line for leaks or breaks. Repair or replace line.
	Broken oil line	Check oil lines. Repair broken line.
5. Low lubricating oil pressure.	Insufficient lubricant	Check supply. Add lubricant.
	Pressure relief valve stuck	Inspect relief valve for chips or flaws. Clean or replace if necessary.
	Sheared drive pin or key in oil pump	Disassemble and repair pump.
	Crankcase oil diluted	Check items under 3 above.
	Clogged oil pump screen	Clean screen.
	Broken or leaking oil lines	Check oil lines. Repair faulty lines.

62. Generator Trouble Chart

Trouble	Possible cause	Checks and remedies
1. Sparking at the brushes.	Load too high	Check ammeter and voltmeter readings to make certain they indicate voltage and current as noted on nameplate. Reduce load.
	Brushes improperly seated. Brushes and commutator dirty.	Check brushes for uneven wear and dirt on brushes and commutator. Adjust brushes with fine sandpaper. Check fit of brushes in holders.
	Rough or eccentric commutator	Check for uneven wear. Use coarse cloth or fine sandpaper to smooth commutator if slightly rough. If very rough send unit to depot.
	Open armature	Check to see if coil lead is disconnected or coil open. Solder coil lead back on or return to depot.
	Grounded, open, or shorted field winding.	Check for breaks or shorts. Replace open or shorted fields. Repair a grounded field by insulating at the point where ground occurs. Send unit to depot for repair.
2. Voltage too low	Engine speed low	Check engine speed with tachometer. If too low, adjust governor control.
	Brushes improperly set	Remove brushes and check for wear. Reseat brushes.
3. Voltage drops excessively upon increase in generator load.	Exciter field rheostat turned too far towards *resistance-all-in.*	Turn exciter field rheostat clockwise to correct position.
	Voltage regulator switch in OFF position.	Put voltage regulator in service by snapping switch to ON position.
	Excessive engine speed drop	Check for obstructions in engine fuel system.
4. Voltage rises when load is applied.	Incorrect compensating resistor connections in rear of switchboard panel.	Check to see that terminals CO–2 and VO on voltage regulator rectifier unit are properly connected to current transformer on phase T–2 as shown in fig. 12. If connections are incorrect, reverse leads CO–2 and VO on rectifier unit.
	Engine speed rises because of incorrectly positioned solenoid plunger.	Adjust setting of solenoid plunger (par. 92).

Trouble	Possible cause	Checks and remedies
5. Generator or exciter heats up excessively.	Excessive load	Check ammeter readings and reduce load.
	Grounded or shorted turns in rotor windings.	Check rotor for grounds or shorts. Have armature rewound.
	Dirt in air passages	Blow out the dirt.
	Poor ventilation	Provide sufficient air space around units.
	Rotor rubbing on stator	Determine cause of misalinement and correct. Inspect pole pieces and armature for probable damage which may necessitate new pole pieces and/or rewinding the armature.
6. Sparking at commutator or slip-ring brushes.	Dirt or oil on commutator, slip-rings, or brushes.	Clean. Check for oil leakage. Wipe off surfaces of brushes, rings, and commutator.
	Exciter or slip-ring brushes worn	Replace brushes.
	Exciter or slip-ring brushes making improper contact because of improperly adjusted spring pressure, weak or broken springs.	Increase spring tension or replace springs.
	Exciter or slip-ring brushes sticking in holders.	Remove brushes and clean holders. Check brushes for high spots. Reseat brushes.
	Rough commutator or slip-rings	Dress commutator or slip-rings.
	High mica between commutator bars	Undercut mica.
	Vibration of brush holder studs	Check brush holders and yoke. Tighten.
	Slip rings or commutator worn eccentric.	Remove and turn down in lathe.
		Undercut mica between commutator segments.
	Loose leads	Connect leads properly.
	Open or grounded field coils	Replace defective coils.
	Shorted exciter armature windings	Have armature rewound.
	Load too heavy	Reduce load.
	Soft brushes causing spotted commutator or slip-rings.	Replace with correct brushes.
7. Commutator or collector rings heat up.	Excessive brush pressure	Decrease brush tension.
	Incorrect grade of brushes	Replace with grade as specified by manufacturer.
	Overload	Reduce load.
	Excessive sparking	Check and correct items under 6 above.
8. Voltage rises when load is applied.	Incorrect compensating resistor in rear of switchboard.	Check to see that terminals CO–2 and VO on voltage regulator rectifier are properly connected to current transformer on phase T–2 as shown in fig. 12. If connections are incorrect, reverse leads CO–2 and VO on rectifier.
	Engine speed rises due to incorrectly adjusted solenoid plunger.	Adjust solenoid plunger (par. 92).

63. Control Panel Trouble Chart

Trouble	Possible cause	Checks and remedies
1. Voltmeter fails to register.	Loose or broken leads	Check wiring. Tighten or replace leads.
	Blown fuse	Check circuit including fuses. Replace fuse.
	Voltmeter switch in OFF position	Turn switch to a phase position.
	Alternator not functioning	See par. 62 for alternator trouble information.
	Broken voltmeter	If alternator functions and wiring is perfect, replace voltmeter.

Trauble	Possible cau3e	Checks and remedies
2. Ammeter fails to register.	Loose or broken leads	Check wiring. Tighten or replace leads.
	Ammeter phase switch inoperative	Check switch on each phase. If it fails to show a reading on any phase, switch is defective. Replace it.
	Alternator not functioning	See par. 62 for alternator trouble information.
	Ammeter broken	If trouble is not located after these checks, ammeter is defective and should be replaced.
3. Frequency meter does not register.	Loose or broken leads	Check wiring. Tighten or replace leads.
	Fuse blown	Check circuit. Replace fuse.
	Frequency meter defective	If circuit check does not reveal trouble, meter is defective and must be replaced.
4. Voltmeter fluctuates excessively.	Engine not operating properly	See par. 61 for engine trouble information.
	Load unevenly distributed on phases	Check ammeter readings on each phase, and readjust load.
	Incorrect wiring	Check all wiring (fig. 12). Correct.
5. Circuit breaker trips to off position.	Overload device trips breaker	Reduce load.
	Short circuit trip operates to trip breaker.	Check lines for breaks or crossed wires. Repair or replace wiring.
	One generator taking power from another when operating in parallel causes reverse power relay to trip breaker.	Increase speed of unit that tripped. Check engine's fuel filters for clogging. Clean or replace element.
6. Automatic voltage regulator does not function.	Open circuit. No a-c voltage on rectifier terminals V, CO–2 (fig. 12).	Check wiring. Repair broken circuit.
	Damping transformer secondary open between transformer and regulator.	Check wiring. Replace damping transformer.
	Exciter connection to damping transformer open.	Check wiring. Repair or replace defective wiring.
	Open circuit between exciter field and regulating resistance.	Check wiring. Repair or replace defective wiring.
	Exciter field rheostat not properly positioned.	Turn rheostat to or near *resistance-all-out* position.
	Obstruction in air gap or voltage regulator magnetic circuit.	Check air gap. Blow out with compressed air.
	Regulator switch in OFF position	Turn to ON position.
	Short circuit across upper terminals RR–1 and RR–2 (fig. 12) of regulator.	Check terminals and insulation for breaks or dirt. Replace or repair broken insulation. Remove dirt or obstructions.
7. Sparking at voltage regulator buttons.	Dirt or dust between buttons	Check gap between buttons. Clean or blow out with—compressed air.
	Open circuit or poor connection between silver buttons and regulating resistance.	Check circuit from regulating resistance to buttons. Tighten connections. Repair or replace defective wires.
	Open circuit in regulating resistance	Check regulating resistance for current flow.
8. Erratic voltage	Loose or poor connections	Check all connections. Clean and tighten.
	Exciter circuit to damping transformer open.	Check exciter circuit, replacing all broken or corroded wiring.
	Wrong polarity on damping transformer primary EX— and EX+ (fig. 12).	Check polarity markings on cables and transformer, and interchange wires.
	Wires interchanged at DT–1 and DT–2 (fig. 12) terminals of damping transformer.	Check positions of wires and interchange.

Section IV. SPECIAL TOOLS

64. Tool for Undercutting Mica

To improvise a tool for undercutting the mica between the commutator segments, grind a piece of broken hack saw blade to the exact width of the mica. Grind one end of the blade to enable the fitting of a wooden handle, and fit the handle to the blade.

65. Injection Pump Wrenches

Two special injection pump wrenches are provided with each unit. Use them to disassemble the injector nozzle assembly.

Section V. DISASSEMBLY, REPAIR, AND REASSEMBLY

66. Oil Engine Disassembly, Repair, and Reassembly

A separate paragraph is devoted to each system accessory and major component of the oil engine. Each paragraph contains detailed instructions for disassembling, inspecting (if necessary), repairing, and reassembling each item.

67. Pilot Lights on Instrument Panel

Unscrew and remove the lamp jewel, press the lamp in lightly, and turn the lamp counterclockwise. Replace the lamp if defective.

68. Pilot Lamp Receptacles

Remove the lamp (par. 67). Use a 7/16-inch open-end wrench and unscrew the hexagonal nut in front of the panel which holds the receptacle to the panel. Pull the receptacle out far enough to permit inspection of the wiring; see that it is secure and not frayed or cracked. Check the receptacle itself to see that it is not cracked. If the receptacle is defective, unsolder the connection and replace the lamp receptacle by soldering the connection to the new receptacle terminal. Push the receptacle into position in the panel and replace the hexagonal nut securing the lamp receptacle to the panel.

69. Lubricating Oil Pressure Gage

a. Removal. Use a 7/16-inch open-end wrench, and disconnect the flexible lubricating oil line from the gage. Remove the two 10–32 nuts with a 3/8-inch wrench and remove the two clamps holding the gage in place. Gage can now be slipped from the front of the panel. Replace the gage if defective.

b. Replacement. Insert the gage in the panel, and tighten the gage clamps. Straighten the meter before tightening the clamps; reconnect the flexible lubricating oil line.

Note. If it is necessary to run the engine without the gage installed, plug the oil line by removing the entire flexible lubricating oil line from its connection in the engine block and by inserting a 1/8-inch pipe plug in its place. The safety system will still operate, provided that the toggle switch is in the ON position. The unit will automatically shut down if the lubricating oil pressure drops too low.

70. Cooling Water Temperature Gage

a. Removal. Locate the water temperature gage element. Do this by tracing the flexible cable containing the capillary tube. The element is located in the rear of the water outlet manifold on top of the No. 5 cylinder. Using a 7/16-inch open-end wrench, remove the element by unscrewing the smallest bushing holding the element in place. Remove the clamps holding the gage in place by removing the two 10–32 nuts with a 3/8-inch wrench. The gage will slip out of the front of the panel with the capillary tube attached. Replace the gage if defective.

b. Replacement. Insert the capillary tube through the gage mounting hole. Insert the gage, and clamp in place. Connect the capillary tube to the outlet water manifold by inserting the element and making up the 1/4-inch pipe bushing. To prevent leaks at this connection, wrap the bushing threads with pipe wicking and coat the threads with white lead.

Note. If it is necessary to run the unit with the gage disconnected, plug the water manifold tubing connection with a 1/4-inch pipe plug. The safety system will still operate if the toggle switch is in the ON position and will shut the unit down if the cooling water temperature rises too high.

71. Vacuum Gage

a. Removal. Remove the vacuum gage tubing at the gage. Take out the three 10–32 screws

securing the gage to the board, and remove the gage.

b. REPLACEMENT. Insert the gage in position. Tighten the three 10–32 mounting screws. Reconnect the tubing to the gage.

Note. If it is necessary to run the unit with the gage disconnected, install a ⅛-inch pipe plug in the intake manifold where the gage tubing is connected.

72. Fuel Oil Pressure Gage

a. REMOVAL. Using a 9/16-inch open-end wrench, remove the fuel line from the rear of the gage. Remove the clamps holding the gage in position by taking off the two 10–32 nuts. Remove the gage from the front of the panel.

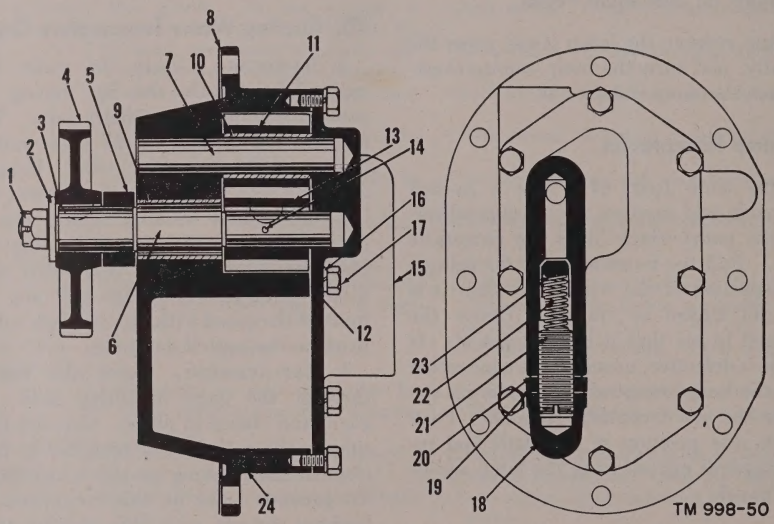
b. REPLACEMENT. Insert the gage in position. Tighten the clamps. Reconnect the fuel oil line at the back of the gage.

Note. If the unit must be run with the gage removed, disconnect the other end of the flexible fuel oil line at the top of the fuel oil clarifier. Insert a ⅛-inch pipe plug in the opening.

73. Lubrication Oil Pump (fig. 39)

a. REMOVAL. Remove the lower fan belt guard by unscrewing the two ½-inch cap screws, using a ¾-inch socket wrench. Disconnect the oil line leading from the pump to the lubricating oil cooler by unscrewing the four ⅜-inch cap screws (two at each end of the line). Using a ¾-inch socket wrench, unscrew the eight ½-inch cap screws (17, fig. 39) that secure the pump unit; lift off the pump.

b. REPLACEMENT. Before replacing the pump, examine the gaskets for tear or cracks. Replace any defective gaskets. Place the pump in position, and tighten the eight ½-inch cap screws. Connect the oil line from the pump to the lubricating oil cooler by screwing in the four ⅜-inch cap screws. Then replace the lower fan belt guard.



1. Oil pump drive shaft castle nut.
2. Oil pump drive shaft washer.
3. Oil pump drive shaft key.
4. Oil pump drive gear, large.
5. Oil pump drive shaft spacer.
6. Oil pump drive shaft, long.
7. Oil pump idler gear shaft.
8. Oil pump body to pan gasket.
9. Oil pump drive shaft bushing.
10. Oil pump idler bushing.
11. Oil pump gear, idler.
12. Oil pump body to cover gasket.
13. Oil pump gear, driver.
14. Oil pump drive gear pin.
15. Oil pump body cover.
16. Oil pump body to cover lockwasher.
17. Oil pump body to cover cap screw.
18. Relief valve acorn nut.
19. Relief valve locknut.
20. Relief valve nut washer.
21. Relief valve adjusting screw.
22. Relief valve spring.
23. Relief valve plunger.
24. Oil pump body.

Figure 39. Lubricating oil pump assembly.

74. Oil Pump Relief Valve (fig. 39)

a. Disassembly. Unscrew the acorn nut (18, fig. 39), with a 1 5/16-inch open-end wrench. Remove the acorn nut, locknut (19), and washer (20). Insert a screw driver in the slotted end of the plunger adjusting screw (21) and remove this screw by turning clockwise. Then remove the coil spring (22) and plunger (23). Adjust the screw as described in paragraph 47, item 19.

b. Reassembly. Replace the plunger (23), coil spring (22), and plunger adjusting screw (21). Tighten plunger adjusting screw (par. 47) by inserting a screw driver in the slotted head and turning counterclockwise. Replace the washer (20), locknut (19), and acorn nut (18).

75. Lubricating Oil Cooler

a. Removal. Drain all coolant from the cooling system. Disconnect the hose connections at the radiator and water pump ends. Remove the two oil lines at the cooler end by removing the four 3/8-inch cap screws, using a 9/16-inch socket wrench. Loosen the two engine crankcase hold-down bolts with a 1 5/8-inch open-end wrench. These bolts secure the oil cooler bracket to the engine; remove the cooler.

b. Cleaning Oil Cooler. To clean the oil cooler, proceed as follows:

(1) Select a location away from open flames or sparks. Use benzol to clean the cooler. Be extremely careful as it is highly explosive and dangerous to handle in a closed room.

(2) Fill a pail with benzol, and submerge the entire cooling element in the fluid for at least 15 minutes. Move the element in the solution so that air can escape, and so that the fluid comes in contact with every inside surface.

(3) After 15 minutes, connect a pressure gun to either the intake or outlet of the element. With the element still in the solvent, pump the pressure gun vigorously for several minutes to remove the dissolved sludge and gum deposits.

(4) Remove the pressure gun, drain the solvent out of the element, and blow out the oil passages with 50–80 pounds air pressure. *Do not put the full line pressure on the unit.*

(5) Submerge the element a second time in a clean solution of benzol. Connect the pressure gun, and pump the gun about 12 times. If the element is thoroughly cleaned, the solvent will remain clear.

c. Replacement. Before reassembling the unit, be sure all gaskets are in good condition. Replace any defective gaskets. When reassembling the cooler, the gaskets between the unit and the case must be oiltight and watertight. Oil passages in the case casting must be clear and unobstructed by the gaskets. Position the cooler on its bracket. Tighten the two engine crankcase hold-down bolts securing the bracket to the engine. Replace the two oil lines at the cooler ends, and reinsert and tighten the four 3/8-inch cap screws. Connect the hose at the radiator and water pump ends. Refill the cooling system with coolant.

76. Oil Pump Strainer Screen

The oil pump strainer screen surrounds the intake of the lubricating oil pump. Clean the screen each time the lubricating oil is changed to prevent clogging by carbon and sludge. The screen is located in the crankcase on the front left-hand side of the engine. To remove the screen, unscrew the twelve 1/2-inch cap screws securing the hand-hole cover plates in the side of the base. Clean the screen (par. 40 *h*). Before replacing the screen, examine the gasket for cracks or tears, and replace if necessary.

77. Primary Lubricating Oil Filter

Neither the element not any other part of this filter requires changing. To remove the filter, unscrew the four 3/8-inch cap screws from the oil line headers, and the two 1/2-inch cap screws holding the filter to the engine bracket. Replace the filter by tightening the two 1/2-inch cap screws holding the filter to the bracket. Insert the four 3/8-inch cap screws from the oil line headers and tighten.

78. Lubricating Oil Purifier

To disconnect the purifier, drain the lubricating oil, break inlet and outlet connections and remove the mounting bolts at the feet of the purifier.

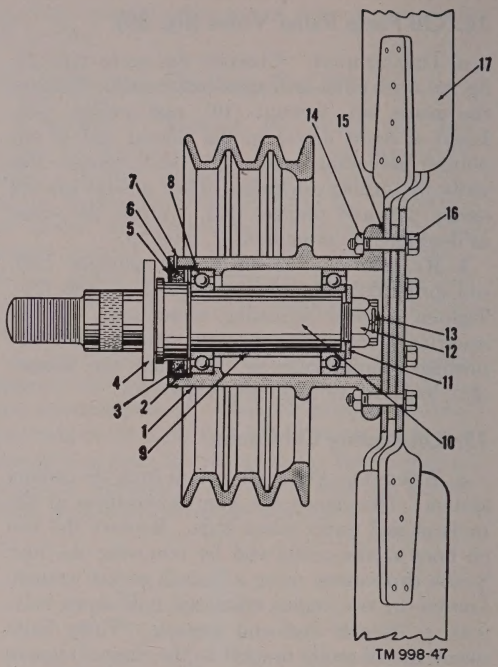
79. Radiator

The radiator is secured to the skid-base by eight cap screws at the radiator feet. Two diagonal braces support the radiator. The braces are secured by four bolts.

a. Removal. Drain all coolant from the cooling system. Loosen the nuts and cap screws that hold the radiator feet and braces. Break the radiator connections at the water inlet and outlet. Remove the fan guard by removing the four ⅜-inch cap screws (with a $^{9}/_{16}$-inch socket wrench) securing the guard to the frame. Using a ⅜-inch socket wrench, remove the ¼-inch cap screws that hold the two sections of the fan guard together. Lift the radiator off the base.

b. Repair. Inspect the radiator as described in paragraph 47, item 16. If the core sections require repair, remove the shroud and wire guard by loosening the four ½-inch cap screws, using a ¾-inch socket wrench. The radiator core is divided into nine sections, each section held in place by four ½-inch square head bolts. To remove any core section, loosen the two nuts at the top and bottom end of each section.

c. Replacement. Reassemble the two halves of the fan guard. Replace the fan guard by inserting and securing the four ⅜-inch cap screws. Make radiator connections at water inlet and outlet. Tighten the bolts securing the diagonal braces, and replace and tighten the eight cap screws securing the radiator feet to the base.



1. Fan hub.
2. Fan cork retaining washer.
3. Fan oil gasket.
4. Fan clamp washer.
5. Fan cork retainer.
6. Fan cork washer.
7. Fan lock wire.
8. Fan ball bearing.
9. Fan spacer.
10. Fan spindle.
11. Fan cone clamp washer.
12. Fan castle nut.
13. Fan nut cotter pin.
14. Fan bolt nut.
15. Fan gasket.
16. Fan bolt.
17. Fan blade.

Figure 40. Fan assembly.

80. Fan (fig. 40)

a. Removal. To remove the fan, first remove the radiator (par. 79). Use a $^{7}/_{16}$-inch open-end wrench, and loosen the six bolts (16, fig. 40) and lock-washers holding the fan assembly to the fan drive pulley.

b. Replacement. Replace the fan by positioning the fan assembly to the fan drive pulley. Insert the six bolts and lockwashers (16) and tighten them securely.

81. Fan Belts

a. Removal. The fan is driven by three belts. To remove them, loosen the 1½-inch hexagonal nut holding the fan pulley spindle to the fan bracket, using a $2^{5}/_{16}$-inch open-end wrench. Use a 1¼-inch open-end wrench and unscrew the fan belt adjusting screw, until enough slack is obtained to permit removal of the belts from the crankshaft drive pulley. Lift the fan belts over the fan blades to remove them.

b. Replacing Fan Belts. Slip the fan belts over the fan blades. Place the fan belts in their grooves in the crankshaft drive pulley and the fan pulley. Tighten the fan belt adjusting screw to take up the slack. Tighten the 1½-inch hexagonal nut holding the fan pulley spindle to the fan bracket.

82. Water Pump (fig. 41)

a. Removal. To remove the water pump, proceed as follows:

(1) Drain the cooling system.

(2) Disconnect all fittings at the lubricating supply oil pump. Remove the two grease cup fittings and the right-hand instrument panel hold-down bolt.

(3) Disconnect the flexible coupling on the water pump drive shaft by removing the six hexagonal cap screws. Use a ⅜-inch socket wrench to remove these screws.

(4) Disconnect the inlet and outlet fittings at the fuel supply pump, and remove the fuel supply pump from its bracket by unscrewing the four ¼-inch cap screws. Cap all fuel lines and openings to prevent dirt from entering the fuel lines.

(5) Using a ¾-inch socket wrench, remove the eight ½-inch cap screws at the inlet and outlet flanges, and the four ½-inch cap screws at the water pump bracket bearing caps.

b. Inspection. Remove the water intake fitting, and see if the pump rotor is tight with the shaft. If it is not tight, replace the pump.

c. Replacement. Replace the water pump on its bracket by tightening the 12 cap screws. Replace the fuel supply pump, and tighten the four ¼-inch cap screws securing the pump to its bracket. Connect the inlet and outlet fittings at the fuel supply pump. Replace the flexible coupling on the water pump drive shaft. Secure the six hexagonal cap screws with a ⅜-inch socket wrench. Replace the right-hand instrument panel hold-down bolt, and also the two grease cup fittings. Make all connections at the lubricating oil supply pump. Refill the cooling system.

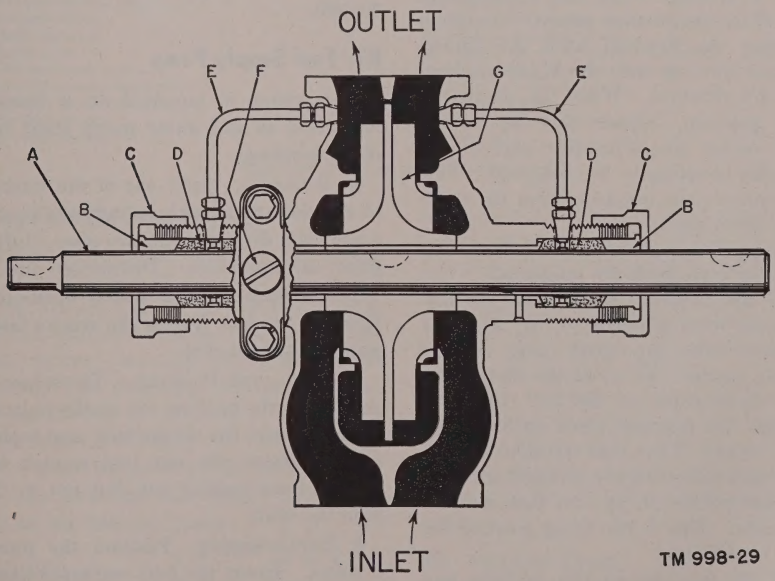
83. Thermostats

a. Removal. Four thermostats are mounted in the top water outlet. To remove the thermostats, drain the cooling system, disconnect the water connection at the thermostat housing, remove the eight ⅜-inch cap screws joining the thermostat housing, and remove the gasket.

b. Testing. Inspect the thermostat to see that the bellows is working freely and that the valve is seating properly. To test the thermostat, place it in a pan of water, and heat. Check the water temperature with a thermometer. If the thermostat does not start to open at 165° F. and become fully open at 190° F., the thermostat is defective and should be replaced.

84. Magneto (fig. 42)

a. Removal. Unscrew the six magneto cable fittings at the magneto cap. Pull out the six spark plug cables. Remove the four ⅜-inch cap screws (2, fig. 42) holding the magneto to the magneto bracket. Slide the magneto toward the



A. Shaft.
B. Packing gland.
C. Packing nut.
D. Packing.
E. Bypass line.
F. Grease cup.
G. Impeller.

Figure 41. Water pump assembly.

power generator until the magneto coupling is disengaged; lift off the complete magneto.

b. Inspection. Inspect and lubricate the magneto (par. 47, item 35). Remove the distributor block and wipe it with a clean, dry cloth to remove dust. Smooth and polish the brush track with fine crocus cloth and examine the brushes to see that they slide freely in their holder.

c. Replacement. Place the magneto on its bracket and slide the magneto toward the coupling until the coupling is engaged. Replace the four ⅜-inch cap screws securing the magneto to the bracket. Replace the six spark plug cables, and tighten the magneto cable fittings at the magneto cap.

d. Timing. Before checking the magneto timing, or retiming the magneto, set the breaker points so that, when fully separated, the gap between the points is 0.014 inch. To check the timing, crank the engine until No. 1 cylinder is on the compression stroke. The ignition spark should occur at the instant that the timing pointer over the flywheel lines up with the MAG marking on the flywheel. If timing adjustment or retiming is necessary, proceed as follows:

(1) Crank the engine until the piston of No. 1 cylinder is at the approximate top of its compression stroke. Continue turning the flywheel until the timing pointer lines up with the MAG marking on the flywheel. With the engine in this position, release the cap screws that secure the adjustable part of the impulse coupling to the magneto. This disconnects the magneto from the magneto drive shaft.

(2) Remove the interrupter cap and distributor plate from the magneto.

(3) Turn the magneto shaft until the distributor rotor segment (6, fig. 29) is in contact with the spark plug contact brush, marked No. 1, on the face of the distributor plate (13, fig. 29). Continue to turn the magneto shaft until the impulse snaps. Then turn the shaft back ½ turn and turn it slowly forward until the breaker points (9, fig. 29) just start to separate. This is the firing position for No. 1 cylinder.

(4) Hold the magneto in this position and carefully recouple the magneto to the magneto drive shaft.

(5) Replace the distributor plate and cap.

85. Impulse Coupling

The impulse coupling is of two-piece construction. One half is keyed to the magneto extension shaft, and the other is notched into the magneto drive disk. To remove the impulse coupling, remove the magneto (par. 84); cut the sealing wire; remove the two ¼-inch hexagonal head cap screws. To replace the coupling, replace the cap screws, the sealing wire, and the magneto. Time the magneto (par. 84*d*) after the impulse coupling and magneto have been replaced.

86. Spark Plugs

The spark plugs are encased in aluminum caps for radio suppression. To remove the plugs, unscrew the fitting nut directly above the spark plug shield. Pull out the spark plug lead. Using a ¾-inch open-end wrench, unscrew the metal suppressor case. Remove the plug itself by using the spark plug wrench supplied with the unit. Inspect and service the plugs (par. 47, item 36). To replace the plugs, insert the plug in the cylinder head and tighten. Replace the metal suppressor case, the spark plug lead, and the fitting nut. Tighten the fitting nut with a ¾-inch open-end wrench.

