# OPERATOR'S MANUAL

GM
GENERAL MOTORS
DIESEL POWER

## THREE, FOUR, SIX-CYLINDER MARINE PROPULSION UNITS

*Built by*

**DETROIT DIESEL ENGINE DIVISION**

GENERAL MOTORS CORPORATION

DETROIT 23, MICHIGAN

# THREE, FOUR, AND SIX-CYLINDER SERIES 71, TWO-CYCLE

# DIESEL MARINE PROPULSION UNITS

# OPERATOR'S MANUAL

DETROIT DIESEL ENGINE DIVISION
GENERAL MOTORS CORPORATION
DETROIT 23, MICHIGAN

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# FOREWORD

General Motors two-cycle Diesel engines have given an excellent account of themselves in both industrial and marine fields of operation; yet, for satisfactory performance, any machine requires a reasonable amount of intelligent care on the part of its operator.

This Manual is published to assist Operators of Series 71 Diesel Marine Propulsion Units in acquiring knowledge of the construction, operation, and routine maintenance of their engines. When major repairs are required, authorized G. M. Diesel Service Dealers, who are equipped to handle all service problems, will be found within easy reach.

The conscientious operator, who realizes that careful operating, together with thorough and regular maintenance, pays dividends in low-cost, dependable service, will read his manual carefully and keep it in a handy place for reference on operating and maintenance problems.

# SECTION I

## Engine Data

# ILLUSTRATIONS . . . Three, Four and Six Cylinder Single and Twin Engine Marine Propulsion Units.

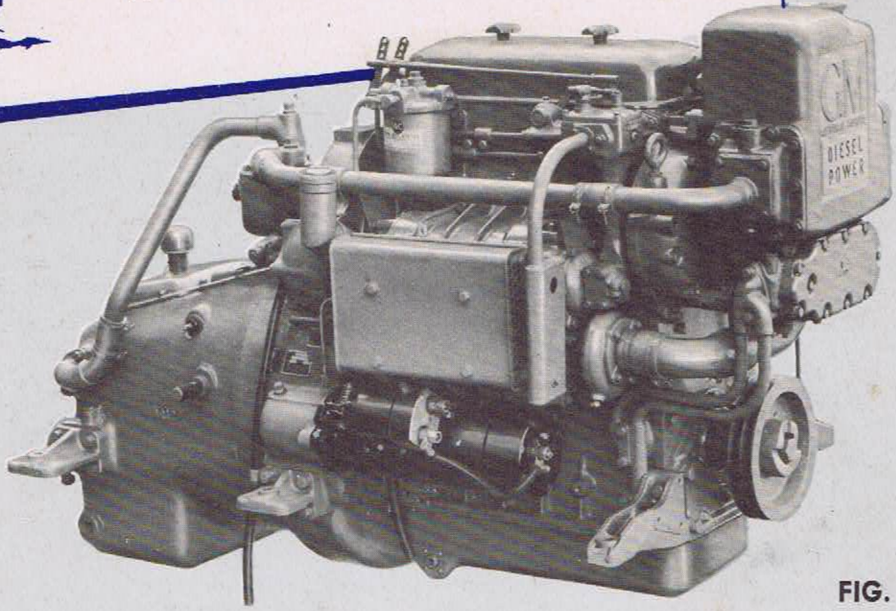



FIG. 1

MODEL 3073 THREE CYLINDER DIESEL PROPULSION UNIT WITH TWIN DISC REVERSE GEAR.

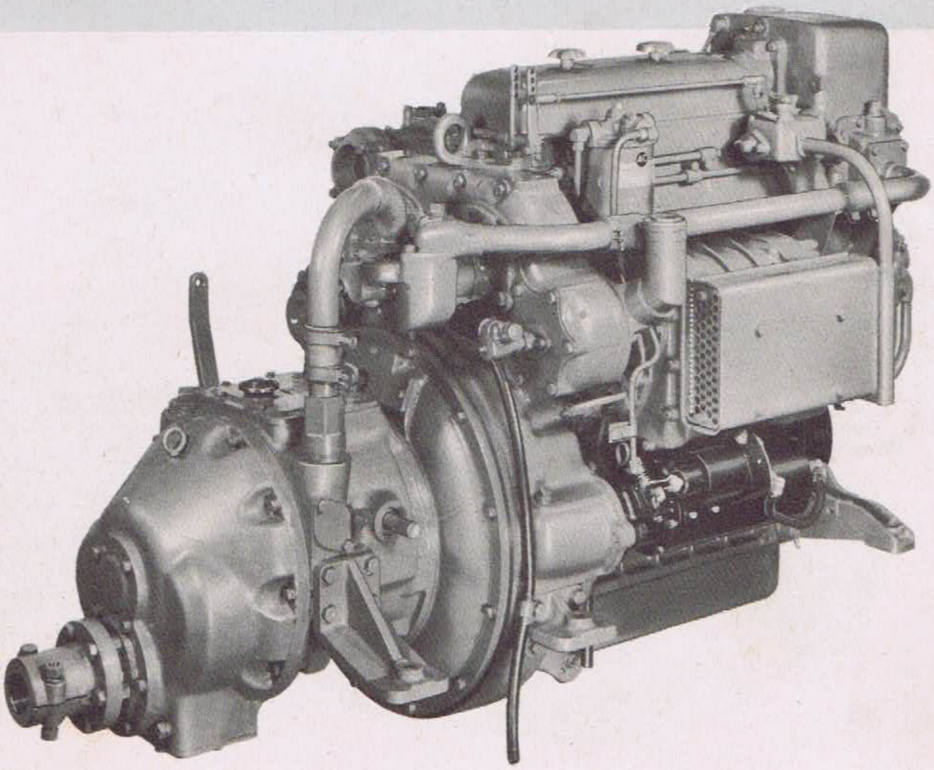
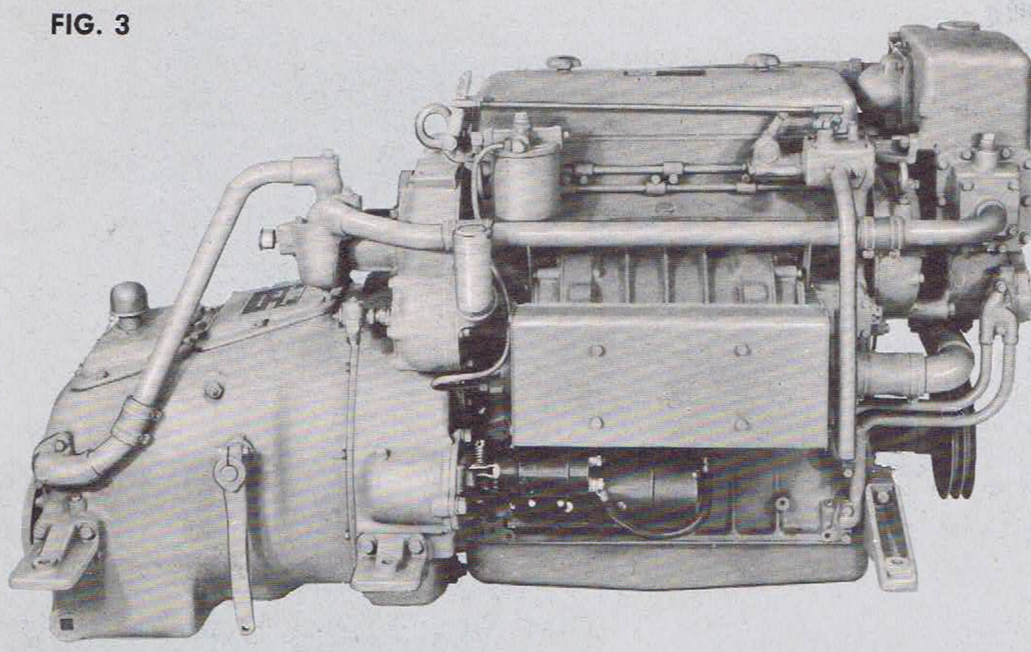


FIG. 2

MODEL 3073 THREE CYLINDER DIESEL PROPULSION UNIT WITH S-N REVERSE GEAR.

MODEL 4073 FOUR CYLINDER DIESEL PROPULSION UNIT WITH TWIN DISC REVERSE GEAR.

FIG. 3



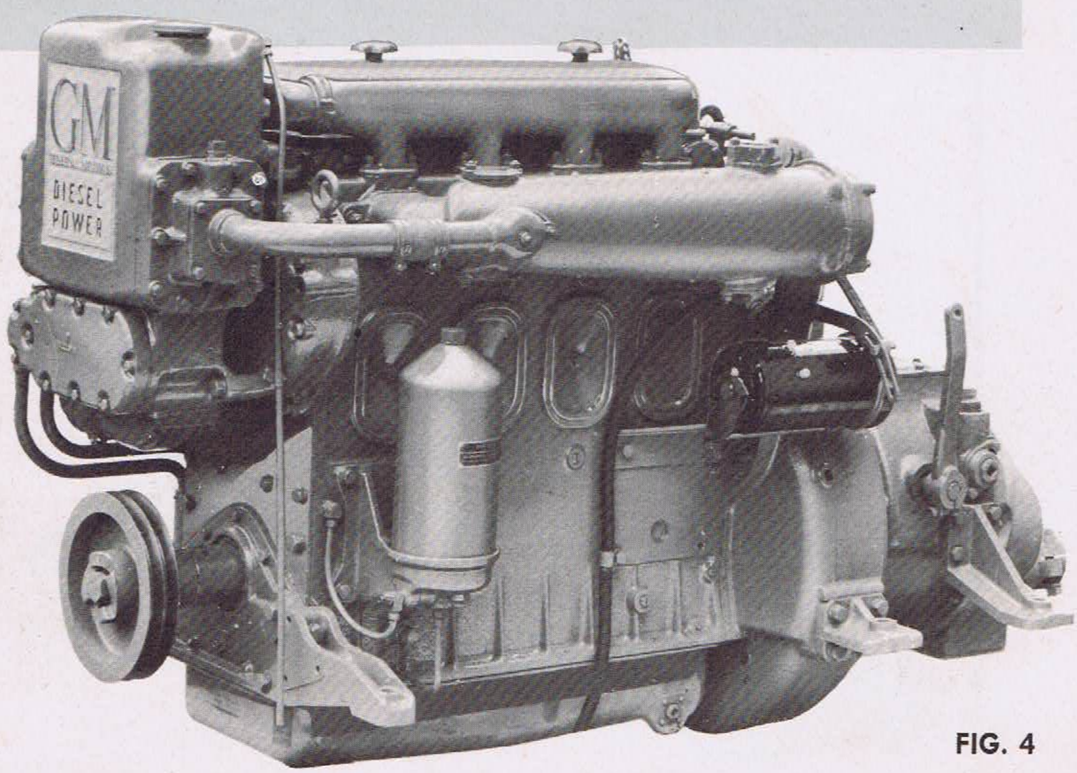



FIG. 4

MODEL 4073 FOUR CYLINDER DIESEL PROPULSION UNIT WITH S-N REVERSE GEAR

MODEL 6073 SIX CYLINDER DIESEL PROPULSION UNIT WITH TWIN DISC REVERSE GEAR AND FRONT POWER TAKE-OFF.

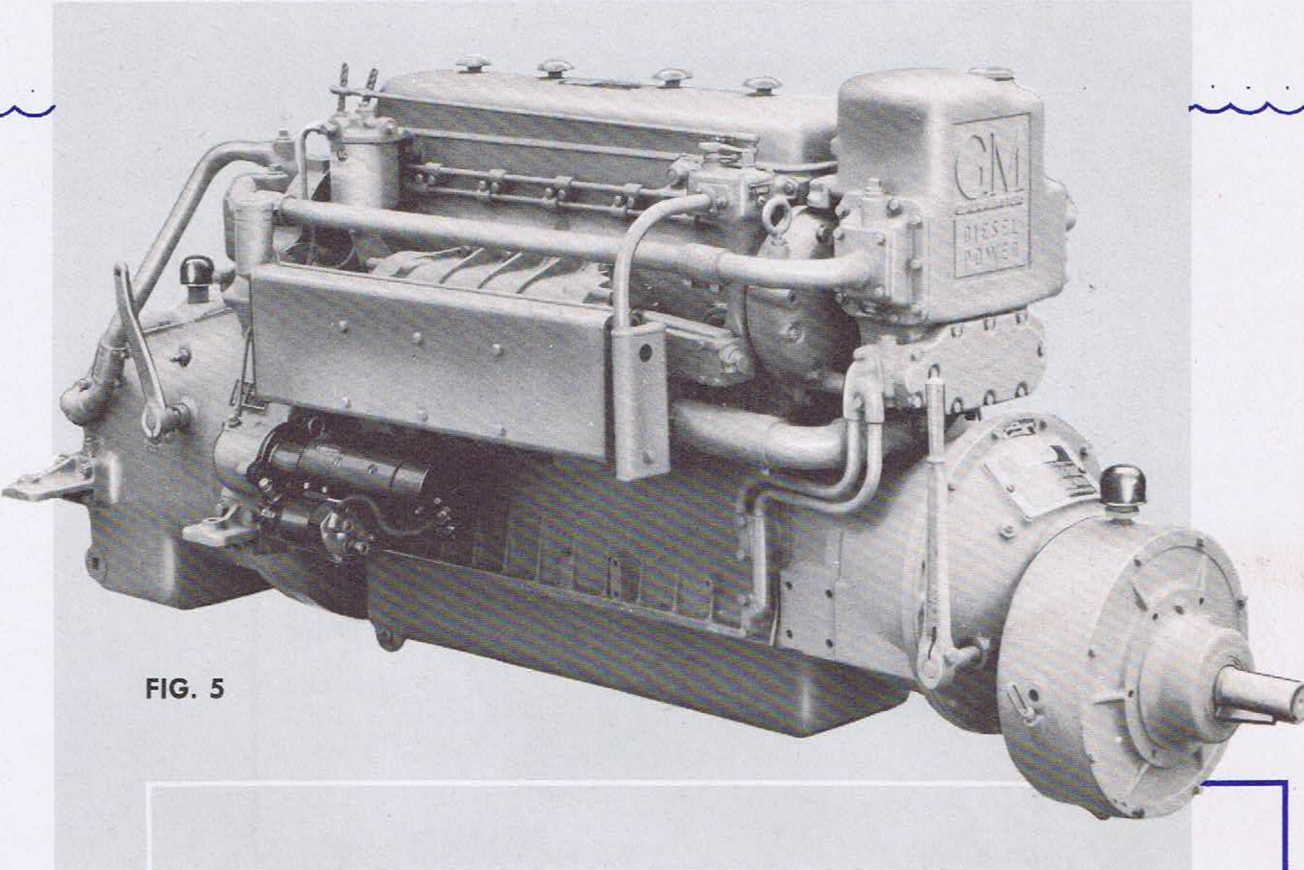



FIG. 5

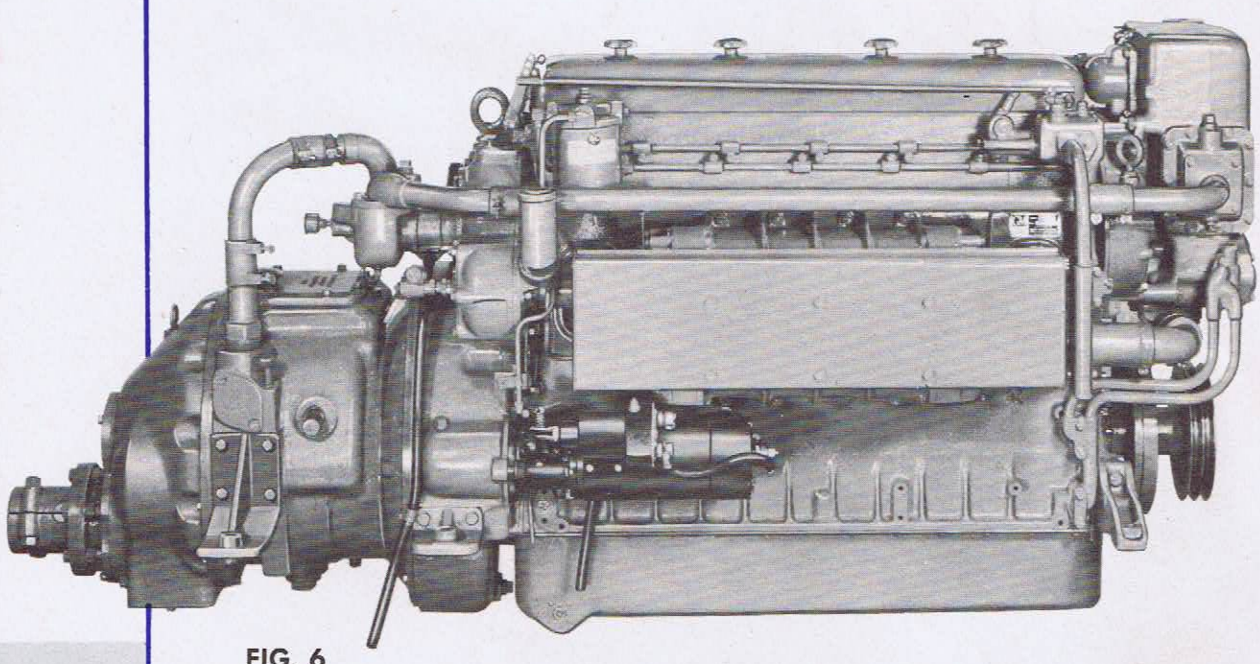


FIG. 6

MODEL 6073 SIX CYLINDER DIESEL PROPULSION UNIT WITH S-N REVERSE GEAR.

**TWO VIEWS OF MODEL 12001-A TWIN SIX CYLINDER DIESEL PROPULSION UNIT WITH FRONT POWER TAKE-OFF ON EACH ENGINE.**

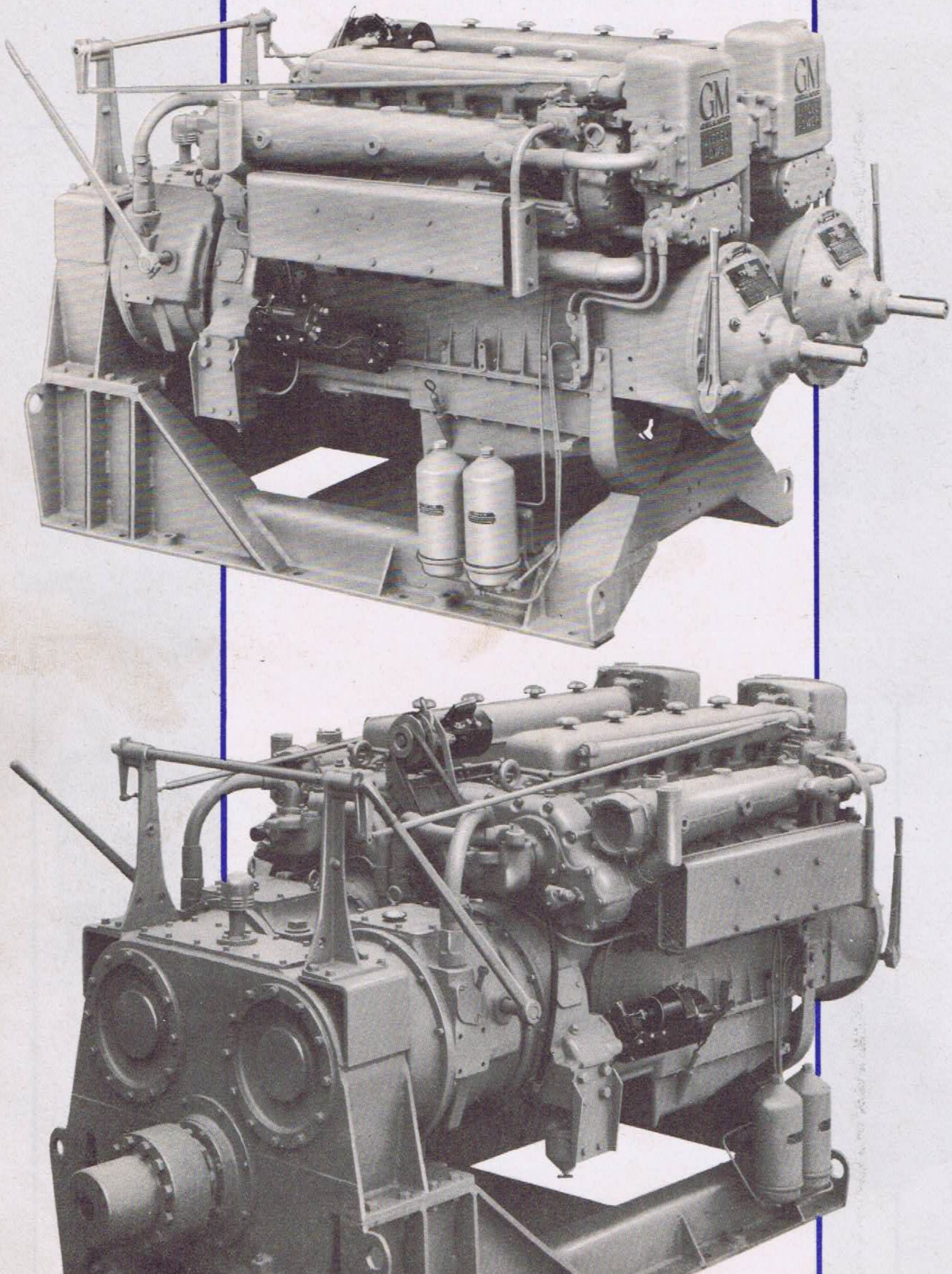



FIG. 7

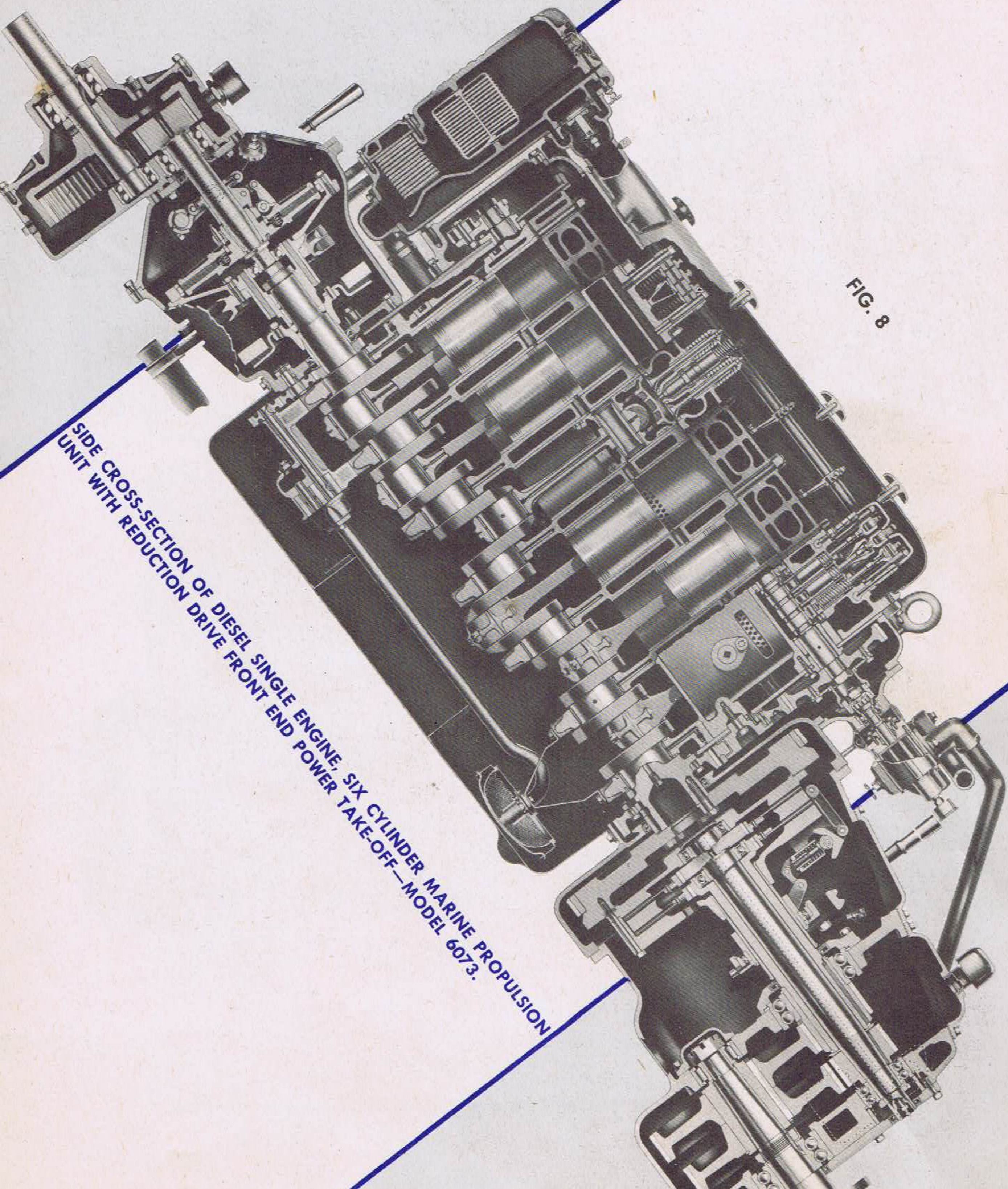
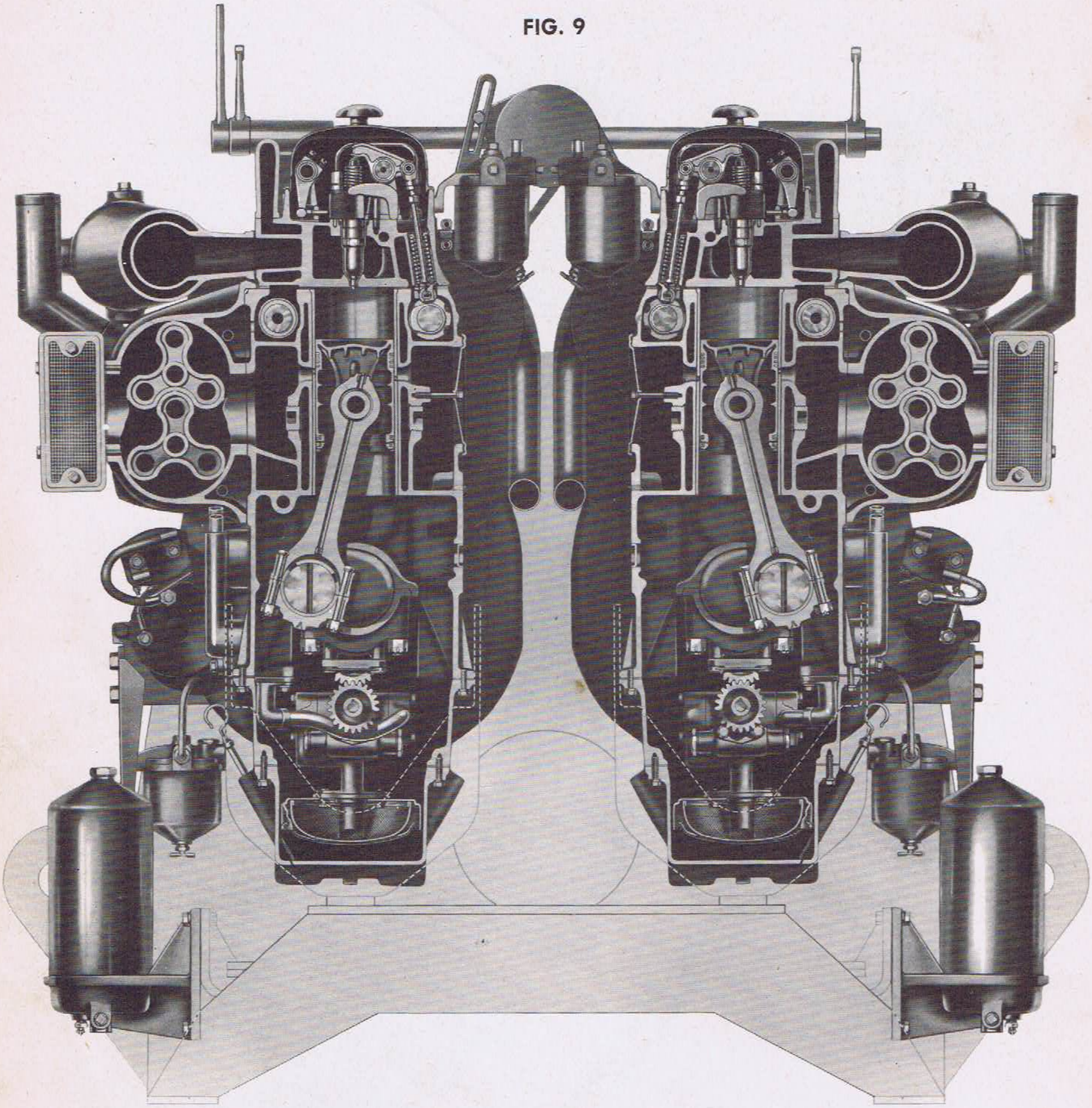


FIG. 8

SIDE CROSS-SECTION OF DIESEL SINGLE ENGINE, SIX CYLINDER MARINE PROPULSION UNIT WITH REDUCTION DRIVE FRONT END POWER TAKE-OFF—MODEL 6073.

FIG. 9



END CROSS-SECTION OF DIESEL TWIN SIX CYLINDER MARINE PROPULSION UNIT.

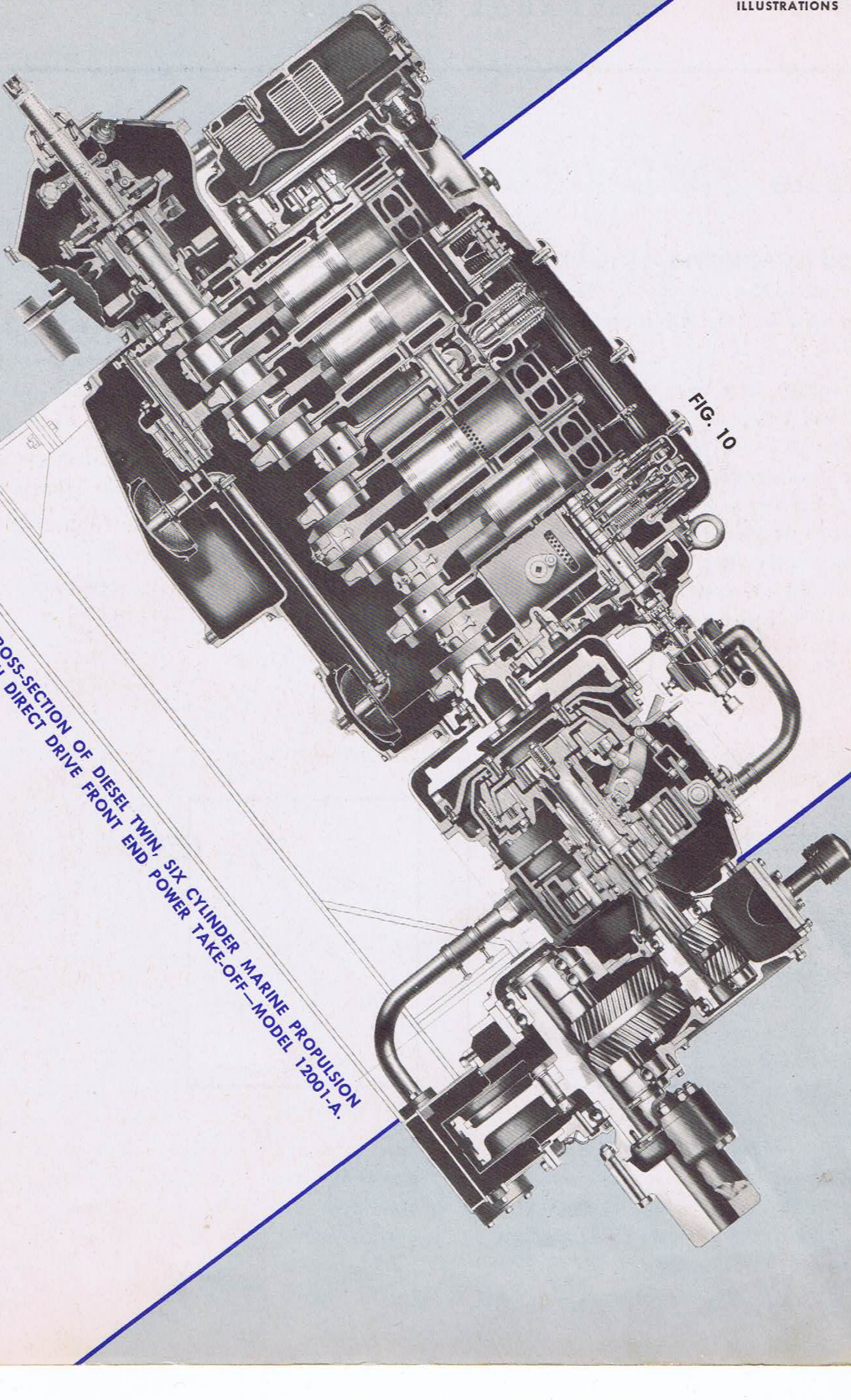


FIG. 10

SIDE CROSS-SECTION OF DIESEL TWIN, SIX CYLINDER MARINE PROPULSION UNIT WITH DIRECT DRIVE FRONT END POWER TAKE-OFF—MODEL 12001-A.

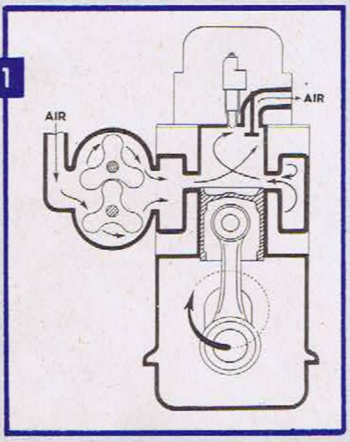
# The TWO-CYCLE DIESEL ENGINE

**THE DIESEL PRINCIPLE**—The Diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

Diesel engines differ from gasoline engines principally in the method used to introduce and ignite the fuel. Gasoline engines draw a mixture of fuel and air through the carburetor into the combustion chamber, where it is ignited by an electric spark. In the Diesel engines, air alone is compressed in the cylinder; then, a charge of fuel is sprayed into the cylinder, after the air has been compressed, and ignition is accomplished by the heat of compression.

**TWO-CYCLE DIESEL ENGINE**—Four strokes are required to complete a cycle in the four-cycle engine, which functions half the time as an air pump. In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes. A two-cycle engine, therefore, does not function as an air pump, so an external means of supplying the air is provided. A specially designed blower, bolted to the side of the engine, forces air into the cylinders in order to expel the exhaust gases and fill the cylinders with fresh air for combustion, as shown in Figs. 11, 12, 13, and 14.

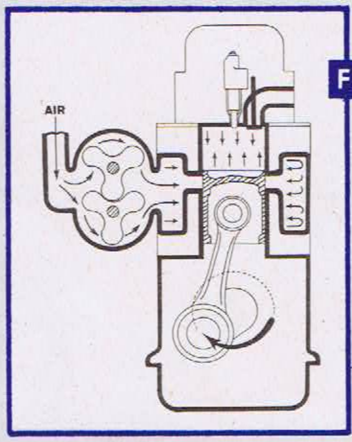
**FIG. 11**




SCAVENGING

A series of ports cut into the circumference of the cylinder wall above the piston in its lowest position admits the precompressed air from the blower into the cylinder as soon as the top face of the piston uncovers these ports. The one-way flow of air toward the exhaust valves sweeps out the exhaust gases, leaving the cylinder full of clean air when the piston covers the ports again.

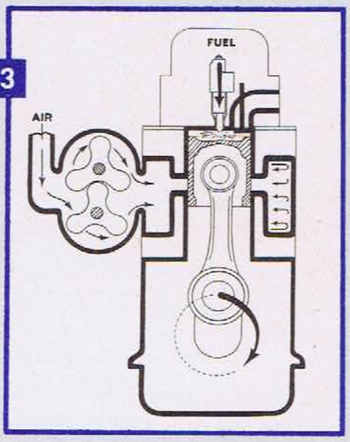
**FIG. 12**




COMPRESSION

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is compressed to one-sixteenth of its initial volume. This happens on every upward stroke of the piston in a two-cycle engine.

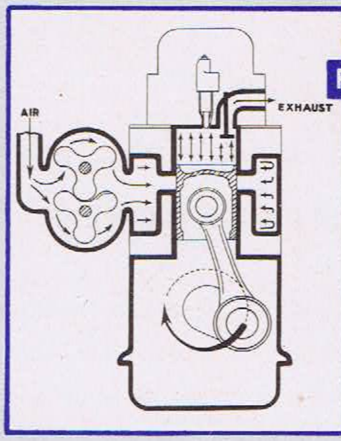
FIG. 13




INJECTION-COMBUSTION-POWER

Shortly before the piston reaches its highest position, the required amount of atomized fuel is sprayed into the combustion space by the unit fuel injector. The intense heat generated during the high compression of the air ignites the fine fuel spray immediately, and the combustion continues as long as fuel enters the cylinder. The resulting pressure forces the piston downward until the exhaust valves are opened again.

FIG. 14



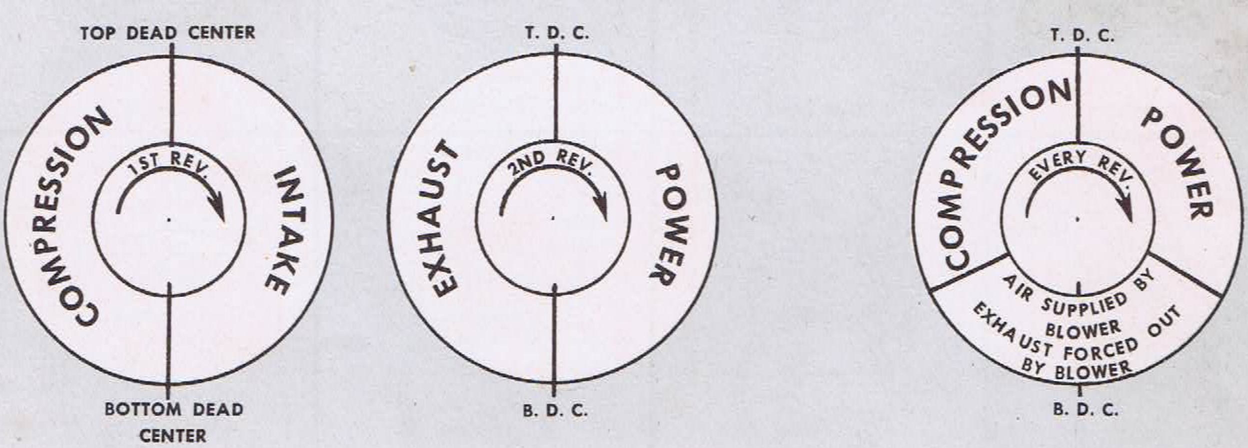

EXHAUST

The burned gases escape into the exhaust manifold and the cylinder volume is swept with clean scavenging air as the downward moving piston uncovers the inlet ports. This entire combustion cycle is repeated in each cylinder for each revolution of the crankshaft. The quantity of fuel burned during each cycle is controlled by the injector, and is varied by the operator or the governor.

## COMPARISON OF TWO-STROKE CYCLE ENGINE WITH FOUR-STROKE CYCLE ENGINE

THE FOUR EVENTS OF THE FOUR-CYCLE ENGINE

THE FOUR EVENTS OF THE TWO-CYCLE ENGINE




TWO CRANKSHAFT REVOLUTIONS REQUIRED FOR THE FOUR-STROKE CYCLE

ONE CRANKSHAFT REVOLUTION REQUIRED FOR THE TWO-STROKE CYCLE

FIG. 15

# SERIES 71 DIESEL ENGINE FEATURES

## FLEXIBILITY OF ROTATION AND ACCESSORY ARRANGEMENT

The two-cycle Diesel engines discussed in this text are offered in three, four, and six cylinder models having the same bore and stroke and using the same parts wherever possible. Thus, different power capacities are available in the same type of engine, in which the major working parts, such as injectors, pistons, connecting rods, and all bearings and other numerous parts are interchangeable. Engines with either direction of rotation can be supplied to suit specific requirements.

Furthermore, the blower, water pump, oil cooler, oil filter, governor, and fuel pump form a group of standard accessories which can be located on either the right or left side of the engine, regardless of the direction of rotation. Further flexibility in meeting installation requirements is met by placing the exhaust manifold and the water outlet manifold on either side of the engine. This flexibility in the arrangement of parts is obtained by having both the cylinder

ROTATION AND ACCESSORY ARRANGEMENTS—3, 4 and 6 Cylinder Engines

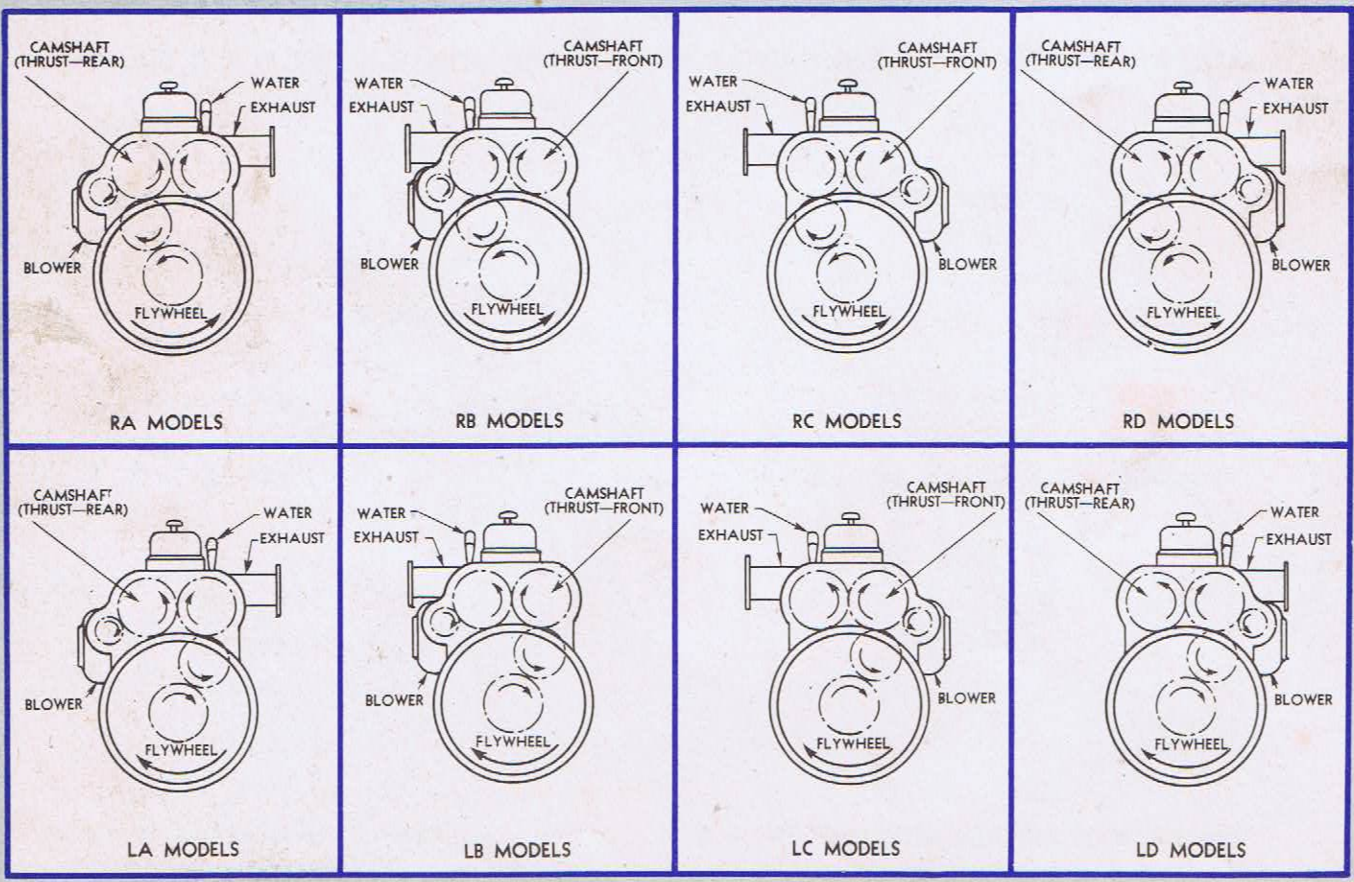



FIG. 16

## ACCESSORY AND MANIFOLD ARRANGEMENTS (Viewing Engine from the Rear)

| Engine Type | On Left Side | On Right Side |
|---|---|---|
| A | All standard accessories | Exhaust outlet. Water outlet |
| B | All standard accessories<br>Exhaust outlet<br>Water outlet | |
| C | Exhaust outlet<br>Water outlet | All standard accessories |
| D | | All standard accessories<br>Exhaust outlet<br>Water outlet |

block and cylinder head symmetrical at both ends and with respect to each other. Fig. 16 shows these various arrangements of accessories which are designated by the letters A, B, C, or D in the model number. Letters R or L in the model number designate the direction of rotation.

## UNIT FUEL INJECTOR

The unit fuel injector is the heart of the General Motors Two-Cycle Diesel engine.

The unit fuel injector is designed to:

1. Measure the quantity of fuel to be injected.
2. Develop the high pressure necessary for injection.
3. Atomize the fuel during injection.

Mounted in the cylinder head, the *fuel injector* provides a complete and independent injection system for each engine cylinder with motion for operating the injector plunger coming from the camshaft through the push rod and rocker arm.

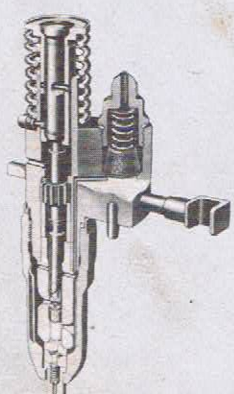


FIG. 17

Control over the engine speed is accomplished by varying the position of the geared rack located horizontally in the body of the injector. The rack is connected through a mechanical linkage with the speed control governor and the hand throttle.

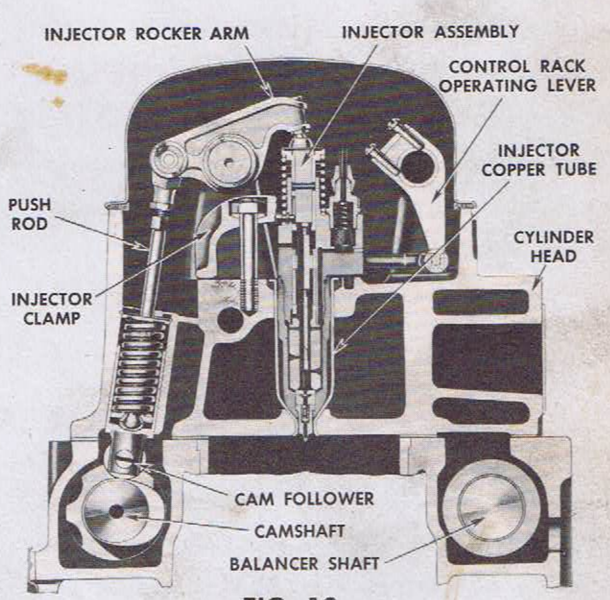



FIG. 18

A fuel supply line and return line connect to each injector, and, as the engine runs, the fuel transfer pump circulates fuel under low pressure through the injector thus maintaining even injector operating temperature as well as keeping the system free of air.