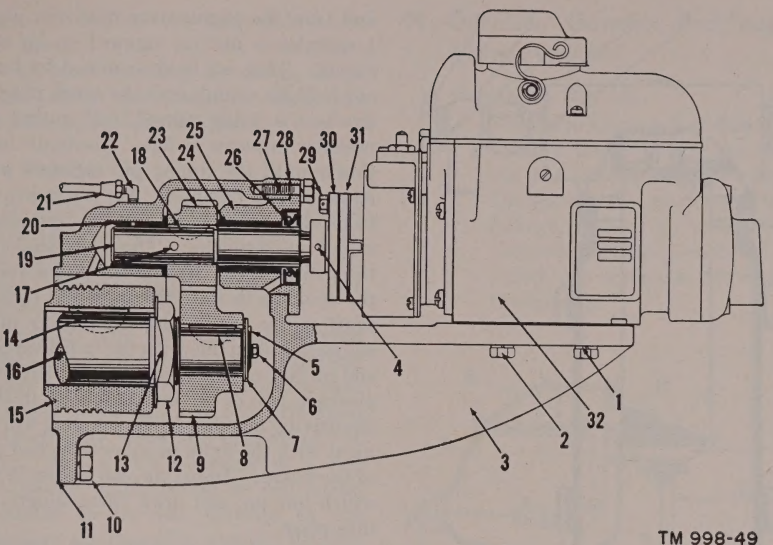
87. Fuel Supply Pump

This pump is mounted on a bracket. It is connected to the water pump shaft by a silent chain coupling.

a. Removal. Split one of the washers at any of the chain links with an ordinary chisel. Using a drift pin, drive out the two pins. Lift the chain from the sprockets. Disconnect the inlet and outlet fittings with a 1-inch open-end wrench. Remove the four ¼-inch cap screws fastening the pump to the bracket.

b. Replacing Packing. To replace the packing, loosen the packing nut on the right side of the pump, remove the old packing, and replace it with new. Tighten the nut just enough to prevent fuel oil from leaking out, but not so tight as to bind the shaft.

c. Replacement. Position the pump to the bracket. Insert the four cap screws and tighten. Connect the inlet and outlet fittings. Install new washers at the chain coupling and peen over the ends of the pins.



1. Magneto mounting screw lockwasher.
2. Magneto mounting screw.
3. Magneto bracket.
4. Magneto coupling taper pin.
5. Magneto drive gear lock.
6. Magneto drive gear cap screw.
7. Magneto drive gear retaining washer.
8. Magneto drive gear woodruff key.
9. Magneto drive gear (driver).
10. Magneto bracket cap screw.
11. Magneto bracket gasket.
12. Magneto drive shaft spacer locknut.
13. Magneto drive shaft spacer locknut lock.
14. Magneto drive shaft spacer woodruff key.
15. Magneto drive shaft spacer.
16. Magneto drive shaft (driver).
17. Magneto drive gear pin.
18. Magneto drive gear woodruff key.
19. Magneto drive gear shaft (driven).
20. Magneto bracket bushing.
21. Oil line union nut.
22. Magneto drive oil line elbow fittings.
23. Magneto drive gear (driven).
24. Magneto drive shaft bushing.
25. Magneto drive bushing retainer.
26. Magneto drive shaft oil seal.
27. Magneto drive bushing retainer cap screw.
28. Magneto drive bushing retainer gasket.
29. Magneto coupling cap screw.
30. Magneto coupling.
31. Magneto coupling adjusting ring.
32. Magneto.

Figure 42. Magneto drive bracket assembly.

88. Primary Fuel Oil Filter (fig. 43)

a. Removal. Disconnect the fuel line fitting (E, fig. 32) from the fuel filter supply pump, and the fuel line fittings (A) to the delivery pump. Using a ⅜-inch open-end wrench, remove the four ¼-inch cap screws fastening the filter to the engine housing. To clean and service the filter, refer to paragraph 40*l*.

b. Replacement. Position the filter to the engine, and replace the four cap screws. Remove connection (E) from the fuel supply pump and fittings (A) to the delivery pump.

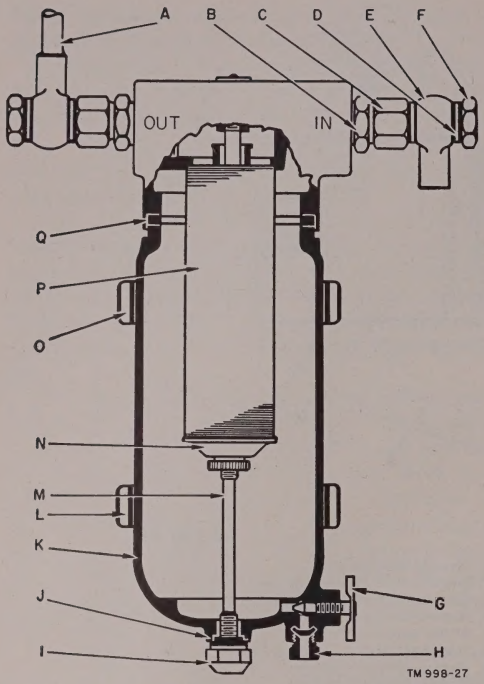
89. Fuel Oil Clarifier

a. Removal. Disconnect the fuel line fittings from the fuel delivery pmup, to the injection pump safety valve, and to the oil gage on the engine instrument panel. Plug or cap all fuel line fittings to prevent dirt from entering the fuel lines. Remove the four ⅜-inch cap screws fastening the filter to the bracket. To replace the filter element, refer to paragraph 40*k*.

b. Replacement. Place the filter in position on the bracket, replace the four cap screws, and tighten. Then make connections from the fuel delivery pump to the injection pump safety valve and to the fuel oil gage on the engine instrument panel.

90. Injection Pump

a. Removal. Thoroughly clean the outside of the injection pump, fuel lines, and fittings. Pre-



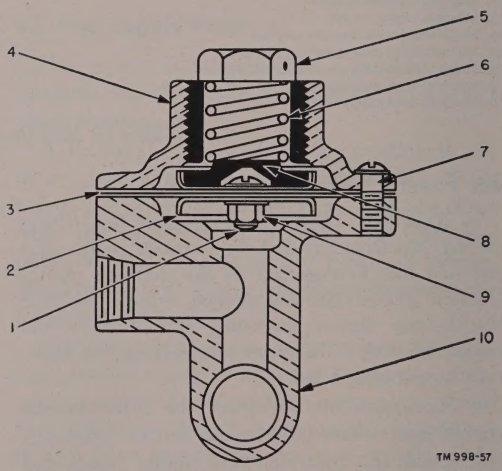
A. Fuel filter connection, filter to pump.
B. Fuel line connection bushing.
C. Fuel line connection adapter.
D. Copper washer.
E. Fuel line connection, inlet.
F. Fuel line connection bolt.
G. Filter bowl drain valve.
H. Filter bowl weatherhead nut.
I. Filter bowl retaining nut.
J. Filter bowl nut washer.
K. Filter bowl.
L. Filter bracket, lower.
M. Filter assembly tie bolt.
N. Filter element retainer plate and nut.
O. Filter bracket, upper.
P. Filter element.
Q. Filter bowl gasket.

Figure 43. Primary fuel oil filter.

pare a clean place on the workbench to place the pump when it is removed from the engine. Shut off the fuel supply. Disconnect the fittings at the nozzles, solenoid valve, and intake manifold. For easy identification, tag all fittings and pipes removed. Cap all fuel line openings to prevent dirt from entering the fuel lines. Drain the injection pump by unscrewing the plug marked "drain" at the bottom of the housing. Remove the six ½-inch cap screws at the bottom of the pump which secure the pump to the engine bracket. Pull the pump from the coupling and remove it to the clean workbench.

b. Timing. Remove the spark plug from each cylinder. Remove the coupling guard from the flywheel end of the engine. Insert the cranking bar in one of the holes in the rim of the flywheel and turn the engine over until the piston of No. 1 cylinder is moving upward on its compression stroke. This can be determined by having someone hold his thumb over the spark plug hole as the flywheel is being turned, and noting when compression pressure is felt. Continue barring over slowly until the timing pin registers with the FP mark on the flywheel. Do not move the engine from this position during the remainder of the timing adjustments. These are made by moving the pump itself. Rotate the pump and its half of the coupling in the same direction that its driving shaft moves, and bring the timing mark on the coupling hub in line with the indicator point on the end of the pump housing. With the pump in this position, two of the multiple holes in the flange of the driving member of the coupling will be in alinement with the drive member attached to the shaft of the pump. Insert the cap screws in these holes, which line up, and draw them snugly and evenly into place.

c. Surge Dampener (fig. 44). To remove the surge dampener, break the connection from the fuel oil clarifier to the fuel solenoid valve. Remove the cap screw securing the dampener to the pump, and remove the solenoid valve and dampener as a unit. Unscrew the solenoid valve from



1. Surge dampener diaphragm screw.
2. Surge dampener diaphragm protector.
3. Surge dampener diaphragm.
4. Surge dampener cover.
5. Surge dampener spring adjusting nut.
6. Surge dampener spring.
7. Surge dampener body attaching screw.
8. Surge dampener spring seat.
9. Surge dampener diaphragm hexagonal nut.
10. Surge dampener body.

Figure 44. Surge dampener assembly.

the dampener. To replace the surge dampener, connect the solenoid valve to the dampener. Replace the cap screw securing the dampener to the pump, and make the connection from the solenoid valve to the fuel oil clarifier.

91. Injection Nozzles

a. Removal. Disconnect the steel injection line tubes from the injection nozzles, and cap all openings to prevent the entrance of foreign matter. Use a 1⅞-inch socket wrench to remove the injector nozzles from the engine.

b. Disassembling and Cleaning Injection Nozzles. Before disassembling the injection nozzles, prepare a thoroughly clean working area on the workbench, wash all dirt and grit from hands, and thoroughly clean the outside of the nozzle. Clamp the injector assembly in a vice between two blocks of hardwood or soft metal protective shields to prevent damage to the injector. Remove the assembly nut (D, fig. 32), the checks (E), and the balls (F), and wash them carefully in clean fuel oil. Make certain that all foreign matter has been removed from all parts of the injector assembly before reassembling. When reassembling, be sure that the flat face of the ball checks face toward the nozzle end of the assembly (fig. 32). Do not disassemble the tip and insert unless it is absolutely necessary. If it must be disassembled, clamp the small tang (K, fig. 32) in a vice and very gently tap the body of the tip (C) to drive it off. Use extreme care to avoid bending or burring the tang. Do not loosen the small locating dowel. After disassembling the tip, clean the oil passages (B) milled in the insert with a sewing needle. Clean the two spray holes (A) with a piece of hard brass wire not larger than #28 or 0.0126 inch. Wash all parts thoroughly clean before reassembling. When reassembling the nozzle, be sure that the tip, insert, and locating pin are correctly positioned.

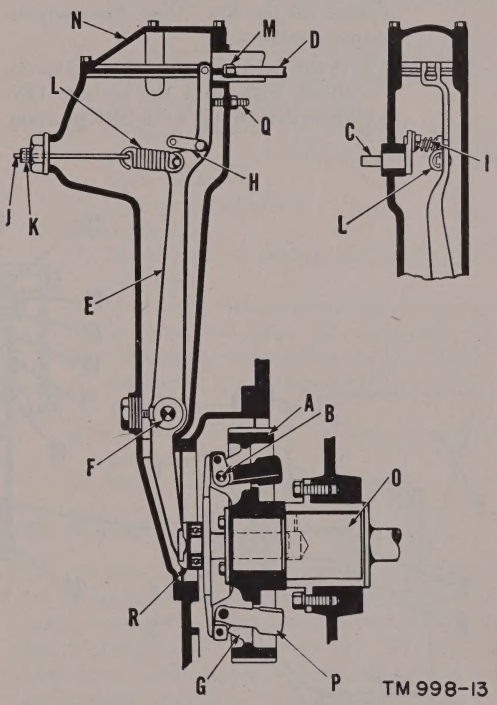
Caution: Keep all parts for each nozzle assembly separate, as the parts of each assembly are individually fitted and not interchangeable with those of other nozzles.

c. Replacement. Replace the nozzles in the engine and tighten them with a socket wrench. Reconnect the steel injection line tubes to the nozzles.

92. Governor, Governor Rod, and Butterfly Valve Assembly

a. Governor (fig. 45).

(1) *Removal.* Using a 5/16-inch socket wrench, unscrew the six ⅜-inch cap screws securing the cap to the governor housing. Disconnect the governor arm, butterfly linkage, and spring within the housing. Remove the three ½-inch nuts and seven ½-inch cap screws at the bottom end of the housing.



A. Camshaft gear.
B. Pins holding governor weights.
C. Connecting crank.
D. Reach rod.
E. Governor lever.
F. Governor lever pin.
G. Governor weight support.
H. Connecting link.
I. Connecting link spring.
J. Speed adjusting screw.
K. Adjustment locking nuts.
L. Governor spring.
M. Ball joint.
N. Cover.
O. Drive shaft.
P. Governor weights.
Q. Stop screw to prevent surging
R. Governor shifting plate.

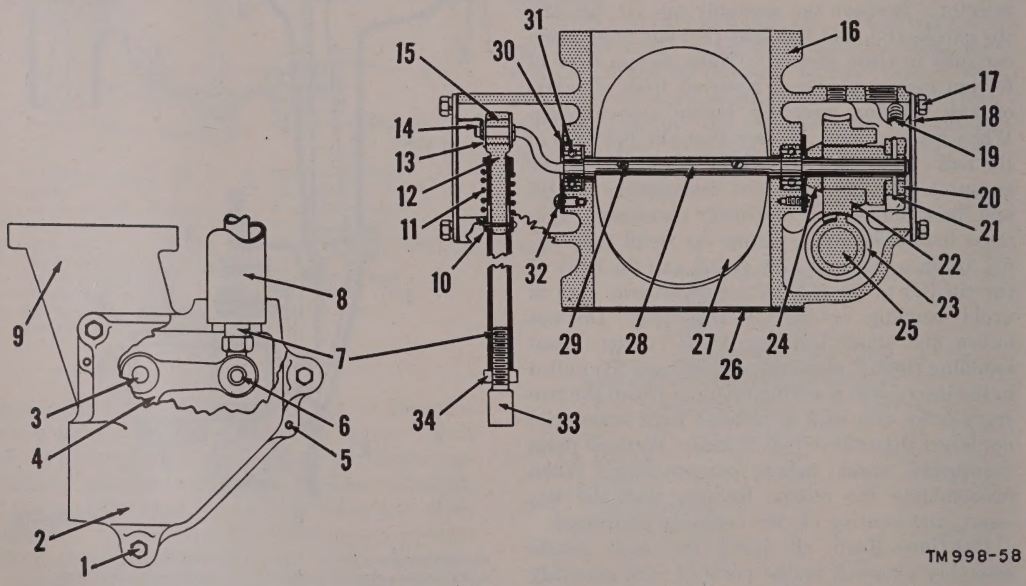
Figure 45. Governor assembly.

(2) *Replacement.* Position the governor housing, and replace the three ½-inch nuts and seven ½-inch cap screws at the bottom end. Connect the governor arm, spring, and butterfly linkage within the housing. Secure the cap by fastening the six ⅜-inch cap screws.

(3) *Governor adjustment.* Normally, no governor adjustment should be necessary. However, if the governor has been removed, disassembled, or replaced, it may be necessary to adjust the engine speed and the setting of the solenoid plunger (B, fig. 33). Make these adjustments as follows:

(*a*) With the engine running at rated speed, with no load, snap the rectifier ON-OFF switch (B, fig. 4) to OFF position. Loosen the outer adjustment nut (K, fig. 45) and turn the inner nut in or out until the frequency meter (L, fig. 4) reads 59.5 cycles. Hold the inner nut and lock it in position by tightening the outer nut against it.

(*b*) The solenoid plunger should project 1⅛ inches above the top of the solenoid. To get a rough adjustment, loosen the Allen-head setscrews (C, fig. 33) on the speed adjusting lever, turn the lever on its shaft until the plunger projects about 1⅛ inches and retighten the setscrews. For final adjustment, loosen the locknuts on the solenoid shaft and turn the shaft in the required direction until the plunger is exactly 1⅛ inches above the top of the solenoid. Hold



1. Governor rod support housing cap screw.
2. Governor rod support housing cover.
3. Governor rod lever pivot pin.
4. Governor rod lever.
5. Taper pin.
6. Governor rod end pin.
7. Governor rod assembly to butterfly valve housing.
8. Governor rod tube.
9. Governor rod support housing.
10. Governor rod end spring collar pin.
11. Governor rod end spring.
12. Governor rod end.
13. Governor rod end washer.
14. Governor rod end cotter pin.
15. Governor rod end needle bearing.
16. Butterfly valve housing.
17. Butterfly valve housing cover cap screw.
18. Butterfly valve housing cover.
19. Butterfly valve stop screw.
20. Butterfly valve stop lug.
21. Butterfly valve stop lug taper pin.
22. Butterfly valve worm gear.
23. Butterfly valve worm.
24. Butterfly valve worm gear spacer.
25. Butterfly valve hand wheel shaft.
26. Butterfly valve housing gasket.
27. Butterfly valve.
28. Butterfly valve shaft.
29. Butterfly valve to shaft screw.
30. Butterfly valve shaft ball bearing retainer.
31. Ball bearing.
32. Butterfly valve shaft ball bearing retainer screw.
33. Governor rod end.
34. Governor rod end locknut.

Figure 46. Butterfly valve and governor rod assembly.

the shaft in this position and tighten the locknuts.

(*c*) Snap the rectifier switch to ON and turn the governor control rheostat (P, fig. 4) until the frequency meter reads 60 cycles.

b. Butterfly Valve and Governor Rod Assembly (fig. 46).

(1) *Removal.* Remove the four cap screws securing the butterfly housing and lift off the housing and the governor rod assembly. Remove the governor cap and disconnect the linkage.

(2) *Replacement.* Connect the linkage at the governor, replace the governor cap, and then secure the butterfly valve housing by replacing the four cap screws.

93. Intake Manifold and Air Cleaners

a. Removal. Using a ¾-inch box wrench, remove the two air cleaners by taking out the four cap screws securing them to the butterfly valve housing. Remove the butterfly housing (par. 92*b*). Disconnect the water outlet fitting at the cranking engine and the water pipe clip on the manifold. Disconnect the fittings from the manifold to the vacuum gage and the fuel injection pump. Cap the opening to the fuel injection pump to keep dirt out of the fuel lines. Using a ¾-inch box wrench, remove the 18 nuts at the manifold flange.

b. Air Cleaner Inspection. To disassemble the air cleaner, lift off the rain cap, and remove the wingnuts securing the ring clamps which hold the cup in position. After detaching the cup, lift out the oil covered disk. Drain the oil from the cup, and clean the accumulated sediment. Press up, and turn the prefilter slightly and pull it down. If it is covered with fiber or chaff, wash the prefilter in solvent (SD), or blow out the dust and dirt with compressed air. To reassemble the cleaner, fill the cup with engine oil (OE) of the correct grade, replace the prefilter cup, and then the rain cap.

c. Replacement. When replacing the manifold, use all new gaskets. Place the manifold in position, and replace the 18 nuts (3 at each flange). Make connections from the manifold to the vacuum gage and the fuel injection pump. Reconnect the water pipe clip on the manifold and the water outlet fitting at the cranking engine. Replace the butterfly valve housing. Replace the air cleaner by positioning the gaskets and spacers between cleaners and butterfly valve housing, and tighten the cap screws. Be sure all joints are tight so that all air entering the engine passes through the cleaners.

94. Exhaust Manifolds

a. Removal. The engine has a front and rear exhaust manifold. They are not interchangeable. To remove either or both manifolds, proceed as follows:

(1) Drain coolant from the cooling system until there is no water left in the manifold water jackets.

(2) Disconnect the hose at the thermostat housing.

(3) Disconnect the water fittings at the manifold leading to the cranking engine and temperature element bulb.

(4) Using a 1⅛-inch box or socket wrench, remove the 12 hexagonal nuts securing each manifold.

(5) Lift off the manifold.

b. Replacement.

(1) Discard all old gaskets and replace with new ones.

(2) Mount the exhaust manifolds and gaskets in place, and fasten the hexagonal nuts.

(3) Connect the water fittings at the manifold leading to the cranking engine and temperature element bulb.

(4) Connect the hose at the thermostat housing.

(5) Refill the cooling system.

95. Air-fuel Ratio Adjustment

a. General. Although the air-fuel ratio is set at the factory and should not require adjustment, it may be necessary to alter this ratio if the fuel is changed, or if a carbon and valve job has been done on the engine. If the engine operates satisfactorily and delivers required power, do not alter the ratio. If adjustment seems necessary, check all other operating conditions which might affect the operating efficiency of the unit: dirt or air in the fuel lines, fouled air or fuel cleaners, fouled spark plugs, etc. If all other conditions are satisfactory, and the engine still does not operate smoothly, change the air-fuel ratio as outlined in *b*, below.

b. Adjustment (fig. 31).

(1) Remove the protecting cap (T). This exposes the adjusting screw locknut (B)

(or cotter pin on some engines), and the piston stem (C), which has two flats milled on the end to take a ⅝-inch (15.9 mm) wrench.

(2) Hold the piston stem and loosen locknut (B).

(3) Insert a screw driver in the slot (A) of the threaded extension, and hold the extension securely. Turn the piston stem clockwise for a leaner mixture and counterclockwise for a richer mixture. This adjustment can be made while the engine is running idle, but thoroughly warmed, by turning the piston stem (C) counterclockwise until the engine begins to miss and white smoke appears in the exhaust. When this happens, turn the piston stem clockwise just enough to obtain uniform firing and a clean exhaust (at full load). With proper adjustment, the vacuum gage will show a depression of between 19 and 21 inches with engine thoroughly warmed and idling. With engine operating at rate speed (900 rpm) and with full load, the gage will show a depression of not more than 1¼ inches.

c. Checking for Free Travel (fig. 31). If the vacuum control springs are replaced, the shims which control the movement of these springs must be checked and adjusted for free travel. Do this in the following manner:

(1) Remove the piston (K), retainer (X), and spring (D).

(2) Place the drawn steel spring retainer (X) on a flat surface.

(3) Place a flat disk (W) (not furnished) approximately ⅛-inch thick on the top flange of the retainer (X), and place the soft outer spring (H) on the bottom flange.

(4) Add enough 0.010-inch shims between the bottom flange and the spring to bring the top of the spring exactly level with the top of the disk, checking with a straight edge.

(5) Measure the thickness of the disk with a micrometer and check this dimension against the free travel, which should be 0.160 inch.

(6) If the free travel is greater than the disk thickness, add enough shims to make up the difference. If free travel is less, take away shims. Permissible tolerance on this adjustment is plus or minus 0.005 inch.

96. Crankcase

a. Removal.

(1) Drain the cooling system.

(2) Remove the cylinder heads (par. 99).

(3) Using a socket wrench, remove the fourteen 1-inch cap screws securing the crankcase and the oil pan.

(4) Lift the crankcase off the oil pan. Place it reverse side up on wooden blocks.

b. Replacement.

(1) Place the crankcase in position.

(2) Replace and tighten the 14 cap screws securing the crankcase to the oil pan.

(3) Replace the cylinder heads.

(4) Fill the cooling system.

97. Main and Connecting Rod Bearings

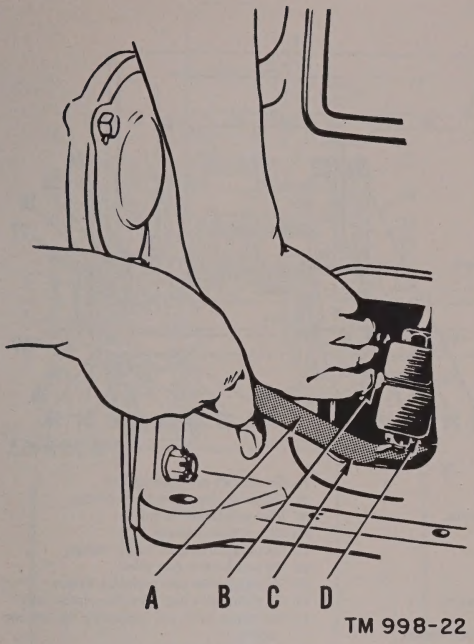
a. Inspection. To locate a loose connecting rod bearing, run the engine at rated speed, and then close the throttle. If any bearing is loose, it will rattle as the engine speed decreases. To locate a loose main bearing (fig. 47), proceed in the following manner:

(1) Remove the spark plugs to prevent the engine rocking over on compression.

(2) Remove the inspection plate.

(3) Insert the end of a prybar under the bearing. Rest the prybar on the engine case as a fulcrum and place the hand on the bearing while pushing down on the prybar. Any looseness will be evident.

b. Bearing Adjustment. The engine has thick-wall, babbit-lined bearing shells in both main and rod bearings. Remove shim thicknesses evenly on both sides to prevent cocking the bearing cap. Do not remove so many shims that the cap pinches the shaft when the nuts are pulled down to full tension. The shim projects across the full face and width of the shell. It clears the shaft by 0.003–0.005 inch. When the cap and shims are removed, the upper half of the main bearings can be removed without dropping the shaft, merely by rolling the upper half around the shaft.



A. Prybar.
B. Fingers overlap rod end and crank cheek.
C. Fulcrum point on case.
D. Connecting rod lower end.

Figure 47. Testing bearings by hand.

98. Crankshaft, Crankshaft Bearings, and Flywheel (fig. 48)

a. Removal.
(1) Drain cooling system.
(2) Remove cylinder heads.
(3) Remove crankcase.
(4) Seven main bearing caps hold the crankshaft to the crankcase. Remove the 60 cotter pins and 60 castellated nuts (10 and 19, fig. 48) securing the caps to the crankcase.

b. Flywheel Removal.
(1) Remove the eight cotter pins and castellated nuts (2 and 3, fig. 48) holding the flywheel to the crankshaft.
(2) Three $\frac{5}{8}$″–11 tapped holes are provided on the flywheel face. Insert a threaded eyebolt through these holes for lifting the flywheel on and off its holding studs.

c. Flywheel Replacement.
(1) Position the flywheel on its holding studs.
(2) Replace the eight castellated nuts and cotter pins.

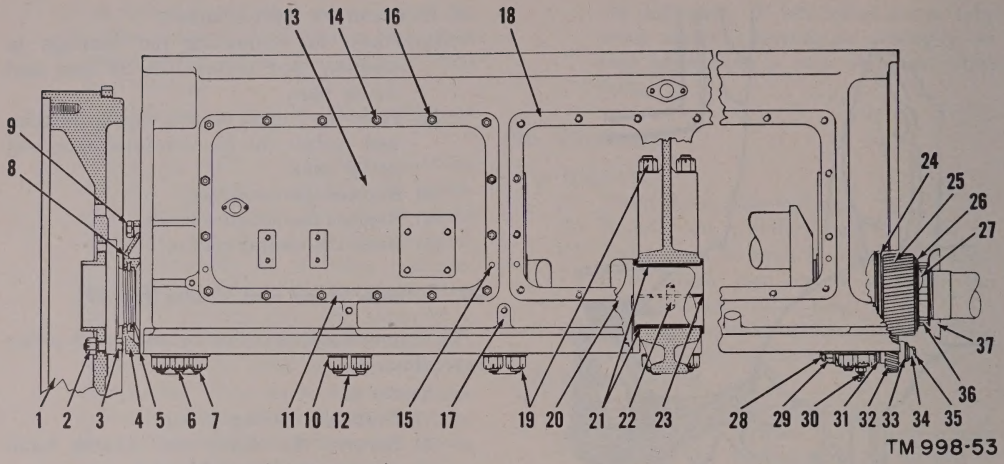
d. Crankshaft Replacement.
(1) Place the connecting rod bearings in position, and replace the 24 nuts and cotter pins.
(2) Place the 7 main bearing caps in position and replace the 60 castellated nuts and cotter pins.
(3) Replace the crankcase.
(4) Replace the cylinder heads.
(5) Refill the cooling system.

99. Cylinder Head and Valves (fig. 49)

The engine has three cylinder heads; each covers two cylinders.

a. Removal.
(1) Drain the cooling system.
(2) Remove the intake and exhaust manifolds (pars. 93 and 94).
(3) Disconnect the lubricating oil fittings, one at each end of the engine, and disconnect the six oil leads to the rocker arm shafts.
(4) Using a $\frac{3}{4}$-inch socket or box wrench, remove the valve housing cover.
(5) Using a $\frac{3}{4}$-inch socket or box wrench, remove the rocker arm support assembly.
(6) Tag the rocker arm push rods to be sure of returning them to their original positions, and remove the push rods.
(7) Using a $1\frac{1}{8}$-inch socket or box wrench, remove the 12 hexagonal nuts at each cylinder head (28, fig. 49).
(8) Lift the cylinder head assembly from the engine.

b. Valve Testing.
(1) Hold the fuel injection pump lever in the fuel shut-off position.
(2) Bar the engine over until the No. 1 piston is coming up on compression. Valve should seat fully and hold a charge so that the pistons bounce back. If there is no bounce-back, it is evidence of compression leakage. Have the engine cranked over while listening for a hissing noise at the air intakes and exhaust outlets. Disconnect the exhaust line and remove the air cleaners to determine the source of the sound. If the hiss appears to come from the intake, it may be assumed that the intake valve in the cylinder under compression at the time is not seating properly. If the hiss appears



1. Flywheel.
2. Flywheel bolt nut cotter pin.
3. Flywheel bolt.
4. Lower oil retainer.
5. Oil retainer gasket.
6. Main bearing stud, short.
7. Main bearing stud, long.
8. Upper oil retainer.
9. Oil retainer cap screw.
10. Main bearing stud washer.
11. Crankcase door gasket (under door).
12. Main bearing cap, intermediate.
13. Crankcase door, rear.
14. Crankcase door stud.
15. Crankcase door taper pin.
16. Crankcase door hexagonal nut.
17. Crankcase.
18. Crankcase door gasket.
19. Main bearing stud nut.
20. Crankshaft.
21. Main bearing, front and center.
22. Main bearing cap dowel.
23. Main bearing shim, front and center.
24. Crankshaft gear thrust washer.
25. Crankshaft gear.
26. Crankshaft gear shim.
27. Crankshaft gear locknut lock.
28. Oil pump drive gear idler spindle.
29. Idler spindle castle nut.
30. Idler spindle setscrew.
31. Oil pump idler gear thrust washer.
32. Oil pump drive gear idler.
33. Oil pump idler gear retaining washer.
34. Oil pump idler gear retaining washer lock.
35. Oil pump idler gear retaining washer cap screw.
36. Crankshaft gear locknut.
37. Crankshaft gear oil thrower.

Figure 48. Crankshaft and crankcase assemblies.

to come from the exhaust, it is evident that the exhaust valve, in the cylinder under compression at the time, is not seating properly. If the noise is not detected at the exhaust or intake, listen at the crankcase breather. If the hiss appears to come from there, it may be assumed that compression is leaking past the piston and rings. Check for leakage around the cylinder heads for possible leakage at those points. If it appears that the valves are at fault, remove the cylinder heads, inspect the valves, and regrind them if the need is indicated.