## OIL COOLED PISTONS

All pistons, whether standard or oversize, are weight-balanced within close limits making it possible to mix new and old, standard and oversize, pistons in the same engine without upsetting the engine balance and smoothness. In addition to the piston cooling furnished by the flow of water through the engine water jacket and the flow of fresh scavenging air through the combustion chamber during each piston cycle, the bottom of the piston crown is continually being pressure-sprayed with cooled lubricating oil. The drilled oil passage in each crankshaft journal registers with an oil groove in the bearing shell, thus permitting oil to enter a drilled passage leading to the piston pin and the spray nozzle at the upper end of the connecting rod. A large capacity oil cooler holds oil temperatures within the range required for maximum engine efficiency.

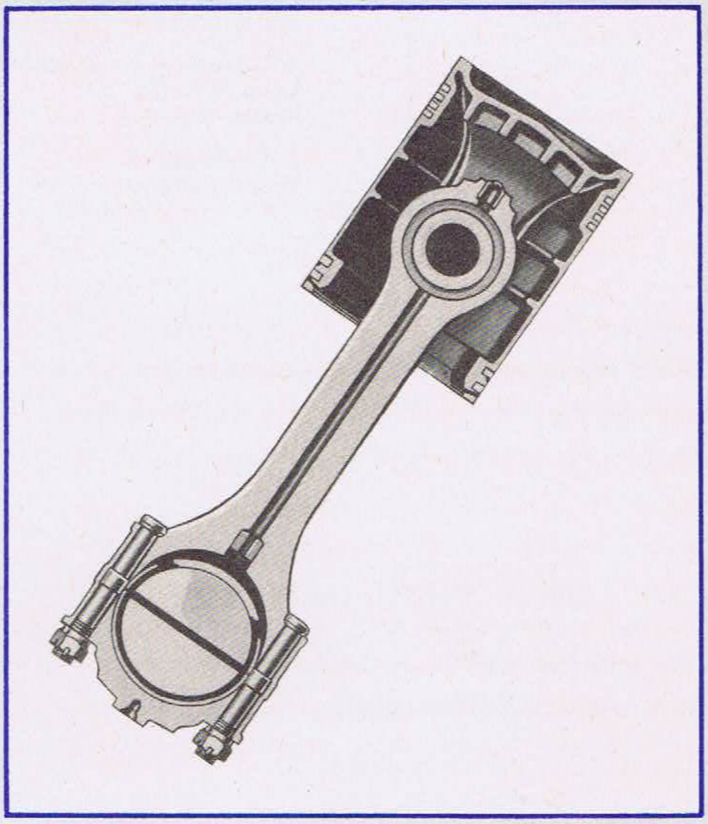


FIG. 19

## REPLACEABLE CYLINDER LINERS

In order to get the longest useful life from the engine and stretch the repair dollar as far as possible, a replaceable dry liner is inserted between the bore of the cylinder block and the moving piston. Liners may be removed and honed when necessary and oversized pistons installed to bring piston-to-liner clearance back to new engine specifications. When necessary, new liners may be installed and standard pistons used again.

FIG. 20

## BALANCED MOTION

Owners and operators often ask what makes the series 71 Diesel engines operate so smoothly and vibration-free throughout their entire speed range. The reason for this smoothness is the perfect balance of all the reciprocating and rotating masses of the engine.

The eccentric rotating masses of the crankshaft and connecting rod are balanced by counterweights on the crankshaft cheeks. The reciprocating masses (the piston and part of the rod) produce an unbalanced couple by virtue of an arrangement on the crankshaft in which reciprocating masses, though equal, are not opposite.

This unbalanced couple, which tends to rock the engine from end to end, is balanced by an arrangement of rotating counterweights, which produce a couple equal and opposite in magnitude. Consequently, the engine will operate smoothly and in perfect balance throughout the entire speed range. The balance weights consist of two eccentric weights at each end of the engine, as shown in Fig. 22. Each set of weights rotates in opposite directions with respect to each other.

When the two weights at either end of the engine are in a vertical plane, their centrifugal forces are in the same direction, and oppose the unbalanced couple at the crankshaft. In a horizontal plane the balance weight centrifugal forces are opposite, and therefore cancel. The front balance weights are eccentric in a direction opposite to the rear balance weights; therefore, rotation will result in the desired couple, effective only in a vertical plane. The balance weights at the rear end of the engine are integral with the camshaft and balancer shaft drive gears. The weights at the front end consist of eccentric slugs. On six cylinder engines only, these weights are flexibly mounted, and spring loaded to serve also as torsional vibration dampers. The weights in the camshaft and balancer shaft gears are an integral part of these gears for the three cylinder engines; one crescent-shaped weight is bolted to each gear for the four cylinder engine, and two small, square weights are attached to each gear for the six cylinder engine.

**CRANKSHAFT ASSEMBLY**

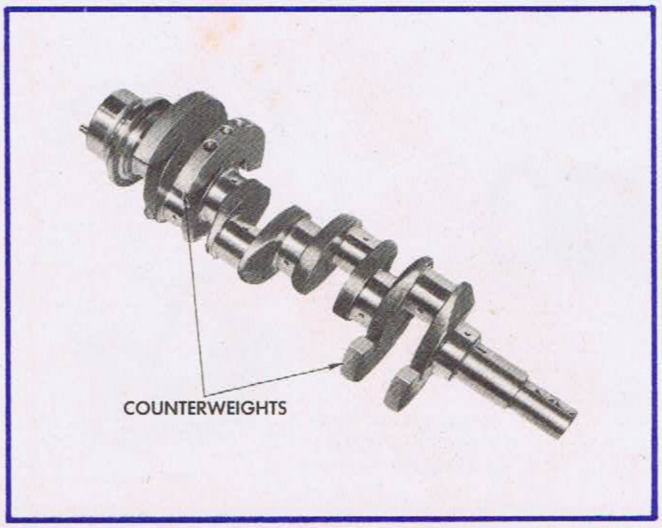



FIG. 21

**CAM AND BALANCER SHAFT ASSEMBLIES**

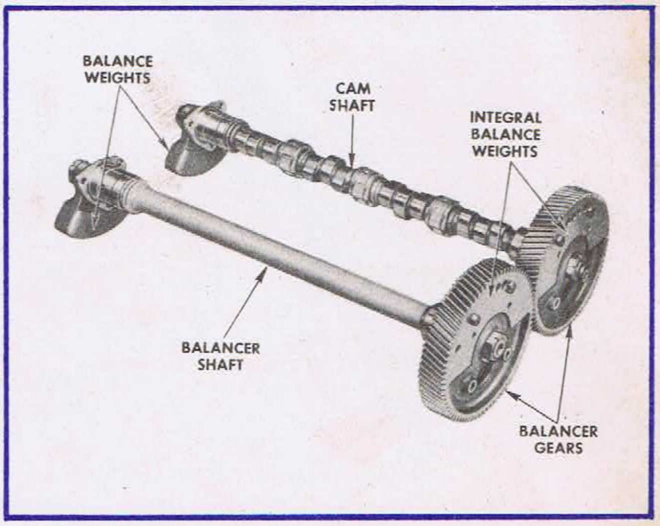
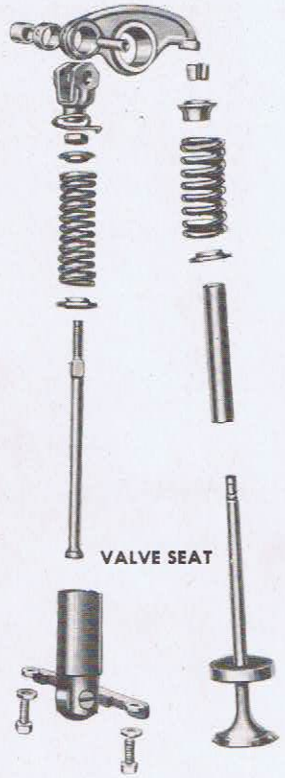



FIG. 22

## INTERCHANGEABILITY of Major Wearing Parts

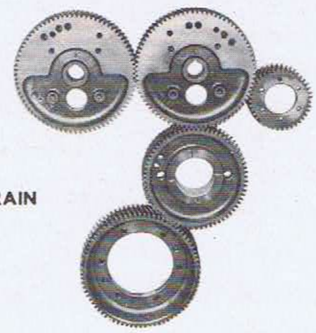
VALVE AND INJECTOR OPERATING MECHANISM

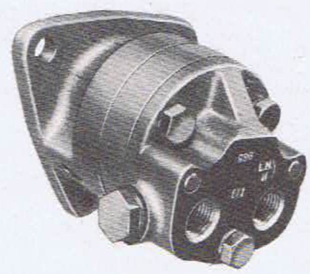


VALVE SEAT

VALVE

GEAR TRAIN



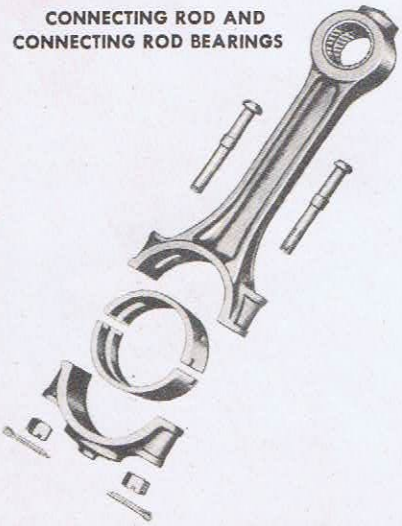


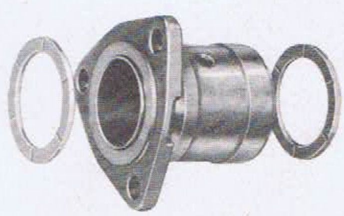
FUEL TRANSFER PUMP

Many of the major wearing parts are interchangeable between the three, four, and six cylinder engine models. Parts illustrated and named here are used on all three, four, and six cylinder models and are those most often required when rebuilding a worn engine.

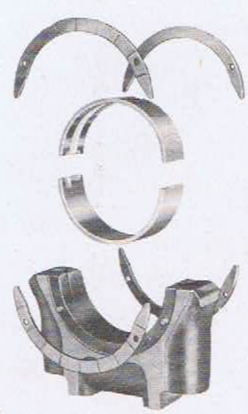
Many other parts not illustrated here are completely interchangeable—castings, gaskets, seals, nuts, bolts,

CONNECTING ROD AND CONNECTING ROD BEARINGS



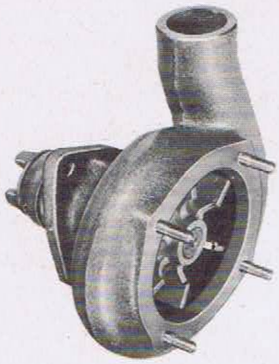


CAMSHAFT END BEARINGS AND THRUST WASHERS

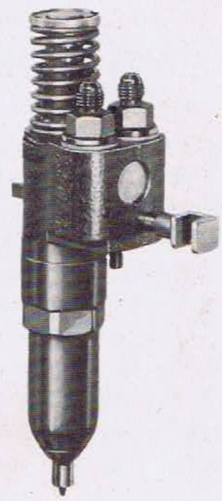


CRANKSHAFT MAIN BEARING SHELLS AND THRUST WASHERS

## etween All 3, 4 and 6 Cylinder Models



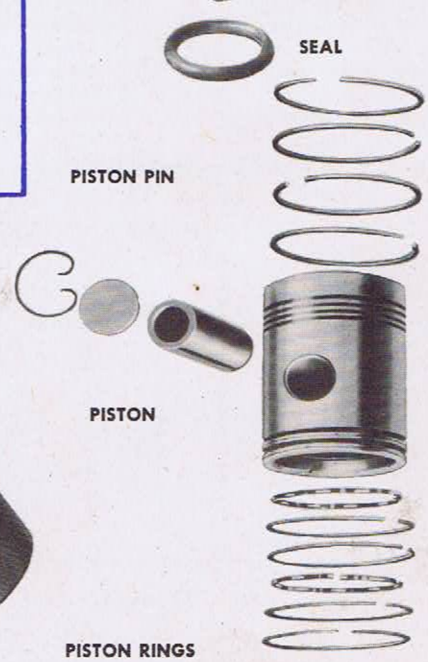






end plates, plugs, hole covers, etc.—while still another group of parts is interchangeable between *several,* but not *all* models.

All pistons, whether standard or oversize, are weight balanced within close limits making it possible to mix new and old, standard and oversize, pistons in the same engine without upsetting the engine balance and smoothness.



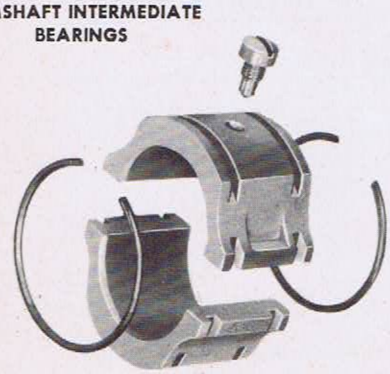





FIG. 23

# DESCRIPTION

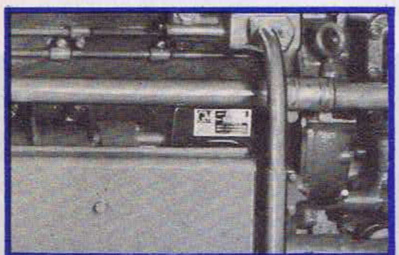
## Marine Propulsion Units—3, 4 and 6 Cylinder Series 71 Diesel Engines

## MODEL DESIGNATION AND SELECTION

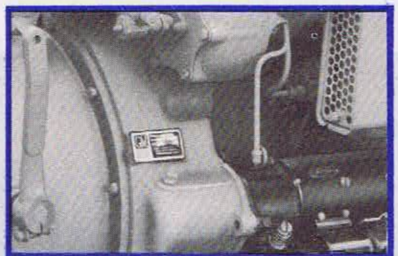
Series 71 Diesel Marine Propulsion Units are available in a wide variety of engine models having horsepower ratings from 83 to 400 B. H. P., either right or left engine rotation, right or left hand mounting of the basic engine accessories (blower, governor, exhaust manifold, etc.) and a choice of four different speed reduction ratios or direct drive. These variations make it possible to furnish an engine suitable for any marine application requiring up to 400 B. H. P. on one propeller shaft. The series 71 engines may be particularly well adapted to twin screw applications. (See diagrams on page 18.)

To simplify engine and unit model identification, name plates are attached to the unit at the locations illustrated below. One plate, at the top forward corner of the cylinder block, gives the basic engine model and serial number while the other plate, located either on the flywheel housing for single engine units or on the gear box for twin engine units, gives the model and serial number of the complete propulsion unit. These numbers should always be referred to when ordering parts.

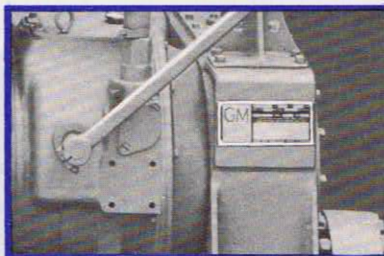
**FIG. 24**



*Location of Basic Engine Name Plate Showing Basic Engine Model Number and Serial Number.*



*Location of Single Engine Propulsion Unit Name Plate Showing Unit Model Number and Unit Serial Number.*



*Location of Twin Engine Propulsion Unit Name Plate Showing Unit Model Number and Unit Serial Number.*

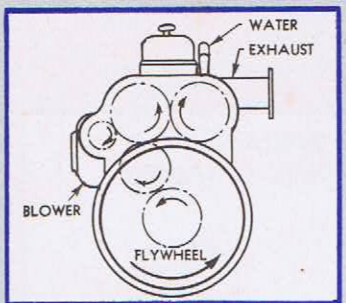
Tabulated below are all the single engine marine models showing the model number relation between three, four, and six cylinder engines, together with rotation, accessory arrangement, and reduction gear ratios for each model.

| Unit Model Number | | | Rotation* | Accessory Arrangement | Available Gear Ratios | | | |
|---|---|---|---|---|---|---|---|---|
| 3 Cyl. | 4 Cyl. | 6 Cyl. | | | | | | |
| 3071 | 4071 | 6071 | R | A | 1.5 to 1 | 2 to 1 | 3.0 to 1 | 4.4 to 1 |
| 3072 | 4072 | 6072 | L | C | 1.5 to 1 | 2 to 1 | 3.0 to 1 | 4.4 to 1 |
| 3073 | 4073 | 6073 | R | C | 1.5 to 1 | 2 to 1 | 3.0 to 1 | 4.4 to 1 |
| 3074 | 4074 | 6074 | L | A | 1.5 to 1 | 2 to 1 | 3.0 to 1 | 4.4 to 1 |
| 3075 | 4075 | 6075 | L | A | Direct Drive | | | |
| 3076 | 4076 | 6076 | R | C | Direct Drive | | | |
| 3077 | 4077 | 6077 | L | C | Direct Drive | | | |
| 3078 | 4078 | 6078 | R | A | Direct Drive | | | |

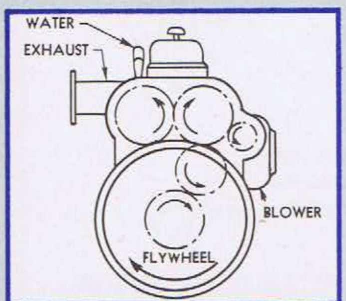
***Viewing Heat Exchanger End.***

***Note: Four cylinder engine models are available with either light duty or heavy duty reverse gear assemblies in direct drive or the reduction ratios specified above.***

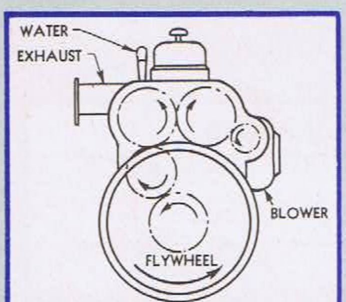
The propulsion unit models listed above are regrouped on page 17 to show the various models that originate from each basic engine. Weights and horsepower ratings are also given to show how these values vary between three, four, and six cylinder engines.



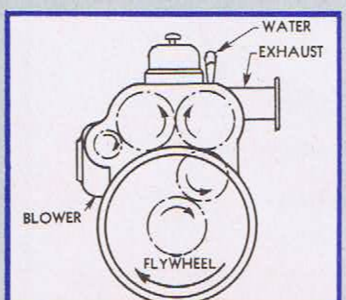

"A" Type Accessory Arrangement—Right-Hand Rotation (RA Basic Engine)




"C" Type Accessory Arrangement—Left-Hand Rotation (LC Basic Engine)




"C" Type Accessory Arrangement—Right-Hand Rotation (RC Basic Engine)




"A" Type Accessory Arrangement—Left-Hand Rotation (LA Basic Engine)

FIG. 25

## MODELS AVAILABLE USING RA BASIC ENGINE

*Note: First Digit in Model Number Designates the Number of Cylinders*

| | Model No. | Drive | Weights (Complete Unit) | B. H. P. Rating |
|---|---|---|---|---|
| 3 cyl. | 3071 | Reduction | 2230 to 2400 lbs. | 83 @ 1850 r.p.m. |
| | 3078 | Direct | 2180 lbs. | 100 @ 2000 r.p.m. (Pleasure craft only) |
| 4 cyl. | 4071 | Reduction | 2460 to 2630 lbs. | 110 @ 1850 r.p.m. |
| | 4078 | Direct | 2410 lbs. | 133 @ 2000 r.p.m. (Pleasure craft only) |
| 6 cyl. | 6071 | Reduction | 2880 to 3050 lbs. | 165 @ 1850 r.p.m. |
| | 6078 | Direct | 2830 lbs. | 200 @ 2000 r.p.m. (Pleasure craft only) |

## MODELS AVAILABLE USING LC BASIC ENGINE

*Note: First Digit in Model Number Designates the Number of Cylinders*

| | Model No. | Drive | Weights (Complete Unit) | B. H. P. Rating |
|---|---|---|---|---|
| 3 cyl. | 3072 | Reduction | 2230 to 2400 lbs. | 83 @ 1850 r.p.m. |
| | 3077 | Direct | 2180 lbs. | 100 @ 2000 r.p.m. (Pleasure craft only) |
| 4 cyl. | 4072 | Reduction | 2460 to 2630 lbs. | 110 @ 1850 r.p.m. |
| | 4077 | Direct | 2410 lbs. | 133 @ 2000 r.p.m. (Pleasure craft only) |
| 6 cyl. | 6072 | Reduction | 2880 to 3050 lbs. | 165 @ 1850 r.p.m. |
| | 6077 | Direct | 2830 lbs. | 200 @ 2000 r.p.m. (Pleasure craft only) |

## MODELS AVAILABLE USING RC BASIC ENGINE

*Note: First Digit in Model Number Designates the Number of Cylinders*

| | Model No. | Drive | Weights (Complete Unit) | B. H. P. Rating |
|---|---|---|---|---|
| 3 cyl. | 3073 | Reduction | 2230 to 2400 lbs. | 83 @ 1850 r.p.m. |
| | 3076 | Direct | 2180 lbs. | 100 @ 2000 r.p.m. (Pleasure craft only) |
| 4 cyl. | 4073 | Reduction | 2460 to 2630 lbs. | 110 @ 1850 r.p.m. |
| | 4076 | Direct | 2410 lbs. | 133 @ 2000 r.p.m. (Pleasure craft only) |
| 6 cyl. | 6073 | Reduction | 2880 to 3050 lbs. | 165 @ 1850 r.p.m. |
| | 6076 | Direct | 2830 lbs. | 200 @ 2000 r.p.m. (Pleasure craft only) |

## MODELS AVAILABLE USING LA BASIC ENGINE

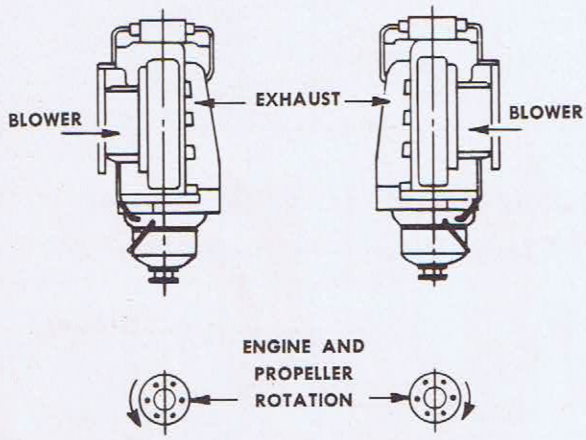
*Note: First Digit in Model Number Designates the Number of Cylinders*

| | Model No. | Drive | Weights (Complete Unit) | B. H. P. Rating |
|---|---|---|---|---|
| 3 cyl. | 3074 | Reduction | 2230 to 2400 lbs. | 83 @ 1850 r.p.m. |
| | 3075 | Direct | 2180 lbs. | 100 @ 2000 r.p.m. (Pleasure craft only) |
| 4 cyl. | 4074 | Reduction | 2460 to 2630 lbs. | 110 @ 1850 r.p.m. |
| | 4075 | Direct | 2410 lbs. | 133 @ 2000 r.p.m. (Pleasure craft only) |
| 6 cyl. | 6074 | Reduction | 2880 to 3050 lbs. | 165 @ 1850 r.p.m. |
| | 6075 | Direct | 2830 lbs. | 200 @ 2000 r.p.m. (Pleasure craft only) |