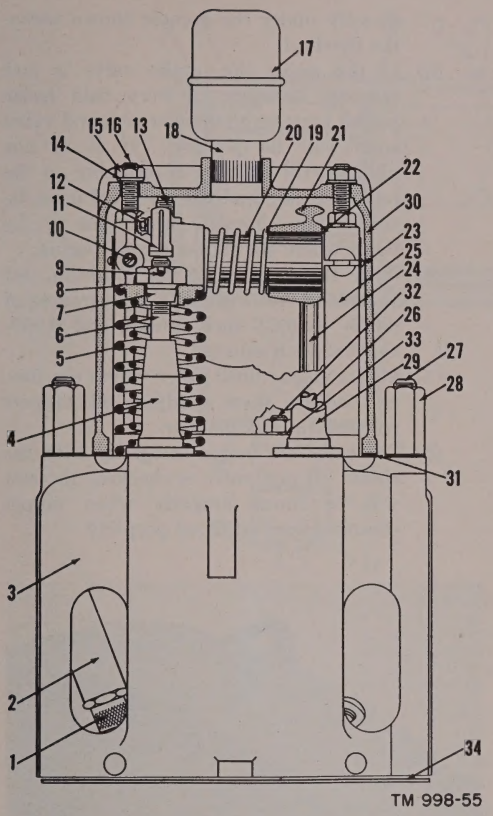
c. Push Rod Inspection. When the push rods have been withdrawn, examine each rod to see that it is straight. Upper and lower ends should be in good condition. If rods are bent, replace them. Do not attempt to straighten any bent rods. Also replace any ball or socket fittings, pressed into the ends of the rods, that show signs of wear. If the sockets at the rocker arm end are worn so deep that the upper edge rides the adjusting locknut or rocker arm at any point, replace the sockets.

d. Valve Spring Retainers. A shallow steel cup is fitted at the end of each valve stem. This cup provides a bearing for the upper end of the valve spring and is held in place by the valve stem nut and locking pin. To remove the valve springs, remove the locking pin from the valve stem nut and unscrew the retainer nut. Replace all weak, broken, or otherwise unserviceable springs.

e. Valve Inspection. Inspect each valve in the following manner:

(1) Remove all carbon and burned oil. Check valve stem and its fit in the guide. If either stem or guide show excessive wear, replace valve or guide, or possibly both, before grinding the valves.

(2) Examine exhaust valve guide and valve stem shoulder. Guide should not project into valve gas passage. Shoulder on valve stem should be sharp. Shoulder should be one-thirty-second to one-sixteenth inch below top of valve guide when valve is seated. Carbon around



1. Spark plug.
2. Radio suppression cap.
3. Cylinder head.
4. Cylinder head intake valve guide.
5. Valve spring, outer.
6. Intake valve stem.
7. Valve spring retainer cup
8. Valve spring retainer, intake.
9. Valve spring retainer nut.
10. Rocker arm support oil pipe plug.
11. Rocker arm intake.
12. Rocker arm adjusting screw lock.
13. Rocker arm adjusting screw.
14. Rocker arm cover washer.
15. Rocker arm support stud nut.
16. Rocker arm support and cover stud.
17. Rocker arm cover breather.
18. Rocker arm cover breather tube.
19. Rocker arm shaft spring.
20. Rocker arm shaft.
21. Rocker arm exhaust.
22. Rocker arm bushing.
23. Rocker arm support oil pipe plug.
24. Push rod tube.
25. Rocker arm support.
26. Exhaust valve stem.
27. Cylinder head stud.
28. Cylinder head nut.
29. Cylinder head exhaust valve guide.
30. Rocker arm cover.
31. Rocker arm cover gasket.
32. Rocker arm support stud.
33. Rocker arm support lockwasher
34. Cylinder head gasket.

Figure 49. Cylinder head assembly.

the guide and stem will be cut off each time valve is lifted. This prevents valve sticking.

(3) Inspect valve guides for wear. Replace if necessary. Guides are a pressed fit in cylinder head casting and are machined to press in place and give proper stem clearance. When new guides are installed, recut valve seat in block concentric with the guide (*f* below).

f. Valve Grinding. Grind valves in the seats from which they were removed.

(1) *Machine grinding.* If it is possible to have the valves machine ground, do so. For machine grinding, the pilot mandrel must be a snug push fit in the valve guide, and must not wobble at the upper end. The seat will not be ground true if there is any upper end movement. Replace guides that are so worn they cannot give the mandrel good support. Follow the manufacturer's instructions for dressing the grinding wheel to obtain a good seat.

(2) *Hand grinding.* The valves can be ground by hand as follows:

(*a*) Apply a good medium grinding compound sparingly around the entire valve seat.

(*b*) Slip a light lifting spring over the stem, lubricate the stem, and drop valve into its original place in cylinder head. Spring should barely hold the valve off its seat.

(*c*) Place the grinding tool in the two holes or slot in the valve head and press the valve down onto its seat. Turn valve one-quarter turn, first in one direction, then another. Repeat this three or four times.

(*d*) Release pressure on valve. The spring will lift it off its seat.

(*e*) Turn the valve 15° to another position, and repeat step (*c*) above. Do this until all the grinding compound is rubbed off the seat.

(*f*) Remove the valve. Apply new grinding compound and repeat the grinding.

(*g*) Occasionally clean valve and seat and check progress of grinding. When pits and grooves have disappeared, clean valve and valve seat. Place 8 or 10 equally spaced lead pencil marks on the seat. Drop the valve in place, rotate it one-quarter turn, and remove. If the pencil marks are evenly smudged all the way around, a perfect seat is indicated. If the marks are not evenly smudged, continue grinding.

(*h*) When grinding is complete, check for concentric valve seat with dial indicator. Oil valve stem. Remove all traces of grinding compound from valve chamber and parts, and reassemble each valve in its own seat.

g. Cylinder Head Replacement. Always use new gaskets when replacing the cylinder head.

(1) Place the cylinder heads in position over the studs. Tighten the 12 hexagonal nuts at each cylinder head, following the bolt tightening sequence (fig. 25).
(2) Replace the push rods.
(3) Replace the rocker arm support assembly.
(4) Replace the valve housing cover.
(5) Connect the six oil leads to the rocker arm shafts. Test the leads to be sure they are not clogged. Connect the two lubrication oil fittings at each end of the engine.
(6) Replace the intake and exhaust manifolds.
(7) Refill the cooling system.

h. Valve Tappet Clearance. The adjustable valve tappets are screwed into one end of the rocker arm. Intake and exhaust rocker arms are not interchangeable, as intake rocker arms have no oil groove leading to the valve stem. Intake running clearance should be 0.025 to 0.027 inch. Exhaust clearances should be 0.030 to 0.032 inch. After valves have been ground, add 0.002 inch to these clearances for the first 10 operating hours. This must be done to avoid valve burning. These clearances apply to a cold engine.

i. Valve Adjustment (fig. 50). Check the valve setting in the following manner:

(1) Adjust the valve clearances for No. 1 cylinder to 0.0105 inch for the intake and 0.0155 inch for the exhaust valves.
(2) Bar the engine over until the IN–0–1 mark on the flywheel (indicating intake valve opening on No. 1 cylinder) comes directly under the pointer shown above the flywheel.
(3) At this point the intake valve is just starting to open. A very thin feeler placed between the rocker arm and valve stem will be pinched. If it is not pinched, the cylinder is probably on the power stroke, and the flywheel must be turned one complete revolution to the point where the intake stroke begins.
(4) With the engine in this position, set tappets of No. 1 cylinder to clearances of 0.025- to 0.027-inch intake, and 0.030- to 0.032-inch exhaust.
(5) Rotate engine until other valves are free, and adjust them. Adjust all tappets correctly in this manner.
(6) The cams are forged integrally with the shaft. If one valve is checked, the rest will be timed properly when tappet clearances are adjusted properly.

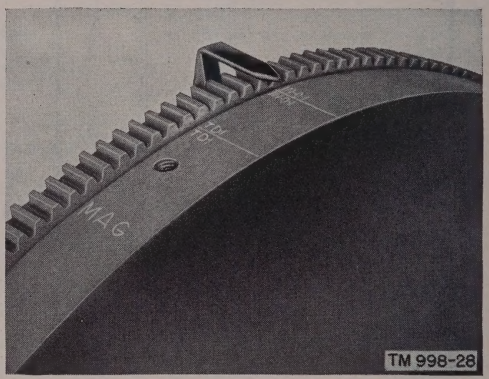
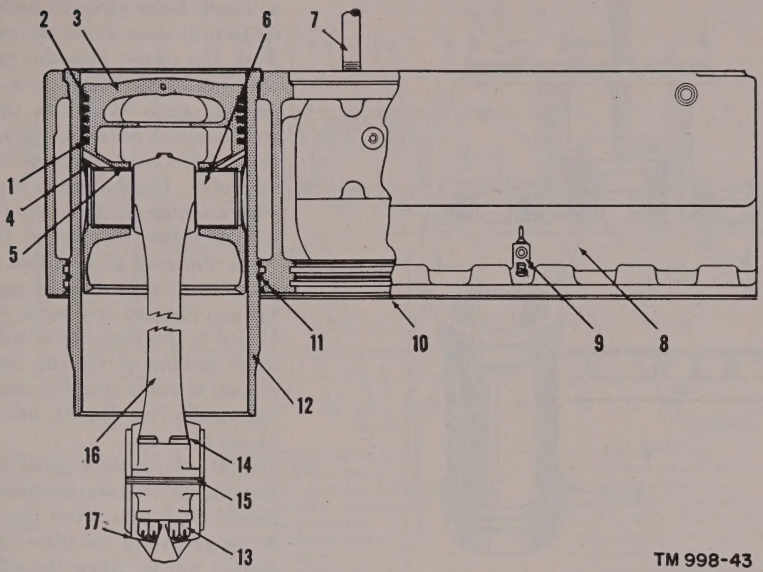


Figure 50. Flywheel timing marks.

100. Cylinder Sleeves

a. General. The engine has removable wet cylinder sleeves (12, fig. 51). The top of the sleeve is held tightly on its seat and sealed by the cylinder head and gasket. Rubber packing rings (11, fig. 51) are fitted in recessed grooves at the bottom of the water jacket to keep the lower end tight. Telltale holes (H, fig. 52) are located at the base of the water jacket in the cylinder block, opposite each cylinder. Water dripping from one of these holes indicates water is seeping past the packing rings.



1. Oil ring.
2. Compression ring.
3. Piston.
4. Piston pin lock.
5. Piston pin bushing.
6. Piston pin.
7. Cylinder head stud.
8. Cylinder block.
9. Cylinder block drain cock.
10. Cylinder block base gasket.
11. Cylinder sleeve packing ring.
12. Cylinder sleeve.
13. Connecting rod castle nut.
14. Connecting rod bolt.
15. Connecting rod shim.
16. Connecting rod assembly.
17. Connecting rod bearing cap.

Figure 51. Cylinder.

b. Sleeve Inspection. Force a piston ring into the bottom of the sleeve, at right angles to the operating position of the ring, with the gap up. Measure the gap opening. Move the ring upward, keeping it at the same angle with respect to the engine axis, to 1½ inches below the top of the sleeve. Measure the gap in this position. If the difference in gap is more than 0.010 inch, sleeve is worn and must be replaced. When replacing a sleeve, also replace the piston and piston rings.

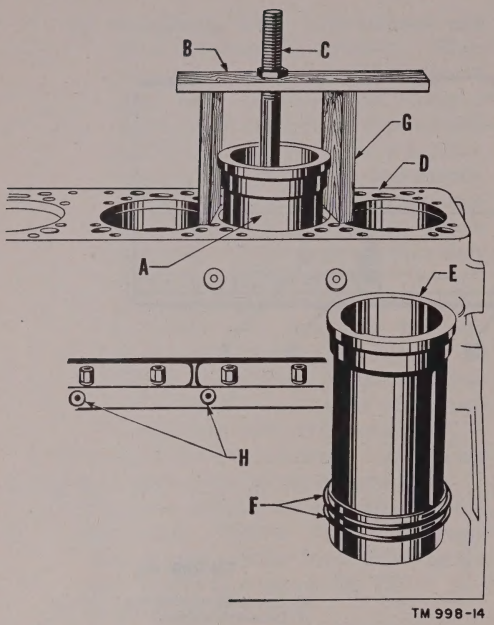
c. Sleeve Removal (fig. 52). Pull the cylinder sleeve out of the block with a sleeve puller. A puller can be fabricated by inserting a long bolt with a steel crossbar at the bottom and a wooden or steel bar at the top. Support the latter on two wooden blocks (fig. 52). Tighten the top nut to withdraw sleeve.

d. Sleeve Replacement. Before replacing the sleeve, clean the bore in the cylinder block thoroughly. Install new rubber packing rings. When removing the old rings, be careful not to let pieces fall into the crankcase. Clean the ring grooves thoroughly. Inspect and clean the new packing rings so that they are entirely free from all foreign matter. Coat the outside of the cylinder sleeves with a thin coating of light clean oil. Cover the top of the sleeve with a wooden block, and push or tap gently into place.

101. Pistons

a. Removal. The pistons can be removed in the following manner:

(1) Remove the cylinder head (par. 99).
(2) Using a ¾-inch box or socket wrench, remove the six handhole plates from the left side of the engine.
(3) Rotate the crankshaft by barring the engine over until each connecting rod bearing is accessible.
(4) Mark the connecting rod bearing caps so that each cap may be reinstalled in the exact position from which it is removed. Remove the four cotter pins and connecting rod nuts by using a $^{9}/_{16}$-inch box or socket wrench. This frees the lower bearing cap and shim.



A. Old sleeve being withdrawn.
B. Bar used as yoke for puller.
C. Long stud with nut pulls sleeve when nut is screwed down. T bar across bottom of sleeve is not shown.
D. Cylinder block.
E. New sleeve. Head gasket holds joint tight at top flange.
F. Rubber sealing rings.
G. Wood blocking.
H. Leak detection holes.

Figure 52. Removing cylinder sleeves.

(5) Push the piston upward through the cylinder.

(6) Tag each piston for easy identification. They must be replaced in the cylinders from which they were removed and facing the same way on the crankshaft as they were before disassembly.

(7) To remove connecting rod from piston, remove the piston pin retaining rings from the piston and force out the pin. In rebushing either piston or connecting rod, piston and connecting rod bearing must be in parallel alinement.

b. Piston Inspection.

(1) *Piston clearance.* The pistons are cam-ground. The sides which take the thrust from the connecting rod have the largest diameter, and are the points where clearance measurements should be taken. The smallest diameter is in line with the piston pin. To check the clearance, lay a ½-inch feeler strip 10 inches long and 0.018-inch thick along the cylinder bore. Push the piston into the cylinder. An easy push fit indicates a correct fit. A hard push fit is too tight. If the weight of the piston will drop it through the cylinder, it is too loose.

(2) *Ring cap.* Place a piston in the cylinder without rings so that the top is about 1 inch below the top of the cylinder. Press the ring to be fitted flat against the piston. Use a feeler gage to check the gap (for gap clearances, see sec. VII). If gap is less than 0.050 inch, file off a small amount of the ring tips until gap measures within specified limits. A small gap causes ring seizure, and a large gap causes blow-by.

(3) *Ring fit.* Both the sides of the rings and the ring grooves are tapered. The rings should fit so that, when they are pressed in the groove in one place only, the ring surface will be below the side surface of the piston by 0.005 to 0.010 inch. When the top limit is exceeded by 0.002 inch, rings are worn and replacement is necessary.

c. Ring Grooves. Whenever a piston and rings are removed, clean the grooves, particularly the side surfaces.

d. Replacement. Replace the pistons in the following manner:

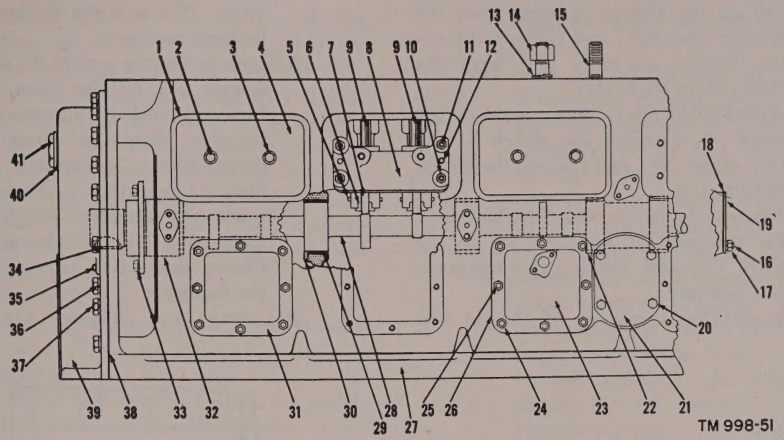
(1) To assemble the connecting rod to the piston proceed as follows: Insert the piston pin part way into the piston and place the connecting rod inside the piston. Line up the upper end of the connecting rod with the piston pin and force the pin through the connecting rod bushing and into the piston pin boss on the opposite side of the piston. Center the pin in the piston and insert the two piston pin retaining rings in the piston pin holes on both sides of the piston.

(2) Check the tags so that each piston is returned to its proper cylinder. Push the piston from the top into the cylinder.

(3) Assemble the lower bearing cap and shim to the upper bearing half, and replace the four cotter pins and connecting rod nuts.

(4) Replace the six handhole plates.

(5) Replace the cylinder head.



1. Valve tappet door gasket (under).
2. Valve tappet door cap screw.
3. Valve tappet door cap screw washer.
4. Valve tappet door.
5. Valve tappet roller pin.
6. Valve tappet.
7. Valve tappet roller.
8. Valve tappet bracket.
9. Pushrod.
10. Valve tappet bracket hexagonal nut.
11. Valve tappet bracket stud.
12. Valve tappet bracket taper pin.
13. Cylinder hold down stud lockwasher.
14. Cylinder hold down stud nut.
15. Cylinder hold down stud.
16. Camshaft and plate stud.
17. Camshaft and plate stud hexagonal nut.
18. Camshaft end plate gasket.
19. Camshaft end plate.
20. Cover plate cap screw.
21. Cover plate.
22. Camshaft bushing.
23. Crankcase door.
24. Crankcase door stud hexagonal nut.
25. Crankcase door stud.
26. Crankcase door gasket (under).
27. Crankcase.
28. Camshaft.
29. Camshaft bushing.
30. Camshaft bushing dowel.
31. Crankcase door.
32. Camshaft bushing, front.
33. Camshaft bushing cap screw.
34. Camshaft gear woodruff key.
35. Gear cover taper pin.
36. Gear cover cap screw lockwasher.
37. Gear cover cap screw.
38. Gear cover gasket.
39. Gear cover.
40. Gear cover nut washer.
41. Gear cover nut.

Figure 53. Camshaft and crankcase assembly.

102. Camshaft (fig. 53)

Remove the front gear cover (39, fig. 53). Using a ¾-inch box or socket wrench, loosen the four ⅜-inch cap screws which hold the timing gear. Pull out the timing gear. Remove the two ½-inch cap screws that hold the front bushing (32, fig. 53) in place, using a ¾-inch socket wrench, and pull out the bushing. Pull the camshaft out through the front of the engine. To remove the camshaft bushings, remove the eight camshaft bushing pins in the camshaft bearing support and push the bushings out.

103. Cranking Engine

a. General. The following subparagraphs contain instructions for dismounting the cranking engine from the oil engine, and disassembling and reassembling the various components of the cranking engine.

b. Dismounting Cranking Engine. Drain the cooling, fuel, and lubricating systems. Break top and bottom water connections. Remove the choke wire bracket and disconnect the fuel supply line at the carburetor intake. Unscrew the two cap screws which hold the starter Bendix housing to the coupling guard of the main engine. Remove the bolts which hold the front support of the starting unit. Remove the cranking engine to a workbench for repairs. Two men can lift the engine, but it is advisable to use crane facilities if they are available.

c. Replacing Cranking Engine. Position the cranking engine on the oil engine, and secure the bolts which hold the front support. Replace the two cap screws holding the Bendix housing to the coupling guard. Remake fuel supply line connections at the carburetor intake, and replace the choke wire bracket. Make top and bottom water connections. Then fill the cooling, fuel, and lubricating systems.

d. Transmission and Clutch (figs. 54 and 55).

(1) *Removal and disassembly* (fig. 54).

(*a*) Unscrew the cap screws which hold the clamping segments (33) and loosen the Bendix housing lockscrews. This releases the Bendix housing from the transmission housing (28).

(*b*) Pull off the Bendix housing from the Bendix assembly, and remove the entire Bendix assembly (35) from the spline drive shaft (32).

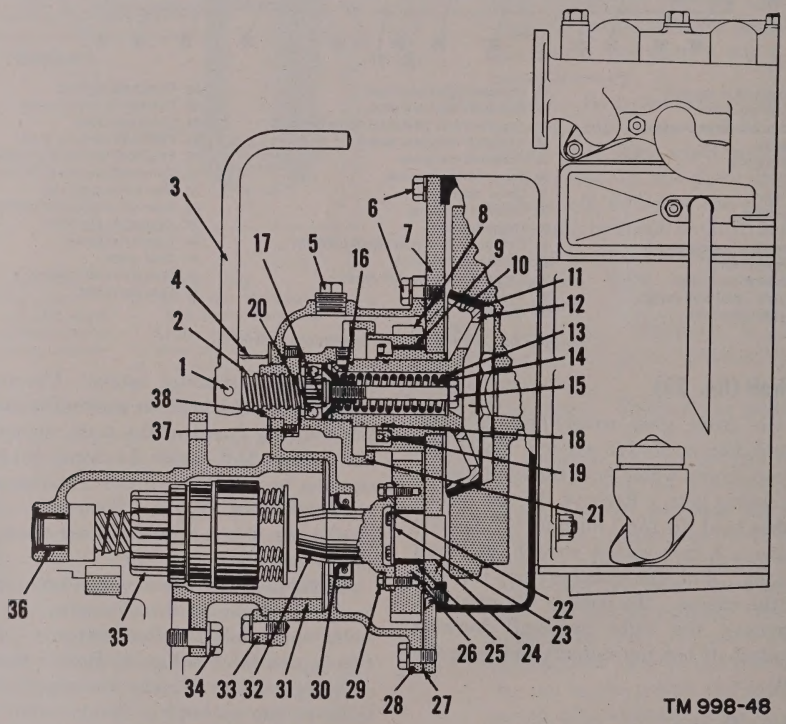
(*c*) Drive out the pin (1), remove the clutch lever (3), unscrew the clutch handle stop screw (37), and remove the clutch handle stop.

(*d*) Unscrew the cap screws (6) which hold the transmission housing (28) to the plate (7), and remove the transmission housing.

(*e*) Inspect the condition of the oil seal (30). If it is worn or shows signs of leaking, replace it.

(*f*) Remove the cap screws (6) and flathead screws holding the plate (7) to the flywheel housing, and remove the plate together with the clutch cone and drive flange assemblies. Lock the plate (7) securely in a vise and unscrew the setscrew which locks the flange (21) to the clutch cone assembly. Clamp the clutch cone and unscrew the flange.

(*g*) Unwire and unscrew the four cap



1. Hand lever pin.
2. Thrust screw.
3. Clutch lever.
4. Clutch handle stop.
5. Oil filler plug.
6. Clutch housing plate cap screw.
7. Clutch housing plate.
8. Main drive gear.
9. Drive gear bushing.
10. Clutch lining screw.
11. Clutch lining.
12. Clutch cone.
13. Clutch spring stud washer.
14. Clutch spring.
15. Clutch spring stud.
16. Clutch spring pad.
17. Thrust bearing snap ring.
18. Oil ring.
19. Drive gear retaining nut.
20. Thrust bearing.
21. Drive flange.
22. Driven gear cap screw.
23. Driven gear retaining washer.
24. Driven gear bearing.
25. Driven gear bushing.
26. Driven gear.
27. Transmission housing gasket.
28. Transmission housing.
29. Bendix drive shaft cap screw.
30. Transmission housing oil seal.
31. Bendix housing.
32. Spline drive shaft.
33. Bendix housing clamping segment.
34. Cap screw.
35. Bendix drive gear.
36. Bendix assembly needle bearing.
37. Clutch handle stop screw.
38. Clutch spring adjusting nut.

Figure 54. Starting unit transmission.

screws (29) and remove the Bendix drive shaft (32). Then remove the driven gear retaining washer (23), the cap screws (22), the driven gear bearing stud (24), and the gear (26).

(*h*) Unscrew the hollow point Allen-head setscrew through the hole in the drive gear (8), unscrew the drive gear retaining nut (19), and finally remove the drive gear (8), bushing (9), and stud.

(2) *Replacement.*

(*a*) Insert the flat headscrews in the proper holes. Then replace the gears and bushings.

(*b*) Replace the retainer nut (19), install the setscrew through the hole in the drive gear, and replace the driven gear retaining washer (23).

(*c*) Replace and tighten the clutch cone assembly (12) and drive flange (21). Be sure the flange is pulled snug against the shoulder of the clutch cone and that the hole in the flange registers with the hole in the shaft of the clutch cone so that the setscrew will hold the two securely.

(*d*) Mount the drive plate to the flywheel housing. Be certain the flathead screws are sufficiently tight to prevent the possibility of oil leakage from the transmission housing into the flywheel housing. Make sure the gasket (27) is in good condition when assembling the transmission housing on the plate.

(*e*) Replace the clutch handle stop and the clutch handle. Tighten the clutch lever adjusting nut so that the clutch engages when the lever is in a convenient position. An inclination of about 15° off vertical toward the operator is best. To determine the engaging point, tighten or loosen the nut and at the same time move the lever back and forth. Hold the handle tightly so that the point of engagement can be accurately determined. When the point of engagement has been determined, set the clutch handle stop (4) in a position so that the handle is

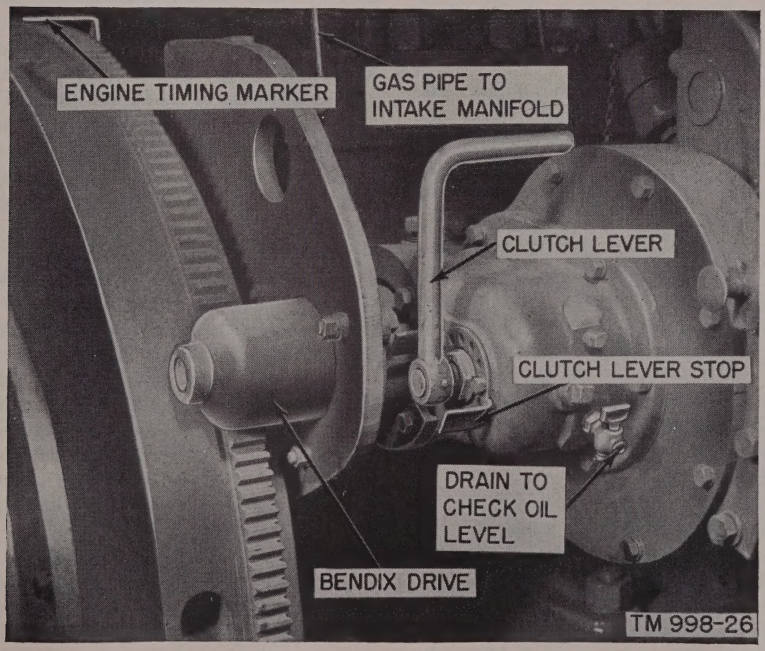


Figure 55. Starting engine clutch and Bendix drive.

midway between the two ends. Insert the cap screw (37), move the adjusting nut slightly until the screw slips into one of the threaded holes in the inside flange of the adjusting nut, and tighten the cap screw.

(*f*) Replace the Bendix assembly on the spline drive shaft (32), and replace the Bendix housing on the Bendix assembly. Replace the cap screws which hold the clamping segments (33), and tighten the Bendix housing lockscrews.

e. Oil Pump.

(1) *Removal.* To remove the oil pump, drain the lubricating oil system. Remove the oil pan by unscrewing the 18 ¼-inch hexagonal head cap screws with a ⅜-inch wrench. Unscrew the oil pump screen and pipe assembly. Loosen the three No. 10 roundhead machine screws which hold the pump cover to the body, and remove the pump body retainer screw. Lift the pump off the unit.

(2) *Cleaning screen.* Soak the oil pump screen in solvent (SD) until any carbon which may have accumulated has softened. Scrape the carbon off the screen with a putty knife; be careful not to damage the screen.

(3) *Replacement.* Position the pump. Replace the pump body retainer screw and the three machine screws securing the pump cover to the body. Replace the screen and pipe assembly, and the oil pan.

f. Oil Pressure Relief Valve. To remove the oil pressure relief valve, unscrew the protecting cap, the adjusting screw lock and screw, pressure contact spring, and the cylindrical valve plunger. Wash all parts thoroughly in solvent (SD), including the valve seat. Scrape away any hardened carbon. To replace the valve, replace the cylindrical valve plunger, pressure contact spring, screw and adjusting screw lock, and finally the protecting cap.

g. Water Pump.

(1) *Removal.*

(*a*) Remove the carburetor (*k* below).

(*b*) Remove the water inlet and outlet connections, bypass connections, and break the connection between the governor lever and throttle rod.

(*c*) Remove the cap screws holding the water pump and governor assembly to the gear and front plate. Disengage the gears carefully, and withdraw the entire assembly to a workbench for repair.

(2) *Replacing water pump seal.* To replace the water pump seal, first remove the pump cover. Drive out the pin holding the impeller to the shaft; be careful not to distort the shaft. Using a gear puller, pull the impeller from the shaft. If the impeller is stuck, place that portion of the assembly in penetrating oil, and allow it to stand for several hours. This will loosen the impeller and seal. Before installing new seals, clean the shaft with very fine emery cloth. Install the seals, replace the impeller on the shaft, and drive in the pin holding the impeller to the shaft. Replace the pump cover.