# SYMMETRICALLY MATCHED PAIRS FOR TWIN SCREW INSTALLATIONS

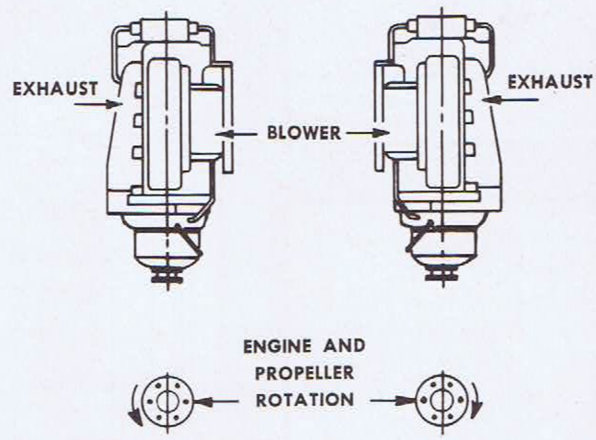
## MATCHED PAIRS WITH DIRECT DRIVE

### BLOWERS OUTBOARD EXHAUST MANIFOLDS INBOARD




| RA BASIC ENGINE | | | LC BASIC ENGINE | | |
|---|---|---|---|---|---|
| Model | 3078 | (3 Cyl.) | Model | 3077 | (3 Cyl.) |
| Model | 4078 | (4 Cyl.) | Model | 4077 | (4 Cyl.) |
| Model | 6078 | (6 Cyl.) | Model | 6077 | (6 Cyl.) |

### BLOWERS INBOARD EXHAUST MANIFOLDS OUTBOARD

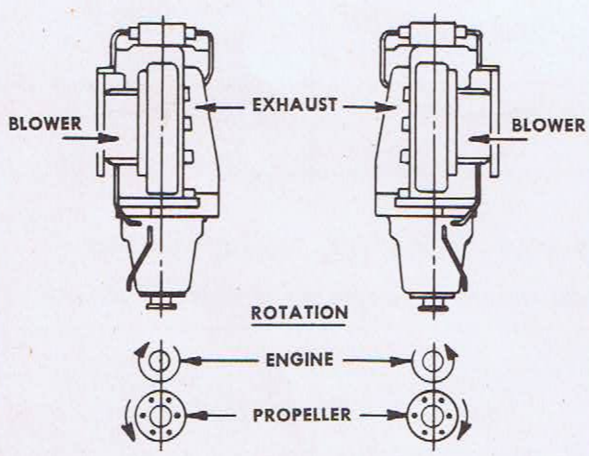



| RC BASIC ENGINE | | | LA BASIC ENGINE | | |
|---|---|---|---|---|---|
| Model | 3076 | (3 Cyl.) | Model | 3075 | (3 Cyl.) |
| Model | 4076 | (4 Cyl.) | Model | 4075 | (4 Cyl.) |
| Model | 6076 | (6 Cyl.) | Model | 6075 | (6 Cyl.) |

FIG. 26

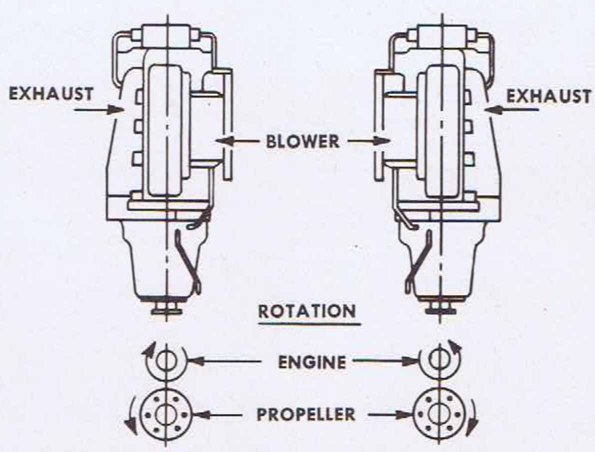
## MATCHED PAIRS WITH REDUCTION DRIVE

### BLOWERS OUTBOARD EXHAUST MANIFOLDS INBOARD




| LA BASIC ENGINE | | | RC BASIC ENGINE | | |
|---|---|---|---|---|---|
| Model | 3074 | (3 Cyl.) | Model | 3073 | (3 Cyl.) |
| Model | 4074 | (4 Cyl.) | Model | 4073 | (4 Cyl.) |
| Model | 6074 | (6 Cyl.) | Model | 6073 | (6 Cyl.) |

### BLOWERS INBOARD EXHAUST MANIFOLDS OUTBOARD




| LC BASIC ENGINE | | | RA BASIC ENGINE | | |
|---|---|---|---|---|---|
| Model | 3072 | (3 Cyl.) | Model | 3071 | (3 Cyl.) |
| Model | 4072 | (4 Cyl.) | Model | 4071 | (4 Cyl.) |
| Model | 6072 | (6 Cyl.) | Model | 6071 | (6 Cyl.) |

FIG. 27

**A SYMMETRICALLY MATCHED PAIR OF SIX CYLINDER ENGINES Mounted On A Single Base And Coupled To A Single Gear Box Constitutes The "TWIN SIX" Series 71 Diesel Marine Propulsion Unit.**

**TWIN SIX ENGINE ARRANGEMENT FOR TWIN SCREW INSTALLATION**

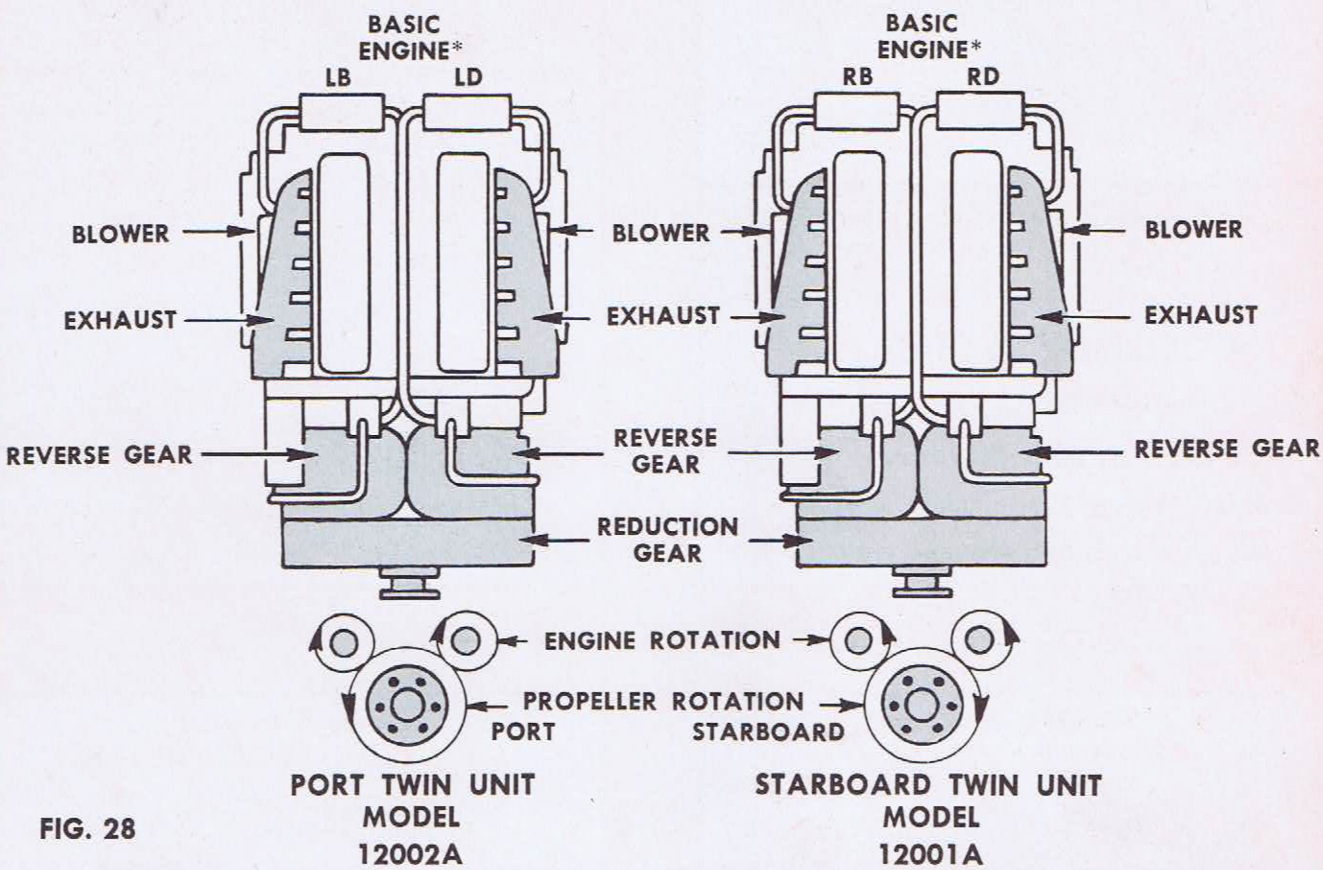



FIG. 28

For Single Screw Application, Model 12001A (Starboard) unit is used alone

Available Reduction Gear Ratios:

| | |
|---|---|
| 1.75 to 1 | 4 to 1 |
| 3 to 1 | 5 to 1 |
| | 6 to 1 |

Weight: (Either Twin Unit)

Approx. 7160 lbs. Fully Equipped.

Horsepower Ratings: (Either Twin Unit)

330 Max. B.H.P. @ 1850 r.p.m. for Fishing and Tow Boats

400 Max. B.H.P. @ 2000 r.p.m. for Yachts and Cruisers

*See "Flexibility of Rotation and Accessory Arrangement", page 10, for explanation of "B" and "D" type basic engines

## LUBRICATION SYSTEM

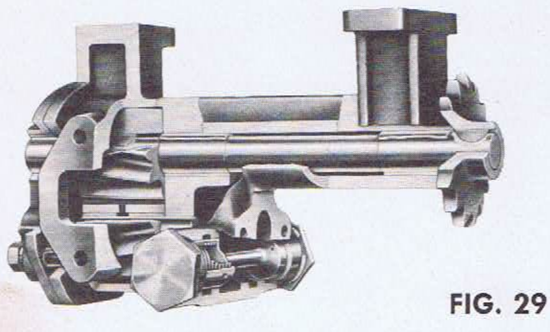


FIG. 29

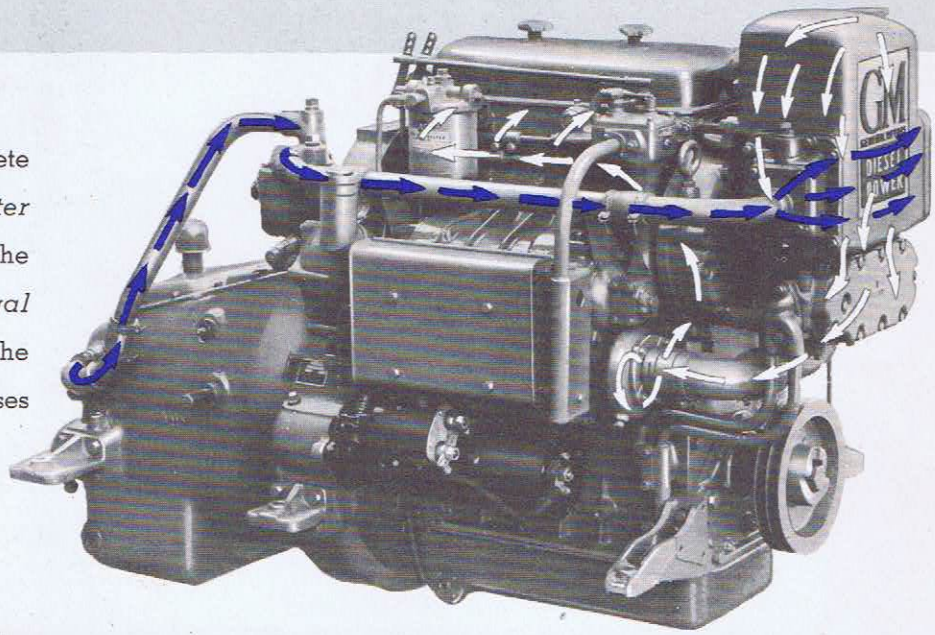
LUBRICATING OIL PUMP ASSEMBLY

A wet sump oil system with a gear type pump is used on all three, four, and six cylinder engines. Reverse and reduction gear assemblies are splash-lubricated from an oil reservoir in the reduction gear housing. Refer to pages 18 and 19, section IV for diagrams showing distribution of lubricating oil through engine and gears.

Gears and shaft bearings of the reduction gear front end power-take-off units are splash-lubricated by oil in the housing while pilot and throw-out bearings of both the reduction and direct drive front power-take-off assemblies are pressure lubricated with grease.

## COOLING SYSTEM

The cooling system consists of two complete but separated water flows. *Fresh soft water* is circulated through the water jacket of the cylinder block and head by a *centrifugal pump* attached to and driven from the blower. This circulating fresh water passes through the core of the heat exchanger where it gives up heat to the colder raw water surrounding the core in much the same way cooling is accomplished in the conventional radiator by the air stream from the cooling fan.



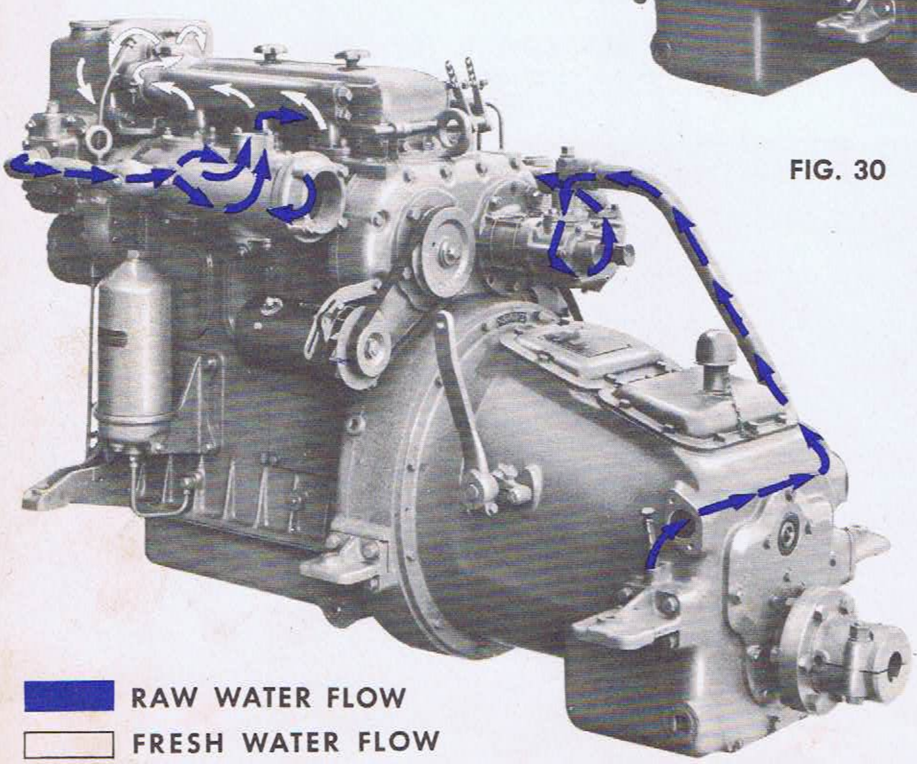



FIG. 30

RAW WATER FLOW

FRESH WATER FLOW

## COOLING WATER CIRCULATION Through By-pass Passages with Thermostats Closed and Through Heat Exchanger with Thermostats Open

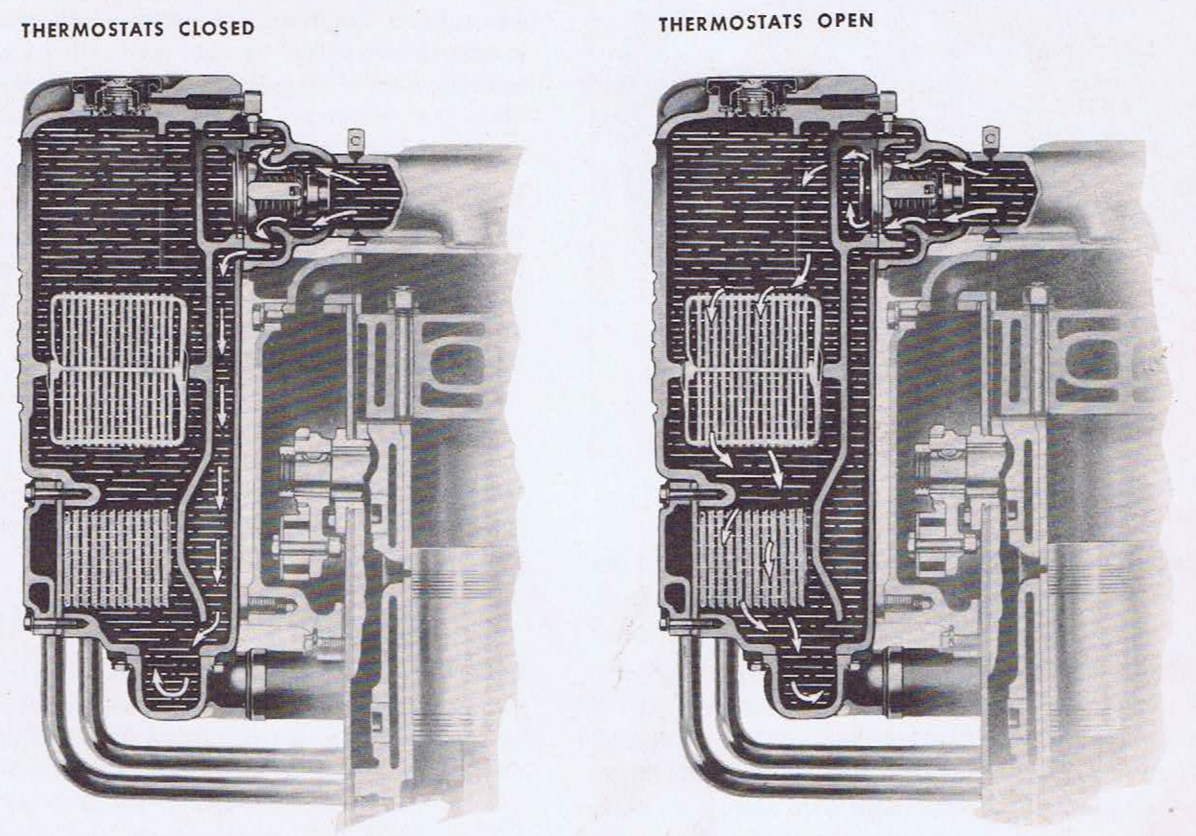



FIG. 31

CENTRIFUGAL FRESH WATER PUMP ASSEMBLY

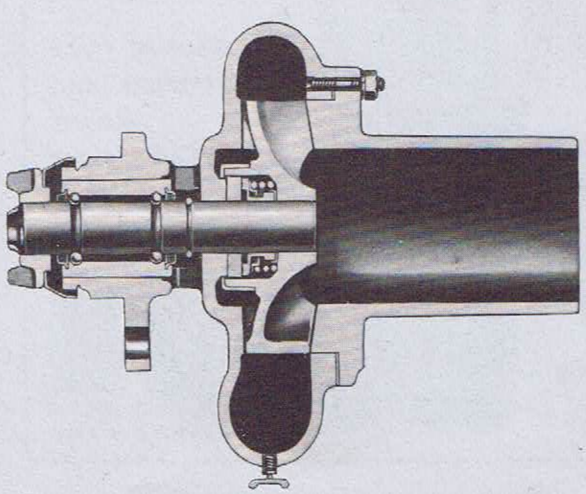


FIG. 32

**RAW WATER** is circulated by a gear type, neoprene-impeller pump mounted on the flywheel housing and driven, through a coupling, by the camshaft. The pump draws cool sea water from outside the hull, circulates it through the reverse gear housing, the heat exchanger housing (around the outside of the core), and through the water jacket of the exhaust manifold. After cooling the exhaust manifold, the raw water may be piped overboard or discharged together with the exhaust gases.

Zinc electrodes are threaded into the sea water inlet and outlet flanges of the heat exchanger to protect the heat exchanger from the destructive action of electrolysis. The electrodes gradually corrode away and must be replaced before they become ineffective.

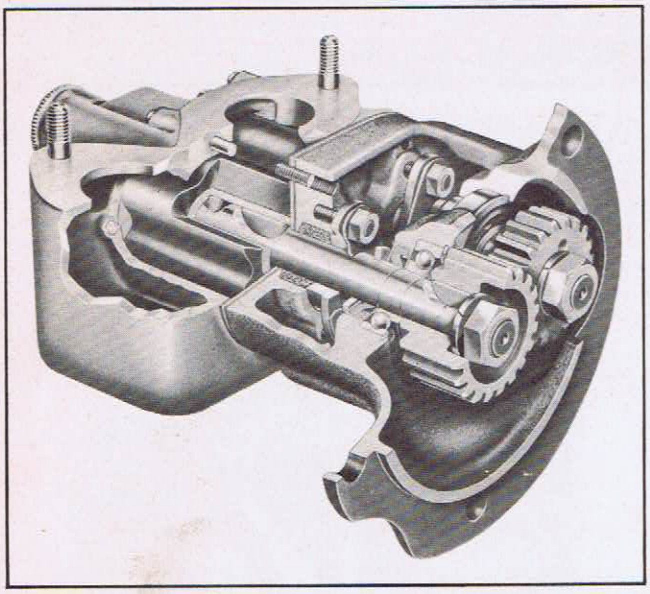


FIG. 33—RAW WATER PUMP ASSEMBLY.

**FRESH WATER COOLING** prevents corrosion in the engine water jacket and cylinder head; keeps sand, dirt, and mineral deposits from plugging water passages in the block and head; prevents "dry starts" and dangerous overheating; and permits quick warm-up, and close thermostatic control of engine temperature. The engine cooling water does not circulate through the heat exchanger until after the engine reaches operating temperature and the thermostat opens. The use of suitable antifreeze makes cold weather draining of engine cooling system unnecessary.

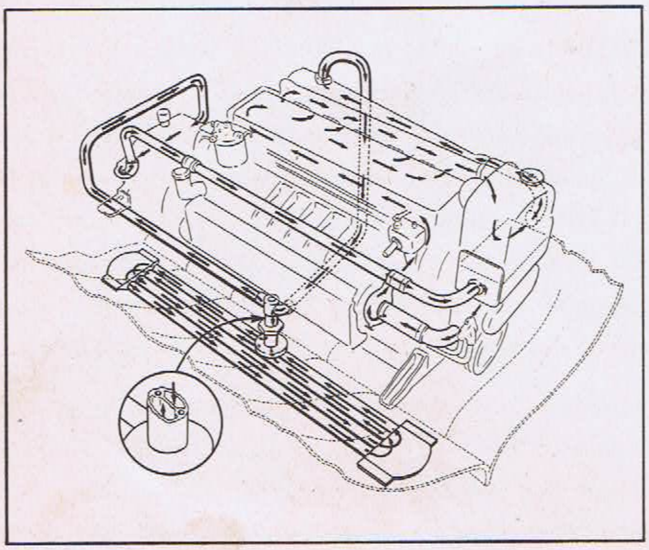


FIG. 34—TYPICAL KEEL COOLING INSTALLATION DIAGRAM.

**RAW WATER PUMP**—The reservoir type raw water pump with its neoprene impellers will give long periods of trouble-free service with little attention. Should the supply of raw water be shut off due to plugging of the inlet, the water within the reservoir keeps recirculating to cool and lubricate the impellers. After a long lay-up or draining of the reservoir, the priming cap may be removed and the reservoir filled with water.

**KEEL COOLING** is sometimes used on marine installations. In this system the fresh water is cooled by passing through pipes fastened to the outside of the ship's hull which are surrounded with raw water. When the 71 engines are used in connection with this system of cooling, certain modifications are made within the engine cooling system. In all cases, therefore, where the 71 engines are applied to keel cooling, the naval architect handling the installation and the factory should be consulted. A typical keel cooling installation is shown on this page. Also on page 5, Sec. II.

## AIR INDUCTION SYSTEM

**BLOWER**—Fresh air under pressure for combustion and sweeping the burned exhaust gases from the cylinder is supplied by the blower. At all speeds of the engine, more air is supplied than is needed for complete combustion. This over supply of air helps to cool the tops of the pistons, the cylinder liners, the cylinder head, and especially, the valves as illustrated in Fig. 35.

The one-way flow of fresh air through blower, cylinders, past the exhaust valves, and out the exhaust

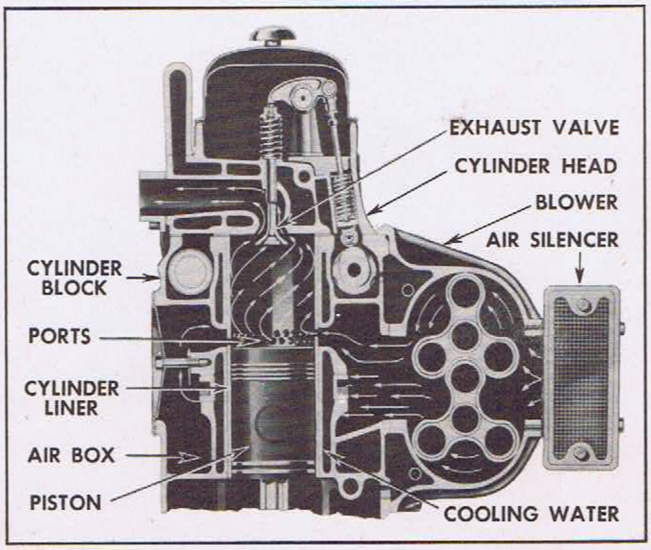



FIG. 35—AIR INTAKE SYSTEM THROUGH BLOWER AND ENGINE.

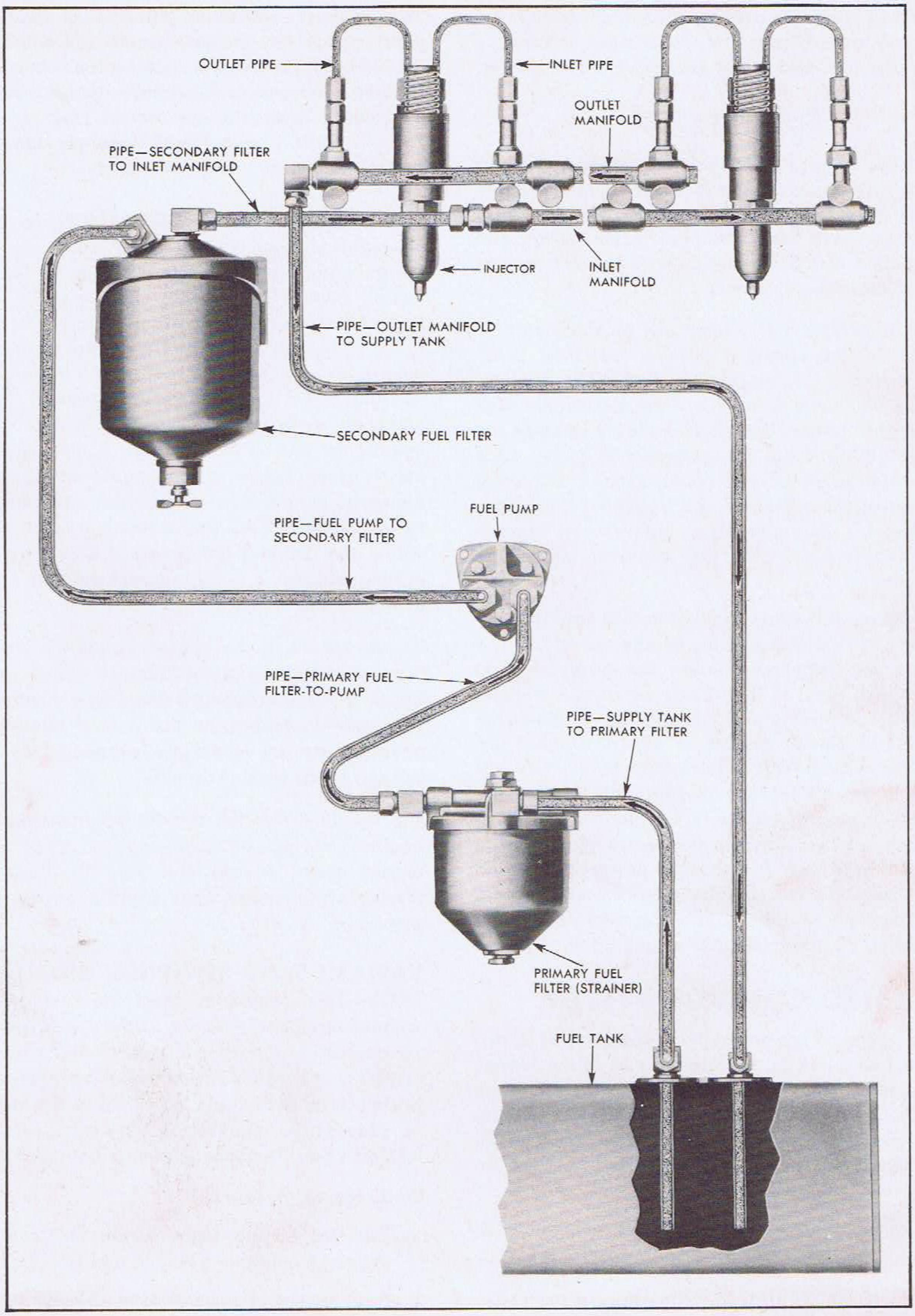



FIG. 36—FUEL SUPPLY SYSTEM GENERALLY USED ON SERIES 71 ENGINES.

manifold, is known as UNIFLOW SCAVENGING. Air is supplied to the blower through a single, heavy-duty air silencer mounted at the air intake of the blower.

## FUEL SYSTEM

One of the main requirements for satisfactory operation of a Diesel engine is that clean fuel at suitable pressure be supplied to the injectors. The necessary precautions have been observed in the design and arrangement of the various units in the fuel system to insure these requirements.

Fig. 36 illustrates the system used on the series 71 engines. In this system a primary fuel filter is installed between the supply tank and the fuel pump. The fuel oil pump draws fuel from the supply tank through the primary filter and forces it through the secondary filter. From the secondary filter, the oil is forced through the inlet manifold, which is the lower of the two pipes on the side of the cylinder head, then by means of the inlet pipe, through the injector filters and finally to the fuel chamber within the injectors.

The capacity of the fuel supply pump is considerably in excess of that required for engine operation. The injectors are designed to allow the surplus fuel to flow through them so that it may serve as a coolant. In addition to serving as a coolant, circulation of the surplus fuel bleeds any air or vapor, which forms within the system, back to the supply tank where it is vented to the atmosphere. Surplus fuel leaving the injectors flows through the outlet pipe to the return manifold and then through the return pipe back to the fuel supply tank. A restriction in the outlet of the return manifold provides sufficient resistance to build up a pressure of from 40-50 lbs. (approximately) throughout the system at 1200 engine r.p.m.

## SPEED CONTROL SYSTEM

Engine speed is controlled by a mechanical flyball governor mounted to the forward end of the blower and driven from the blower upper rotor shaft. Either a variable speed, as illustrated in Fig. 38, or a limiting speed governor, as illustrated in Fig. 37, may be used depending on requirements and type of installation.

The two governors vary somewhat mechanically, also in operating characteristics.

**THE LIMITING SPEED GOVERNOR** has a pair of low speed weights and a separate pair of high speed weights; also, a low speed and a high speed spring. The governor controls the idling speed and the maximum speed—intermediate speeds are controlled by the operator. Provision is made on the governor cover for both a governor control lever and a throttle control lever. Three throttle control lever positions—"Stop", "Idle", and "Run"—are provided in the control cam on the governor cover.

**THE VARIABLE SPEED GOVERNOR** has one pair of weights and one control spring. The control cam on the governor cover has two positions for the throttle control lever—"Stop" and "Run"—at the extreme ends of the cam, also a governor control lever clamped to the same shaft as the throttle control lever. A speed control lever is fixed to a shaft which is mounted in a housing bolted to the governor housing. This shaft and lever are operated by a second lever which bears against the end of the governor control spring. The entire speed range of the engine is controlled by the speed control lever. The engine can be set at any speed between IDLE and maximum r.p.m. and held within the limits of the governor droop. These governors maintain a uniform speed yet may be varied at will by the operator.

Engine speeds of the Marine Propulsion Twin Units are controlled by a mechanical flyball governor. Either variable or limiting speed type governors may be used—depending on the type of operation. The governor control levers are connected by suitable linkage to the master throttle.

Fig. 39 illustrates the throttle arrangement on twin engines having *variable speed governors* for engine speed control and Fig. 40 illustrates the throttle arrangement when using a *limiting speed governor.*

**VARIABLE SPEED GOVERNOR THROTTLE CONTROL**—Two conditions must be met when two engines equipped with *variable speed governors* are coupled to and drive a common load where either engine may be de-clutched while the other engine is loaded, or partly loaded; an example of which would be when either engine is driving a front end power take-off when the other engine is not operating.

These two conditions are:

I. The two engines must divide the load equally under all conditions of load and speed.

II. Each governor must control its own engine independently should different loads be demanded from the two engines.

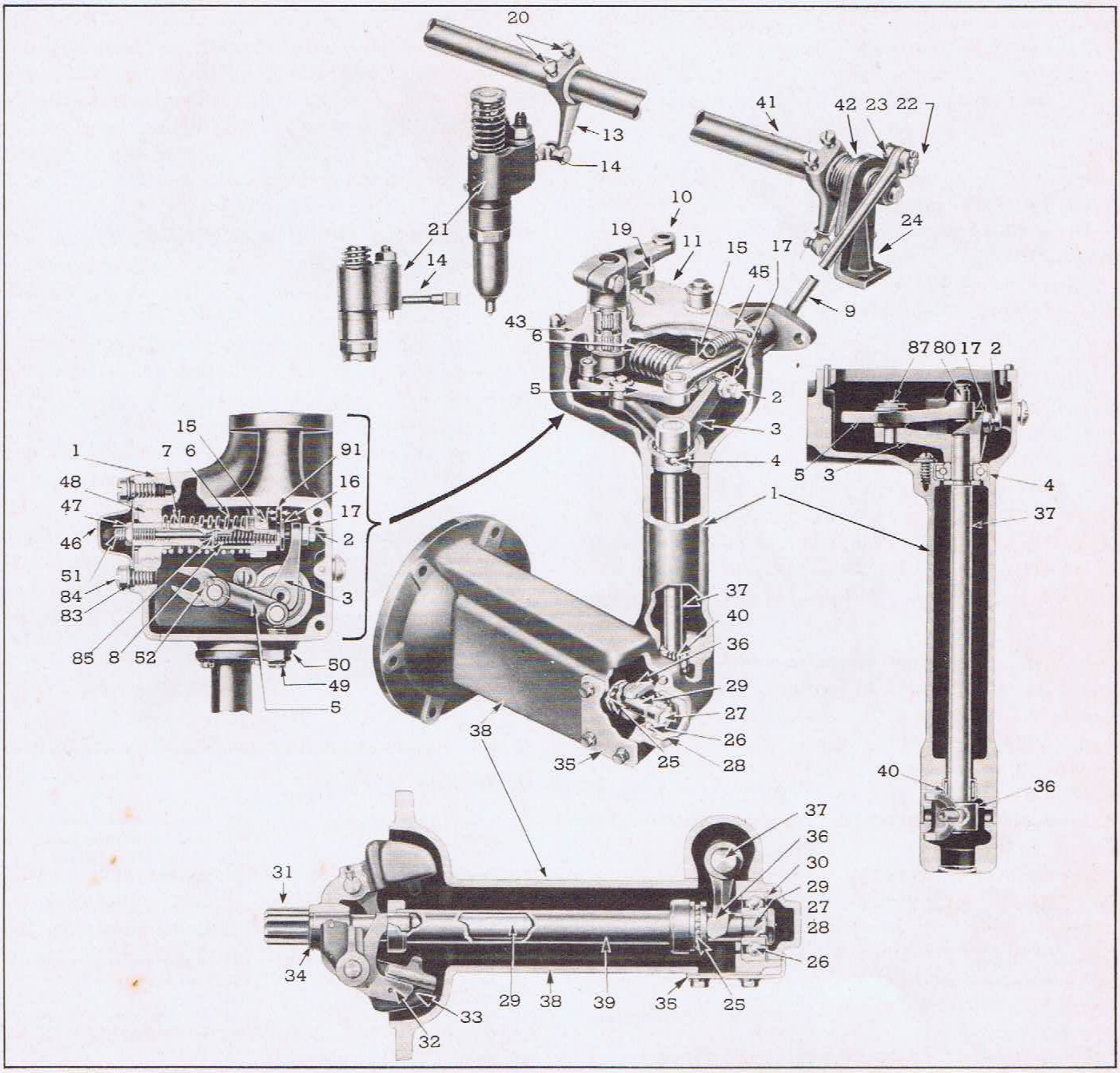


FIG. 37—LIMITING SPEED GOVERNOR ASSEMBLY.

1. Housing—Governor Control.
2. Screw—Low-Speed Spring Gap Adjusting.
3. Lever—Operating.
4. Bearing—Operating Shaft Upper.
5. Lever—Differential.
6. Spring—High-Speed.
7. Plunger—Governor Spring.
8. Spring—Low-Speed.
9. Link—Control.
10 Lever—Control.
11. Cam—Control.
13. Lever—Rack Control.
14. Rack—Injector.
15. Support—Governor Spring Plunger (Integral with Control Housing).
16. Cap—Low-Speed Spring.
17. Lock Nut—Low-Speed Spring Gap Adjusting Screw.
19. Lever—Pedal Control.
20. Screw—Rack Control Lever Adjusting.
21. Injector.
22. Pin—Control Link.
23. Lever—Control Tube.
24. Bracket—Control Tube.
25. Bearing—Weight Shaft Thrust.
26. Bearing—Shaft.
27. Screw—Shaft Bearing Retaining.
28. Cap—Weight Housing.
29. Shaft—Weight Carrier.
30. Gasket—Weight Housing Cap.
31. Splined End of Governor Shaft.
32. Weight—High-Speed.
33. Weight—Low-Speed.
34. Weight Carrier.
35. Cover—Weight Housing.
36. Fork—Operating (Yoke).
37. Shaft—Operating.
38. Housing—Weight.
39. Riser.
40. Bearing—Operating Shaft Lower.
41. Tube—Injector Control.
42. Spring—Control Tube Return.
43. Cover—Governor.
45. Spring—Control Cam.
46. Cover—Low Speed Spring Adjusting Screw.
47. Lock Nut—Low-Speed Spring Adjusting Screw.
48. Nut—High-Speed Spring Retaining.
49. Buffer Screw.
50. Lock Nut—Buffer Screw.
51. Screw—Low-Speed Adjusting.
52. Pin Clip.
80. Pin—Differential Lever.
83. Gasket—Low-Speed Spring Adjusting Screw Cover.
84. Fillister Head Screw.
85. Low-Speed Spring Seat.
87. Pin—Operating Lever.
91. Low-Speed Spring Gap.

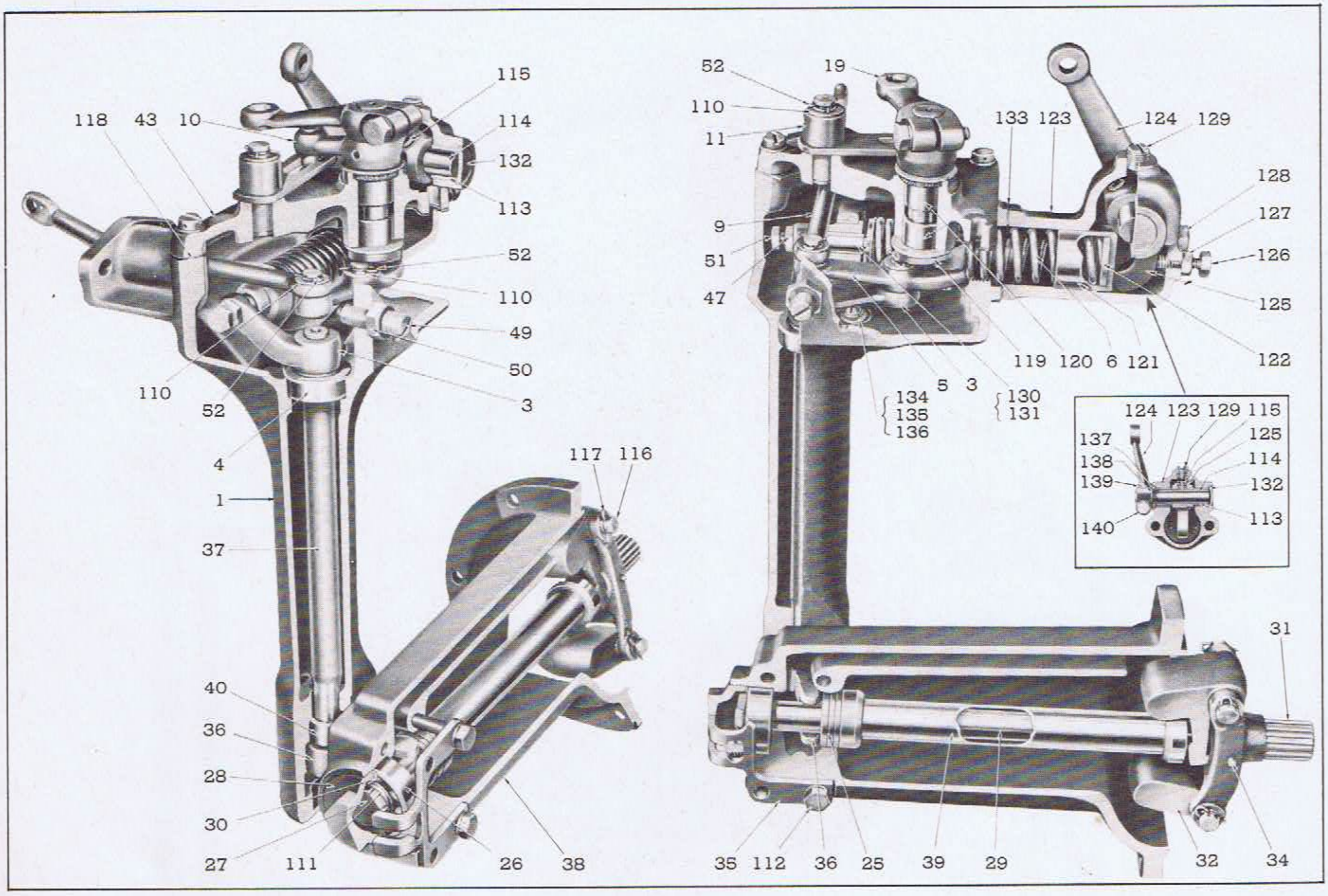



**FIG. 38—VARIABLE SPEED GOVERNOR ASSEMBLY.**

1. Housing—Governor Control.
3. Lever—Operating.
4. Bearing—Operating Shaft Upper.
5. Lever—Differential.
6. Spring—Governor.
9. Link—Control.
10. Lever—Throttle Control.
11. Cam—Control.
19. Lever—Governor Control.
25. Bearing—Weight Shaft Thrust.
26. Bearing—Shaft.
27. Screw—Shaft Bearing Retaining.
28. Cap—Weight Housing.
29. Shaft—Weight Carrier.
30. Gasket—Weight Housing Cap.
31. Splined End of Governor Shaft.
32. Weight.
34. Weight Carrier.
35. Cover—Weight Housing.
36. Fork—Operating (Yoke).
37. Shaft—Operating.
38. Housing—Weight.
39. Riser.
40. Bearing—Operating Shaft Lower.
43. Cover—Governor.
47. Lock Nut
49. Buffer Screw.
50. Lock Nut—Buffer Screw.
51. Screw—Governor Gap Adjusting.
52. Pin Clip.
110. Flat Washer.
111. Lock Washer—Shaft Bearing Retainer Screw.
112. Bolt—Weight Housing Cover.
113. Bushing.
114. Shaft—Spring Lever.
115. Allen Lock Screw.
116. Pin—Weight (Pivot).
117. Pin Clip.
118. Gasket.
119. Throttle Shaft.
120. Bearing—Throttle Shaft.
121. Spring Retainer.
122. Washer Shim.
123. Housing—Governor.
124. Lever—Speed Control.
125. Lever—Governor Spring.
126. Screw—Idling Speed.
127. Lock Nut.
128. Bolt.
129. Headless Screw.
130. Plunger Guide.
131. Spring Plunger.
132. Welch Plug.
133. Gasket.
134. Bolt.
135. Shakeproof Lock Washer.
136. Flat Washer.
137. Packing.
138. Washer.
139. Woodruff Key.
140. Bolt.

**CONDITION "I"** is met by using an equalizer (cross) link (45) between the injector control tube levers (30) and (44) on the two engines—hereinafter known as "B" and "D" engines (port and starboard) respectively. This link is adjusted so that the injector racks of the two engines reach full load position simultaneously. It follows then, that in any intermediate position between full and no load, the same quantity of fuel oil will be injected into each engine.

**CONDITION "II"** is met by incorporating a swivel joint between the injector control tube lever (30) and the equalizer link lever (31) at the "B" engine. Lever (30) is pinned to the injector rack control tube (33), lever (31) swivels on the control tube (33).