(3) *Replacement.* Position the water pump and governor assembly with respect to the gear and front plate, and tighten the cap screws. Make connections between the governor lever and throttle rod, the bypass connection, and the water inlet and outlet connections. Replace the carburetor.

h. Thermostat. To remove the thermostat, drain the water from the engine, and disconnect the elbow fitting at the engine inlet. Unscrew the two 5/16-inch hexagonal nuts at the inlet flange. Remove the flange and gasket. To replace the thermostat, replace the flange and gasket, and tighten the two nuts at the inlet flange. Connect the elbow fitting at the engine inlet.

i. Magneto.

(1) *Removal.* Unscrew the four high-tension lead fittings and one ground connection fitting at the magneto. Remove the four roundhead machine screws securing the aluminum radio suppression cover to the magneto. Using a 9/16-inch box wrench, remove the ⅜-inch hexagonal adjusting screw on the front magneto bracket support. Remove the four ¼-inch hexagonal head cap screws holding the magneto to the support.

(2) *Servicing magneto.* Clean the magneto in the following manner: Remove the distributor spool. Wipe it off, and see that the carbon brushes work freely and have a little spring tension. Check the con-

tact points and resurface with a fine stone. Adjust to a maximum of 0.014–0.016 inch. Apply 3 or 4 drops of OE 50 oil to the camwick and one to the breaker bar bearing. Do not get oil on the breaker points.

(3) *Magneto timing.* If it is necessary to replace the magneto, time it in the following manner:

(*a*) Crank the engine until No. 1 piston is approaching top dead center on compression stroke.

(*b*) Open the inspection opening plate on the flywheel housing and watch as the engine is cranked slowly until the top dead center mark on the flywheel is directly beneath the mark on the housing. Keep the engine in this position.

(*c*) Connect a short length of cable to the No. 1 magneto terminal. (The terminal in the upper right-hand corner is considered number one.) Bring the free end of this cable to within about ⅛ inch of the magneto housing and turn the magneto shaft by hand. Assemble the drive gear to the impulse coupling. Keep turning the magneto shaft by hand until the impulse snaps and a spark occurs between the cable and the magneto. This indicates that the internal magneto parts are in approximate position for firing No. 1 cylinder.

(*d*) Hold the shaft and gear as close to this position as possible. Then place the magneto on its mounting pad so that mounting holes and slots line up.

(*e*) To determine exact firing position, turn the body of the magneto in the direction of normal shaft rotation (clockwise, looking at the front) for about 90°. Then bring it back slowly until the impulse just snaps. If steps (*a*) through (*e*) have been handled carefully, the mounting holes and slots will line up so that the magneto may be locked. If they do not line up, shift the position of the gear one or two teeth to a point where, with the body of the magneto in position to be locked, the impulse just snaps.

j. Spark Plugs. To remove the plugs, snap the wire bail which holds the suppression cover together. Using the spark plug wrench provided with the unit, remove the four plugs.

k. Carburetor. To remove the carburetor, disconnect the fuel inlet line, using a 7/16-inch open-end wrench. Disconnect the throttle lever at the governor by removing the cotter pin and yoke pin. Disconnect the hand throttle by loosening the No. 8 roundhead machine screw and remove the throttle wire. Remove the two air cleaner hose clamps. Loosen the two hexagonal nuts at the carburetor flange, using a 7/16-inch box wrench, and lift the carburetor off. To replace, position the carburetor and tighten the two hexagonal nuts at the carburetor flange. Replace the two air cleaner hose clamps. Connect the hand throttle and replace the throttle wire. Connect the throttle lever at the governor, and then the fuel inlet line.

l. Combination Intake and Exhaust Manifold. Remove the four manifold hold-down hexagonal nuts, using a 7/16-inch socket wrench. Remove the carburetor as outlined in *k* above. Replace the manifold by first replacing the carburetor, and then tightening the four manifold hold-down nuts.

m. Cylinder Head and Valves.

(1) *Removal.*

(*a*) Drain the cooling system.

(*b*) Disconnect the ignition cables from the spark plugs.

(*c*) Remove the cylinder head.

(*d*) Remove the manifolds.

(*e*) Remove the valve tappet cover plates.

(2) *Valve removal and grinding.* The head of each valve stem is fitted with a shallow steel cup (retainer) that surrounds the end of the valve spring and is held to the stem by a pair of tapers. Compress the spring so that the tapers will fall away from the valve stem. Remove the retainer, lift out the valve, and remove the spring. Follow the general rules for valve grinding as outlined in paragraph 99. After the valves have been ground, replace them in the reverse order of disassembly.

(3) *Cylinder head replacement.*

(*a*) Replace the valve tappet cover plates.

(*b*) Replace the manifold.

(*c*) Replace the cylinder head, using a new

gasket, and tighten the bolts with a tension indicating wrench. After the head is in place, draw the cap screws and studs fairly tight, starting with the center studs and working toward each end alternately. Tighten in the same order for two or three successive stages.

(4) *Valve timing.* Check the valve timing with the tappets of No. 1 cylinder adjusted to 0.003-inch intake and 0.005-inch exhaust. Rotate the flywheel until the mark alongside the flywheel inspection opening is directly opposite the IN-O mark on the flywheel. With clearance set, and flywheel in this position, the intake valve of No. 1 cylinder should be just starting to open. A thin feeler placed between tappet and end of valve stem will be pinched. If feeler is not pinched, cylinder may be on power stroke. Turn it one complete revolution to the point where the intake stroke begins. If one valve is timed, all valves will be properly timed because the cams are forged integrally in one piece with the shaft.

104. Safety Switches (figs. 56 and 57)

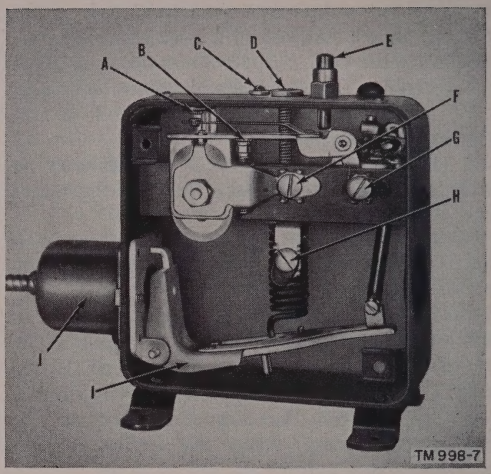
a. Water Temperature Safety Switch (fig. 56). Trace the flexible cable containing the capillary tube to the water temperature gage element. Disconnect the element and, after disconnecting the four cap screws securing the switch, remove the switch and the cable containing the capillary tube.

b. Lubricating Oil Pressure Switch (fig. 57). To disconnect the lubricating oil pressure switch, disconnect the connection to the oil line, and remove the four cap screws securing the switch to its bracket.

105. Generator Sleeve Bearings (fig. 58)

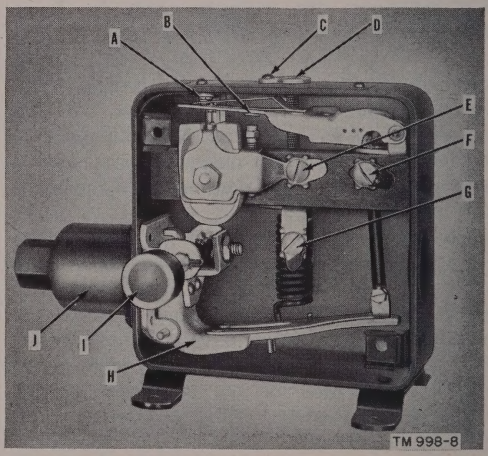
a. Removal. To remove the generator sleeve-bearing lining from the solid bracket, remove the end shield. Remove the oil well cover plate and the oil ring retaining slip. With oil ring disengaged, tap the bearing lining out.

b. Cleaning Sleeve Bearings. Sleeve bearing housings are provided with settling chambers which collect dust, dirt, and oil sludge. Draining the oil flushes the settled material out. When the sleeve bearing has been removed, wash out the bearing housing with solvent (SD). Dry the bearing lining, and cover the shaft with a thin film of oil before assembling. The joint surfaces



A. Auxiliary contacts.
B. Main contacts.
C. Lockscrew.
D. Adjusting screw.
E. Manual reset pin.
F. Oil pressure safety switch connection.
G. Toggle switch connection.
H. Red light and relay connection.
I. Main arm assembly.
J. Water temperature element.

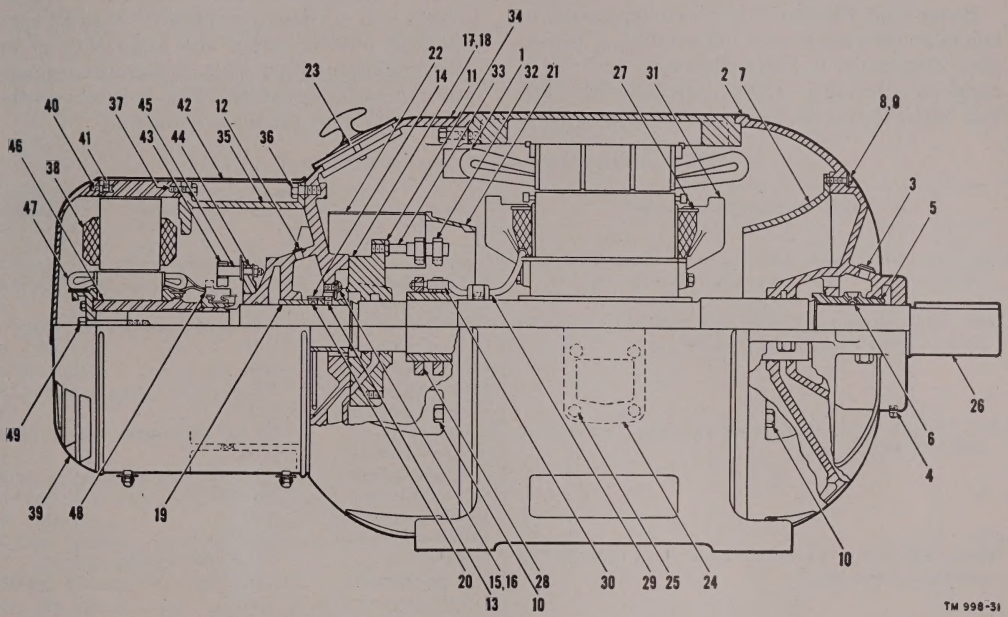
Figure 56. Water temperature safety switch.



A. Auxiliary contacts.
B. Main contacts.
C. Lockscrew.
D. Adjusting screw.
E. Solenoid connection.
F. Water temperature switch connection.
G. Relay and red light connection.
H. Main arm assembly.
I. Manual control knob.
J. Pressure bellows assembly.

Figure 57. Lubricating oil pressure switch.

around the bearing housing are of the split bracket type. They are carefully machined and equipped with drain grooves to prevent leakage. If leakage does occur, clean the joint surfaces thoroughly with solvent (SD), and apply a thin coat of sealing compound before assembly.



1. Stator coil with wedges.
2. End shield, pulley end, with oil well cover, oil gage and pipe plugs.
3. Oil well cover.
4. Pipe plug for oil drain.
5. Bearing lining, two parts, pulley end.
6. Oil ring for bearing lining.
7. Air deflector, pulley end.
8. Screw, fastens air deflector to end shield.
9. Lockwasher.
10. Bolt, fastens end shield, pulley end or collector end, to stator frame.
11. End shield, collector end, with oil well cover, oil gage, oil ring retainer, bearing screw, cover, piping and pipe plugs.
12. Oil well cover.
13. Setscrew for bearing lining.
14. Oil ring retainer.
15. Screw, fastens oil ring retainer to end shield.
16. Lockwasher.
17. Cover for bearing.
18. Gasket for cover.
19. Bearing lining, collector end.
20. Oil ring, collector end.
21. Air deflector, pulley end.
22. Cover for air deflector with bolts and wingnuts.
23. Cover for end shield, collector end, with handle, spring and nut.
24. Conduit box.
25. Cap screw, fastens conduit box to stator frame.
26. Rotor with shaft, fan, collector, rotor coil, and connections.
27. Rotor coil with pole piece and amortisseur winding.
28. Collector.
29. Long lead, rotor coil to collector.
30. Bushing for collector ring.
31. Fan for rotor.
32. Brush holder with pressure arm and pressure spring.
33. Brush-holder stud with insulation and nut.
34. Nut for brush-holder stud.
35. Bracket for exciter.
36. Cap screw, fastens bracket to generator end shield.
37. Cap screw, fastens exciter magnet frame to bracket.
38. Main field coil, shunt-wound.
39. End shield for exciter.
40. Screw, fastens exciter and shield to magnet frame.
41. Setscrew for No. 40.
42. Cover for exciter, with fasteners.
43. Brush holder with pressure spring for exciter.
44. Brush-holder yoke.
45. Brush-holder stud with nut and washer.
46. Armature with winding and commutator.
47. Armature coil with slot insulation.
48. Commutator.
49. Bolt, fastens exciter armature to a-c rotor.

Figure 58. Generator and exciter, cross-section.

Section VI. OTHER REPAIR PROCEDURES

106. Interference Suppression

Power Unit PE–220–C has been suppressed to minimize the radiation of undesirable r-f waves. This suppression is accomplished by the use of capacitors, bonding straps, internal-tooth (IT) and internal-external-tooth (IET) lockwashers. Failure to replace any of the items used to suppress the unit will result in the loss of suppression characteristics. It is vitally important to reinstall each capacitor, bonding strap, and lockwasher in its exact original position when reassembling equipment or replacing parts. The location of the various suppression items is as follows:

Table II. Suppression details for power unit PE–220–C

Description of suppression applications	Suppression components	Size or value	Quantity
Terminals RR–1 and RR–2 of a-c voltage regulator bypassed to regulator mounting bolts (fig. 59).	Capacitor	0.1 mf, 500 v ac/dc	2
	IET lockwashers	¼ in	6
	Tinned copper lugs	No. 8	4
Each output terminal of alternator bypassed to bracket bolted to switchboard frame (fig. 59).	Capacitor	0.1 mf, 500 v ac/dc	3
	IET lockwashers	⅜ in	6
	IET lockwashers	¼ in	9
	Tinned copper lugs	No. 8	3
	Tinned copper lugs	¾ in	3
Each output terminal of main generator bypassed to terminal box (fig. 60).	Capacitor	0.1 mf, 500 v ac/dc	3
	IET lockwashers	½ in	4
	IET lockwashers	¼ in	9
	IT lockwashers	No. 10	6
	Tinned copper lugs	⅜ in	3
	Tinned copper lugs	No. 8	3
Exciter terminals bypassed to panel which is bonded to generator frame (fig. 60).	Capacitor	0.1 mf, 500 v ac/dc	5
	IET lockwashers	¼ in	23
	Tinned copper lugs	¼ in	5
	Tinned copper lugs	No. 8	5
Voltage regulator of charging circuit bonded to panel. Panel bonded to engine block (fig. 61).	Bond strap	¼ in. x 2¼ in	1
	IET lockwashers	5/16 in	5
	IET lockwashers	¼ in	2
	Tinned copper lugs	5/16 in	1
	Tinned copper lugs	¼ in	1
Pigtails of armature and field wire shielding bonded to regulator panel (fig. 61).	IT lockwashers	No. 10	3
	Tinned copper lugs	No. 10	2
Pigtail of battery cable shielding bonded to regulator panel (fig. 61).	IET lockwashers	¼ in	3
	Tinned copper lugs	¼ in	1
Armature terminal of regulator bypassed to regulator panel (fig. 61).	Capacitor	0.25 mf, 100 v dc	1
	IT lockwashers	No. 8	3
	Tinned copper lugs	No. 8	2
Ammeter terminal bypassed to regulator panel (fig. 61)	Capacitor	0.1 mf, 100 v dc	1
	IT lockwashers	No. 10	3
	Tinned copper lugs	No. 8	1
	Tinned copper lugs	No. 10	1
Regulator battery terminal bypassed to regulator panel (fig. 61).	Capacitor	0.25 mf, 100 v dc	1
	IT lockwashers	No. 10	3
	Tinned copper lugs	No. 8	1
	Tinned copper lugs	No. 10	1
Armature and field leads from charging generator to voltage regulator, shielded (fig. 61).	Shielding braid	⅛ in	88 in.
	IT lockwashers	No. 10	3
Charging generator bonded from housing to engine subframe (fig. 61).	Bond strap	1 in. x 5½ in	1
	IET lockwashers	½ in	2
	IET lockwashers	¼ in	4
Charging generator armature terminal bypassed to generator frame at through-bolt (fig. 61).	Capacitor	0.1 mf, 100 v dc	1
	IT lockwashers	No. 10	2
	Tinned copper lugs	No. 10	2

Table II. Suppresion details for power unit PF–220–C—Continued

Description of suppression applications	Suppression components	Size or value	Quantity
Pigtails of armature and field shielding braid grounded to charging generator (fig. 61).	Tinned copper lugs	¼ in	2
Tie bar bonded between engine block and charging generator (fig. 61).	IET lockwashers	½ in	3
Radiator bonded to support brackets (fig. 63)	IET lockwashers	⅝ in	24
Fan guard brackets bonded to fan grill (fig. 63)	IET lockwashers	½ in	8
Flywheel guard cover bonded to skid-base and engine block (fig. 63).	IET lockwashers	5/16 in	6
	IET lockwashers	¼ in	4
Main generator bonded to skid-base (fig. 63)	Bond strap	1⅛ in. x 6 in	1
	IET lockwashers	⅜ in	5
Main engine magneto bonded to magneto mounting bracket (fig. 61).	IET lockwashers	5/16 in	4
Ignition cable on main engine (fig. 61)	Shielded ignition wire	24 ft. 7 in	
Spark plug shield assembly (fig. 61)			6
Safety switches bonded to mounting panel (fig. 61)	IET lockwashers	5/16 in	8
	IET lockwashers	¼ in	16
Safety switch mounting panel bonded to engine block (fig. 61).	IET lockwashers	5/16 in	4
	IT lockwashers	5/16 in	4
Horn relays bonded to panel (fig. 61)	IT lockwashers	No. 8	6
Oil safety switch shielding grounded to switch (fig. 61)	IET lockwashers	No. 8	3
	Tinned copper lugs	No. 8	3
Oil solenoid switch shielding bonded to switch (fig. 61)	IET lockwashers	No. 8	1
	Tinned copper lugs	No. 8	1
Water safety switch bonded to switch (fig. 61)	IT lockwashers	No. 8	3
Lead from control panel to water safety switch, shielded (fig. 61).	Shielding braid	⅛ in	33 in.
Lead between water safety switch and oil safety switch, shielded (fig. 61).	Shielding braid	⅛ in	16 in.
Lead between RUN light and oil safety switch, shielded (fig. 61).	Shielding braid	⅛ in	44 in.
Ignition switch lead between ammeter and engine control panel, shielded (fig. 61).	Shielding braid	⅛ in	69 in.
Battery lead to ammeter, shielded (fig. 61)	Shielding braid	⅛ in	33 in.
Magneto shield bonded to timing case (fig. 62)	Bond strap	⅜ in. x 4½ in	1
	IET lockwashers	5/16 in	2
	IT lockwashers	No. 10	2
	Tinned copper lugs	No. 10	1
	Tinned copper lugs	5/16 in	1
Magneto shield halves bonded together	IT lockwashers	No. 10	3
Flywheel housing of cranking engine bonded to main engine block (fig. 62).	Bond strap	⅜ in. x 11½ in	1
	IET lockwashers	5/16 in	2
	IET lockwashers	¼ in	2
	Tinned copper lugs	5/16 in	1
	Tinned copper lugs	¼ in	1
Stop switch lead of cranking engine, shielded (fig. 62)	Shielding braid	⅛ in	29 in.
	IET lockwashers	5/16 in	2
	Tinned copper lugs	5/16 in	1
	Ferrule		1
	Nut coupling		1
High-tension leads from spark plugs to magneto on cranking engine, shielded (fig. 62).	Shielded ignition wire		94¼ in.
Shield assembly for each spark plug of cranking engine (fig. 62).			4

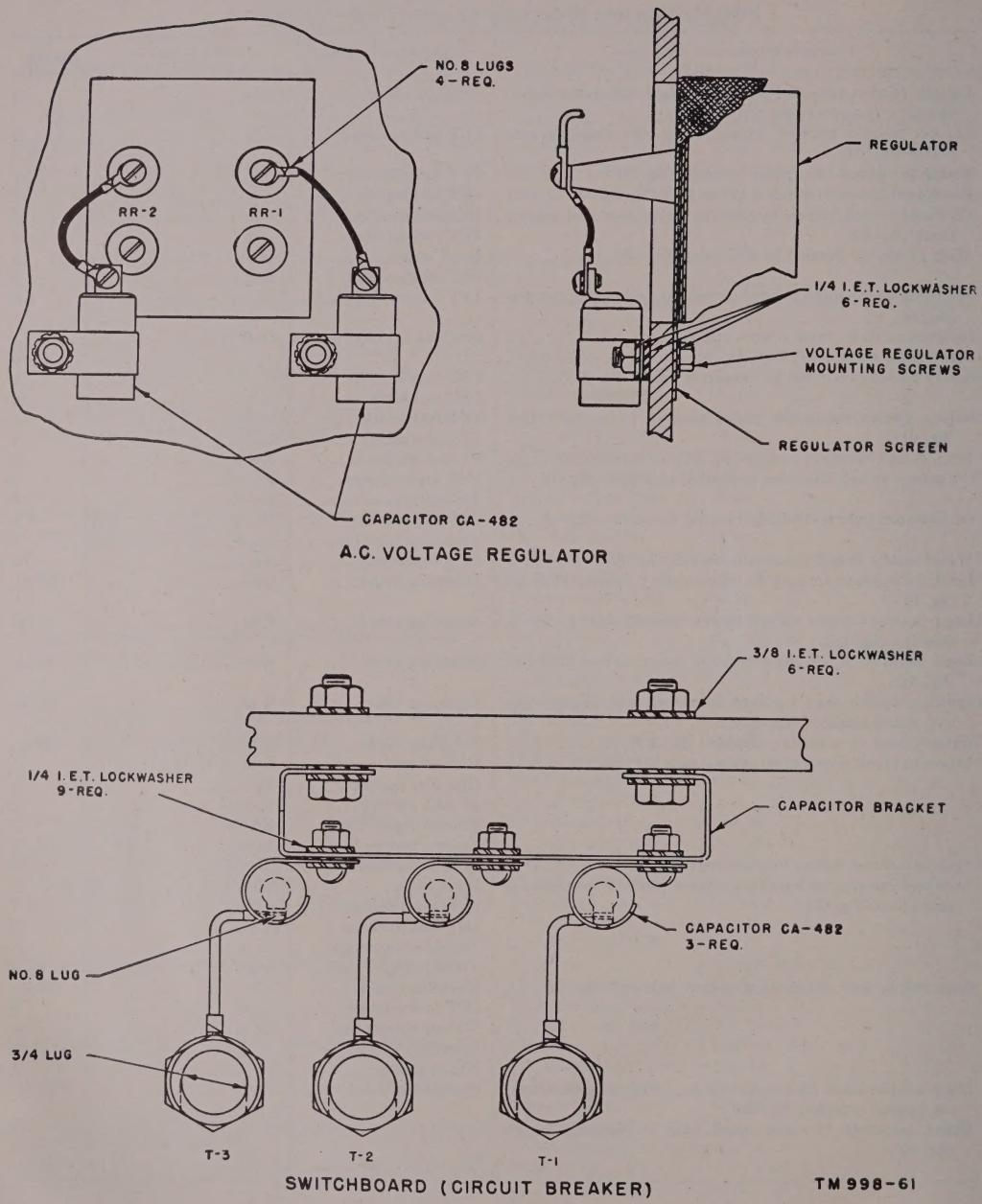


Figure 59. A-c voltage regulator and switchboard, suppression details.

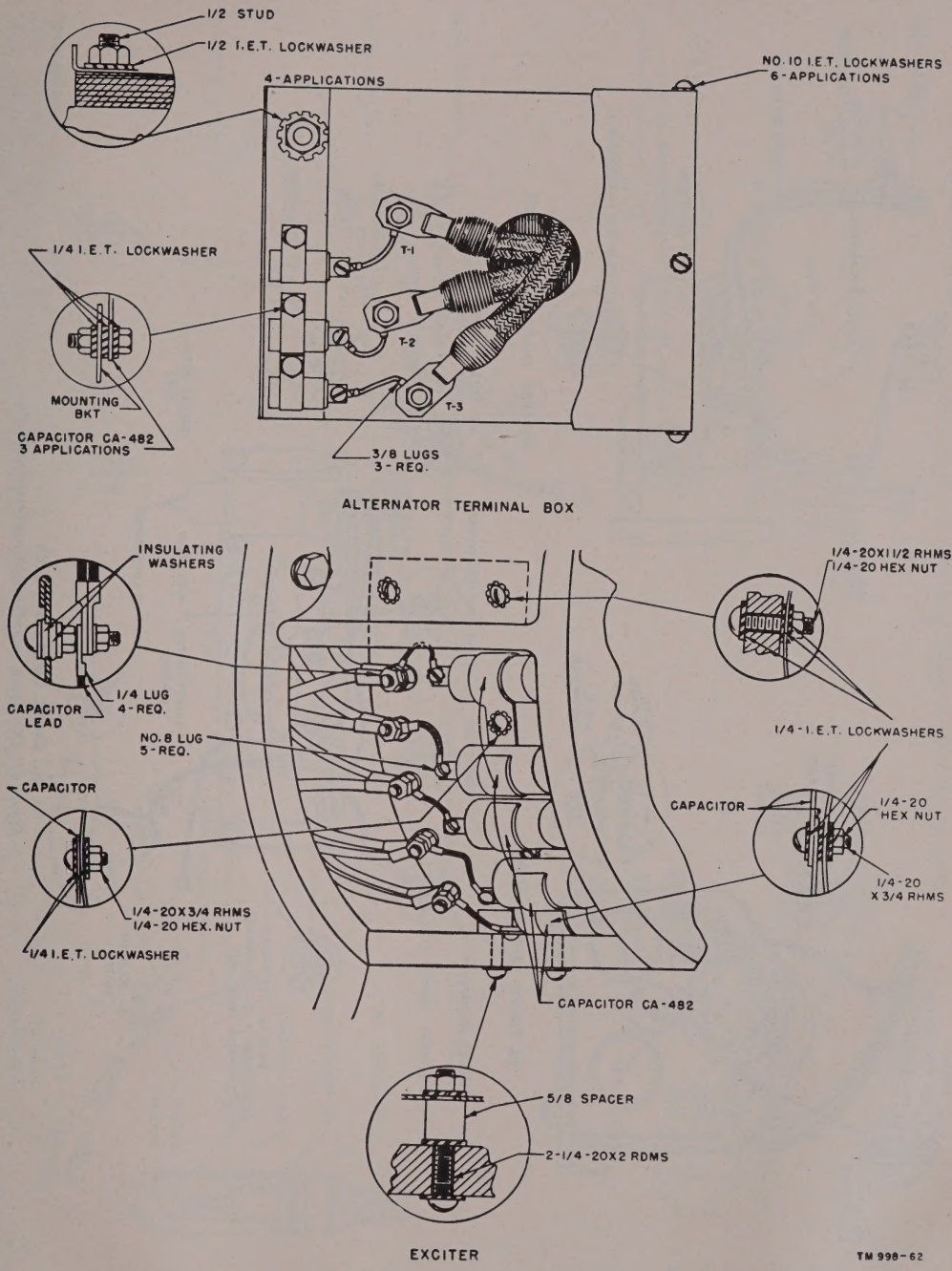
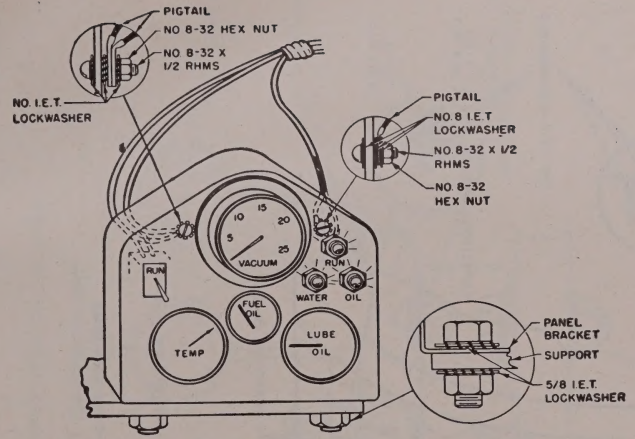
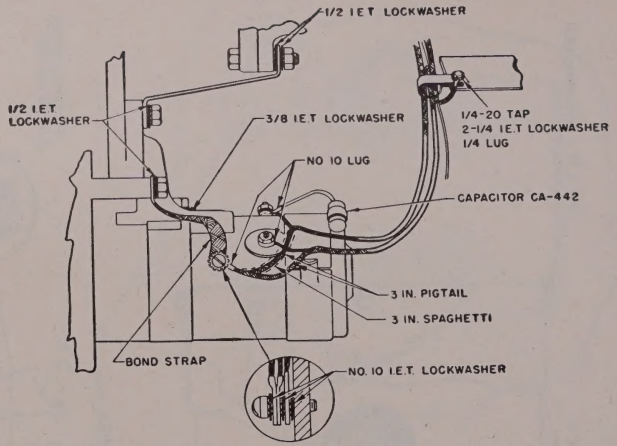


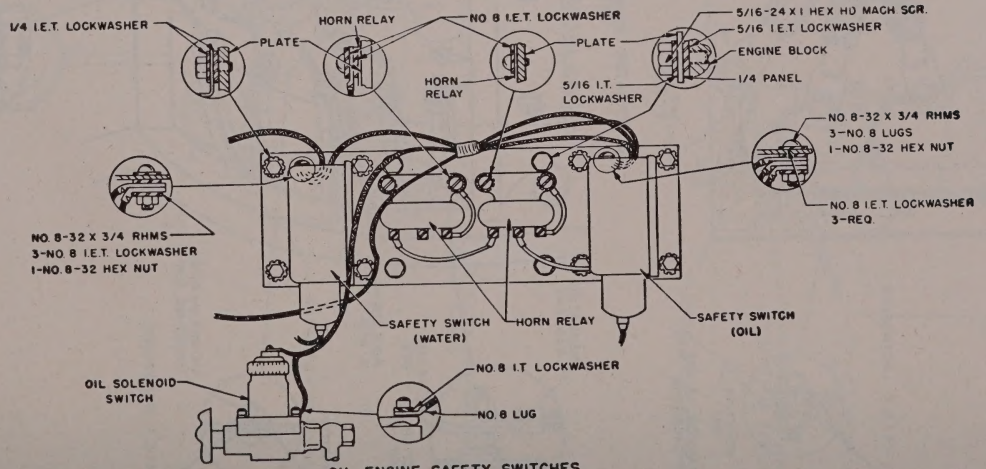
Figure 60. Alternator terminal box and exciter, suppresson details.



OIL ENGINE CONTROL PANEL



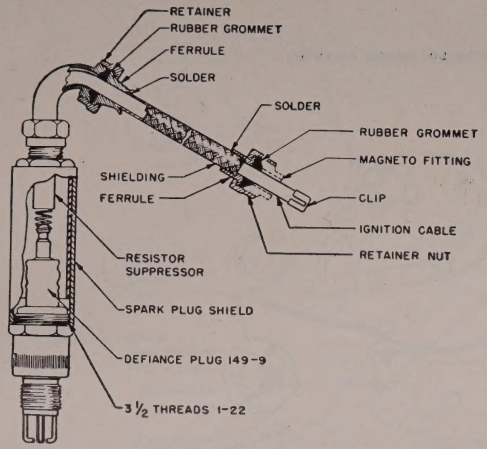
BATTERY CHARGING GENERATOR



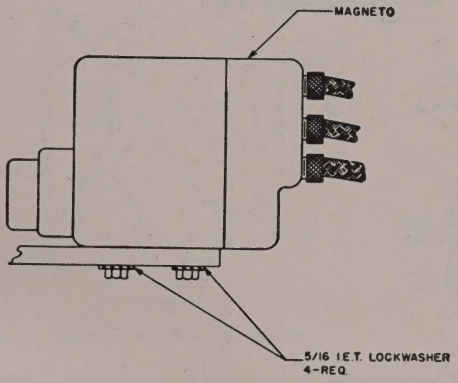
OIL ENGINE SAFETY SWITCHES

TM 998-63①

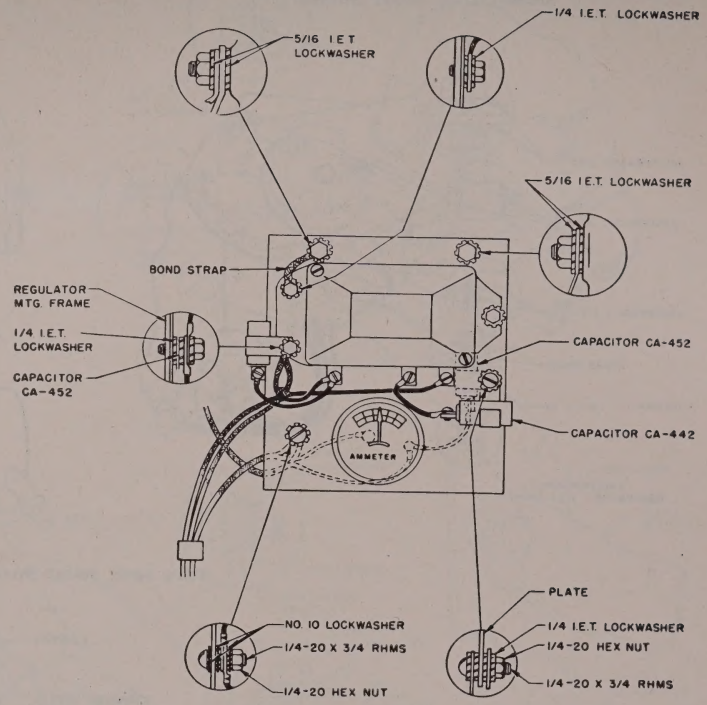
Figure 61. Oil engine, miscellaneous suppression details.



OIL ENGINE SPARK PLUGS

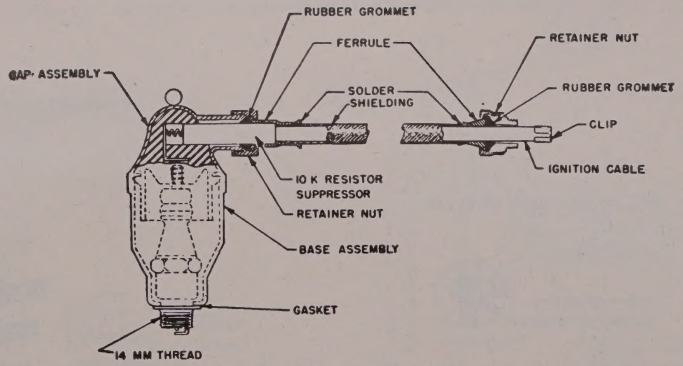


MAGNETO

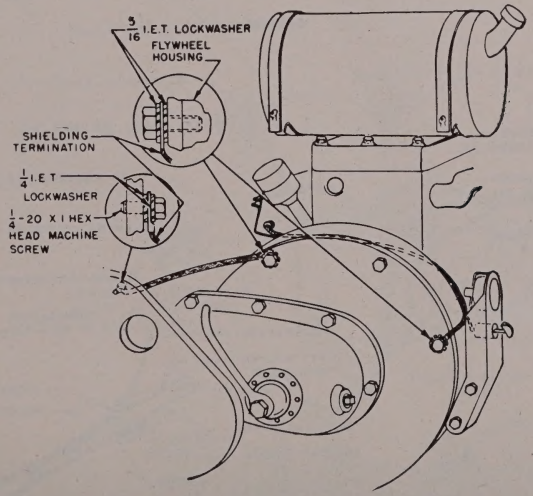


BATTERY CHARGING VOLTAGE REGULATOR

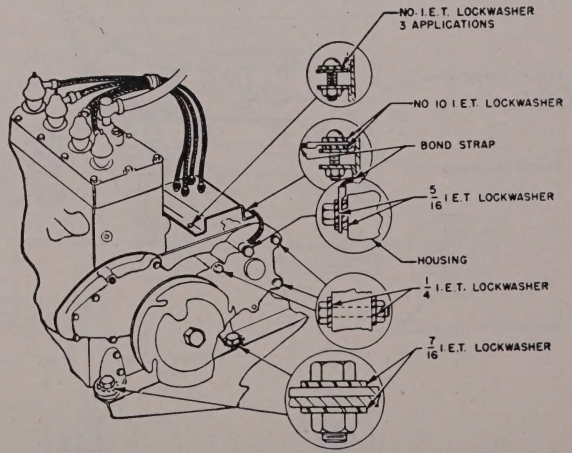
Figure 61. Oil engine, miscellaneous suppression details—Continued.



CRANKING ENGINE SPARK PLUGS



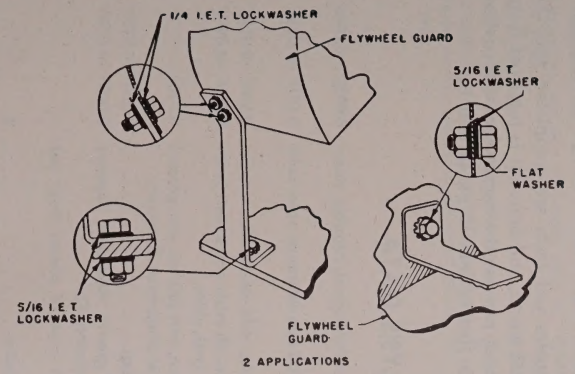
CRANKING ENGINE MISCELLANEOUS



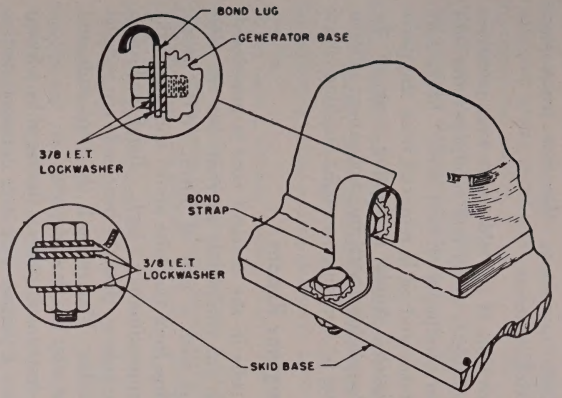
CRANKING ENGINE MISCELLANEOUS

TM 998-64

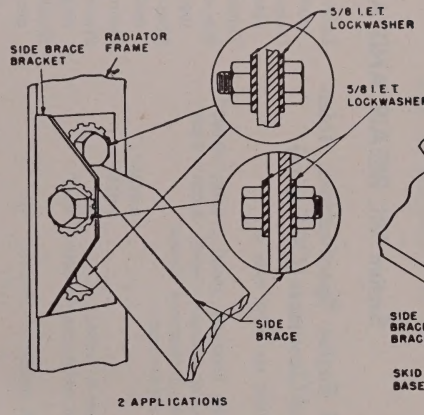
Figure 62. Cranking engine, suppression details.



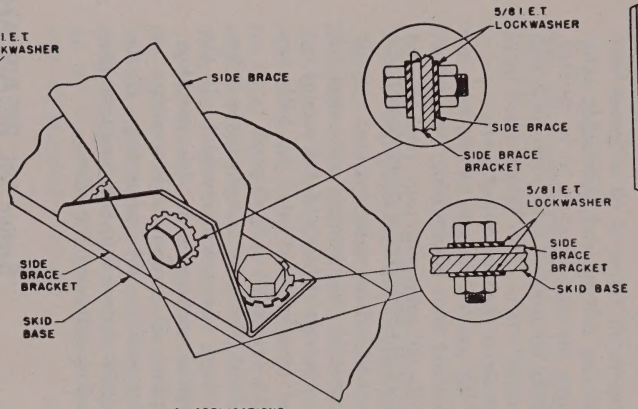
OIL ENGINE FLYWHEEL GUARD



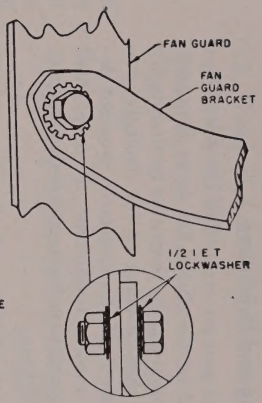
MAIN GENERATOR BASE



RADIATOR SIDE BRACES (UPPER)



RADIATOR SIDE BRACES (LOWER)



FAN GUARD BRACKET

TM 998-65

Figure 63. Oil engine, bonding details.

107. Painting and Refinishing

a. When the painted surfaces of the power unit are scratched or the finish has been damaged, rust and corrosion may be prevented by thoroughly cleaning and then touching up the damaged surface. The extent of the treatment required depends upon various conditions. If only small portions of the unit have been scratched or scraped, proceed as follows:

(1) Remove all traces of oil or grease with cleaning solvent and thoroughly sandpaper the spot or spots to be painted. Apply the paint in light, even coats with a small brush. Two light coats of paint are better than one heavy coat.

(2) If the painted surfaces of the unit are blistered from overheating, remove all of the old paint with paint remover, and thoroughly clean with sandpaper or steel wool all surfaces to be repainted. Apply a smooth, even priming coat; sand the priming coat lightly with fine sandpaper; and complete the paint job with two light, even coats of finish paint.

(3) Refinish the entire unit whenever it has received a complete overhaul. If the painted surface is in fair condition, repaint all scrapes and scratches as instructed in this paragraph. If the painted surface is in bad condition, proceed as instructed in *b* below.

Caution: Avoid getting paint on moving parts in such a manner as to hinder their movement. Do not paint electrical contacts.

b. Remove all of the old paint with paint remover, thoroughly clean and sandpaper the unit using either sandpaper or steel wool. Make sure that all grease and oil is removed from the parts to be painted. Apply a priming coat to the finish, and sand down with fine sandpaper. Finish the painting by applying two light finishing coats.

108. Emergency Repairs

a. If a tube in the radiator core is punctured, and if it is not completely severed, cut the tube or break it with a pair of pliers. With pliers, strip the fins from the tube above and below the break for approximately ½ inch. Bend the broken ends of the tube so that the bent ends are parallel with the tube. Flatten both the bent ends and the tube to stop the flow of water.

b. If the instrument panel is damaged by a flying object, place a jumper wire over damaged meters or circuits.

109. Rustproofing Before Storage or Shipment

When repairs and tests are completed and the engine is still warm, and before it is removed from the test stand, process the engine for rustproofing according to instructions in paragraph 14.

Section VII. REPAIR AND ANALYSIS DATA

110. Table of Engine Specifications, Tolerances, and Clearances (Oil Engine)

Tappet setting taken on valve side of rocker arm:	
Intake—running clearance (cold)	0.025''–0.027''
Exhaust—running clearance (cold)	0.030''–0.032''
Valve timing checking clearance (taken on valve side of rocker arm):	
Intake	0.0105''
Exhaust	0.0155''
Valve stem diameter in inches	7/16''
Exhaust valve head, maximum diameter in inches.	3 1/16''
Intake valve head, maximum diameter in inches.	3¾''
Intake valve seat angle in degrees	30°
Exhaust valve seat angle, degrees	45°
Main crankshaft bearings, running clearance.	0.003''–0.005''
Large end connecting rod, running clearance.	0.0025''–0.0045''
Connecting rod side clearance, total both sides.	0.010''–0.015''
Thrust bearing, side clearance	0.009''–0.012''
Side clearance, all other crankshaft bearings, total both sides.	0.060''–0.090''
Skirt clearance, new pistons, cam ground, cast iron (at maximum diameter).	0.018''
Piston ring gap	0.050''–0.070''
Piston ring groove clearance, tapered rings (dimension X).	0.005''–0.010''
Number and type of piston rings per piston:	
Compression	4
Oil	1
Firing order, standard rotation	1–5–3–6–2–4
Magneto rotation	cw

Spark occurs (fixed spark at all speeds) advance degrees.	12°
Magneto point setting (gap)	0.014″
Spark plug setting (spark gap)	0.018″–0.020″
Injection pump rotation	ccw
Injection ends, advance degrees	27°
Hot lubricating oil pressure (psi)	40
Cooling water capacity (gallons)	65

111. Table of Engine Specifications, Tolerances, and Clearances (Cranking Engine)

Tappet setting, intake running clearance (cold).	0.005″–0.007″
Tappet setting, exhaust running clearance (cold).	0.007″–0.009″
Intake valve timing checking clearance	0.003″
Exhaust valve timing checking clearance	0.005″
Skirt clearance, new pistons	0.0025″
Piston ring gap	0.007″–0.017″
Piston ring groove clearance:	
Top ring	0.0015″–0.003″
Other rings	0.001″–0.0025″
Number and type of piston rings per piston:	
Compression	1
Scraper	1
Oil control	1
Large end connecting rod bearing running clearance.	0.0005″–0.0025″
Connecting rod side clearance, sum of	0.006″–0.010″
Firing order	1–2–4–3
Spark plug gap	0.025″–0.030″
Cooling water capacity (gallons)	⅜
Lubricating oil system capacity (quarts)	3
Maximum oil pressure at governed speed (psi).	15

112. Table of Circuit Resistances, Voltages, and Capacities

a. Alternator Voltages and Other Data

240 v	900 rpm
100 kw	300 amp
125 kva	Three-phase.
60 cy	

b. Exciter Voltages and Other Data.

125 v	900 rpm
3 kw	

c. Control Panel Data.

Exciter field rheostat resistance	45 ohms
Air circuit breaker	400 amp, 600 v
Reverse power relay	10–60 w, 70 v
Governor control rheostat	25 ohms, 300 w
Current transformers (3)	400/5 amp ac
Potential transformers (3)	230/115 v

113. Unsatisfactory Equipment Report

a. DA AGO Form 468 (Unsatisfactory Equipment Report) for Equipment Used by the Army. DA AGO Form 468 will be filled out and forwarded through channels to the Office of the Chief Signal Officer, Washington 25, D. C., when trouble occurs more often than is normal, as determined by qualified repair personnel.

b. AF Form 54 (Unsatisfactory Report) for Equipment Used by the Air Force. AF Form 54 will be filled out and forwarded to Commanding General, Air Matériel Command, Wright-Patterson Air Force Base, Dayton, Ohio, in accordance with AF Regulation 15–54.

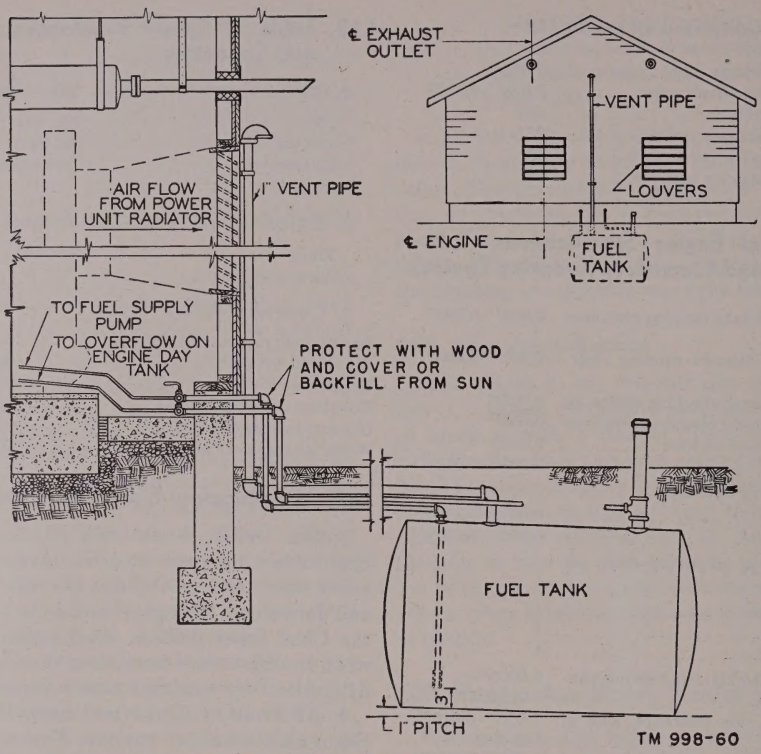


Figure 64. Typical installation diagram.

CHAPTER 5
DEMOLITION TO PREVENT ENEMY USE

114. General

The demolition procedures outlined in paragraphs 115 and 116 will be used to prevent the enemy from using or salvaging this equipment. Demolition of the equipment will be accomplished *only* upon order of the commander.

115. Methods of Destruction

a. Smash. Use sledges, axes, handaxes, pickaxes, hammers, crowbars, and heavy tools.

b. Cut. Use axes, handaxes, and machetes.

c. Burn. Use gasoline, kerosene, oil, flame throwers, and incendiary grenades.

d. Explosives. Use firearms, grenades, and TNT.

e. Other. Use anything immediately available for destruction of this equipment.

f. Disposal. Bury in slit trenches, fox holes, and other holes. Throw in streams. Scatter.

116. Destruction of Components

a. Smash cylinder heads, cylinders, crankcase, carburetor, power generator, magneto, all air and fuel filters, pumps, radiator, and control panel.

b. Cut all electric wiring, cables, hose, and belts.

c. Burn fuel, lubricating oil, and technical manuals.

d. Bend all copper pipes and fuel injection lines.

e. Bury or scatter all smashed pieces after destroying their usefulness.

f. Destroy everything.

APPENDIX I
REFERENCES

Note. For availability of items listed, check FM 21–6 and Department of the Army Supply Catalog SIG 1.

1. Supply Publications

SIG 1	Introduction and Index.
SIG 3	List of Items for Troop Issue.
SIG 4–1	Allowances of Expendable Supplies.
SIG 5	Stock List of All Items.
SB 11–76	Signal Corps Kit and Materials for Moisture- and Fungi-Resistant Treatment.

2. Packaging and Packing Instructions

a. Joint Army-Navy Packaging Specifications.

JAN–D–169	Desiccants, Activated.
JAN–P–100	General Specifications.
JAN–P–106	Boxes, Wood, Nailed.
JAN–P–116	Preservation, Methods of.
JAN–P–125	Barrier Material, Waterproof.
JAN–P–131	Barrier Material, Moisture-Vaporproof, Flexible.

b. U. S. Army Specification.

100–2E	Marking Shipments by Contractors (and Signal Corps Supplement thereto).

c. Signal Corps Instructions.

720–7	Standard Pack.
726–15	Interior Marking.

3. Other Publications

TB SIG 13	Moistureproofing and Fungiproofing Signal Corps Equipment.
TB SIG 23	Rustproofing of Engines.
TB SIG 66	Winter Maintenance of Signal Equipment.
TB SIG 72	Tropical Maintenance of Ground Signal Equipment.
TB SIG 75	Desert Maintenance of Ground Signal Equipment.
TB SIG 183	Preventive Maintenance Guide for Power Equipment.
TB SIG 187	Maintenance of Diesel Fuel Injection Nozzles.
TB ORD 313	Spark Plugs.
TB 11–2525–1	Starting Power Units in Arctic Areas Using Miller Utility Heater Model OG–31–A.
SB 38–5–3	List of Standard Lubricants, Hydraulic Fluids, Liquid Fuels and Preservative Materials Used by the Department of the Army.
SB 11–100	Serviceability Standards for Signal Equipment in Hands of Troops.
TM 1–455	Electrical Fundamentals.
TM 9–2857	Storage Batteries Lead-Acid Type.
TM 9–2858	Cooling Systems: Vehicles and Powered Ground Equipment.
TM 10–580	Automotive Electricity.
TM 11–453	Shop Work.
TM 11–462	Signal Corps Reference Data.
TM 11–483	Suppression of Radio Noises.
TM 37–2810	Motor Vehicle Inspection and Preventive Maintenance Services.
TM 55–405	Preventive Maintenance of Electric Motors and Generators.

4. Abbreviations

a-c, AC	alternating current
amp	ampere
amp-hr	ampere hour
AGO	Adjutant General's Office
BDC	bottom dead center
BHP	brake horsepower
C	centigrade
C. M	circular mil
CL	Compound, rust preventive, light
CG–0	Grease, general purpose No. 0
CG–1	Grease, general purpose No. 1
CCW	counterclockwise
CW	clockwise

d-c, DC	direct current
DA	Oil, fuel, Diesel, grade A.
DX	Oil, fuel, Diesel, grade C.
F	Fahrenheit
fig	figure
ft	feet
HR	hour
in	inch
ID	inside diameter
IET	internal-external tooth
I.D.E	International Diesel Electric Co.
IT	Internal tooth
kw	kilowatts
kva	kilivolt-amperes
lb	pound
LO	Oil, lubricating, light
MM, mm	millimeter
mf	microfarad
maint	maintenance
No	number
NPT	National Pipe Thread
OD	outside diameter
OE	Oil, engine
psi	pounds per square inch
pt	point
PL-Special	Oil, lubricating, preservative, special
PL-Medium	Oil, lubricating, preservative, medium
par	paragraph
PM	preventive maintenance
PET	Petrolatum
rpm	revolutions per minute
r-f	radio-frequency
sp gr	specific gravity
SD	Solvent, dry-cleaning
SAE	Society of Automotive Engineers
SIG, Sig	Signal
sq in	square inch
subpar	subparagraph
TB	Technical Bulletin
TDC	top dead center
TM	Technical Manual
V, v	volt
va	volt-ampere
WB No. 2	Grease, general purpose No. 2
WD	War Department
WP No. 4	Grease, water pump

APPENDIX II
IDENTIFICATION TABLE OF PARTS

Note. The fact that an item appears in this technical manual is not sufficient basis for requisitioning it. Requisitions must cite an authorized basis, such as T/O&E, T/A, T/BA, SIG 6, SIG 7, SIG 8, SIG 7 & 8, SIG 7, 8, 10, SIG 10, list of allowances of expendable material, or another authorized supply basis. The pamphlet of the Department of the Army Supply Catalog applicable to the equipment covered in this manual is listed in paragraph 1 below.

1. Department of the Army Supply Reference

The following information was compiled on 5 October 1948. The appropriate pamphlet of the Department of the Army Supply Catalog is—

Fixed Plant Maintenance Lists

SIG 10 PE–220

For an index of available catalogs, see the latest issue of Department of the Army Supply Catalog SIG 1.

2. Identification Table of Parts for Power Unit PE–220–C

Fig. ref.	Name of part and description	Function of part
	POWER UNIT PE–220–C: 100 kw at 0.8 pf full load; 240 v AC, 60 cy, 3 ph, oil engine driven; engine, spark ignition oil engine, 225 hp, 900 rpm, 6 cyl; liquid cooled.	
	ALTERNATOR GROUP	
58	BEARING, sleeve: alternator; front, 2 halves; GE #6997361G1	Supports front end of rotor shaft.
58	BEARING, sleeve: alternator; rear, one piece; GE #6966160P1	Supports rear end of rotor shaft.
	BRUSH, electrical contact: slip ring; grade D carbon; term mtg ¼″ diam screw; GE #1491535.	Provides electrical contact with slip rings.
58	GENERATOR, AC: 100 kw, 900 rpm; 300 amp, 240 v, 60 cy, 3 ph; open frame; self ventilated; 8 pole; 40° C. temp rise; direct connected exciter, 3 kw, 900 rpm; 125 v; GE #14G–329.	
58	HOLDER, brush: generator; c/o brush holder and spring; cast aluminum; irregular rocker arm shape; one ⅞″ diam hole w/-clamping bosses; adj spring tension mechanism GE #3674562G1.	Provides support for generator brushes.
58	SPRING: motor type; for cont brush holder; two term 30° apart, both on outside ends of spring, one straight other looped. GE #243928.	Holds alternator brushes in contact with slip rings.
	AIR CLEANER GROUP	
	ADAPTER, air cleaner: connected to intake manifold for mtg air cleaners; W.M. #100466.	Provides support for air cleaners.
	CAP: air intake; mushroom shape; held on to breather pipe w/strap clamp; W.M. #116584.	Prefilters air before passing through air cleaner.
	GASKET: between air cleaner and air cleaner connection; W.M. #B–2793.	
	PLATE: between air cleaner and air cleaner connection; W.M. #B–4951.	

Fig. ref.	Name of part and description	Function of part
	CYLINDER BLOCK, CRANKCASE, AND CAMSHAFT GROUP	
49	ARM: rocker; exhaust, w/bushing; steel forging; W.M. #B–8749–B.	Transmits push rod action to valve stem to actuate exhaust valve.
49	ARM: rocker; intake, w/bushing; steel forging; W.M. #B–8748–B	Transmits push rod action to valve stem to actuate intake valve.
49	BRACKET: valve lifter; cast iron; irregular shape; two reamed holes for valve tappet roller, four mtg holes for ½" studs; two holes for #6 taper pins; W.M. #12134.	Provides mounting for valve lifter assembly.
53	BUSHING: camshaft; ctr bearing; cast bronze; W.M. #12048	Supports center of camshaft.
48	BUSHING: crankshaft; front and ctr main bearing; split; steel backed, Babbitt lined; W.M. #12022–B–2.	Supports crankshaft.
	BUSHING: crankshaft; intermediate main bearing; split; steel backed, Babbitt lined; W.M. #12025–B–2.	Supports crankshaft.
	BUSHING: crankshaft; rear main bearing; split; steel backed, Babbitt lined; W.M. #12021–B–2.	Supports crankshaft.
53	BUSHING: camshaft; front bearing; cast bronze; W.M. #12027	Supports camshaft.
	BUSHING: camshaft; intermediate bearing; cast bronze; W.M. #21050.	Supports camshaft.
	BUSHING: camshaft; rear bearing; cast bronze; W.M. #12053	Supports camshaft.
42	BUSHING: magneto shaft; bronze; W.M. #B–2104	Supports magneto shaft.
49	BUSHING: rocker arm; bronze; W.M. #B–7658	Bearing between rocker arm and shaft.
1	CAP: breather; oil filler; steel stamping; W.M. #43071	Filters air passing through breather.
51	CLAMP: piston pin lock; spring steel; W.M. #65495	Secures piston pin in piston.
51	COCK: cyl drain; straight wingnut fitting; W.M. #B–6624	Permits draining coolant from cylinder block.
	COCK: wing handle; drain, brass; spring loaded; W.M. #B–205	
48	CRANKSHAFT: carbon steel forging; 7 main bearing journals; 6 connecting rod bearing journals; W.M. #12111.	Converts reciprocating movement of piston and connecting rod assembly into rotary motion.
	FITTING, elbow: 90°; brass; ⅜" NF thd one end, ⅛" pipe thd other end; W.M. #B–3664.	
	FITTING, straight: brass for 5/16" tubing; 7/16" hex; ⅜" NF thd one end, ⅛" pipe thd other end; W.M. #B–3665.	
	GASKET: oil filler body; W.M. #B–4486	Provides seal between oil filler body and crankcase.
53	GASKET: crankcase cover; vellumoid; W.M. #B–2640	Provides seal between crankcase and crankcase cover.
48	GASKET: crankcase door; ctr door: vellumoid; W.M. #B–2288	Provides seal between center door and crankcase.
48	GASKET: crankcase; handhole cover (front and rear); vellumoid; W.M. #B–2285.	Provides seal between crankcase and handhole cover.
53	GASKET: camshaft rear bearing plate; W.M. #B–2226	Provides seal between bearing plate and crankcase.
48	GASKET: rear oil retainer; vellumoid; W.M. #B–2124	
	GASKET: rear oil retainer; vellumoid; W.M. #B–2242	
53	GASKET: valve tappet chamber; cork; W.M. #B–2119	
53	GASKET: valve tappet chamber door cap screw; copper; W.M. #B–2469.	
	GASKET: viscometer pad cover; vellumoid; W.M. #B–1548	
51	GASKET: cyl base; vellumoid; W.M. #B–10697	Seal between cylinder block and crankcase.
	GASKET: cyl cover; auto sheet packing; W.M. #B–9945	
49	GASKET: cyl head; copper asbestos; W.M. #99000	Provides seal between cylinder head and cylinder block.
48	GEAR: crankshaft; steel forging; helical gear; 45 teeth; W.M. #12012.	Drives timing gears and subassemblies.
49	GUIDE: exhaust valve; W.M. #99209	Holds exhaust valve in position.
49	GUIDE: intake valve; W.M. #99009	Holds intake valve in position.