An equalizer spring (35) is fastened to the injector control tube lever (30) and an adjusting screw (37), in the equalizer link lever (31) bares against the free end of the equalizer spring. A link (42) from the governor on the "B" engine attaches to the lever (30) on the injector control tube, while a similar link (43)

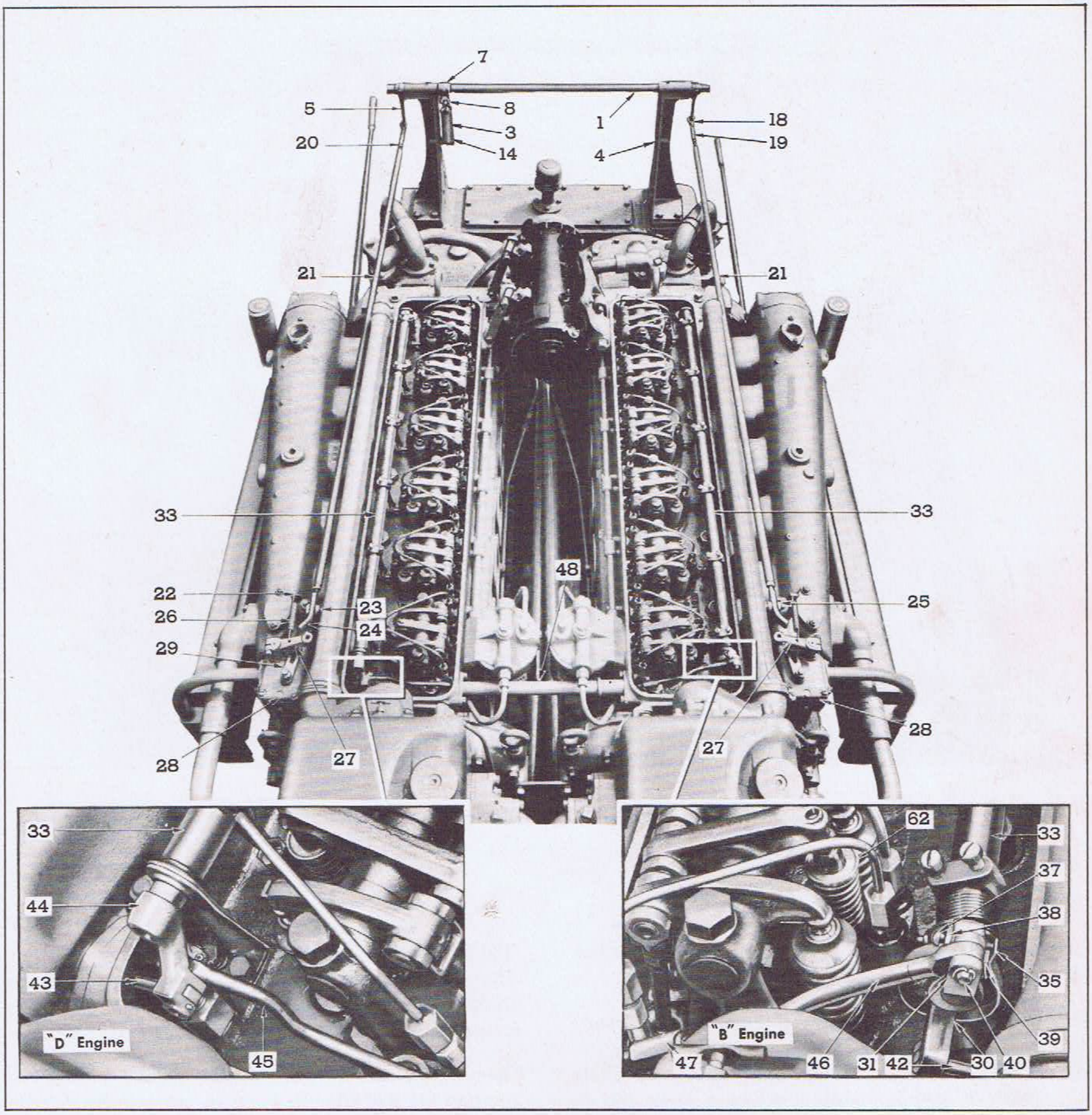



**FIG. 39—THROTTLE CONTROL ARRANGEMENT FOR TWIN ENGINES WITH VARIABLE SPEED GOVERNORS.**

1. Cross Shaft—Throttle Control.
3. Booster.
4. Bracket—Throttle Control Support.
5. Lever—Throttle Control.
7. Lever—Throttle Booster.
8. Pin—Booster to Throttle Booster.
14. Stud—Booster Support.
18. Clevis—Throttle Control Tube.
19. Turnbuckle—Throttle Control Tube.
20. Lock Nut—Throttle Control Tube.
21. Tube—Throttle Control.
22. Clip—Speed Control Lever Retaining Spring.
23. Lever—Speed Control.
24. Link—Throttle Control to Governor.
25. Bolt—Link to Speed Control Lever.
26. Spring—Stop Lever Retracting.
27. Lever—Governor Control.
28. Governor.
29. Control Cam.
30. Lever—Injector Control Tube.
31. Lever—Equalizer Link.
33. Tube—Injector Rack Control.
35. Spring—Equalizer.
37. Screw—Equalizer Spring Adjusting.
38. Lock Nut—Equalizer Spring Adjusting Screw.
39. Stop—Equalizer Spring.
40. Pin—Equalizer Link to Lever.
42. Link—Governor Control (for "B" engine).
43. Link—Governor Control (for "D" engine).
44. Lever—Equalizer Link and Control Tube (for "D" engine).
45. Link—Equalizer (Long).
46. Link—Equalizer (Short).
47. Turnbuckle—Equalizer Links.
48. Cover Tube—Equalizer Link.
62. Injector.

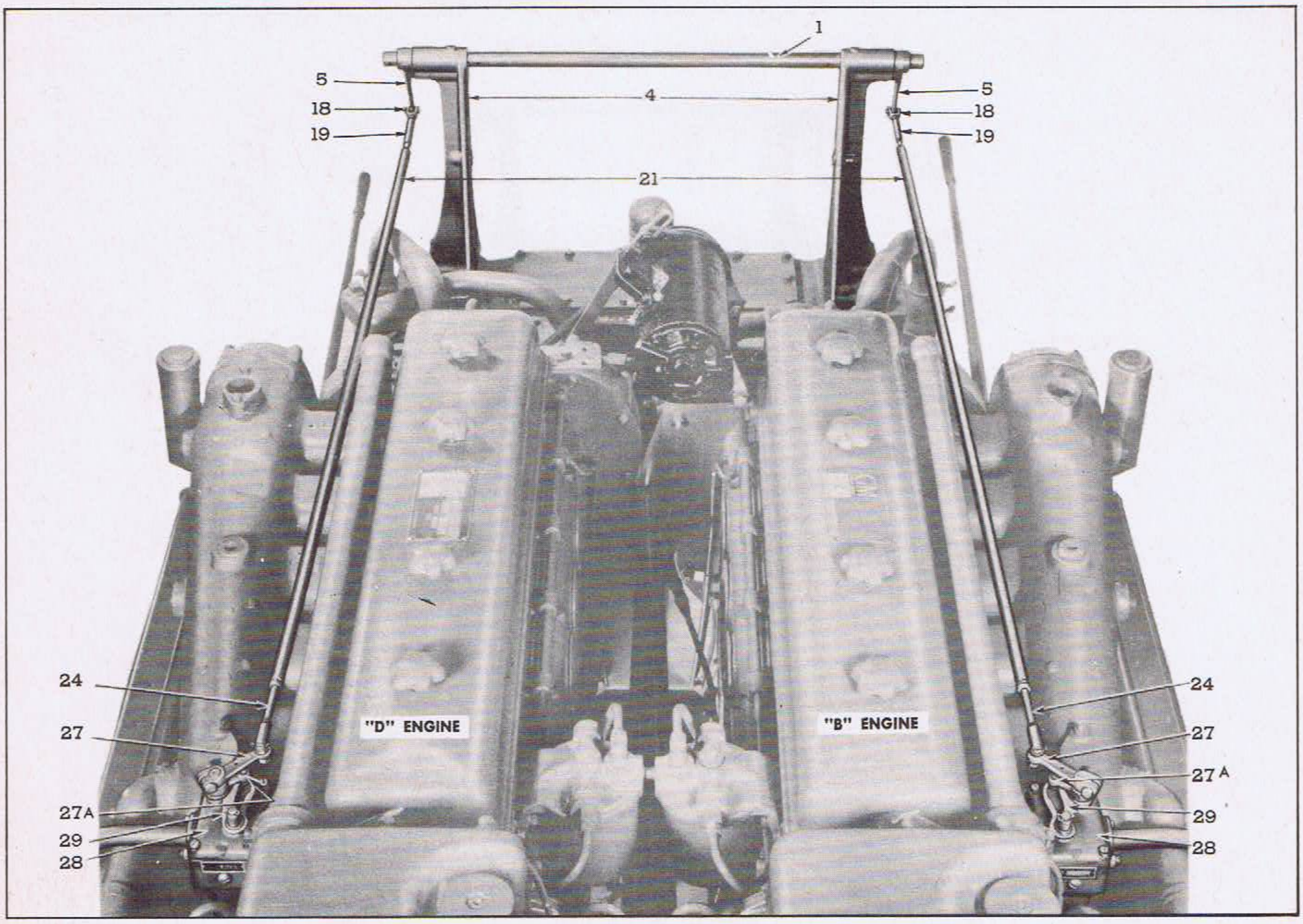



**FIG. 40—THROTTLE CONTROL ARRANGEMENT FOR TWIN ENGINES WITH LIMITING SPEED GOVERNORS.**

1. Cross Shaft—Throttle Control.
4. Bracket—Throttle Control Support.
5. Lever—Throttle Control.
18. Clevis—Throttle Control Tube.
19. Turnbuckle—Throttle Control Tube.
21. Tube—Throttle Control.
24. Link—Throttle Control to Governor.
27. Lever—Governor Control.
27a. Lever—Throttle Control.
28. Governor.
29. Control Cam.

attaches to the injector control tube lever (44) on the "D" engine.

*When the variable speed governors* are used, throttle control tubes (21) to each engine governor (28) are connected to a common throttle control shaft (1), which in turn is manipulated by a lever (2). A slotted link (24), at the governor end of each control tube (21), moves the governor control lever (27) to the stop position when the master throttle is moved to the "OFF" position, and, when the master throttle is moved to the "IDLE" position, allows the control lever to move—by the retracting spring (26)—to "RUN" position before engaging the governor spring with the speed control lever (23). Farther opening of the master throttle allows link (24) to pick up the speed control lever (23), increase the tension on the governor spring and increase the engine speed. "IDLE" position of the master throttle is likewise idling speed on the governor. Any opening of the throttle past idling speed engages the governor spring and increases the engine speed accordingly.

Opening the master throttle past "IDLE" brings two boosters (3) into play to assist in moving the throttle against the tension on the two governor springs. As will be seen from the illustration, the boosters are fulcrumed on a stud (14) to the brackets (4) at the lever ends and attached to the throttle cross shaft (1) by the lever (7) at the upper ends. The throttle control lever (5) is arrested in the "IDLE" position by a ball (50) and spring (49). The increase in effort to open the throttle against the governor springs past the "IDLE" position is counterbalanced by the boosters, which are also more effective the farther the throttle is opened.

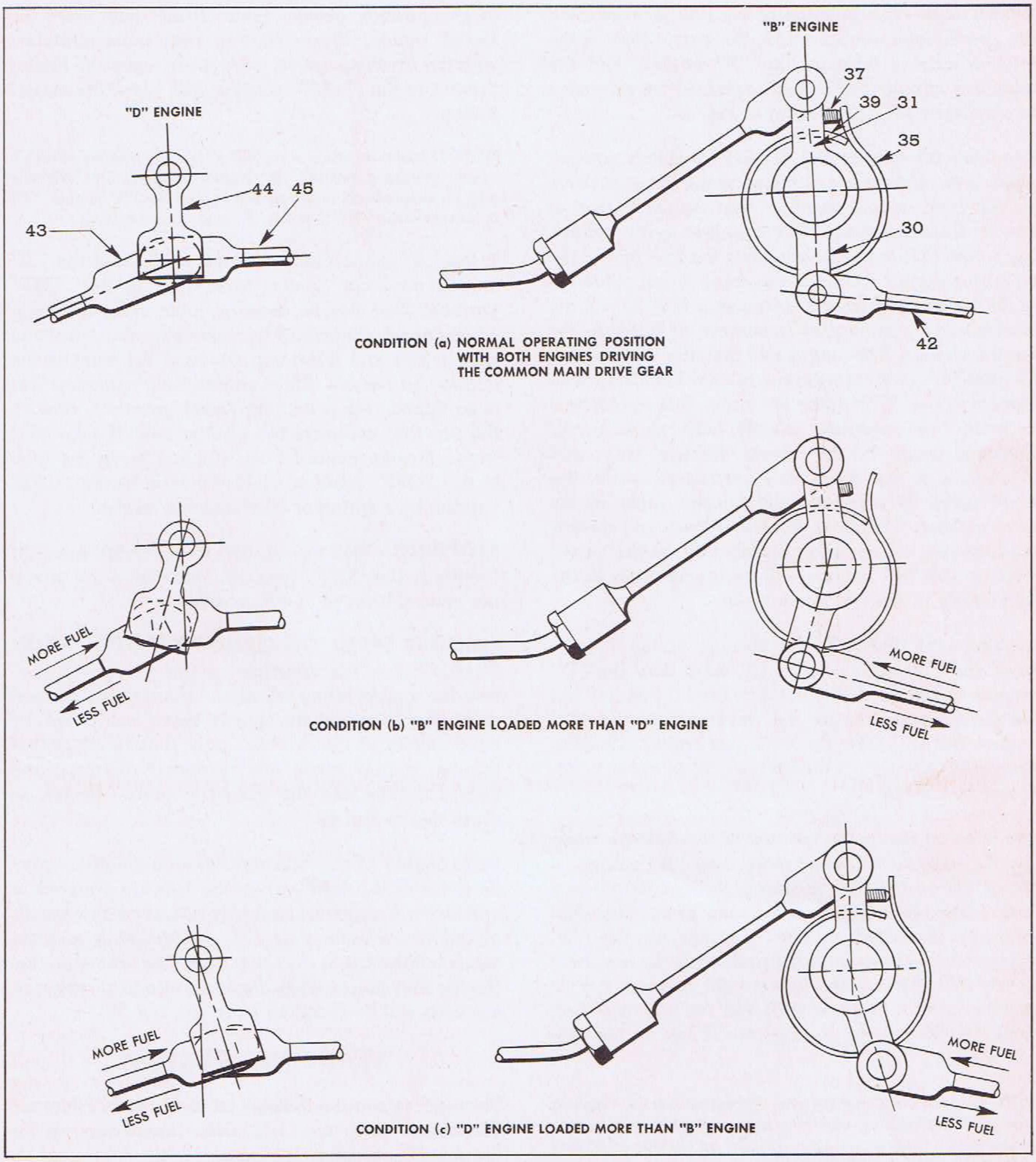



**FIG. 41—POSITIONS OF THROTTLE LINKAGE BETWEEN TWIN ENGINES WITH EQUAL LOAD ON ENGINES, ALSO WHEN UNEQUALLY LOADED (VARIABLE SPEED GOVERNORS).**

30. Lever—Injector Control Tube.
31. Lever—Equalizer Link.
35. Spring—Equalizer.
37. Screw—Equalizer Spring Adjusting.
39. Stop—Equalizer Spring.
42. Link—Governor Control (for "B" engine).
43. Link—Governor Control (for "D" engine).
44. Lever—Equalizer Link and Control Tube (for "D" engine).
45. Link—Equalizer (Long).

**OPERATION**—The function of the link (45) between the two injector control racks, the swivel joint at the injector control tube on the "B" engine, and the equalizer spring (35) is best explained by reference to conditions (a), (b), and (c) in Fig. 41.

**Condition (a)** depicts the normal operating position when both engines are clutched to the common drive so that both governors allow the engines to run at exactly the same speed. The equalizer spring adjusting screw (37) is pressing against the free end of the equalizer spring (35), but the force is not sufficient to lift the spring from the spring stop (39). This force is obtained by setting the governors so that the "D" engine wants a *little more* fuel than the "B" engine, i.e., the "D" engine governor is set a little high with respect to the "B" engine governor. It is impractical to build two governors exactly alike as to spring rates, governor weight masses, linkage ratios and clearances so that when they are run at exactly the same speed they position the injector racks in the same location. Therefore, at various loads and speeds, the force on the equalizer spring (35), at the swivel joint on the "B" engine, will vary according to the differences in the two governors.

**Condition (b)** illustrates the position of the linkage when the "B" engine is loaded more than the "D" engine. In this case, the clutch of the "D" engine has been disengaged when the governor on the "D" engine will withdraw the equalizer spring adjusting screw (37) away from the spring (35) in order to decrease fuel to the "D" engine.

**Condition (c)** shows the position of the linkage when the "D" engine is loaded more than "B" engine. If the clutch on the "B" engine is disengaged for any reason, this engine will tend to run away. This condition is prevented by the governor on the "B" engine which overpowers the preload on the equalizer spring (35) through the swivel joint between the injector control tube lever (30) and the equalizer link lever (31) to reduce the quantity of fuel to the free "B" engine.

NOTE: Because the governor of the "B" engine has the equalizer spring (35) at the swivel joint to overcome, in addition to its own spring, the "B" engine will have a higher no load speed at wide open throttle than the "D" engine.

**ADJUSTMENTS**—Throttle control adjustments for twin engines using variable speed governors will be found on page 31, Sec. IV.

**STARTING**—When starting twin units equipped with *variable speed governors,* open the master throttle to any position greater than "IDLE" and press the starter button. When starting twin units equipped with the *limiting speed governors,* open the master throttle to the "IDLE" position and press the starter button.

NOTE: If master throttle is set in "IDLE" position with the *variable speed governor* and the "B" engine is started first, difficulty may be encountered in attempting to start the "D" engine. This is because of the fast idle on the "B" engine after starting.

If the "B" engine only is to be used, hold the "D" engine governor control lever (27) in the "OFF" position. This may be done on units using the *variable speed governors* by unhooking the retracting spring (26) and fastening it toward the front of the engine. To remove either engine from operation that is equipped with a limiting speed governor, remove the pin that connects the throttle control tube (21) to the throttle control lever (5) and move the tube to the "OFF" position. Hold the tube in the "OFF" position by a spring or other suitable means.

**STOPPING**—Stop the engines by moving the master throttle to the "OFF" position. This moves the governor control lever to "OFF" position.

**LIMITING SPEED GOVERNOR THROTTLE CONTROL**—Since the *limiting speed governor* controls the engine idling speed and the maximum speed only—the intermediate speeds being controlled by hand setting of the throttle—only simple, adjustable throttle control tubes are necessary between the master throttle and the governor control levers, as illustrated in Fig. 40.

Each engine of the twin unit may be made to carry its share of the load—when the two are coupled to and drive a common load—by adjusting the length of the two throttle rods (21) so that both engines reach full throttle at the same time. The procedure for throttle adjustment when *limiting speed governors* are used will be found on page 34, Sec. IV.

## STARTING SYSTEM

Some of the starting systems on the Series 71 Marine Propulsion Units are grounded; others require an insulated (ungrounded) circuit.

Four different starting systems are described and illustrated in this text—according to storage battery voltage, output in watts and battery connections to the starting motors. Each of the systems are illustrated in the following wiring diagrams—Figs. 42, 43, 44 and 45—and include a heavy-duty, solenoidoperated starting motor for each engine, a belt-driven battery charging generator and a voltage regulator. Twin engine installations have only one battery charging generator.

The four systems incorporate the following:

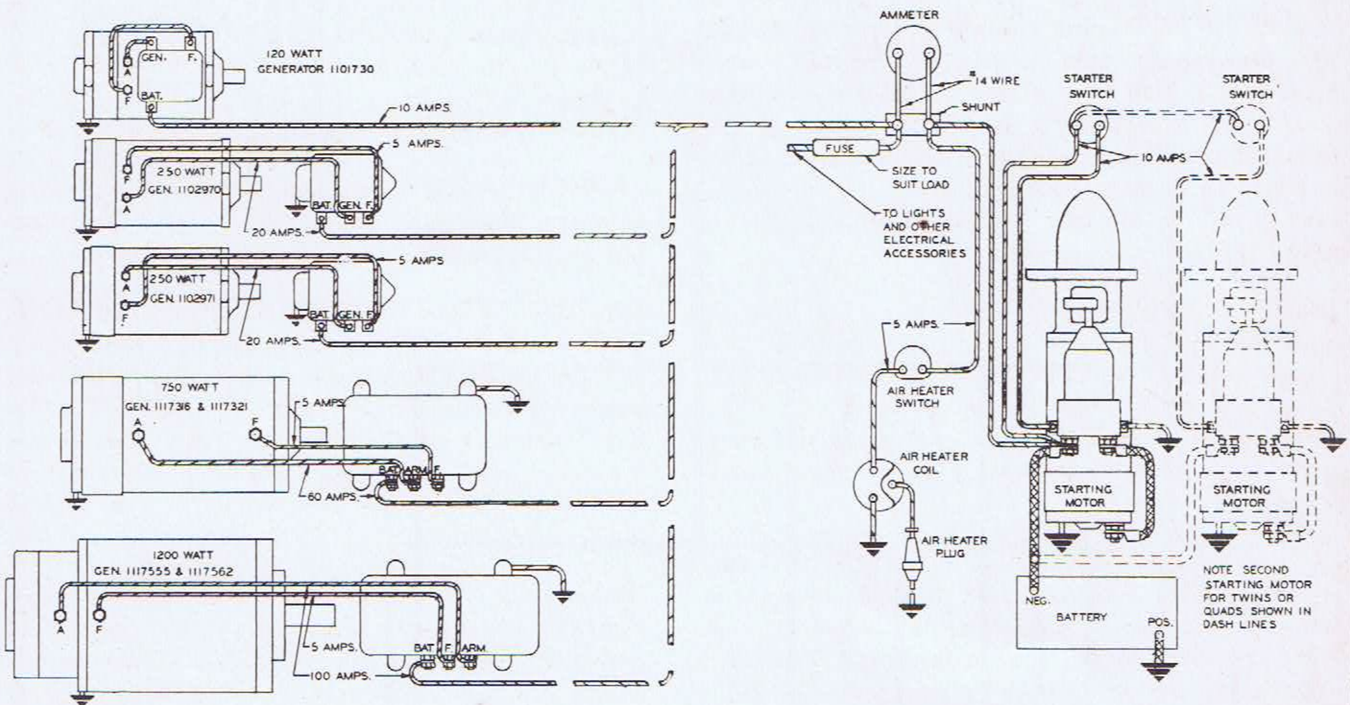
System I—12 Volt grounded with either 250, 750 or 1200 Watt generator and regulator.

System II—12 Volt and 24 Volt ungrounded. The 12 Volt system with either 120 or 250 Watt and the 24 Volt system with 250 Watt generator and regulator.

System III—32 Volt ungrounded with either 900 or 1500 Watt generator and regulator.

System IV—Same as "III" but used on later engines with different battery connections to the starting motor.