Fig. ref.	Name of part and description	Function of part
	CYLINDER BLOCK, CRANKCASE, AND CAMSHAFT GROUP—Continued	
49	HEAD, cylinder: cast iron; W.M. #99002–D	Closes top of cylinders; houses valves and injection nozzle. Provides mounting for valve rocker assembly, and contains combustion chamber.
53	INSERT, valve tappet: steel; W.M. #B–4655	
	INSERT, valve seat: W.M. #65636	Provides replaceable seat for valve.
	KEY, machine: Woodruff; steel; W.M. #21019	
48	LOCK: crankshaft nut; steel stamping; W.M. #B–2264	Locks crankshaft nut.
48	NUT, lock: crankshaft; steel forging; W.M. #B–2193	Secures crankshaft gear on crankshaft.
49	NUT, valve spring washer: steel; W.M. #B–2620	Retains valve spring.
53	PIN, camshaft bushing: brass rod; W.M. #B–435	Prevents bushing from turning.
51	PIN, piston: steel; W.M. #46106	Provides axle upon which upper end of connecting rod swings.
51	PISTON: cast iron; W.M. #99204–D	Receives power impulse and transmits it to connecting rod piston pin assembly. Also, draws air into and forces exhaust gases from cylinder.
	PLUG: steel; ½″–13 U.S.; RH thd, slotted head, ½″ lg; W.M. #B–1059.	
	PLUG; expansion: 1¼″ OD x 0.083″ thk; cad or zinc pl; W.M. #B–432.	
48	RETAINER, oil: lower rear crankshaft; W.M. #12090	Prevents oil leakage around crankshaft.
48	RETAINER, oil: upper rear crankshaft; W.M. #12091	Prevents oil leakage around crankshaft.
49	RETAINER, spring: exhaust valve; W.M. #B–7368	Retains valve spring.
49	RETAINER, spring: intake valve; W.M. #B–6610	Retains valve spring.
51	RING, cylinder sleeve packing: rubber; W.M. #B–4638	Seals lower end of cylinder sleeve to cylinder block.
51	RING, compression: W.M. #99005	Acts as seal between piston and cylinder wall.
51	RING, oil: W.M. #99105	Prevents excessive amount of lubricating oil from reaching combustion chamber.
	ROD, valve push: lower (ball end only); steel; W.M. #B–4657.	
49	ROD, valve push: seamless steel tubing; W.M. #B–10672	Transfers action of cams to rocker arms.
53	ROLLER, push rod: valve; steel, heat treated; W.M. #12137	Provides rolling contact between valve lifter and cams.
49	SCREW, adjustment: rocker arm; W.M. #B–4667	Permits adjustment of clearance between rocker arm and valve stem.
49	SHAFT: rocker arm; W.M. #B–8766	Provides axle for rocker arm.
48	SHIM: front and ctr main bearing; brass lam; W.M. #B–2169	Permits adjustment of bearing clearance.
	SHIM: intermediate main bearing; brass lam; W.M. #B–2170	Permits adjustment of bearing clearance.
	SHIM: rear main bearing; brass lam; W.M. #B–2171	Permits adjustment of bearing clearance.
48	SHIM: crankshaft gear; steel shim stock; W.M. #B–2817	Spacer for crankshaft gear.
48	SHIM: crankshaft gear; steel shim stock; W.M. #B–2816	Spacer for crankshaft gear.
51	SLEEVE, cylinder: cast iron; W.M. #99030	Provides replaceable cylinder within which the piston functions.
	SOCKET, push rod: upper; steel, heat treated; W.M. #B–4668	Provides bearing for upper end of push rod.
49	SPRING: valve; intake, inner; W.M. #14135–A	Returns intake valve to seat.
49	SPRING: valve; intake, outer; W.M. #46035–A	Returns intake valve to seat.
49	SPRING: valve rocker shaft; W.M. #B–7669	Positions rocker arm on shaft.
	STUD: cyl; holddown; steel; W.M. #63119	Secures cylinder block.
53	STUD: cyl; holddown; steel; W.M. #B–2112–A	Secures cylinder block.
48	STUD: main bearing; steel, heat treated; W.M. #B–2220	Provides mounting for main bearing cap.
48	STUD: main bearing; steel, heat treated; W.M. #B–2221	Provides mounting for main bearing cap.
51	STUD: steel, heat treated; ¾″ OD x 4″ lg; W.M. #B–3051	Positions and secures cylinder head to cylinder block.
51	STUD: steel, heat treated; ¾″ OD x 9⅝″ lg; W.M. #B–3032	Positions and secures cylinder head to cylinder block.

Fig. ref.	Name of part and description	Function of part
	CYLINDER BLOCK, CRANKCASE, AND CAMSHAFT GROUP—Continued	
	STUD: steel; 5/16" OD x 1⅛" lg; W.M. #B–9432	Secures cylinder cover to cylinder.
	STUD: water manifold to cyl; steel; ½" OD x 1¾" lg; W.M. #B–838	Secures water manifold to cylinder.
49	STUD: rocker arm support; W.M. #B–838	Secures rocker arm support assembly.
49	STUD: rocker arm support; W.M. #B–8747	Secures rocker arm support assembly.
49	SUPPORT, rocker arm: mal iron; W.M. #B–8746	Supports overhead valve assembly.
53	TAPPET, valve: steel, heat treated; slot for roller and pin, lower end; W.M. #46033.	Transfers action of cam to lower end of valve push rod.
49	VALVE, exhaust: W.M. #99036–B	Opens and closes exhaust port.
49	VALVE, intake: W.M. #46236–A	Opens and closes intake port.
	WASHER, plain: main bearing stud; steel; W.M. #B–2239.	
	COOLING SYSTEM GROUP	
	CLAMP: hose; steel; W.M. #65737.	
	GASKET: thermostat housing; vellumoid; W.M. #41363–A.	Provides seal between thermostat housing and cylinder head.
	HOSE: rubber; 3 ply; 1¼" ID x 1⅝" OD x 5" lg; W.M. #63423–D.	
	THERMAL ELEMENT: vernatherm; begins opening 166° F, fully open 170° F; W.M. #116773.	Controls flow of coolant in cooling system.
	EXCITER GROUP	
58	HOLDER, brush: exciter; c/o brush holder and spring; cast bronze; irregular rocker arm shape; w/adj spring tension mechanism; GE #4813380G13.	Provides support for exciter brushes.
	SPRING: motor type; for cont brush holder; one ctr term and one outer term bent 90° and tangent to OD; mtd on slotted shaft by means of ctr term; GE #3794709.	Holds exciter brushes in contact with commutator.
	EXHAUST MANIFOLD GROUP	
	GASKET: exhaust manifold; cover plate, cork; W.M. #B–7801.	
	GASKET: exhaust manifold; end plate, steel asbestos; W.M. #B–7806.	
	GASKET: water cooled exhaust manifold; copper asbestos; W.M. #B–7804–A.	
16	MANIFOLD, exhaust: water cooled; front; W.M. #46142–A	Conducts exhaust from three front cylinders.
16	MANIFOLD, exhaust: water cooled; rear; W.M. #46242–A	Conducts exhaust from three rear cylinders.
	NUT, hexagon: cad or zinc pl; 5/8" USF thd; W.M. #B–3781–A.	
	PLUG, expansion: steel, cad or zinc pl, 1½" OD x 5/64" thk; W.M #B–1795.	
	STUD: steel; 5/8" diam x 2⅜" lg, 5/8" NC x 15/16" drive end, 5/8" NF x 1" nut end; W.M. #B–5220.	
	STUD: exhaust manifold; steel; ¾" x 9¾" lg; stud end, ¾" NC x 1 3/16"; nut end, ¾" NF x 1½" (rounded end); W.M. #B–7803.	
	WASHER, copper: ⅜" nominal size; 25/64" ID, 3/64" thk; W.M. #B–2747.	
	GOVERNOR GROUP	
46	BEARING, ball: single row radial; dustproof; light duty; cartridge type; not grease packed; W.M. #B–6795.	Supports butterfly valve shaft.
	BEARING, sleeve: butterfly valve control, brass; W.M. #B–8739–A.	
	BLOCK, spacing: ignition cable support; hard rubber; W.M. #B–10041.	Supports spark plug wires.

Fig. ref.	Name of part and description	Function of part
	GOVERNOR GROUP—Continued	
	CLEANER, air: butterfly valve housing cover; W.M. #74150	Filters air passing through butterfly valve housing breather.
46	COLLAR, spacing: butterfly valve worm gear; steel; W.M. #B–8740.	Spacer for butterfly valve drive shaft gear.
	COLLAR, spacing: governor rod; steel; W.M. #44166.	
	CUP, oil: wick feed type; W.M. #B–6872.	
46	GASKET: butterfly valve housing; vellumoid	
46	GEAR: worm, spur; cast iron; 20 teeth; W.M. #B–8112–B	Drives butterfly valve shaft.
46	GEAR: worm; drive gear; soft steel; W.M. #B–8111	Drive gear for butterfly valve.
	HOLDER, strap: ignition cable; steel, zinc pl; W.M. #B–10038	Secures ignition cable spacing block.
	KEY, machine: Woodruff; steel; W.M. #21529	
	PIN, locking: grooved steel; W.M. #B–5071	
	PIN, taper: steel; #000 x 1″ lg; W.M. #21570	
46	RETAINER, bearing: sheet steel; W.M. #B–864–A	Provides dust protection for butterfly valve shaft bearing.
46	SHAFT: butterfly valve; W.M. #B–8718	Provides axle for butterfly valve.
	SHAFT: friction throttle; steel; W.M. #48412	
	SLEEVE, centering: spring; steel; W.M. #85034	
	SPRING: friction throttle; compression type; spring steel wire; 6 working coils; W.M. #B–4843.	
46	VALVE, butterfly: brass; W.M. #B–2722–A	Controls flow of air to engine combustion chamber.
	CAMSHAFT AND TIMING GROUP	
45	AXLE: governor; weight roller; drill rod; W.M. #B–2306	Provides axle for governor weight.
51	BEARING, sleeve: connecting rod; split; steel backed, Babbitt lined; W.M. #12010–A.	Secured connecting rod lower end bearing.
51	BEARING, sleeve: piston pin; W.M. #46018	Secures connecting rod upper end bearing.
45	BLOCK, pivot: governor weight; W.M. #B–2305	
51	BOLT, machine: connecting rod; 5/8″–18 x 4½″; W.M. #B–879–A	Secures connecting rod lower end bearing cap.
53	CAMSHAFT: front; steel forged; W.M. #12123–A	Actuates intake and exhaust valve mechanism.
	CAMSHAFT: rear; steel forged; W.M. #13123–A	Actuates intake and exhaust valve mechanism.
	COUPLING, rigid: camshaft; steel; W.M. #B–6392	Joins front and rear sections of camshaft.
	GEAR: spur, camshaft; cast steel; helical gear; 90 teeth; letter C marked on rim; W.M. #12026–C.	Drives camshaft.
	KEY, machine: camshaft; special key stock	
	KEY, machine: Woodruff #5; steel; W.M. #21019	
51	NUT, castelated: 15/16″ hex. x 5/8″ 36 USF thd; W.M. #B–845	Secures lower end connecting rod cap to rod.
	PIN, locking: camshaft coupling; W.M. #B–6871	
	PIN, dowel: steel; W.M. #B–350	
51	ROD, connecting: w/bushing; steel forging; W.M. #099107–C	Connecting link between piston and crankshaft.
	SCREW, machine: steel; 3/8″ NC, 1″ lg, 9/16″ hex; drilled head; W.M. #B–9046.	
45	SHAFT: governor weight; drill rod, ½″ diam x 2 13/16″; W.M. #B–2353.	Axle for governor weight.
51	SHIM: connecting rod; brass lam; W.M. #B–2114	Permits adjustment of connecting rod lower end bearing.
	COOLING SYSTEM GROUP	
	BELT, fan drive: V–belt; 84″ lg; W.M. #41347	
40	BLADE ASSEMBLY, fan: blade 48″; 8 blades; steel; blower type; W.M. #101582.	Forces air blast through radiator to carry off heat.
	BRACKET: fan; cast steel; W.M. #12332	

Fig. ref.	Name of part and description	Function of part
	COOLING SYSTEM GROUP—Continued	
	CLAMP: radiator hose; carbon steel; 3″ to 4″ hose; W.M. #41236–A.	
	CLAMP: radiator hose; carbon steel; 3½″ to 4½″ hose; W.M. #41236.	
40	GASKET: fan spacer; vellumoid; W.M. #27267	
	GASKET: upper and lower radiator connection; vellumoid; diamond shape; W.M. #B–2858.	
	HOSE: lower radiator connection; 4 ply; rubber; 3″ ID, 8½″ lg; W.M. #B–2602–A.	
	HOSE: upper radiator connection; 4 ply; rubber; 3½″ ID, 6½″ lg; W.M. #78915–B.	
40	HUB: cooling fan; 3 groove; 12½″ OD; W.M. #101571	Supports fan; houses shaft and bearings; provides drive for fan.
	KEY, fan adjusting stud: Woodruff #8; W.M. #21006	
	KEY, Gib: steel; W.M. #63256	
40	NUT, hexagonal: fan spindle; steel; parkerized; 1½″ NC thd; W.M. #44287.	Secures fan hub assembly to shaft.
	NUT, hexagonal: fan adjusting screw; steel; W.M. #B–2433	
	PULLEY: fan drive; cast iron; 10″ OD; W.M. #12095	Driving pulley on crankshaft.
	STUD: fan adjusting; steel; W.M. #B–2429–B	
40	WASHER, plain: fan spindle; steel; parkerized; W.M. #B–2427–A	
	FUEL FILTER GROUP	
	ADAPTER, tube connection: steel; W.M. #48853	
	BRACKET: fuel oil filter; lower bracket; steel; W.M. #44310	
	COCK: drain; brass; ⅛″ pipe thd; W.M. #B–9129	
24	FILTER, fuel oil: Briggs Clarifier; W.M. #60160	Filters foreign matter from fuel.
	SUPPORT, fuel oil filter: steel; W.M. #44311	Supports fuel oil filter.
	SUPPORT, fuel oil filter: upper; steel; W.M. #44309	Supports filter.
	VALVE, pressure relief: W.M. #60188–B	
	FUEL INJECTION PUMP AND VACUUM CONTROL GROUP	
	ADAPTER, vacuum control body: cast iron; W.M. #100461G	
	BREATHER, vacuum control: W.M. #74150	Filters air entering control.
31	BUSHING: vacuum control piston rod; bronze; W.M. #B–8731–A	
	COCK: angle shut off; brass; W.M. #73059	
	COCK: fuel try; brass; W.M. #B–9041	
	CUP, oil: brass; W.M. #B–9142	
44	DIAPHRAGM, surge dampener: W.M. #B–10174	
	Elbow: inverted male; brass; W.M. #73018–A	
17	GAGE, fuel oil pressure: black steel case; white dial; black figures and pointer; W.M. #63727–A.	Indicates fuel oil pressure.
	GASKET: vacuum control adapter; vellumoid; W.M. #B–8768	
31	GASKET: vacuum control cover; steel asbestos; W.M. #B–8640–B	Seal between cover and vacuum control body.
	GASKET: vacuum control; vellumoid; W.M. #B–8641	
	GASKET: vacuum control; inspection hole cover; vellumoid; W.M. #B–8773.	
20	HUB: injection pump coupling; W.M. #B–9991	Part of injection pump drive.
	KEY: fuel pump; manual control lever; steel; Woodruff #1; W. M. #21000.	
20	LEVER: fuel pump; manual control; mal iron; W.M. #B–9153	
	LOCK: injection pump shaft nut; steel stamping; W.M. #B–10013	
	PIN, dowel: fuel pump bracket; steel; W.M. #65698	
	PIN, fuel pump control: steel; W.M. #B–8645–A	
31	PISTON, vacuum control: bronze; W.M. #B–8729–B	Actuates vacuum control.

Fig. ref.	Name of part and description	Function of part
	FUEL INJECTION PUMP AND VACUUM CONTROL GROUP—Continued	
	PLUG, expansion: steel; ½" diam; W.M. #B–536	
	PLUG, vacuum control: steel; W.M. #B–9536	
	PROTECTOR, surge: dampener diaphragm; sheet steel, zinc pl; W.M. #B–10175.	
20	PUMP, fuel injection: American Bosch type PE–6–Z; W.M. #50113–B.	Distributes fuel under pressure to injection nozzles.
31	RETAINER, vacuum control: piston rod, spring steel; W.M. #65170.	
31	RETAINER, vacuum control spring: steel stamping	
31	RING, vacuum control piston: cast iron; W.M. #B–8673	Seal between piston and cylinder.
31	ROD, vacuum control piston: steel; W.M. #B–8730–B	
31	SCREW, surge dampener adjusting: cast brass; W.M. #63982	
31	SCREW, vacuum control stop: steel; W.M. #B–9771	
	SHAFT: manual fuel pump control; CRS; W.M. #B–8726	
31	SHIM: vacuum control spring; shim steel; W.M. #B–9535	
31	SLEEVE, vacuum control body: iron, heat treated; W.M. #B–8721–C.	Cylinder of vacuum control.
	SPRING: coil; fuel pump control; steel spring wire; 7 active coils; W.M. #65114–A.	
	SPRING: fuel pump control; steel spring wire; 3 coils ea end; W.M. #74066.	
44	SPRING: surge dampener; steel wire #9 BWG; cad pl; W.M. #9038–A.	
31	SPRING: vacuum control; inner; spring steel wire; 2½ active coils; W.M. #B–9537–D.	
31	SPRING: vacuum control; outer; spring steel wire; 2¼ active coils; painted black; W.M. #B–9538–E.	
	SPRING: torsion type; vacuum control stop lever; music wire; 3 coils, ends hooked; W.M. #B–9543.	
	WASHER, flat: CRS; W.M. #B–363	
	YOKE, fuel pump: manual control; cast brass; W.M. #B–8774	
	INJECTION TUBING GROUP	
	CLAMP: tube; steel; W.M. #B–9785	
	TUBE, fuel injection: #1 cyl; seamless steel; ⅜" OD, 33 15/16" lg; nut and washer ea end; W.M. #063519–A.	
	TUBE, fuel injection: #2 cyl; seamless steel; ⅜" OD, 28 15/16" lg; nut and washer ea end; W.M. #063519–B.	
	TUBE, fuel injection: #3 cyl; seamless steel; ⅜" OD, 36 15/16" lg; nut and washer ea end; W.M. #063519–C.	
	TUBE, fuel injection: #4 cyl; seamless steel; ⅜" OD, 45 3/16" lg; nut and washer ea end; W.M. #063519–D.	
	TUBE, fuel injection: #5 cyl; seamless steel; ⅜" OD, 66 3/16" lg; nut and washer ea end; W.M. #063519–E.	
	TUBE, fuel injection: #6 cyl; seamless steel; ⅜" OD, 66 3/16" lg; nut and washer ea end; W.M. #063519–F.	
	FUEL PUMP DRIVE GROUP	
	BEARING, ball: single row radial; plain; light series; not grease packed; W.M. #B–10751.	
	BUTTON, drive pawl spring: steel; W.M. #73761	
	COVER: bearing retainer; cast iron; W.M. #B–10723–A	
	COVER: bearing retainer; cast iron; W.M. #B–10725	
	DISK, coupling: intermediate celeron; W.M. #B–9992	
	DISK, pump coupling: intermediate drive; W.M. #B–10615	

Fig. ref.	Name of part and description	Function of part
	FUEL PUMP DRIVE GROUP—Continued	
	ELBOW: street; brass; ⅛″; W.M. #B–10168	
	GASKET: bearing housing; vellumoid; W.M. #B–10754	
	GASKET: bearing retainer; vellumoid; W.M. #B–10750	
	GASKET: fuel pump drive cover; vellumoid; W.M. #B–10714	
	GASKET: fuel pump drive gear housing; vellumoid; irregular egg shaped w/large ctr cut out; W.M. #B–10715.	
	GASKET: tachometer adapter; vellumoid; W.M. #B–10700	
	GEAR: fuel pump drive; LH helical pinion; 19 teeth; W.M. #101010	
	GEAR: fuel pump drive; steel; helical gear; 30 teeth; W.M. #12019.	
	HUB: fuel pump gear; steel; W.M. #63927	
	HUB: pump coupling; drive shaft; steel; W.M. #B–10330	
	KEY, machine: Woodruff; steel; W.M. #21017	
	KEY, machine: Woodruff; W.M. #21020	
	LOCK: ball bearing nut; steel; 6 prongs; W.M. #B–10753	
	NUT, lock: sheet steel; W.M. #B–881	
	NUT, ball bearing lock: steel; 1⅜″–18; W.M. #B–10752	
	PAWL: pump gear drive; steel; W.M. #73760	
	PLATE, fuel pump gear thrust: steel; W.M. #63929	
	RETAINER, bearing: cast iron; W.M. #B–10740	
	RETAINER, pulley: steel; W.M. #B–884	
	RING, fuel pump gear: steel forging; RH helical gear; 57 teeth; W.M. #63928.	
	SCREW, drive: injection pump coupling; W.M. #B–10614	
	SCREW, hexagonal head cap: ⅜″ NC thd; W.M. #B–9046	
	SEAL, bearing: injection pump drive; rawhide; W.M. #B–6982	
	SHAFT: fuel pump drive; steel; 6 13/16″ lg, 1⅝″ largest diam; 1⅜″–18 thd one end, ¾″ NF thd other end; W.M. #73822–A.	
	SHAFT: fuel pump drive; steel; 9 13/32″ lg, 2 3/16″ largest diam; 1⅜″–18 thd one end, ⅜″ NC thd other end; W.M. #101014.	
	SHAFT: tachometer adapter; steel; ⅝″ diam, 2 11/16″ lg; W.M. #63631–A.	
	SPRING: injection pump drive; thrust; spring steel; coil spring 7/16″ OD, 2¼″ free lg; W.M. #7073–D.	
	STUD: steel; 1⅛″ lg; 5/16″ NC thd one end, 5/16″ NF thd other end; W.M. #B–9432.	
	FUEL SUPPLY PUMP BRACKET AND COUPLING GROUP	
	CHAIN: coupling; Morse water pump coupling chain; W.M. #B–7496.	
	COUPLING ASSEMBLY, fuel oil pump: c/o two halves and coupling chain; W.M. #OB7495–E.	
	PUMP, fuel supply: clockwise rotation; cap 1 gal per min at 1800 rpm pump speed; W.M. #48660.	
	GEAR COVER GROUP	
	GASKET: drain plug; vellumoid; W.M. #B–243	
53	GASKET: gear cover; LH; vellumoid; W.M. #B–2254	Seal between gear cover and crankcase.
53	GASKET: gear cover; RH; vellumoid; W.M. #B–2254	Seal between gear cover and crankcase.
	BATTERY CHARGING GENERATOR GROUP	
	ARMATURE, battery charging generator: Delco Radio #1880533	
	BEARING, ball: single row radial; plain; med series; packed w/high temp grease; Delco Radio #903203.	

Fig. ref.	Name of part and description	Function of part
	BATTERY CHARGING GENERATOR GROUP—Continued	
	BEARING, sleeve: generator armature shaft, rear; bronze; Oilite; Delco Radio #812823.	
	BLOCK, swivel: steel; W.M. #B–7387	
	BRUSH, electrical contact: carbon; sq; one pigtail lead w/eyelet term clip for #6 screw; Delco Radio #1866148.	
	GENERATOR, DC: battery charging; 18 amp, 15 v; 1530 rpm w/voltage regulator, hinge mtg; Delco Radio #1102956.	
	HOLDER ASSEMBLY, contact brush: battery charging generator; steel, cad pl; crescent shape plate w/two brush holders; Delco Radio #1856989.	
	SPRING: torsion type; for cont brush holder; spring steel wire; 12¾″ RH turns, one straight end, one 60° hook; Delco Radio #809658.	
	GOVERNOR GROUP	
45	BEARING, ball: single row radial; one shield; light duty; not grease packed; W.M. #B–4645.	Supports governor shaft.
	BEARING, needle: open end, small roll series, steel rollers; not grease packed; W.M. #73596–J.	
	BEARING, needle: open end, steel rollers; not grease packed; Torrington #NB–3.	
	BEARING, needle: open end, small roll series, 21 steel rollers; not grease packed; Torrington #B–610.	
45	BEARING, ball: single row radial; single plate; light duty; 8 steel balls; not grease packed; W.M. #B–9641–A.	Supports governor lever shaft.
	BUSHING: governor spring lever; steel; W.M. #48389	
	BUSHING: shaft; steel; W.M. #48223–A	
	CLAMP: governor control tube; W.M. #41355	
	COLLAR, governor rod end: bronze; 9/16″ OD, ¼″ ID, ½″ lg; W.M. #B–6783.	
	COLLAR, governor rod spring retainer: steel; ¾″ OD, 33/64″ ID, ½″ wd; cad pl; W.M. #B–8798.	
	DOWEL, impulse coupling stop pin: steel; W.M. #B–3803	
46	END, governor rod: steel forging; 2 9/32″ lg, 13/16″ diam collar, 9/16″ hole, ⅜″ NF thd W.M. #B–6785–G.	
46	END, governor rod: steel forging; 3″ lg, 13/16″ diam collar, 9/16″ hole, two 9/64″ holes; W.M. #7291–B.	
	GASKET: governor lever bearing cap; vellumoid; W.M. #B–9643.	
	GASKET: governor lever housing; vellumoid; W.M. #B–9639	
	GASKET: governor lever housing cap; vellumoid; W.M. #B–9645	
	GASKET: plug; governor lever housing; vellumoid; W.M. #B–243	
45	JOINT: governor rod end; RH; steel forging; W.M. #B–6785	
46	JOINT: governor rod end; LH; steel forging; W.M. #B–7291	
	KEY, machine: Woodruff; steel; W.M. #21002	
45	LEVER: governor; cast steel; 24 1/16″ lg, 3″ hub, one ¾″ diam hole and one tapped hole in hub; one end of lever has clear hole for ¼″ screw one side, and hole tapped for ¼″ screw other side; also a hole tapped for ⅜″ screw; W.M. #46131–C.	
45	LEVER: governor rod; mal iron; 2¾″ x 2¾″ x 1 1/32″; one ⅜″ hole, one 21/64″ hole, one 5/16″ NC tapped hole; W.M. #B–8717–B.	
45	LEVER: governor spring; mal iron; 2⅛″ x 2¾″; shaft end, 9/16″ diam; W.M. #B–9753–B.	
	NUT, governor rod: screw stock; no thd; 33/64″ drill, 9/16″ hex, 5/16″ h; W.M. #B–7314.	
	PIN, governor rod: steel; W.M. #80593	
46	PIN, pivot: steel; W.M. #B–8760–B	
	PIN, steel: 15/16″ lg; large diam, ⅜″; small diam, 5/16″; W.M. #41042.	

Fig. ref.	Name of part and description	Function of part
	GOVERNOR GROUP—Continued	
	PLUG, expansion: steel; 2⅜″ OD, 1/16″ thk; W.M. #B–295	
	PULLEY: governor; lever spring; steel; 9/16″ OD, ¼″ ID, 7/32″ wd; W.M. #B–9403.	
45	RETAINER, bearing: steel; W.M. #B–2172	Supports governor shaft.
45	SCREW, bumper: w/screwdriver slot; steel; ½″ NF thd; 1 1/16″ lg; small end, 9/32″ diam; W.M. #B–7440–A.	Permits adjustment of governor arm travel.
	SCREW, governor adjusting: steel; ⅜″ NC thd, 1 29/32″ lg; ends, 9/32″ diam; W.M. #B–5339–E.	
45	SCREW, cap: hex head; steel; 2″ x ⅜″ NF thd; W.M. #41045	
	SCREW, locking: steel; 5/16″ NF thd; 1⅛″ lg; 3/32″ screwdriver slot at threaded end; W.M. #B–8356.	
45	SHAFT: governor lever; steel; 4 11/32″ lg; ¾″ OD; W.M. #B–9640	Pivot for governor lever.
	SHIFTER: governor lever; steel forging; W.M. #12076	
	SPRING: bumper; music wire, 5/64″ diam; 9/16″ lg; 2 1/64″ OD, 9/32″ ID; 4½ to 5 coils, cad pl; W.M. #B–7441.	
	SPRING: governor; wire 0.163″ diam; 11 coils, chrome vanadium; 3⅞″ lg; 1 1/16″ ID, 1 1/64″ OD; W.M. #63984.	
	SPRING: governor rod; spring steel wire; 1 15/16″ lg; 9/16″ ID, ¾″ OD; W.M. #B–9783.	
	STUD: governor; lever housing; steel; ½″ NC thd; 9/16″ lg, stud end; ½″ NF thd; ¾″ lg, nut end; 1¾″ lg overall; W.M. #B–7539.	
	STUD: governor; spring pivot; steel; ⅜″ NC thd; 1⅜″ lg, 9/16″ hex; W.M. #B–9666.	
	HEAT EXCHANGER GROUP	
	CLAMP: hose; steel strap, ½″ wd, 12″ lg; folded ⅞″ from clamp; end threaded right angle piece w/slot with screw; W.M. #65737.	
	COCK: drain; brass; ¼″ pipe thd; 3/16″ ID outlet; handle spring loaded; 15/16″ lg from handle to end of shaft; W.M. #B–205.	
	CONNECTION, hose: rubber; 4 ply; 3″ ID, 4¾″ lg; W.M. #B–2602.	
2	EXCHANGER, heat: cast iron body and cover; cover attached w/10 cap screws; W.M. #100671.	Carries off heat from lubricating oil.
	GASKET: vellumoid; W.M. #B–2858	
	IDLER GEAR GROUP	
	BEARING, ball: single row radial; plain; med type; 8 steel balls; not grease packed; W.M. #78390.	
	GEAR: idler; steel forging; RH helical gear; 98 teeth; W.M. #12215–C.	
	LOCK: idler gear retainer; sheet steel; W.M. #B–881	
	NUT, idler gear spindle: steel; 1¼″ NF thd, LH; W.M. #B–2360	
	SHIM: idler spindle; steel; 1 13/32″ diam, 0.003″ thk; W.M. #B–1027	
	SPINDLE, idler gear: steel; 2″ diam, pilot end; 1¾″ diam, gear end; threaded end 1¼″ NF, LH thd; 8 29/32″ lg; two female tapped holes at gear end for ⅜″ bolts; W.M. #12216–B.	
	WASHER, idler spindle: steel; 2¼″ diam, 7/16″ thk; beveled face w/two holes for ⅜″ bolts; W.M. #B–884.	
	IGNITION GROUP	
	CLAMP: hose; galv steel; for ⅝″ OD hose; W.M. #85853	
	CONNECTION, elbow: brass; std pipe thd at one end; 7/16″–20 SAE thd at other end; W.M. #B–1686.	
	COUPLING, hose: brass; for ¼″ ID hose; ⅛″ male pipe thd; W.M. #B–10096.	

Fig. ref.	Name of part and description	Function of part
	IGNITION GROUP—Continued	
16	MAGNETO: 12 v, 450 rpm; Bosch MJA–6–C–1112; heavy duty; clockwise rotation; fixed spark 31° impulse; W.M. #50121–L.	Provides ignition spark for oil engine.
	TERMINAL, ignition: magneto end; for 7 mm cable; p/o ignition cable assem; W.M. #B–4044.	
	TERMINAL, ignition: spark plug; for 7 mm cable; p/o ignition cable assem; W.M. #73905.	
	INJECTOR GROUP	
32	INJECTOR, fuel: overall lg, 9″; 1¾″–16 thd; 1 15/16″ hex; W.M. #0100423.	Atomizes fuel injected into combustion chamber.
	SCREW, injector locating: steel; ⅜″ NC thd; 7/16″ lg; dowel end, 19/64″ diam; over-all lg, 1⅛″; W.M. #B–8744.	Positions injector.
	INSTRUMENT PANEL GROUP	
	CLAMP: hose; galv steel; for ⅝″ OD hose; W.M. #85853	
	CONNECTION, elbow: brass; flared type; ⅛″ std pipe thd at one end, 7/16″–20 SAE thd at other end; W.M. #B–1686.	
	COUPLING, hose: brass; for ¼″ ID hose; ⅛″ male pipe thd; W.M. #B–10096.	
17	GAGE, oil pressure: dial type; body diam, 2″; white figures on black dial; graduated 0 to 60 lb; ⅛″ female thd; accuracy ±10%; W.M. #50003–E.	
17	GAGE, vacuum: dial type; body diam, 3½″; black figures on white dial; graduated 0 to 30″; ⅛″ female thd; W.M. #44193–A.	
	HOSE: flexible; Resistorflex, lacquered; ¼″ ID; 18″ lg; ⅛″ male pipe thd one end; ¼″ female flared swivel; 7/16″ NF thd other end; W.M. #50865–E.	
	HOSE: rubber; 2 ply; 4 ft lg; ⅝″ OD, ¼″ diam; W.M. #80183–A	
17	INDICATOR, heat: dial type; body diam, 2 19/32″; black figures on white dial; graduated 100° to 215° F; 72″ lg capillary tube; ½″, male pipe thd connection; 1⅜″ max d of bulb; accuracy ±10%; W.M. #101133–B.	
	INTAKE MANIFOLD GROUP	
	GASKET: intake manifold; steel asbestos; 5″ wd; 5 11/16″ lg, 1/16″ thk; irregular ID; three 19/32″ diam holes; W.M. #B–8759.	
	GASKET: manifold; end plug; soft copper; 1 15/16″ OD, 1/32″ thk; single hole, 1 41/64″ ID; W.M. #B–2219.	
20	MANIFOLD, intake: cast iron; approx 62″ lg, 6″ h; W. M. #99041–B.	
	PLUG, intake; manifold end; die cast; white metal, 1 15/16″ diam, 13/16″ h; 1⅝″–16 RH thd; 1¼″ hex; W.M. #1631–F.	
	MAGNETO DRIVE GROUP	
	BEARING, ball: steel; med series; double row; deep groove; no oil seal; 8 steel balls per row; approx 1 49/64″ ID, 3 15/16″ OD, 1 9/16″ wd; W.M. #78391.	
42	BUSHING: bronze; 1⅛″ OD, 1″ ID, 1⅜″ lg; one oil groove, inside ¾16″ wd at 20° to ctr running within ⅛″ of ends of bushing; W.M. #B–9281.	Supports secondary magneto drive shaft.
42	COUPLING, magneto: steel, cyanide treated; 2 9/16″ OD, 1¼″ ID, 5/16″ thk; thickness w/tongue ½″; width of tongue 15/64″; 16 holes ¼″ NF tap; W.M. #B–10485.	Couples magneto to drive assembly. Inside flange.

Fig. ref.	Name of part and description	Function of part
	MAGNETO DRIVE GROUP—Continued	
42	COUPLING, magneto: steel; 2 9/16" OD; 1 1/8" lg overall; flange, 1/4" thk; shaft 3/4" lg, 1 1/4" OD, 3/4" ID; keyway 1 1/8" lg, 5/32" wd; 20 holes, 1 7/64"; 2 holes on shaft, 1/4" NF; W.M. #65422–A.	Outer flange of magneto coupling. Drive member of coupling.
	COVER: retainer oil seal; cast iron; 3 holes 1 7/32" on 5 1/2"; bolt circle, 3 1/32" ID; 3 1/2" counterbore; ribs 5/32" wd; W.M. #B–2241.	
42	GASKET: magneto bracket; vellumoid; 1/32" thk, 4" ID; 3 holes 9/16"; W.M. #B–2246.	
	GASKET: retainer; vellumoid; 0.021" thk, 7 1/4" OD, 5" ID; 3 1/4" from ctr to straight cut-off on OD; 6 holes, 9/16" equally spaced; W.M. #B–2283.	
	GASKET: retainer; 0.010" thk, 3 1/4" OD, 2 5/16" ID; 3 holes 9/32"; W.M. #B–9292.	
	GEAR: drive shaft; cast iron; RH helical; 45 teeth; 5 13/16" OD, 2 1/4" thk, 2" ID; hub tapered 3" OD to 3 1/4" OD; web 1/2" thk; d of web 7/8"; keyway, 5/16" wd x 5/32" d; 2 holes at 3 7/8" ctr 1/2" NC tap; W.M. #12028.	
42	GEAR: magneto drive; steel; LH helical; 30 teeth; 3 5/32" OD x 1 1/4" ID, 1 19/32" lg; keyway, 1/4" wd x 1 19/32 lg; 7/8" diam shaft; W.M. #B–9272.	Driving gear of magneto drive assembly.
42	GEAR: magneto drive; steel; RH helical; 20 teeth; 2 5/32" OD x 7/8" ID, 1 1/4" lg; keyway, 5/32" wd x 1 1/4" lg; 1 1/2" diam shaft; one hole 3/16" diam in shaft; W.M. #B–9273.	Driven member of magneto drive assembly.
	KEY, machine: Woodruff; steel; 1/4" thk; 1" lg, 7/16" h; W.M. #21012.	
	KEY, machine: Woodruff; steel; 5/16" thk, 1 1/2" lg, 5/8" h; W.M. #21017.	
	KEY, machine: Woodruff; steel; 5/32" thk, 3/4" lg, 5/16" h; W.M. #21006.	
42	LOCK: drive gear; sheet steel; dead soft #18 (0.050" approx 3/64"I) 1 1/2" OD; 2 holes 9/32" at 5/8" centers; W.M. #9290.	Locks magneto drive gear to shaft.
	LOCK: drive gear; steel; 1 1/4" diam, 1/4" thk; 2 holes 9/32" at 5/8" centers; 1/16" x 60° chamfer; W.M. #B–9289.	
42	NUT, lock: camshaft; steel stamping; (0.050" approx 3/64"I) gage; 2 15/16" OD, 1 21/32" ID; 2 holes raised 9/32" OD; 1/8" h; W.M. #B–1730–A.	Secures magneto drive shaft end locknut.
42	NUT, lock: steel; 2 1/2" hex, 1 5/8" NF, LH tap; 7/16" h; 2 bosses 1/64" h; W.M. #B–1731.	Secures magneto drive shaft.
42	PIN, dowel: brass rod HD; 1/8" OD, 1/2" lg; W.M. #B–356	Secures magneto driven gear to shaft.
	PIN, dowel: steel; 1/8" OD, 7/16" lg; W.M. #B–4481	
	PULLEY: battery charging generator drive; cast iron; single groove; V–shape; 8" OD; grooved, 1 3/8"; 3" OD on shaft, 1 3/4" ID; W.M. #44252.	
42	SCREW, cap: magneto coupling; steel; heat treated; parkerized; 1/4" NF x 1/2" thd; 5/16" lg; 7/16" hex head; 1/16" hole through head; W.M. #B–10656–A.	Secures magneto coupling plates to each other.
42	SEAL, oil: steel stamping; leather lam or coil spring; 1 53/64" diam, 7/16" thk; opening in leather for 1" shaft; W.M. #B–4725.	Prevents oil leakage around magneto drive shaft.
42	SHAFT: magneto drive; steel; 15 5/8" lg; W.M. #99066	Drive shaft for magneto drive assembly.
42	SHAFT: magneto drive; steel; 5 9/16" lg overall; W.M. #B–9287	Driven shaft of magneto drive assembly.
	SPACER, ball bearing: steel; 2 1/4" OD, 1 49/64" ID, 2 3/16" lg; W.M. #B–2243.	
42	SPACER, drive shaft: cast iron; 3" OD, 1 3/4" ID, 2 5/8" lg; W.M. #B–2245.	Positions magneto drive shaft.
	STUD: steel; 1/2" x 1 3/4" lg; 1/2" NC thd 5/8" lg; 1/2" NF thd 3/4" lg: W.M. #B–838.	
	THROWER, oil: sheet steel; 1/16" thk, 4 3/8" OD, 1 13/16" ID, 5/8" h; W.M. #B–2812.	

Fig. ref.	Name of part and description	Function of part
	IGNITION SUPPRESSION GROUP	
	CABLE ASSEMBLY SET: six cables w/term and screw fittings; 27 mm OD; rubber covered metallic shielded; cables marked 1–2–3–4–5–6–.	Conducts high-tension current from magneto to spark plugs.
61	SHIELD ASSEMBLY, spark plug: brass tubing; zinc pl, screw cap	Shields spark plug.
61	SUPPRESSOR, electrical noise: resistor w/spring; 1 15/16" lg, 3/8" OD; 10,000 ohms.	Suppresses radio interference caused by ignition system.
	OIL DEPTH GAGE GROUP	
16	GAGE, oil: bayonet type; blade 1/4" x 1/16" x 5 3/4" lg; die cast knob; W.M. #B–3998–C.	Used to measure depth of lubricating oil in base of engine.
	PLUG, oil gage hole: #20 gage soft dead steel; 5/8" OD x 3/8" h; W.M. #65446.	
	TUBE, oil gage: #16 gage steel; 5/8" OD, 5" lg; W.M. #B–9779–A	Housing for bayonet gage.
	OIL FILTER GROUP	
	BAIL: steel; 3/4" diam; W.M. #B–2383	
	CARTRIDGE, filter unit: 13" x 5 1/4"; W.M. #50520	
	FILTER, refill: W.M. #101415–D	
26	SPRING: oil relief valve; spring wire; 17 coils; 2 1/16" lg, 5/8" OD; W.M. #B–2384.	Seats relief valve plunger.
	WASHER, relief valve cover: copper asbestos; W.M. #B–1539	
	OIL LINE GROUP	
	ADAPTER, tube connection: steel; 1/2" pipe thd one end, 1 1/2 mm–18 spark plug thd other end; 1 7/16" lg overall; W.M. #48853.	
	ADAPTER, tube connection: steel; 3/8" pipe thd one end, 1 1/2 mm–18 spark plug thd other end; 1 1/4" lg overall; W.M. #B–10116.	
	BOLT, tube connection: steel; 1 1/2 mm–18 spark plug thd; W.M. #B–10110.	
	BOLT, tube connection: steel; 5/8" NF x 2 25/32"; W.M. #48217	
	CONNECTOR, inverted male: brass; 1/4" pipe thd one end, 5/8" NF thd other end; W.M. #73017–G.	
	ELBOW: inverted male; 1/8" pipe thd one end, 7/16" NF thd other end; brass; W.M. #73018–B.	
	ELBOW: inverted male; brass; 1/8" pipe thd one end, 3/8" NF thd other end; W.M. #73018–A.	
	ELBOW: inverted male; brass; 1/4" pipe thd one end, 5/8" NF thd other end; W.M. #73018–G.	
	ELBOW: pipe; brass; 1/8" pipe thd one end, for 1/4" tube one end; W.M. #B–403.	
	ELL, street: brass; 1/8"; W.M. #B–567	
	FITTING, straight: brass; 1/8" pipe thd one end, 7/16" NF thd other end; W.M. #B–4094.	
	FITTING, straight: brass; 1/8" pipe thd one end, for 1/4" tube one end; W.M. #B–404.	
	GASKET: oil header; vellumoid; 1/32" thk; W.M. #B–2694	
	GASKET: oil header; vellumoid; 1/32" thk	
	GASKET: oil header; vellumoid; 1/32" thk; W.M. #B–4672	
	HEADER, oil: 1/2" OD tube; copper; 3 flanges cast bronze; 2 3/8" wd, 24 5/8" lg overall; W.M. #99386.	
	NUT, acorn: steel; chromium pl; 5/8" NF thd, 1 1/2" h, 15/16" hex; W.M. #B–4261–B.	
	SCREEN, scavenger oil: perforated sheet brass #20 gage; screen, 3 1/8" x 7 1/8" x 10 1/16"; tube, 7/8" OD x 4"; flange, 1 3/4" x 2 1/2" x 2 3/4"; overall dimen, 5 17/32" x 7 1/8" x 13 7/8"; W.M. #OB–3993.	

Fig. ref.	Name of part and description	Function of part
	OIL LINE GROUP—Continued	
	STRAINER: bronze; contains 30-mesh screen; T-shape; ⅛″ pipe tap on 3 sides; W.M. #B–9140.	
	TUBE, oil: ½″ OD x 15⅜″; 2 tube end connections ½″; W.M. #044550.	
	TUBE, oil: Resistorflex hose; 3/16″ ID, ⅜″ OD, 24″ lg; ⅛″ pipe thd one end, 7/16″–20 SAE thd other end; W.M. #50864–D.	
	TUBE, oil: supply pump to filter; ½″ OD, 14⅝″ developed lg; ½″ tube end connection each end; W.M. #048280.	
	TUBE, oil: filter to injection pump; ½″ OD, 54″ developed lg; ½″ tube end connection each end; W.M. #044551.	
	WASHER: soft copper; 11/16″ nominal size; 31/32″ OD, 3/32″ thk; W.M. #B–10124.	
	OIL PAN GROUP	
	GAGE, oil temperature: brass; rigid type; 1″ round case; scale lg 4½″; range 40° to 240° F, ½″ pipe thd; W.M. #60216.	
	GASKET: oil pan door long; cork; 9¼″ wd, 32¾″ lg, 1/16″ thk; W.M. #B–2648.	
	GASKET: oil pan door short; vellumoid; 9¼″ wd, 18⅛″ lg, 3/64″ thk; W.M. #B–2647.	
	GASKET: oil pan front; vellumoid; 3⅜″ wd, 21¾″ lg, 1/32″ thk; W.M. #B–2229.	
	GASKET: oil pan rear; vellumoid; 5⅜″ wd, 26¼″ lg, 3/64″ thk; W.M. #B–2228.	
	GASKET: oil pan side; vellumoid; 3⅞″ wd, 75 5/16″ lg, 1/32″ thk; W.M. #B–2227.	
	OIL PUMP GROUP	
	BUSHING: idler gear; bronze; 1½″ OD, 1¼″ ID, 2 1/32″ lg; W.M. #B–1561–A.	
39	BUSHING: oil pump drive shaft; bronze; 1⅝″ OD, 1⅜″ ID, 2⅜″ lg; W.M. #63970.	Supports oil pump drive shaft.
39	BUSHING: oil pump gear; bronze; 1¼″ OD, 1″ ID, 2½″ lg; W.M. #65010.	Supports oil pump driven gear shaft.
39	GASKET: oil pump cover; vellumoid; 0.021″ thk, 5⅝″ x 10⅜″; W.M. #B–4174.	Seal between oil pump body and cover.
39	GASKET: oil pump to pan; vellumoid; 1/32″ thk, 8 13/16″ x 12⅝″; W.M. #B–2633.	Seal between oil pump body and pan.
	GASKET: oil pump inlet; cork; 3/32″ thk, 1¾″ x 3″; W.M. #B–1956.	
39	GEAR: oil pump drive; steel forging; 5 13/16″ diam; 45 teeth; 1¼″ bore, 1¼″ hub thk; W.M. #13051–B.	Drives oil pump assembly.
48	GEAR: oil pump drive idler; steel; 3 9/16″ OD, 2″ lg; 1½″ bore; 24 teeth; W.M. #13058.	Idler gear between crankshaft gear and oil pump drive gear.
39	GEAR: oil pump driver; steel; 2⅜″ OD, 2½″ lg; 1″ bore; 12 teeth; W.M. #13181.	Driving member of oil pump assembly.
39	GEAR: oil pump idler; steel; 12 teeth; W.M. #13185–A	Driven member of oil pump assembly.
	KEY, machine: Woodruff; 3/16″ x 1″; steel; W.M. #21011.	
	LOCK: oil pump idler gear; steel stamping; W.M. #B–741.	
26	NUT: acorn; adj screw; 1½″ hex, NF thd; W.M. #B–2234	Protection cover for oil pressure adjusting screw.
26	NUT, lock: relief valve; 1½″ hex, NF thd; W.M. #B–2237	Locks adjustment of oil pressure relief valve screw.
	NUT: thin hex; ⅜″ NC thd; W.M. #21191	
39	PIN: oil pump gear; brass; 3/16″ OD x 1 7/16″	Secures gear from turning on shaft.
39	PLUNGER: relief valve; ⅞″ OD x 1″; 25/32″ counterbore, ⅝″ d; W.M. #B–2232.	Receives pressure of oil and actuates valve.
	SCREW, set: oil pump; steel; ⅜″ NC thd; 1¼″ lg, ⅜″ sq head; cup point w/7/64″ drilled hole in head; W.M. #78411.	

Fig. ref.	Name of part and description	Function of part
	OIL PUMP GROUP—Continued	
39	SCREW: relief valve; 1″ OD x 2⅛″; 1″ NF thd; W.M. #B–2233–A.	Permits adjustment of lubricating-oil pressure.
39	SHAFT: oil pump drive; steel; 1⅜″ x 8⅝″; ⅝″ NF thd one end; W.M. #13084.	Oil pump driving shaft.
48	SHAFT: oil pump idler; steel; 1¼″ OD x 6⅞″; ⅝″ NF thd one end, ⅜″ NC thd other end; W.M. #B–2257–A.	Supports fuel pump drive idler gear.
39	SHAFT: oil pump idler; steel; 1″ diam, 5½″ lg; W.M. #13083.	Supports driven gear in oil pump assembly.
	SHIM: steel shim stock; 0.003″ thk, 3½₃₂″ OD, ²⁵⁄₆₄″ hole; W.M. #B–926.	
39	SPACER, idler shaft: steel; 1¾″ OD, ²½₃₂″ ID x 3⁄16″ thk; W.M. #B–2251.	Prevents oil pump driving gear from working off shaft.
39	SPACER, oil pump gear: steel; 2″ OD x 1″ lg; 1¼″ hole; W.M. #B–3995.	Spaces oil pump driving gear from oil pump housing.
39	SPRING: relief valve; steel spring wire; ¾″ OD, 2⅝″ full lg; 13½″ coils; W.M. #74025–A.	Resists pressure of oil and holds plunger to seat.
	WASHER: idler retainer; steel; 2″ OD, ¹³⁄₃₂″ ID, 3⁄16″ thk; W.M. #B–1567.	
	WASHER: oil pump thrust; steel; 2″ OD, 1½₃₂″ ID, ¼″ thk; W.M. #B–2250.	
	WASHER: relief valve nut; soft copper; 1½″ OD, 1½₃₂″ ID x ¾₄″; W.M. #B–2236.	
	WASHER: spring lock; ½″ nominal size; 3⁄16″ wd, ⅛″ thk; W.M. #44281–E.	
	WASHER: spring lock; ⅜″ nominal size; ⅛″ wd, ³⁄₃₂″ thk; W.M. #44281–C.	
	PRIMER GROUP	
15	COCK: shut off; brass; ⅛″ pipe tap; ⅛″ pipe thd; T-shape handle; W.M. #B–9041.	Shut off for fuel line from primer.
	FITTING, elbow: brass; for 3⁄16″ OD tubing; ⅛″ pipe thd, ⅜″ NF thd; W.M. #B–3664.	
	NOZZLE: sprayer bolt; brass; ¹³⁄₃₂″ overall; ⁷⁄₃₂″–32 thd; W.M. #73062.	
15	PRIMER: c/o tank w/built-in pump; overall h approx 10″; OD of tank, 4¾″; h of tank, 4⅝″; two mtg straps; W.M. #63754.	Injects gasoline to aid in starting.
	WASHER: soft copper; plain; ¹⁵⁄₃₂″ ID, ¹⁵⁄16″ OD, ½₃₂″ thk; W.M. #B–5149.	
	RADIO SUPPRESSION GROUP	
	CAPACITOR, fixed: paper; 0.1 mf, 100 v DC, paper dielectric; CA–442.	
	CAPACITOR, fixed: paper; 0.25 mf, 100 v DC, paper dielectric; CA–452.	
	PLUG, spark: 18 mm, hot type, #8–32 thd term, 1″–20 thd above hex to receive shield; Defiance #149–9 Special.	
	ROCKER ARM COVER GROUP	
19	CAP: breather; stamped steel shell; wire crimp packing; 1¹³⁄16″ ID, 2½″ OD, 3⅝″ lg; W.M. #B–9037.	Filters air entering rocker arm assembly cover.
	CLAMP: hose; steel; ½″ x 12″; slotted head screw in fold of strap ⅞″ from end; threaded right angle piece with slot for strip; for hose 1″ to 3½″ OD; W.M. #65737.	
	COCK: drain; brass; ⅜″ pipe thd; ⅜″ ID outlet, spring loaded; W.M. #B–558.	
	GASKET: rocker arm cover; cork; 9½″ wd x 11⅝″ lg x ⅛″ thk; W.M. #73173.	

Fig. ref.	Name of part and description	Function of part
	ROCKER ARM COVER GROUP—Continued	
	GASKET: water inlet manifold; 1/32" thk x 4 1/4" lg x 2 1/2" wd; W.M. #B–2286.	
	GASKET: water pump inlet elbow; 1/32" thk x 5" x 5 1/4"; W.M. #B–2267.	
	HOSE: connection; rubber; 4 ply; 2 1/4" ID, 2 5/8" OD; 5" lg; W.M. #8744–A.	
	PIPE: water inlet; seamless steel, galv; 90° tube turn; 2 1/4" OD x 8 3/8" x 6" overall; W.M. #B–10755.	
	PIPE: water inlet; seamless steel, galv; 90° tube turn; 2 1/4" OD x 20 3/8" x 6" overall; W.M. #101017.	
	WATER LINES GROUP	
	CONNECTOR, inverted male: brass; 1 1/8" lg; 1 1/16" hex; 17/32" hole; tube size 5/8"; 3/8" pipe thd; 3/4"–18 thd; W.M. #73017–M.	
	ELBOW: inverted male; brass; 1/2" pipe thd; tube size 5/8" OD; W.M. #73018–N.	
	NUT, inverted: steel pl; for 5/8" tubing 7/8"–18 thd; W.M. #73016–G.	
	WATER MANIFOLD GROUP	
	CLAMP: hose; steel; 12" lg x 1/2" wd; for hose 1" to 3 1/2" OD; W.M. #65737.	
	GASKET: front and rear outlet elbow; sheet packing; 1/32" thk, 3 1/2" diam, 5 1/4" lg; W.M. #B–1916.	
	HOSE: rubber, 4 ply; 3 1/4" OD, 3 3/4" lg; W.M. #15027.	
	STUD: outlet elbow; steel, 1 15/16" lg, 1/2" NF thd one end, 1/2" NC thd other end; W.M. #B–1525.	
	WATER PUMP GROUP	
	BUSHING: water pump; bronze; 1 3/8" OD, 1 1/8" ID; 1 5/8" OD of flange; flange 3/16" thk, 2 11/32" lg; groove width 3/8"; one 1/4" diam hole at groove; W.M. #12068–B.	
41	COLLAR, packing: phosphor bronze; 1 5/32" ID, 1 3/4" OD; shoulder 1 7/8" OD; 1 1/8" lg overall; W.M. #B–2215.	Retains water pump packing gland.
	CONNECTOR, inverted male: brass; for 1/4" tubing; 7/16"–24 thd; 17/32" hex; W.M. #73017–B.	
22	CUP, grease: brass; 1/2 oz cap; 1/8" pipe thd; 1 7/16" from end of pipe thd to body of cup; cup 1" diam; W.M. #B–1859.	Permits lubrication of water pump shaft.
	GASKET: connection, water pump; sheet packing; 1/32" thk; rectangular, 5 1/4" x 4 3/8"; two rectangular openings 2 1/2" x 1 1/2"; W.M. #B–2268.	
	GASKET: water pump; sheet packing; 1/64" thk; 10 1/4" OD, 8 5/16" ID, 11 1/8" lg; W.M. #B–2214.	
41	GLAND: water pump; 1 3/4" OD, 1 1/8" ID, 7/16" lg; brass; W.M. #65988.	Retains water pump packing.
	KEY, machine: Woodruff; steel, 1/4" thk, 1 1/4" lg, 17/32" h; WM #21015.	
	KEY, machine: Woodruff; steel, 1/4" thk, 7/8" lg, 3/8" h; W. M. #21010.	
	NUT, inverted: steel pl; for 1/4" tubing; 7/16"-24 thd; 7/16" hex; W. M. #73016–B.	
41	NUT, packing: LH; brass; 2 1/2" NF; LH tap 3 1/4" OD; 1 1/2" lg; W.M. #B–2212.	Retains water pump packing gland and packing.
41	NUT, packing: RH; brass; 2 1/2" NF; RH tap 3 1/4" OD; 1 1/2" lg; W.M. #B–2213.	Retains water pump packing gland and packing.
41	PACKING: water pump; 1 3/4" OD, 1 1/8" ID, 5/16" thk; cut through one side; W.M. #B–4836–B.	Prevents leakage at pump shaft.

Fig. ref	Name of part and description	Function of part
	WATER PUMP GROUP—Continued	
22	PUMP ASSEMBLY: water; shaft driven; cast iron; four ⅛″ female pipe taps; two 2½″ NF thd male fittings; W.M. #099060–E.	Circulates engine coolant.
41	VANE, water pump: bronze; 11 vanes 3/16″ thk, 6½″ OD; W.M. #12063–A.	Impeller for water pump.
	WATER PUMP DRIVE GROUP	
	COUPLING, water pump drive: flexible; lam steel disks, ¼″ x 9/64″; two flanged hubs 1⅛″ diam; W.M. #74442.	
	GASKET: oil retainer; vellumoid; 5⅜″ OD, 3½″ ID, 0.021″ thk; W.M. #B–9347.	
	GEAR: water pump drive; steel; 3.395″ OD x 2⅝″; 30 teeth; LH helical; bore 1½″ diam; W.M. #12019.	Drives water pump and magneto.
	KEY, machine: Woodruff; water pump coupling; W.M. #21015	
	KEY, machine: Woodruff; water pump drive gear; W.M. #21017	
	LOCK: water pump gear; sheet steel; 2⅛″ x 1″; W.M. #B–881	
	RETAINER, oil: water pump drive shaft; cast iron; 5⅜″ diam x 1 5/16″; W.M. #B–2196.	
	SHAFT: water pump drive; steel; 8 17/32″ lg overall; 1½″ diam x 2 1/16″; gear end, 1⅛″ diam x 2⅞″ coupling end; W.M. #12054.	
	SHAFT: jack; water pump; steel; 1⅛″ diam x 13½″; W.M. #101015	
	STARTING UNIT SUPPORT GROUP	
	STUD: steel; 1 1/16″ lg; ½″ NC thd one end; ½″ NF thd other end; W.M. #B–5763.	
	AIR CLEANER GROUP	
	BRACKET: air cleaner; sheet steel, 2 piece; one piece 3¾″ x 6½″; other piece ⅝″ x 4⅜″; W.M. #Y–18296.	
3	CLAMP: hose; soft steel wire, galv; for 1½″ diam hose; W.M. #Y–6503; Sig C stock No. 3H1926–21658.	Secures air cleaner hose to air cleaner or carburetor.
3	CLEANER, air: Vortox; 8⅞″ lg, 3¼″ OD; W.M. #Y–18373	Filters air entering carburetor.
	GASKET: air cleaner; vellumoid; 2¾″ lg, 1½″ wd, 1/32″ thk; W.M. #73305.	
	HOSE: rubber; 1⅝″ OD, 3¾″ lg; 3 ply; W.M. #63423	
	STRAP, air cleaner: 14 gage steel; developed lg 7½″, ⅝″ wd; W.M. #Y–18424.	
	BREATHER GROUP	
3	ADAPTER, breather: cast aluminum; 1½″ diam, 2⅝″ lg; W.M. #Y–14426.	
	CAP: breather; steel stamping; W.M. #B–9037-B	Excludes foreign matter from breather.
	CHAIN: breather cap; 6″ lg; W.M. #B–9842	Prevents loss of cap.
	CAMSHAFT GROUP	
37	CAMSHAFT: 13 15/16″ lg overall; bearing diam 1¼″; pilot bearing surface ¾″ diam x ⅝″ lg; ⅝″ NF thd front end; W.M. #121123	Actuates valve mechanism.
37	GEAR: camshaft drive; cast iron; RH helical; 48 teeth; 4 13/16″ OD, ¾″ ID; W.M. #121026.	Drives camshaft.
	KEY, machine: Woodruff; steel; 5/32″ x ¼″ x ⅝″; W.M. #21005	
37	NUT, cam gear lock: steel; ⅝″ NF thd; ¼″ thk; 15/16″ hex; W.M. #B–5004.	Secures camshaft gear.
	PLATE, camshaft thrust: steel; ⅛″ x 1½″ x 2⅞″; W.M. #73283.	