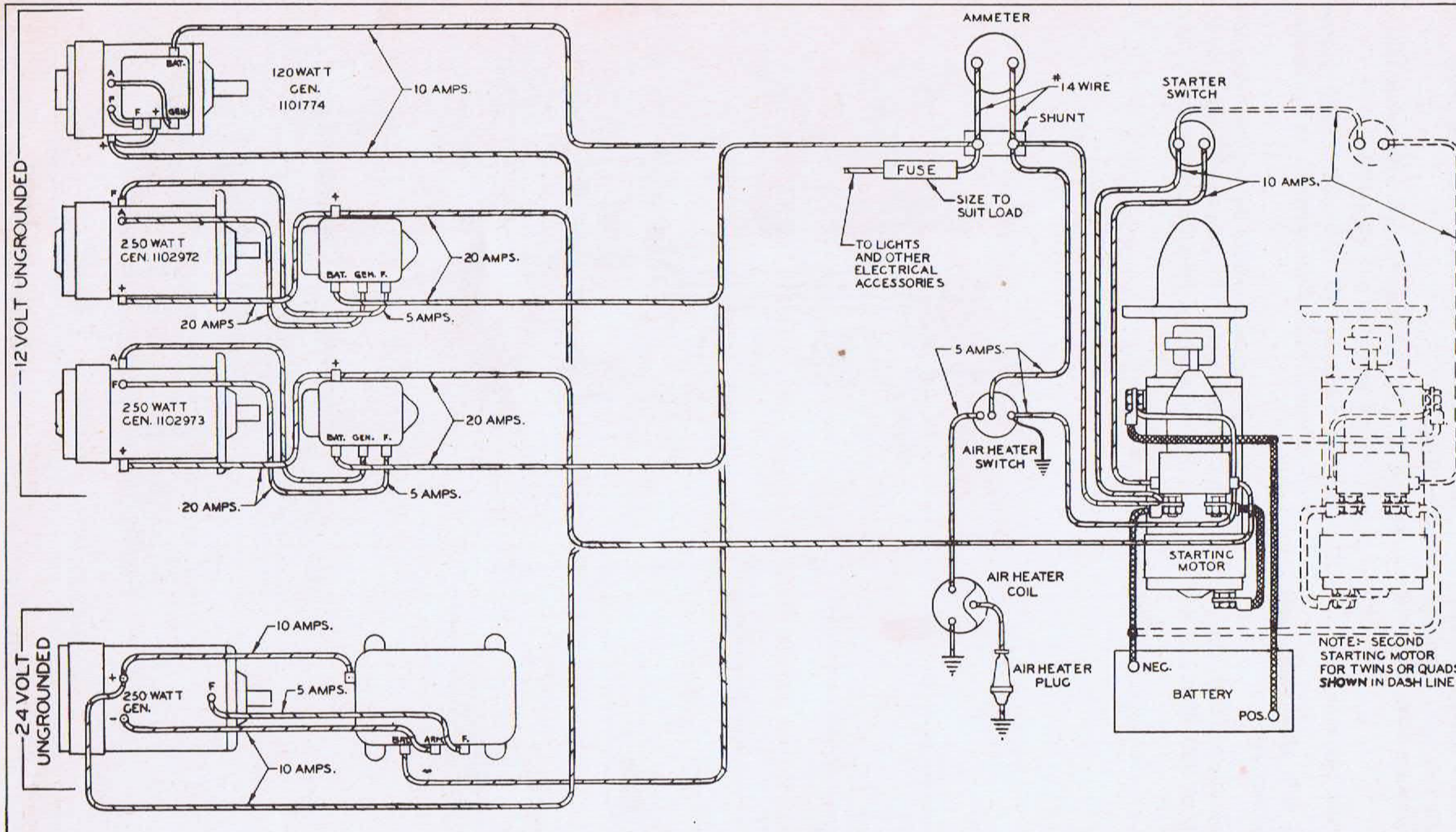
Each wiring diagram specifies the correct cable sizes for the starting motor circuit and wire sizes for the generator circuits for a given length of cable or wire.




| STARTING MOTOR CIRCUIT | |
|---|---|
| CABLE SIZE B & S GAGE | TOTAL LENGTH |
| 0 | 10 FT. |
| 00 | 12 " |
| 000 | 16 " |
| 0000 | 20 " |
| 2 PARALLEL CABLES | |
| 00 00 | 24 " |
| 000 000 | 32 " |
| 0000 0000 | 40 " |

| RECOMMENDED WIRE SIZES FOR GENERATOR CIRCUITS | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CAPACITY OF CIRCUIT AMPERES | WIRE SIZE | | | | | | | | | | | | |
| | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| | TOTAL LENGTH OF CIRCUIT FEET | | | | | | | | | | | | |
| 5 | 13 | 16 | 20 | 26 | 32 | 40 | 50 | | | | | | |
| 10 | 6.5 | 8 | 10 | 13 | 16 | 20 | 25 | 32 | 40 | 50 | | | |
| 15 | | 5 | 6.5 | 8.5 | 10 | 13 | 17 | 21 | 26 | 34 | 42 | | |
| 20 | | | 5 | 6.5 | 8 | 10 | 12.5 | 16 | 20 | 25 | 32 | | |
| 30 | | | | | 5 | 6.5 | 8.5 | 10.5 | 13 | 17 | 21 | | |
| 40 | | | | | | | 6.5 | 8 | 10 | 13 | 16 | | |
| 50 | | | | | | | 5 | 6.5 | 8 | 10 | 13 | 16 | |
| 60 | | | | | | | | 5 | 6.5 | 8 | 10 | 13.5 | 17 |
| 70 | | | | | | | | | 6 | 7 | 9 | 11.5 | 14.5 |
| 100 | | | | | | | | | | 5 | 6.5 | 8 | 10 |

**FIG. 42—STARTING SYSTEM WIRING DIAGRAM FOR 12 VOLT GROUNDED SYSTEM.**




**24 VOLT STARTING MOTOR CIRCUIT**

| CABLE SIZE B&S GAGE | TOTAL LENGTH |
|---|---|
| 0 | 10 FT. |
| 00 | 15 |
| 000 | 20 |
| 0000 | 30 |

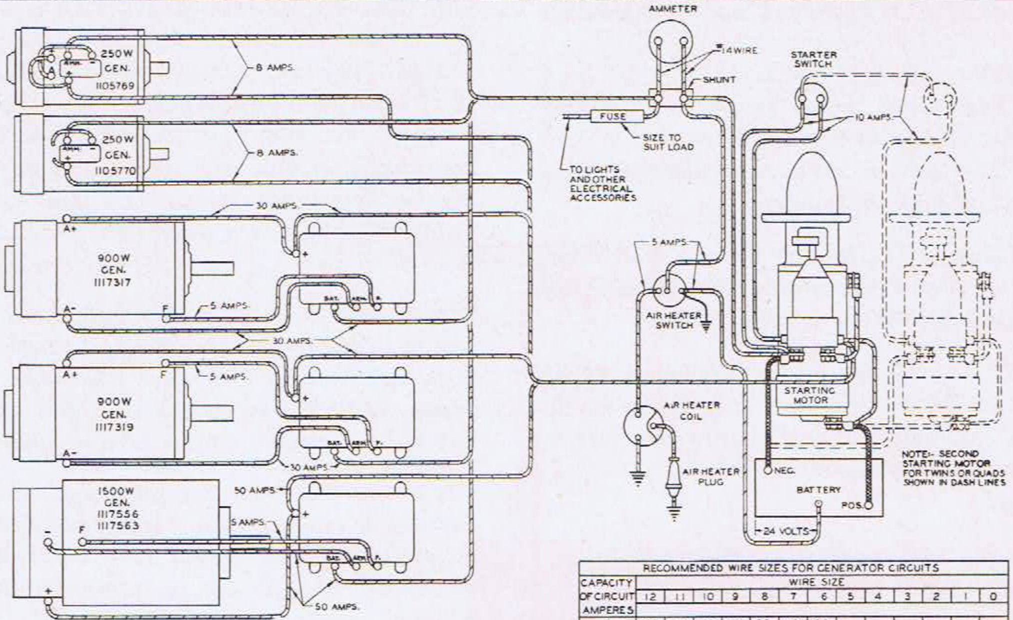
**12 VOLT STARTING MOTOR CIRCUIT**

| CABLE SIZE B&S GAGE | TOTAL LENGTH |
|---|---|
| 0 | 10 FT. |
| 00 | 12 " |
| 000 | 16 " |
| 0000 | 20 " |
| 2 PARALLEL CABLES | |
| 00 00 | 24 " |
| 000 000 | 32 " |
| 0000 0000 | 40 " |

**RECOMMENDED WIRE SIZES FOR GENERATOR CIRCUITS**

| CAPACITY OF CIRCUIT AMPERES | WIRE SIZE 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 13 | 16 | 20 | 26 | 32 | 40 | 50 | | | | | | |
| 10 | 6.5 | 8 | 10 | 13 | 16 | 20 | 25 | 32 | 40 | 50 | | | |
| 15 | | 5 | 6.5 | 8.5 | 10 | 13 | 17 | 21 | 26 | 34 | 42 | | |
| 20 | | | 5 | 6.5 | 8 | 10 | 12.5 | 16 | 20 | 25 | 32 | | |
| 30 | | | | | 5 | 6.5 | 8.5 | 10.5 | 13 | 17 | 21 | | |
| 40 | | | | | | | 6.5 | 8 | 10 | 13 | 16 | | |
| 50 | | | | | | | 5 | 6.5 | 8 | 10 | 13 | 16 | |
| 60 | | | | | | | | 5 | 6.5 | 8 | 10 | 13.5 | 17 |
| 70 | | | | | | | | | 6 | 7 | 9 | 11.5 | 14.5 |
| 100 | | | | | | | | | | 5 | 6.5 | 8 | 10 |

FIG. 43—STARTING SYSTEM WIRING DIAGRAM FOR 12 AND 24 VOLT UNGROUNDED SYSTEM.

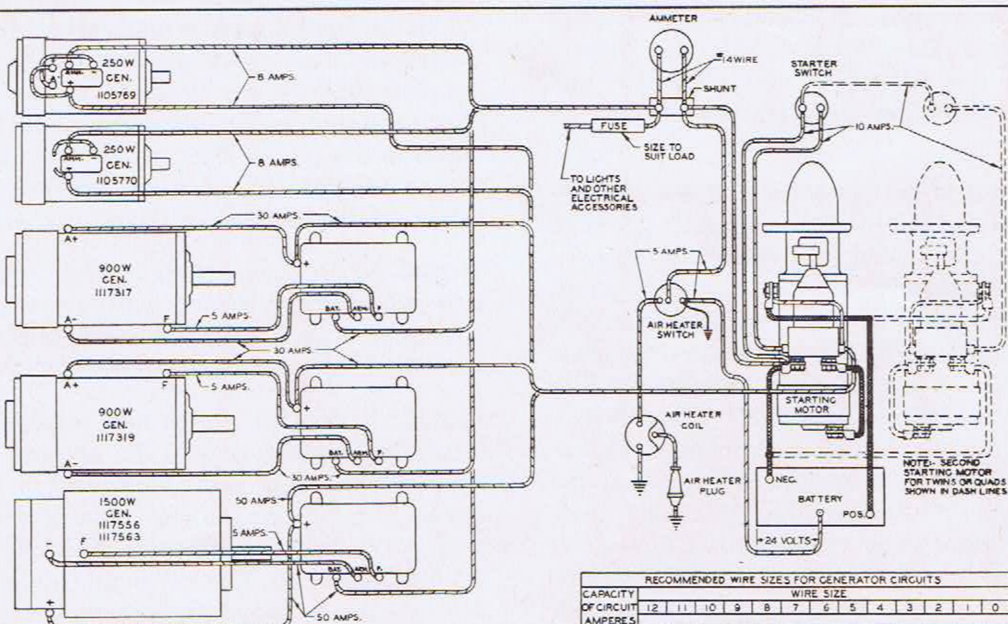



| 32 VOLT STARTING MOTOR CIRCUIT | |
|---|---|
| CABLE SIZE B&S GAGE | TOTAL LENGTH |
| 0 | 10 FT. |
| 0 0 | 15 " |
| 0 0 0 | 20 " |
| 0 0 0 0 | 30 " |

RECOMMENDED WIRE SIZES FOR GENERATOR CIRCUITS

| CAPACITY OF CIRCUIT AMPERES | WIRE SIZE 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 13 | 16 | 20 | 26 | 32 | 40 | 50 | | | | | | |
| 10 | 6.5 | 8 | 10 | 13 | 16 | 20 | 25 | 32 | 40 | 50 | | | |
| 15 | | 5 | 6.5 | 8.5 | 10 | 13 | 17 | 21 | 26 | 34 | 42 | | |
| 20 | | | 5 | 6.5 | 8 | 10 | 12.5 | 16 | 20 | 25 | 32 | | |
| 30 | | | | | 5 | 6.5 | 8.5 | 10.5 | 13 | 17 | 21 | | |
| 40 | | | | | | | 6.5 | 8 | 10 | 13 | 16 | | |
| 50 | | | | | | | 5 | 6.5 | 8 | 10 | 13 | 16 | |
| 60 | | | | | | | | 5 | 6.5 | 8 | 10 | 13.5 | 17 |
| 70 | | | | | | | | | 6 | 7 | 9 | 11.5 | 14.5 |
| 100 | | | | | | | | | | 5 | 6.5 | 8 | 10 |

**FIG. 44—STARTING SYSTEM WIRING DIAGRAM FOR 32 VOLT UNGROUNDED SYSTEM.**




| 32 VOLT STARTING MOTOR CIRCUIT | |
|---|---|
| CABLE SIZE B&S GAGE | TOTAL LENGTH |
| 0 | 10 FT. |
| 0 0 | 15 " |
| 0 0 0 | 20 " |
| 0 0 0 0 | 30 " |

RECOMMENDED WIRE SIZES FOR GENERATOR CIRCUITS

| CAPACITY OF CIRCUIT AMPERES | WIRE SIZE 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 13 | 16 | 20 | 26 | 32 | 40 | 50 | | | | | | |
| 10 | 6.5 | 8 | 10 | 13 | 16 | 20 | 25 | 32 | 40 | 50 | | | |
| 15 | | 5 | 6.5 | 8.5 | 10 | 13 | 17 | 21 | 26 | 34 | 42 | | |
| 20 | | | 5 | 6.5 | 8 | 10 | 12.5 | 16 | 20 | 25 | 32 | | |
| 30 | | | | | 5 | 6.5 | 8.5 | 10.5 | 13 | 17 | 21 | | |
| 40 | | | | | | | 6.5 | 8 | 10 | 13 | 16 | | |
| 50 | | | | | | | 5 | 6.5 | 8 | 10 | 13 | 16 | |
| 60 | | | | | | | | 5 | 6.5 | 8 | 10 | 13.5 | 17 |
| 70 | | | | | | | | | 6 | 7 | 9 | 11.5 | 14.5 |
| 100 | | | | | | | | | | 5 | 6.5 | 8 | 10 |

**FIG. 45—STARTING SYSTEM WIRING DIAGRAM FOR 32 VOLT UNGROUNDED SYSTEM USED ON LATER ENGINES.**

## REVERSE AND REDUCTION GEARS

Fig. 46 illustrates the application of an "A" type Reverse-Reduction Gear on a single, six-cylinder engine. Fig. 48 illustrates the application of a "B" type reverse gear and a separate Reduction gear unit on a twin engine installation.

*On Single Engine Units* the Reverse-Reduction Gear housing is bolted to the engine flywheel housing and the clutch is bolted to the engine flywheel.

Either type "A" or "B" Reverse-Reduction gears, as illustrated in Figs. 46 and 48, may be used on single engine units. These units are available in direct drive or the following gear reduction: 1.5:1, 2.0:1, 2.5:1, 3.0:1, and 4.4:1.

**Description—Type "A" (Twin Disc) Reverse and Reduction Gear**—Model G.M. 165 Reverse and Reduction gear unit shown in Fig. 46 accomplishes both forward and reverse drives by a unique arrangement of a duplex clutch through a forward reduction with a 2.0:1 ratio and a reverse gear with a 2.0:1 ratio.

Actually, there are separate dry-disc clutches and separate gear trains—one for forward and one for reverse speeds—but so constructed that the unit may be operated for sustained periods in either direction of rotation. Reverse speed is accomplished through one clutch driving plate (56) and shaft (69); forward speed through the second driving plate (57) and sleeve (70) surrounding but independent of the reverse shaft.

A front plate (60) of the duplex clutch is bolted directly to the flywheel (147), likewise a back plate (63). A floating plate (64)—with lugs engaging the front plate—is placed between the front and back plates and revolves with them. Between the back plate (63) and the floating plate (64) is a reverse driving plate (56) and between the front plate and the floating plate is a forward driving plate (57). The reverse driving plate is connected by gear teeth to the reverse shaft (69), which is in turn supported at the forward end by a pilot ball bearing (67) in the back plate and at the rear end by a double-row ball bearing (142) in the transmission housing (1). The forward driving plate, on the other hand, is connected by gear teeth to the forward sleeve (70), which is in turn supported at the forward end by a pilot ball bearing (68) on the reverse shaft and at the rear end by a large double-row ball bearing (129) in a cross member of the transmission housing.

A countershaft (32) driven by a constant mesh gear (38) from the forward sleeve (70) is mounted on a double-row ball bearing (33) aft and a roller bearing (43) forward and carries a reverse gear (37) in constant mesh with an idler gear (51). The idler gear is mounted on a stub shaft (50) with two single-row ball bearings (52) and (53) and a spacer (54) between the bearing inner races. This idler gear also constantly meshes with a gear (139) keyed to the reverse shaft (69).

Either forward or reverse speed is accomplished at will by a hand-operated lever, through a yoke (79), throwout bearing (72), and six toggle joints (109), which, when moved fore or aft, will engage either the forward or reverse clutch driving plates as desired.

Oil temperatures in the gear box are lowered by coming in contact with a water manifold in the gear housing inside of which raw water is continually circulated through the gear box by the raw water pump.

**Operation**—When the control lever is operated for forward speed, the floating pressure plate (64) exerts pressure against the forward driving plate (57) (the one farthest from the engine flywheel). This engaging action takes the drive from the flywheel to the gear (128) on the forward sleeve. In this rotation, two gears are under load.

When the control lever is operated for reverse speed, the floating plate exerts pressure on the reverse driving plate (56) (the one closest to the engine flywheel). This engaging action takes the drive from the flywheel to the pinion (139) on the solid reverse shaft, thence through the idler gear (51) to the countershaft (32). In this rotation, three gears are under load.

To prolong life of reversing clutches, a good practice is to reduce engine speed when reversing direction of rotation in normal operation. *Gear should not be reversed at full engine speed except in emergency.*

**LUBRICATION**—The clutch and reverse gear unit is lubricated separately from the engine. The housing should be filled up to the high mark on the oil depth gauge in gear housing (see "Lubrication", page 3, section IV), with a good grade of S.A.E. viscosity No. 50 lubricating oil. Old oil should be removed from transmission by use of sump pump, and a refill made with fresh oil every 300 hours of operation, or at least twice a season. *Do not overfill,* because too much oil in reverse gear will cause excessive temperatures, due to hydraulic pressures set up between the gears.

*To Use Sump Pump,* remove the oil depth stick and fit the rubber tubing on the pump over the head of

1. Housing—Reverse and Reduction Gear.
2. Bolt—Gear Housing Attaching.
3. Lock Washer.
7. Cover—Reverse and Reduction Gear (Front).
8. Gasket—Reverse and Reduction Gear Cover.
9. Bolt—Cover Attaching.
10. Lock Washer.
13. Cover—Reverse and Reduction Gear (Rear).
14. Gasket—Reverse and Reduction Gear Cover.
15. Bolt—Cover Attaching.
16. Lock Washer.
17. Breather Cap.
20. Cover—Reverse and Reduction Gear End.
21. Gasket—Reverse and Reduction Gear End Cover.
22. Bolt—Cover Attaching.
23. Lock Washer.
24. Breather Nipple.
25. Breather Baffle.
29. Pipe Plug—¾" Water Drain.
32. Countershaft.
33. Ball Bearing—Countershaft.
34. Lock Nut—Countershaft Bearing.
35. Lock Washer.
36. Oil Seal—Countershaft.
37. Gear—Reverse.
38. Gear—Forward.
39. Sleeve—Countershaft.
40. Key—Gears to Sleeve.
41. Snap Ring—Countershaft Sleeve.
42. Key—Sleeve to Countershaft.
43. Roller Bearing—Countershaft Pilot.
44. Nut (Slotted)—Countershaft.
45. Cotter Pin.
46. Cover—Countershaft Pilot Bearing.
47. Gasket—Countershaft Pilot Bearing Cover.
48. Bolt—Cover Retaining.
49. Lock Washer.
50. Shaft—Idler Gear.
51. Gear—Idler.
52. Ball Bearing—Idler Gear Shaft.
53. Ball Bearing—Idler Gear Shaft.
54. Spacer—Idler Gear Bearing.
55. Nut—Idler Gear Shaft.
56. Plate Assembly—Reverse Driving.
57. Plate Assembly—Forward Driving.
58. Bolt—Clutch to Flywheel.
60. Front Plate and Sliding Sleeve Support Assembly.
61. Cotter Pin—Idler Shaft Nut.
63. Back Plate.
64. Floating Plate.
65. Expansion Plug—Back Plate.
66. Snap Ring—Sliding Sleeve Support.
67. Ball Bearing—Reverse Shaft Pilot.
68. Ball Bearing—Forward Sleeve Pilot.
69. Reverse Shaft.
70. Forward Sleeve.
71. Sliding Sleeve.
72. Ball Bearing—Sliding Sleeve.
73. Snap Ring—Sliding Sleeve Collar.
74. Collar—Sliding Sleeve.
75. Spacer—Sliding Sleeve.

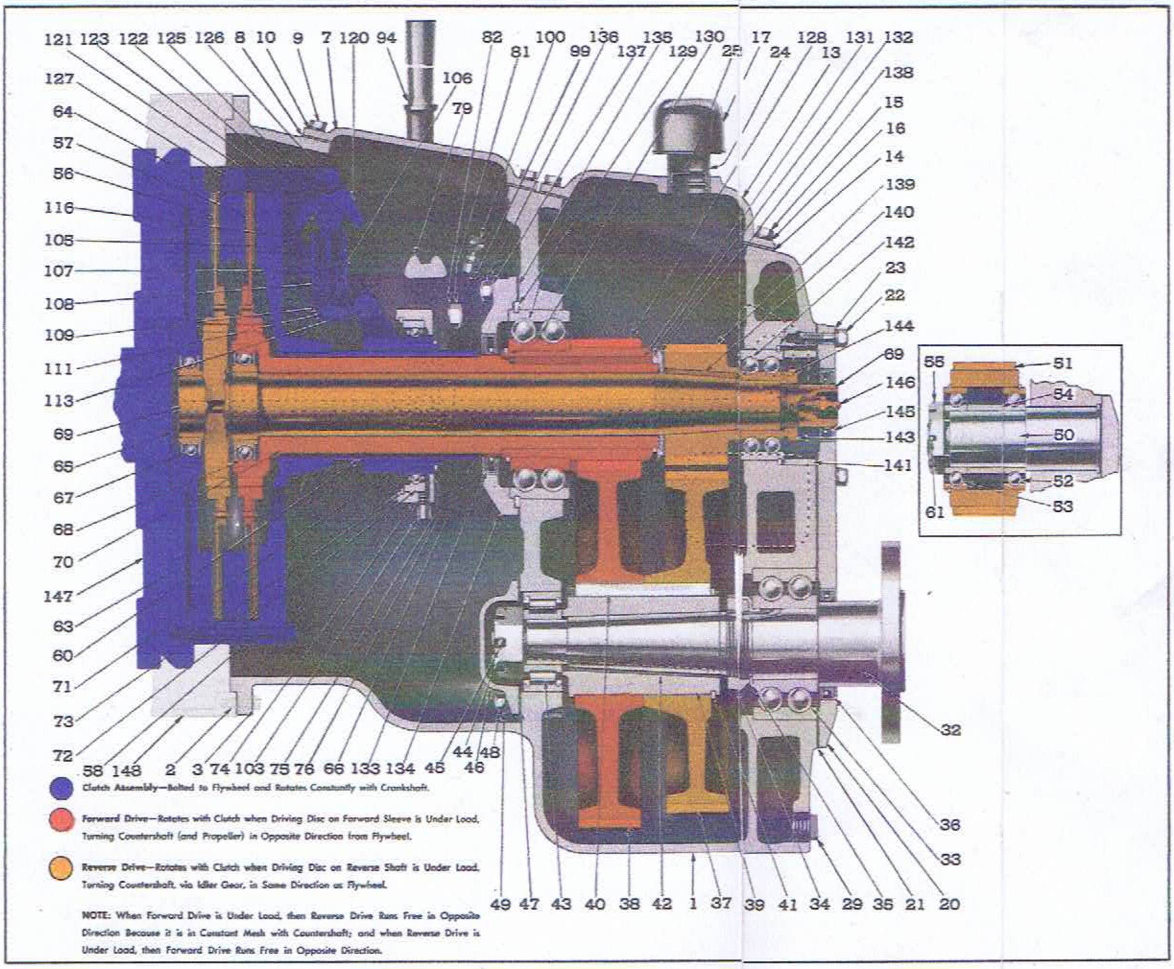



**FIG. 46—TYPE "A" (TWIN DISC) REVERSE AND REDUCTION GEAR ASSEMBLY.**

76. Snap Ring—Sliding Sleeve.
79. Operating Yoke—Throwout Fork.
81. Bolt—Yoke Clamping.
82. Lock Washer.
94. Lever—Operating.
99. Flexible Hose.
100. Adapter.
103. Elbow—Sliding Sleeve Collar.
105. Spring Cup.
106. Spring.
107. Pin—Spring.
108. Nut—Spring Adjusting.
109. Link—Sleeve to Cup.
111. Pin—Link to Cup.
113. Pin—Link to Sleeve.
116. Bracket—Lever.
120. Wishbone Lever.
121. Roller.
122. Needle Bearing.
123. Pin—Roller.
125. Engaging Link.
126. Pin—Engaging Link.
127. Pin—Link to Floating Plate.
128. Forward Pinion.
129. Ball Bearing—Forward Pinion.
130. Snap Ring—Bearing to Forward Pinion.
131. Key—Forward Pinion to Forward Sleeve.
132. Snap Ring—Pinion to Forward Sleeve.
133. Oil Seal—Forward Pinion Bearing Cover.
134. Cover—Forward Pinion Bearing.
135. Gasket—Forward Pinion Bearing Cover.
136. Bolt—Cover Attaching.
137. Lock Washer.
138. Oil Slinger—Reverse and Forward Pinion.
139. Reverse Pinion.
140. Key—Pinion to Reverse Shaft.
141. Spacer—Reverse Pinion Bearing.
142. Ball Bearing—Reverse Pinion.
143. Lock Nut—Reverse Shaft Bearing.
144. Lock Washer.
145. Oil Seal—Reverse Shaft Bearing.
146. Alemite Fitting—Reverse Shaft.
147. Flywheel Assembly.
148. Flywheel Housing.

the oil gauge tubing, which extends to the bottom of the housing. The old oil may then be removed by suction of the pump. (See Lubrication and Preventive Maintenance", page 10, section IV.)