Fig. ref.	Name of part and description	Function of part
	CARBURETOR GROUP	
3	CARBURETOR: Marvel Schebler T5V–15; 5/8" SAE flange; approx 3 1/8" wd, 4 3/8"; W.M. #51071.	Mixes fuel and air in proper proportions for combustion.
	GASKET: carburetor; terne pl asbestos; 1 7/16" x 2 3/8" x 5/64"; two bolt holes 9/32" diam, ctr hole 15/16" diam; W.M. #73928.	Seal between faces of carburetor mounting flanges.
	STUD: carburetor; steel; 1/4" diam x 1", 1/4"–20 NC thd both ends; W.M. #B–9922.	Secures carburetor to manifold.
	MANIFOLD GROUP	
	GASKET: manifold; steel asbestos; 1/16" thk, 11 1/4" lg, 1 7/16" wd; four holes 7/8" diam; two holes 13/16" diam; four holes 11/32" diam; W.M. #73303.	Seal between manifold and cylinder block.
37	MANIFOLD, combination: cast iron; 11 25/32" x 3 15/16" x 5 5/8" overall; carburetor flange 1 7/16" wd, 2 3/8" lg, 5/16" thk; 1 5/16" cored ID; two holes 9/32" at 1 13/16" ctr; exhaust flange 2 5/16" wd, 3 1/2" lg, 1/4" thk; 1 3/8" cored ID; 1 hole 3/8" NC tap; 1 hole 13/32" diam; 3 holes 1/8" pipe tap; 6 port holes; W.M. #121142–A.	Provides passage for incoming fuel-air mixture and outgoing exhaust gases.
	NUT, hex: brass; 5/16" NF thd; 17/64" thk; W.M. #B–1294	Secures manifold.
	STUD: steel; 5/16" diam, 1 3/16" lg, 5/16" NC thd x 1/2" x 45° chamfer stud end; 5/16" NF thd x 1/2" nut end; W.M. #B–2047.	Provides mounting for manifold.
	STUD: steel; 5/16" diam, 1 1/8" lg, 5/16" NC thd stud end; 5/16" NF thd nut end; W.M. #B–9432.	
	CONNECTING ROD GROUP	
	BOLT, connecting rod: steel; 5/16" NF thd; 1 23/32" lg; 1 hole 5/64" drill; special lock head 1/2" diam, 11/16" h; W.M. #73218.	Secures connecting rod lower end bearing cap.
	BUSHING: connecting rod: steel, Babbitt lined 1 9/16" ID, 1 5/8" OD, 1" wd; one 3/16" diam hole; 1 oil groove 1/32" x 3/32" wd x 7/8" lg; W.M. #121110–A.	Provides bearing for lower end of connecting rod.
	BUSHING: piston pin; graphite bronze, 1 1/16" diam, 7/8" lg; 0.6095" to 0.6115" ID; one 3/32" hole; no oil grooves; W.M. #121008–A.	Provides bearing for upper end of connecting rod.
37	ROD, connecting: steel forging; 7 11/16" lg, 2 13/16" wd, 1 1/4" thk; 1 1/16" pin diam; 1 21/32" bearing diam; W.M. #121207–C.	Connecting link between piston and crankshaft.
	SHIM: connecting rod; sheet steel, 0.006" thk, 1 13/16" lg, 3 1/32" wd; 5/16" hole in ctr; W.M. #73255.	Permits adjustment of connecting rod lower end bearing clearance.
	CRANKSHAFT GROUP	
37	BEARING, ball: single row radial; double plate; med series; bore 1.378", OD 2.8346", #0.6693" wd; 9 steel balls; not grease packed; W.M. #B–10751–B.	Supports crankshaft.
	BUSHING: pilot; bronze; Oilite; 7/8" OD, 3/4" ID, 5/8" lg; W.M. #73908.	
	COLLAR, bearing spacer ring: steel; 1 7/8" OD, 1 7/16" ID, 3/32" thk; W.M. #73530.	
37	CRANKSHAFT: steel forging; 18 1/4" lg, 5 5/16" wd overall; 2 single throw, one double throw; 4 bearing journals, 1 9/16" diam front and rear main bearings 1 3/8" diam; one keyseat 5/16" d x 1/4" wd at main bearing and 1 1/4" NF thd one end; two keyseats, one 1/4" wd x 15/64" d and one 3/16" wd x 5/16" d, 1" NF thd other end; W.M. #121111–E.	Converts reciprocating movement of piston and connecting rod assembly into rotary motion.
	GASKET: retainer; vellumoid; 1/32" thk, 5 17/32" OD, 4 9/64" ID; 4 holes 11/32" diam on 4 7/8" bolt ctr; W.M. #73529.	
37	GEAR: crankshaft; steel; 2 31/64" OD, 1 3/8" ID, 61/64" wd; 24 teeth; marks C and X, 6 1/2 tooth spaces apart; W.M. #121012–A.	Drives timing gears and accessory drive gears
	KEY, machine: Woodruff; steel; 3/16" thk, 3/4" lg, 5/16" h; W.M. #21007.	
	KEY, machine: Woodruff; steel; 1/4" thk, 1" lg, 7/16" h; W.M. #21012.	

Fig. ref.	Name of part and description	Function of part
	CRANKSHAFT GROUP—Continued	
	NUT, half: ½″ thk, 1 7/16″ hex, 1″ NF thd; shoulder 1 7/16″ diam x 1/64″ h; W.M. #B–6034.	
37	PULLEY: cranking; cast iron; 8″ OD groove ½″ d x ⅞″ wd; lips of groove 3/16″ thk; W.M. #73938–A.	Sheave for starting rope.
	RETAINER, bearing: rear; cast iron; 5 9/16″ OD; bore 2 27/32″ to 2 29/32″; 2 15/16″ counterbore ¼″ d; flange ¼″ thk; W.M. #73279–A.	
	RING, retainer: ball bearing; spring steel; 3″ OD; ⅛″ wd, ⅛″ thk; ⅝″ wd opening; W.M. #75122.	
	SEAL, oil: steel and leather stamping; 3″ OD; ¼″ wd ID in leather to fit 2″ diam shaft; W.M. #73339.	
	THROWER, oil: crankshaft; sheet steel; 1/32″ thk, 2 15/16″ OD, 1 13/32″ ID, 5/16″ wd; W.M. #73284.	Distributes lubricating oil.
	WASHER: plain; sheet steel stamping; 1¾″ OD, 1 1/32″ ID, 5/32″ thk; W.M. #B–4458.	
	WASHER: shakeproof; ext lock; steel; twisted prongs 1/16″ thk, 1⅝″ OD; W.M. #21617.	
	CRANKCASE AND RELIEF VALVE GROUP	
	BALL, relief valve check: steel; 5/16″ diam; W.M. #B–5874.	
	BUSHING: front and rear camshaft; steel backed, Babbitt lined; split; 1¼″ ID, 1⅜″ OD, ¾″ lg; W.M. #121027.	Provides bearing for camshaft.
	BUSHING: ctr camshaft; steel backed, Babbitt lined; split; 1¼″ ID, 1⅜″ OD, ½″ lg; W.M. #121050.	Provides bearing for camshaft.
	BUSHING: distributor drive shaft; steel backed, Babbitt lined; split; 0.491″ ID, 0.625″ OD, ⅝″ lg; W.M. #73337.	
	GASKET: relief valve adjusting screw; copper asbestos; ½″ ID, ¾″ OD, 3/32″ thk; W.M. #B–2469.	
	NUT, acorn: relief valve cap; steel; ¾″ hex, 13/16″ h, ½″ NF–20 tap; W.M. #78119.	Protects relief valve.
	NUT, lock: relief valve; steel; ¾″ hex, 3/16″ h, ½″ NF–20 tap; W.M. #78118.	
	PIN, cam bushing dowel: steel; 3/32″ diam, 5/16″ lg; W.M. #74662	
	PLUG, expansion: steel; cad pl; 1½″ OD; W.M. #B–1795–A	
	PLUG, expansion: steel; ½″ OD; W.M. #B–536	
	SCREW, relief valve adjusting: steel; ½″ NF–20 thd; slotted end; W.M. #78117–A.	Provides means for adjusting relief valve.
	SPRING: relief valve; steel wire; 1 1/32″ OD, ⅞″ lg; 7 active coils; W.M. #73589–A.	
	CYLINDER GROUP	
37	BLOCK, cylinder: cast iron; 5 3/32″ h, 5 7/16″ wd, 12¼″ lg; 4 cyl bores 2½″ diam; 8 valve seats; valve seat inserts in exhaust valve seats only; valve guides installed; W.M. #0121101–C.	Contains cylinders, coolant passages, exhaust and intake ports, and valves.
	GASKET: cyl base; vellumoid; 12¾″ lg, 5 1/16″ wd, 0.021″ thk; W.M. #73396.	
	GASKET: valve door; cord; 2⅜″ x 12″ x ⅛″ thk; W.M. #73397	
	GUIDE, exhaust valve: cast iron; ½″ OD, 1 7/16″ lg, 5/16″ diam ream; W.M. #121009–A.	Holds valve in correct alinement with valve seat.
	GUIDE, intake valve: cast iron; ½″ OD, 1 11/16″ lg, 5/16″ diam ream; W.M. #121009.	Holds valve in correct alinement with valve seat.
	INSERT, valve seat: exhaust; cast iron; 1 1/16″ OD, 3/16″ h, 13/16″ ID; 45° x 0.015″ seat; W.M. #78077.	Enables replacement of exhaust valve seat.
37	LIFTER, valve: steel; 13/16″ diam, 1 61/64″ lg, ⅜″–24 NF female thd for adjusting screw; W.M. #121037–C.	Transmits cam action to valve stem.
37	NUT, lock: tappet adjusting screw; ⅜″–24 NF thd; W.M. #73655	Locks valve tappet adjustment.
	PLUG, expansion: steel; 1¼″ diam; W.M. #B–432.	
	RETAINER, valve spring: steel; ¾″ OD, ⅜″ h, 37/64″ diam spring seat; 14° taper; W.M. #73278.	Holds valve spring in position on valve stem.

Fig. ref.	Name of part and description	Function of part
	CYLINDER GROUP—Continued	
	SCREW, valve tappet adjusting: steel; ⅜″–24 NF thd; ½″ hex head crowned; 0.171″ h; W.M. #73618.	Enables adjustment of valve tappet clearance.
	SPRING: valve; intake and exhaust; carbon steel wire; $1\frac{11}{32}$″ ID, $3\frac{19}{32}$″ free lg; LH helix 10½ coils; W.M. #123035–D.	Returns valves to seats.
	STUD: cyl to crankcase; (long) steel; ⅜″ diam, 1⅝″ lg, ⅜″–16 USF thd stud end; ⅜″–24 USF thd nut end; W.M. #B–3715.	Positions cylinder block on crankcase.
	STUD: cyl to crankcase; (short) ⅜″ diam, $1\frac{7}{16}$″ lg, ⅜″–16 USF thd stud end; ⅜″–24 SAE thd nut end; W.M. #B–291.	Positions cylinder block on crankcase.
	TAPER: valve spring retainer; steel; 14° taper for $\frac{5}{16}$″ diam valve stem; ⅜″ h; W.M. #B–9792.	
	VALVE, exhaust: steel; $1\frac{5}{16}$″ diam head; 45° seat; $\frac{5}{16}$″ diam stem; $3\frac{29}{64}$″ lg; W.M. #121136–A.	Opens and closes exhaust port.
	VALVE, intake: steel; 1⅛″ diam head; 45° seat; $\frac{5}{16}$″ diam stem; 3⅜″ lg; W.M. #121036.	Opens and closes intake port.
	WASHER: soft copper; $\frac{1}{32}$″ thk, $\frac{17}{64}$″ ID, ⅜″ OD; W.M. #B–4188.	
	WASHER: copper; $\frac{1}{32}$″ thk, $2\frac{1}{64}$″ ID, ½″ OD; W.M. #B–2135	
	CYLINDER HEAD GROUP	
	GASKET: cyl head; steel asbestos; $\frac{1}{16}$″ thk, 12″ lg, $5\frac{7}{16}$″ wd; 4 combustion chamber holes; W.M. #121200–A.	
37	HEAD, cylinder: cast iron; $12\frac{1}{8}$″ lg, $5\frac{7}{16}$″ wd, $1\frac{9}{16}$″ thk; 4 holes for 14 mm spark plugs; W.M. #121202.	Covers top of cylinders. Contains combustion chambers.
	NUT, jam: hex; steel; ⅜″ NF thd; $\frac{7}{32}$″ thk; Parkerized; W.M. #44286–A.	
	SCREW, cap: cyl head; steel; $2\frac{11}{32}$″ lg, 0.330″ shank diam, $\frac{9}{16}$″ hex, ⅜″–16 NC thd; Parkerized; W.M. #73376–A.	Secures cylinder head to cylinder block.
	STUD: cyl head; steel; ⅜″ NC thd stud end; ⅜″ NF thd nut end; $3\frac{3}{16}$″ lg overall; W.M. #B–1212.	Positions and secures cylinder head.
	STUD: water manifold flange; steel; $\frac{5}{16}$″ NC thd stud end; $\frac{5}{16}$″ NF thd nut end; $1\frac{7}{16}$″ lg overall; W.M. #B–2575.	
	EXHAUST PIPE GROUP	
3	MUFFLER: exhaust; 6½″ OD, $3\frac{7}{16}$″ h; neck to fit exhaust pipe; W.M. #101275–C.	Silences exhaust from engine.
	PIPE, exhaust: steel tubing; #16 gage welded; 1½″ OD, 3″ lg; W.M. #73864–C.	Conducts exhaust from engine.
	FLYWHEEL GROUP	
37	FLYWHEEL: cast iron; 10¼″ OD, $2\frac{31}{64}$″ thk; W.M. #73790–A	Stores energy to carry engine through nonpower producing strokes.
	GASKET: fuel pump cover; vellumoid; 2½″ wd, $2\frac{1}{16}$″ lg, 0.021″ thk; W.M. #73842.	
	KEY, machine: flywheel lock; steel; Woodruff; ¼″ x 1″; W.M. #21012.	
	NUT, lock: flywheel; special hex; steel; 1⅞″ hex, 1¼″–12 NF RH thd; W.M. #73335.	
	SCREW, cap: hex head; ⅜″–24 NF thd x 1⅜″; steel; W.M. #73377	
	WASHER: shakeproof; flywheel lock nut; steel; 1¼″ ID; W.M. #21639.	
	GASOLINE TANK GROUP	
	ELBOW: brass, ⅛″ std pipe thd one end; $\frac{7}{16}$″–20 SAE male thd other end; W.M. #B–1686.	
	NIPPLE, close: pipe; wrought iron; ⅛″ std close nipple ¾″ lg; W.M. #B–8678.	

Fig. ref.	Name of part and description	Function of part
	GASOLINE TANK GROUP—Continued	
	TANK, gasoline: 2 gal cap; #22 gage terne plate; 7⅝″ OD, 10⅝″ lg; filler neck steel tubing 1½″ OD; W.M. #044272–A.	
	TRAP, sediment: fuel strainer; 2¼″ x 3″ x 3½″ overall; ⅛″ pipe inlet; ⅛″ pipe outlet; wing-type shutoff; W.M. #74179–A.	Filters foreign matter from gasoline.
	VALVE, gasoline: tank ball check; W.M. #Y–18681	
	GEAR COVER GROUP	
	COVER: timing gear; cast iron; 12 15/16″ wd, 9⅞″ h, 1 17/32″ thk; W.M. #121145.	
	GASKET: front plate; vellumoid; 7 9/16″ wd, 8 5/16″ h, 1/32″ thk; W.M. #73307.	
	GASKET: gear cover; vellumoid; 14⅞″ lg overall; 10 15/32″ h, 1/32″ thk, 9/16″ wd; W.M. #73563.	
	GOVERNOR AND WATER PUMP GROUP	
	BEARING, ball: single row radial; narrow type; bore, 0.9843″, 2.0472″ OD, 0.3543″ wd; 9 steel balls; not grease packed; W.M. #B–9086.	
	BEARING, thrust: steel; 1 1/16″ OD, 27/64″ wd, 17/32″ ID; W.M. #74398.	
	BEARING, thrust: steel; 1 1/16″ OD, 7/16″ ID, 19/32″ wd; W.M. #74399.	
	BUSHING: water pump body; bronze; 1″ OD, 7/16″ ID, 1 1/16″ wd; W.M. #121168.	
	BUSHING: thrust bearing; 17/32″ OD, 27/64″ wd; W.M. #74397	
	CAGE, ball bearing: 1″ OD, ½″ ID; W.M. #73436	
	CARRIER, governor weight: cast iron; 1 7/32″ diam, 1⅞″ lg; W.M. #74197.	
	CLAMP: hose; brass; 1⅛″ ID, ½″ wd; for std ¾″ ID hose; W.M. #B–7912.	
	CONNECTION, hose: rubber; 1¼″ OD, ⅞″ ID, 2″ lg; 3 ply; W.M. #73400–A.	
	GASKET: water pump and governor housing; vellumoid; 4″ lg overall; 1/32″ thk; W.M. #73294.	
	GASKET: water pump cover; sheet packing; 3⅜″ OD, 2⅜″ ID, 1/32″ thk; W.M. #73289	
	GEAR: drive; water pump and governor; 1 29/32″ OD, 27/32″ wd; LH helical; 18 teeth; W.M.	
37	LEVER: governor; mal iron; 4 3/16″ lg, ½″ wd; W.M. #74848	Transmits governor action of engine throttle.
37	NUT, adjusting: governor; steel; ¼″ NC thd; W.M. #B–6164–B	Permits adjustment of spring tension.
	RETAINER, oil seal: steel; ¾″ diam, ¼″ thk; 13/32″ ID; W.M. #B–6316.	
	RING, spring: retainer lock; spring steel; 2¼″ OD, 3/32″ sq, ⅞″ gap in ring; W.M. #B–8643.	
	ROD, governor: steel; #10–32 thd NF; 2¾″ lg; developed lg, 3⅜″; W.M. #117203.	
	ROD END, governor: steel forging; 5/16″ diam, 1 1/16″ #10–32 NF tap one end; SAE std 5/16″ yoke; W.M. #B–6121.	
	SCREW, governor spring adjusting: steel; ¼″ NC thd; ⅞″ lg, 5/32″ diam; eye one end; W.M. #B–6163–C.	
	SCREW, bumper: steel; 5/16″ NF thd; 15/32″ lg, ⅜″ hex; overall lg ¾″; W.M. #80661–A.	
	SEAL, water pump: spring loaded rubber; 1¼″ OD; ½″ shaft diam; 17/32″ free wd; W.M. #74044.	

Fig. ref.	Name of part and description	Function of part
	GOVERNOR AND WATER PUMP GROUP—Continued	
	SEAL, oil: 1″ OD, ⅜″ wd; for 7/16″ diam shaft; rawhide enclosed in steel; W.M. #73949.	
	SHAFT: water pump and governor; steel; 7/16″ diam, 5⅝″ lg; W.M. #121056–B.	
	SHAFT: governor; cross lever; steel; ⅜″ diam, 3¾″ lg; W.M. #73401–B.	
	SPRING: bumper; stainless steel, spring wire; 0.028″ diam, 5/16″ free lg; ⅛″ ID, 6 LH coils; W.M. #B–6161.	
	SPRING: governor; chrome vanadium, spring wire; 0.1055″ diam, 15/16″ OD; 2⅝″ free lg; 13½ coils; W.M. #27277–A.	
	WASHER, water pump thrust: 1 1/16″ OD, 29/64″ ID, ⅛″ thk; W.M. #74045–A.	
	WASHER, oil seal: graphited cork; 1 1/16″ OD, 25/64″ ID, 7/32″ thk; W.M. #B–6315.	
	WEIGHT, governor: mal iron; 1 3/16″ lg, 1 1/16″ wd, 1 1/32″ h; W.M. #74400.	
	IDLER GEAR GROUP	
	GEAR: idler assem; cast iron; RH helical; 35 teeth; 3 9/16″ OD; marks X and M on face; W.M. #0121015.	
	LOCK: idler gear screw; soft CRS; #18 U.S. gage; ¾″ x 13/16″ x ⅛″ x 5/16″; W.M. #73556.	
	SHIM: idler gear; 27/32″ diam, 0.003″ thk; 21/64″ hole in ctr; W.M. #73557.	
	SPINDLE, idler gear: steel; large diam, ⅞″, 1″ lg; 5/16″ NC tap; 2 11/16″ overall lg; 7/16″ NF thd one end; W.M. #121016.	
	WASHER, idler spindle: steel; 1⅜″ OD, 5/32″ thk; W.M. #73555.	
	MAGNETO: Edison-Splitdorf model RM–4, RH, 4 cyl; impulse coupling; W.M. #050713.	
	INSTRUMENT PANEL GROUP	
3	GAGE, oil pressure: 2⅛″ x 2¼″ OD; black dial face, white markings, white pointer, 0 to 60 lb; W.M. #50003–E.	Indicates lubricating-oil pressure.
3	SWITCH, ignition: permanent key, OFF-ON etched on flange; W.M. #50022–B.	Short circuits magneto to stop engine.
	DISTRIBUTOR GROUP	
	BLOCK, distributor: magneto; 4 cyl, jump spark; Edison #29760	
	BRUSH AND CAP, center: Edison #51436	
64	CABLE ASSEMBLY SET: magneto; 4 cables	
	CAPACITOR: Edison #6286	
	COIL: Edison #6406	
64	COVER, ignition distributor: sheet steel	
	GASKET: distributor block; cork composition; 2 15/16″ x 4 15/32″ x 3/64″; Edison #6356.	
	PLUG, spark: Champion #J–9	
	ROTOR, distributor: Edison #6787	
	SCREW: distributor block; Edison #6440	
	SCREW: cont bracket attaching; Edison #51272	
	SCREW: cam wiper; Edison #35251	
	SCREW: breaker bar spring; Edison #3327	
	SCREW: braker lead; Edison #3327	
	SCREW: coil attaching; Edison #16766	
	SCREW: capacitor attaching; Edison #35251	
	SET, breaker bar and bracket: Edison #6291	
64	SHIELD, ignition distributor: sheet steel	

Fig. ref.	Name of part and description	Function of part
	DISTRIBUTOR GROUP—Continued	
64	SHIELD, spark plug: brass, zinc pl	
	SUPPRESSOR, electrical noise: resistor 10,000 ohms; bakelite case.	
	WASHER, lock: distributor block screw; Edison #23149	
	WIPER, cam: Edison #6403	
	PISTON, PISTON PIN, AND PISTON RING GROUP	
37	PIN, piston: steel; 5/8" OD, 2 1/8" lg, 3/8" ID; W.M. #121106	
37	PISTON: cast iron; 2 1/2" diam x 2 11/32"; 3 ring grooves; W.M. #121204.	
	RETAINER, piston pin: spring steel wire; W.M. #121030	
	RING, piston: compression; cast iron; 2 1/2" x 1/8" x 0.115"; W.M. #121705.	
	RING, piston: oil scraper; cast iron; 2 1/2" x 1/8" x 0.115"; W.M. #121405.	
	RING, piston: oil type; cast iron; 2 1/2" x 5/32" x 0.115" W.M. #12120	
	STARTER TRANSMISSION GROUP	
	BEARING, needle: 3/4" ID, 1" OD, 3/4" wd; closed end bearing; W.M. #85813.	
	BUSHING: drive gear; bronze; 2 5/8" OD, 15/16" wd, 2 7/16" ID; W.M. #73778.	
	BUSHING: idler gear; bronze; 1 1/2" OD, 27/32" wd, 1 5/16" ID; W.M. #73779.	
	CLUTCH, starter: tapered clutch; largest diam 5 13/16", 7 15/16" lg hand lever 5/8" diam x 6 1/8" lg; W.M. #73791.	
	GASKET: transmission housing; vellumoid; 11 1/8" lg, 7 1/2" wd, 1/32" thk; W.M. #73783.	
	GEAR, drive: steel; 3 3/4" OD, 1 5/8" wd, 21 teeth; W.M. #73786	
	GEAR, driven: steel; 4 3/4" diam, 15/16" wd; 27 teeth; W.M. #73787–A	
	NUT, lock: drive gear; seamless steel tubing; 2 3/4" OD, 7/16" thk 2 1/8" NF LH thd; W.M. #73776.	
	PINION, Bendix drive: assem; drive gear and worm shaft; 12 tooth pinion 3 1/64" diam, assem 7 11/32" lg over-all; W.M. #73795.	
	RETAINER, idler gear: steel; 1 9/16" diam, 3/32" thk; W.M. #73780	
	SEAL, oil: 2 3/8" diam, 1/2" thk; for 1 1/2" shaft; W.M. #75117	
	SHAFT: Bendix drive; steel forging; 7/8" spline diam; 3" diam x 1/4" thk flanged end; 6 13/32" lg; W.M. #73781.	
	STOP, clutch lever: sheet steel; 11 gage; 2 11/16" diam, 2 ears 3/4" wd x 1 1/4" lg; W.M. #73789–A.	
	WATER PUMP MOUNTING	
4	AMMETER: 0 to 400 amp range; sq steel case; projection mounting; 5 1/2" x 5 1/2" x 4 1/2" over-all; black numerals on white background.	
4	BREAKER, circuit: magnetic trip and thermal trip; 3 pole, 2 position; 600 v; 400 amp; molded black bakelite case; 22" h, 8 1/4" wd, 7" thk over-all; manual reset.	
	BRUSH, electrical contact: exciter; 1 9/16" lg, 5/8" wd, 3/8" thk; GE #K–5804446.	
	CAPACITOR, fixed: paper dielectric; 0.1 mf, 500 v AC/DC; Sig C #CA–482.	
	CAPACITOR, fixed: paper dielectric; 0.1 mf, 500 v AC/DC; Sig C #CA–482.	

Fig. ref.	Name of part and description	Function of part
	WATER PUMP MOUNTING—Continued	
5	FUSE, cartridge: 6 amp, 250 v, nonrenewable; mica body; ferrule terminals; nonindicating; 2″ lg, 9/16″ diam over-all.	
	GASKET: water pump inlet; sheet packing; 1/32″ thk; 1¼″ x 2⅝″ one ctr hole ¾″ diam; W.M. #73909.	
	GASKET: water pump outlet; sheet packing; 1/32″ thk, 2⅛″ diam x 3 3/16″ lg; one hole ctr 1½″ ID; W.M. #73666.	
4	LAMP, incandescent: 10 w, 120 v; S–14 clear; 3½″ lg; miniature screw base; C–9 filament.	
4	METER, frequency: AC type; 58 to 62 cy; round phenolic case; flush mounting; 60 cy, 230 v rating. J.G. Biddle #4964.	
4	METER, time: 3½″ diam flange; 2¾″ diam body; 2¾″ d; 240 v, 60 cy, AC; molded phenolic case; Westinghouse type NH35 #1205858.	
5	REACTOR: reverse power relay type; 1 section; 60 cy, 70 v, 30 ohms DC resistance; perforated metal case w/cast iron ends; 5 1/16″ h, 5 1/16″ d, 2⅞″ wd; Westinghouse #304790.	
5	RECTIFIER, metallic: selenium type; 30 to 36 v single phase, 60 cy input; 23 v 2 amp output; cylindrical; 4⅝″ diam, 7 9/16″ lg.	
4	REGULATOR, voltage: metal case, black finish; 240 v; 10½″ d, 5 13/16″ wd, 12 11/16″ h overall; Westinghouse type SRA–2, S. O. 774756.	
5	RELAY, reverse power: 60 cy, 70 v AC; ⅛″ diam silver cont; potential coil 70 v; current coil 5 amp; 10 to 60 w range; Westinghouse type CW #1056072.	
5	RESISTOR, variable: ribbon wire on porcelain core; 300 w 25 ohms; porcelain body 6″ diam x 4⅜″ overall; Ohmite model N, #0658.	
5	RESISTOR, variable: stationary cont buttons; vitreous enamel embedded; 45 ohms; pressed steel case; WL S. O. 4775384.	
5	SWITCH, knife: 3 pole, single throw; 2 position; 400 amp, 500 v; copper cont blades; nonfusible; ebony asbestos base; no case; 12″ x 12″ x 6¾″ overall; Westinghouse type NA, #NY–3964.	
4	SWITCH, rotary (ammeter): 4 pole, 8 position; single section; 125 v AC, 10 amp; 250 v 7.5 amp; 600 v 1.5 amp; 125 v DC, 4 amp; 250 v 2 amp; 600 v 0.5 amp; 8½″ lg, 2⅝″ wd; Westinghouse type W. #1040745.	
4	SWITCH, rotary (regulator transfer): 6 pole, 3 position; single section; 125 v AC, 10 amp; 250 v 7.5 amp; 600 v 1.5 amp; 125 v DC, 4 amp; 250 v 2 amp; 600 v 5 amp; silver cont; steel and phenolic case; 10⅛″ lg, 4⅞″ h, 2⅝″ wd.	
4	SWITCH, rotary (synchronizing lights): DPST, 2 position; 2 decks; 10 amp; silver button cont; black bakelite; 3⅛″ lg, 2″ wd, 1½″ thk; Westinghouse #1224530A.	
4	SWITCH, rotary: 4 pole, 8 position; single section; 125 v AC, 10 amp; 250 v 7.5 amp; 600 v 1.5 amp; 125 v DC, 4 amp; 250 v 2 amp; 600 v 0.5 amp; silver cont; steel and phenolic case; 6¼″ lg, 4⅞″ h, 2⅝″ wd; Westinghouse type W #1040750.	
4	VOLTMETER: 0 to 300 v range; sq steel case; 5½″ x 6½″ x 4 1/16″ overall; projection mounting; black numerals on white background.	

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