*Pilot Bearing* should be lubricated every 25 hours of operation with pressure grease gun. Grease fitting is located at center of rear end of reverse shaft just above the propeller shaft coupling. Use only high-grade, short fibre, smooth texture, sodium soap grease to accommodate operating temperatures of 200° F. Never use ordinary cup grease. One or two strokes of a gun, holding one pound of grease, every 25 hours should be sufficient. Use good judgment when greasing this bearing. Too much grease will throw over on the clutch driving plates and cause slippage.

*Clutch Throwout* should be lubricated every 25 hours of operation with pressure gun. Use same grease as specified for pilot bearing above.

*Other Clutch Parts* should be lubricated with light engine oil every 50 hours of operation to insure against binding caused by rust. Oil cups are provided at operating shaft bearings for lubrication. In addition, remove cover plate and apply a few drops of oil to all pivot pins, trunnion blocks on ball bearing throwout collar and sliding sleeve support.

**Adjustment—Clutch**—The heavy-duty duplex spring-loaded over-center clutch is loaded by means of the spring pressure of the springs in each of the six clutch action units. This spring-loaded mechanism is designed to follow up and it compensates for the wear on the friction surfaces, thus requiring no adjustment. The operating mechanism is designed to allow $\frac{1}{16}$" clearance on each side of one driving plate with the other plate in the engaged position.

This clearance will increase to a maximum of $\frac{1}{8}$" in the worn-out position. The simplest means to check

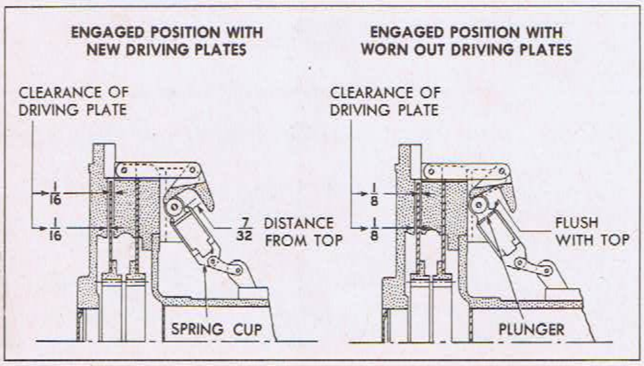



**FIG. 47—SPRING-LOADED CLUTCH OPERATING MECHANISM.**

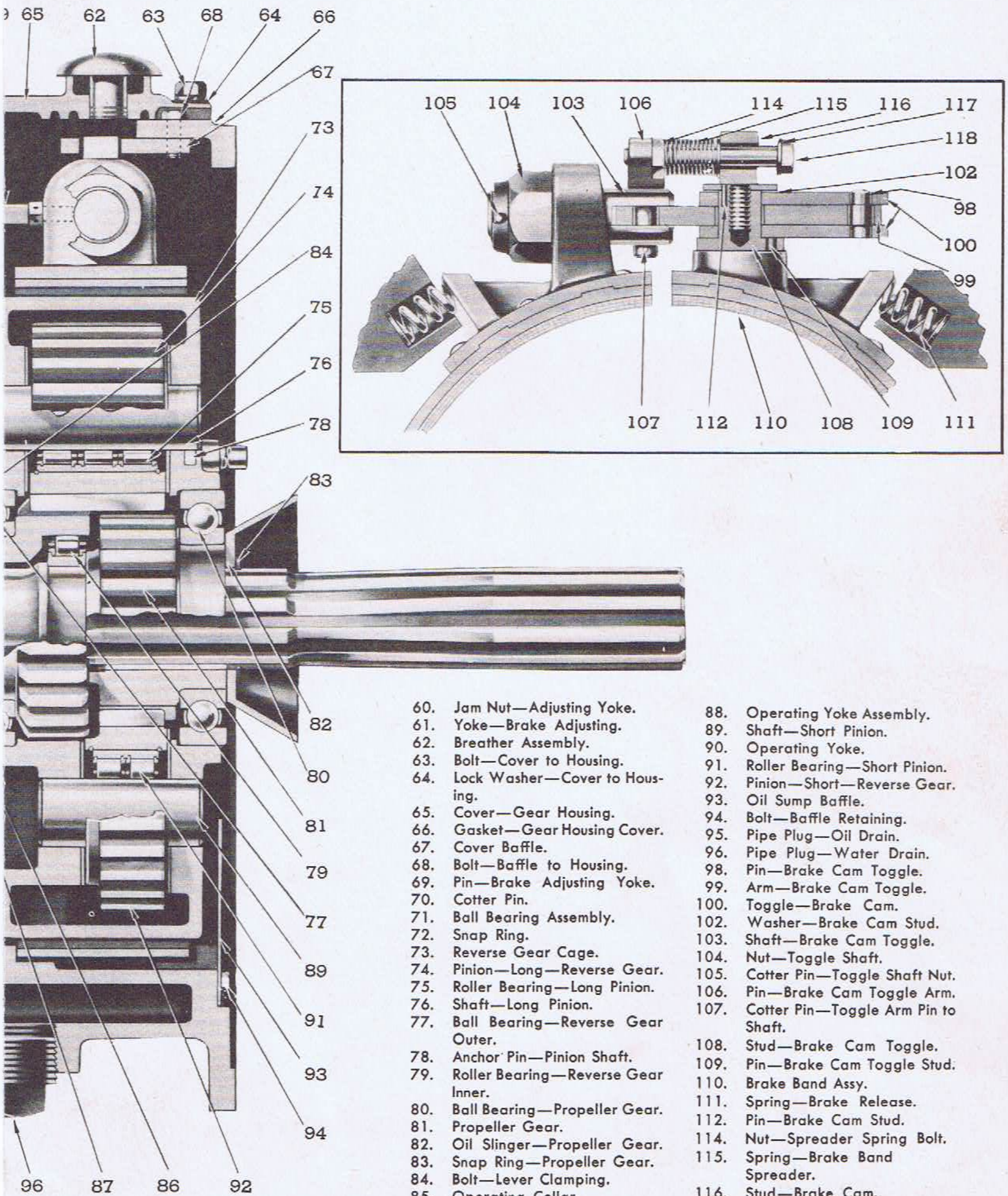
the relative wear of the friction surfaces and to determine when the driving plates need replacing is to check the position of the plunger in the engaging mechanism. (See Fig. 47). When the driving plates are new, the plunger comes within $\frac{7}{32}$" of the top of the spring cup with the clutch engaged in either direction. When the plates are worn to a point where they need replacing, the plunger is flush with the top of the spring cup. The gears are all mounted on ball bearings in permanently fixed centers and they do not require any adjustment whatsoever.

**Description—Type "B" (S-N) Reverse and Reduction Gear**—Fig. 48 illustrates the Type "B" Reverse and Reduction Gear used on single, also twin, engine installations. Drive to the reverse gear from the prime mover is through a ring bolted to the clutch case of the former and the flywheel of the latter. An adapter bolted to the reverse gear housing and to the engine flywheel housing holds the unit rigidly in place.

Functional major parts of the reverse gear shown in Fig. 48 consist of: The forward double cone clutch (15); a drive shaft (36), mounted at the forward end on a ball bearing (39) inside the clutch cover hub, and aft on a roller bearing (79) inside the gear (37) keyed to the cover hub; a reverse gear cage (73) mounted on the two ball bearings (77) and (80)—one on the gear (37) keyed to the cover hub, the other on the gear (81) splined to the drive shaft (36); a reverse clutch band (110) together with its operating toggles and linkage; and a hand control lever (1).

*The Forward Clutch* is *"Spring Loaded"* and has two special features of design: (a) While the toggles apply pressure at three points on the pressure plate, the multiple springs distribute the engaging pressure uniformly over the whole area of the cones. (b) The action of the compressed springs automatically compensate for normal wear and for expansion or contraction of the metals, lining surfaces, etc. The clutch is, therefore, "spring loaded for its life," and the life of the clutch is lengthened materially.

*The Reversing Mechanism* consists of a clutch (110) and a gear cage (73). The reverse clutch is a brake band assembly entirely independent of the forward clutch, but actuated by the same control lever. When either clutch is engaged, the other is fully disengaged. The gear cage encloses three pairs of pinions (74) and (92) equally spaced around the driving gear (37) and the driven gear (81). Gear (37) is keyed to the clutch assembly and is always turning with the engine. This gear is in constant mesh with the longer pinions (74) within the gear cage (73).




60. Jam Nut—Adjusting Yoke.
61. Yoke—Brake Adjusting.
62. Breather Assembly.
63. Bolt—Cover to Housing.
64. Lock Washer—Cover to Housing.
65. Cover—Gear Housing.
66. Gasket—Gear Housing Cover.
67. Cover Baffle.
68. Bolt—Baffle to Housing.
69. Pin—Brake Adjusting Yoke.
70. Cotter Pin.
71. Ball Bearing Assembly.
72. Snap Ring.
73. Reverse Gear Cage.
74. Pinion—Long—Reverse Gear.
75. Roller Bearing—Long Pinion.
76. Shaft—Long Pinion.
77. Ball Bearing—Reverse Gear Outer.
78. Anchor Pin—Pinion Shaft.
79. Roller Bearing—Reverse Gear Inner.
80. Ball Bearing—Propeller Gear.
81. Propeller Gear.
82. Oil Slinger—Propeller Gear.
83. Snap Ring—Propeller Gear.
84. Bolt—Lever Clamping.
85. Operating Collar.
86. Key—Reverse Gear.
87. Snap Ring—Yoke Assembly to Collar.
88. Operating Yoke Assembly.
89. Shaft—Short Pinion.
90. Operating Yoke.
91. Roller Bearing—Short Pinion.
92. Pinion—Short—Reverse Gear.
93. Oil Sump Baffle.
94. Bolt—Baffle Retaining.
95. Pipe Plug—Oil Drain.
96. Pipe Plug—Water Drain.
98. Pin—Brake Cam Toggle.
99. Arm—Brake Cam Toggle.
100. Toggle—Brake Cam.
102. Washer—Brake Cam Stud.
103. Shaft—Brake Cam Toggle.
104. Nut—Toggle Shaft.
105. Cotter Pin—Toggle Shaft Nut.
106. Pin—Brake Cam Toggle Arm.
107. Cotter Pin—Toggle Arm Pin to Shaft.
108. Stud—Brake Cam Toggle.
109. Pin—Brake Cam Toggle Stud.
110. Brake Band Assy.
111. Spring—Brake Release.
112. Pin—Brake Cam Stud.
114. Nut—Spreader Spring Bolt.
115. Spring—Brake Band Spreader.
116. Stud—Brake Cam.
117. Washer—Spreader Spring Bolt.
118. Bolt—Spreader Spring.

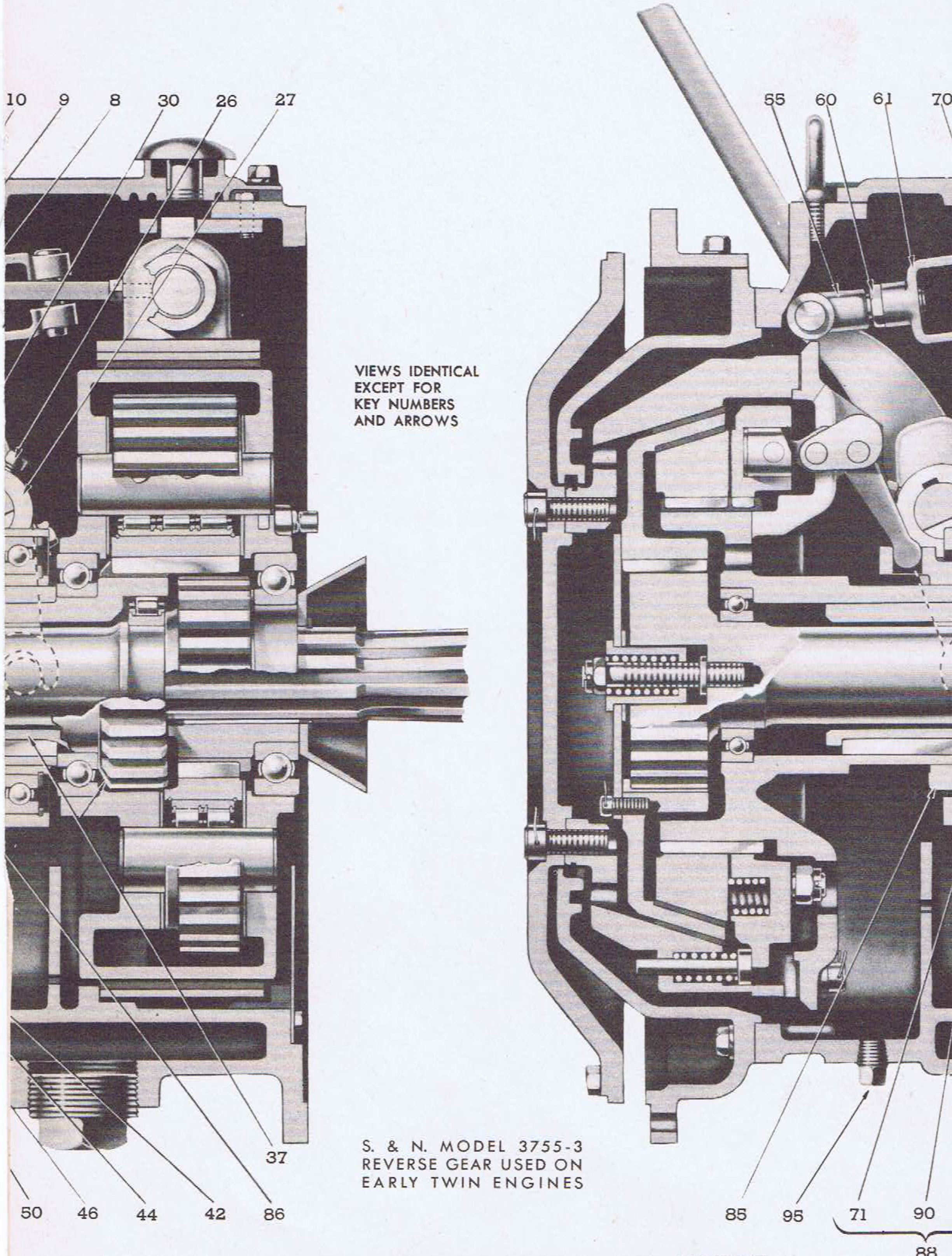



FIG. 48—TYPE "B" (S-N) REVERSE GEAR ASSEMBLY.

1. Lever—Reverse Gear Hand Operating.
2. Eye Bolt—Reverse Gear Lifting.
3. End Pin—Operating Lever Yoke.
4. Cotter Pin—Yoke End Pin.
5. Bolt—Cover to Adapter.
6. Lock Washer—Cover to Adapter.
7. Cover—Reverse Gear Housing Adapter.
8. Brake Lever.
9. Cover—Reverse Gear Clutch.
10. Shim—Clutch Case Adjusting.
11. Case—Reverse Gear Clutch.
12. Adapter—Reverse Gear Housing.
13. Ring—Reverse Gear Driving.
14. Pressure Plate.
15. Cone Assembly—Driven.
16. Cone—Pressure Plate.
17. Toggle Assembly.
18. Toggle Plunger.
19. Pin—Toggle.
20. Toggle Link.
21. Pin—Toggle Adjusting.
22. Toggle.
23. Bolt—Toggle Anchor.
24. Nut—Toggle Bolt.
25. Cotter Pin.
26. Setscrew.
27. Operating Jaw.
28. Woodruff Key—Jaw to Shaft.
29. Operating Shaft.
30. Operating Fork.
31. Stud—Driven Cone Release.
32. Cotter Pin.
33. Nut—Spring Retaining.
34. Spring—Driven Cone Release.
35. Sleeve—Cone Release Spring (Model 3755-3).

35a. Sleeve—Cone Release Spring (Model 3755-7).

36. Drive Shaft (Model 3755-3).

36a. Drive Shaft (Model 3755-7).

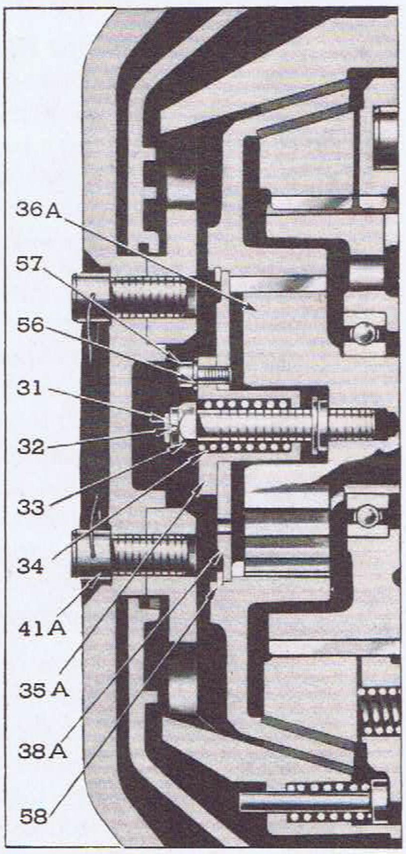
37. Reverse Gear.
38. Release Plate—Reverse Gear. Driven Cone (Model 3755-3).

38a. Release Plate—Reverse Gear Driven Cone (Model 3755-7).

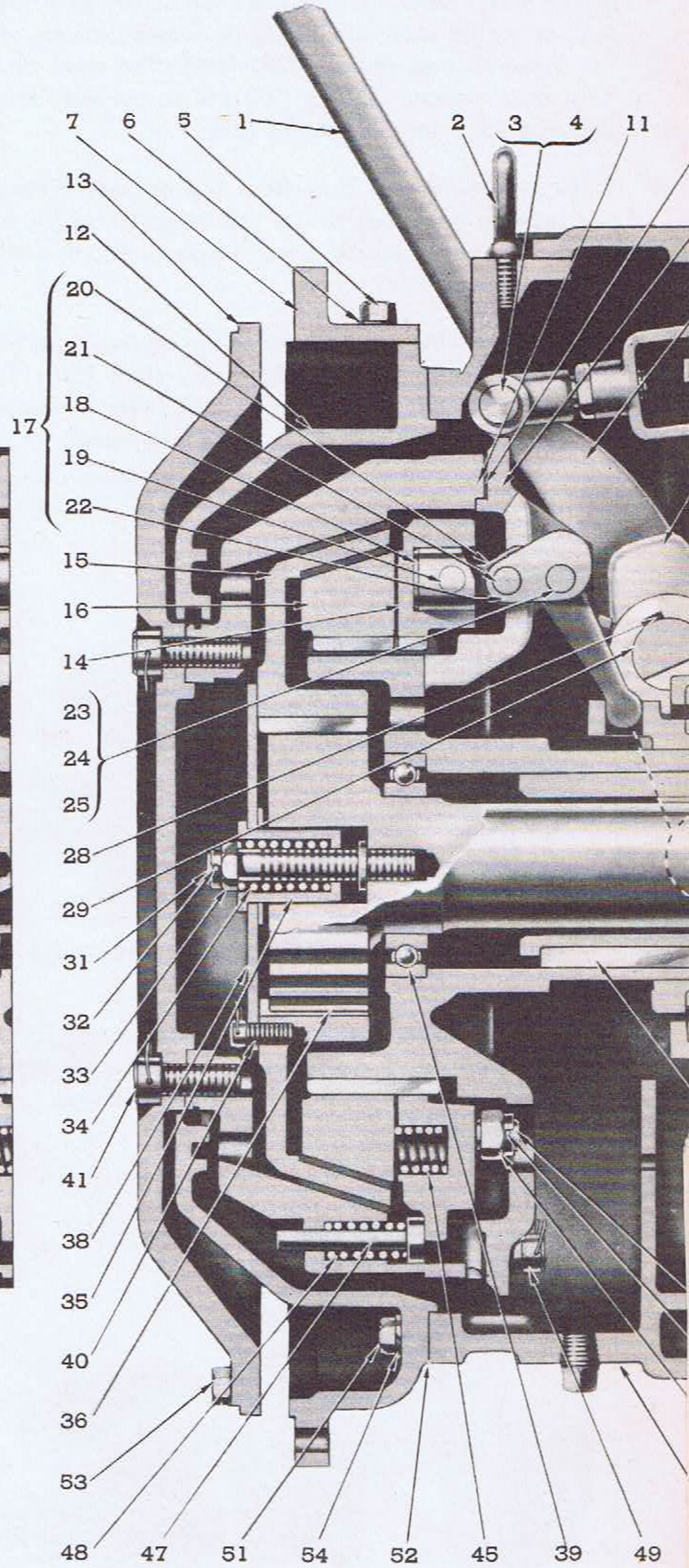
39. Ball Bearing—Drive Shaft.
40. Socket Head Screw—Release Plate to Cone Subassembly.
41. Driving Ring Bolt (Model 3755-3).

41a. Driving Ring Bolt (Model 3755-7).

42. Stud—Pressure Plate.
44. Cotter Pin.
45. Spring—Pressure Plate.
46. Nut—Plate to Cone.
47. Plunger—Clutch Case Spring.
48. Spring—Clutch Case.
49. Bolt—Clutch Cover.
50. Housing—Reverse Gear.
51. Bolt—Adapter to Housing.
52. Gasket—Gear Housing Adapter.
53. Shipping Bolt.
54. Lock Washer—Adapter to Housing.
55. Yoke End—Brake Lever to Brake Yoke.
56. Lock Washer—Sleeve to Plate.
57. Bolt—Sleeve to Plate.
58. Snap Ring—Release Plate to Cone.



S. & N. MODEL 3755-7 SHOWING VARIATIONS FROM THE 3755-3



At the after end of the gear cage the driven gear (81), splined to the engine shaft, is in constant mesh with the three shorter pinions (92) inside the gear cage. The three shorter pinions (92) are in constant mesh with the three longer pinions (74).

**OPERATION**—Power flow from the engine, through the reverse gear and to the reduction gears for forward drive and reverse drive, respectively, is shown in Figs. 49 and 50.

*In Forward Drive* the power of the engine goes in a line-drive direct through the drive shaft (36). The reverse gearing and the gear cage (73) are by-passed but revolve with the drive shaft like a flywheel.

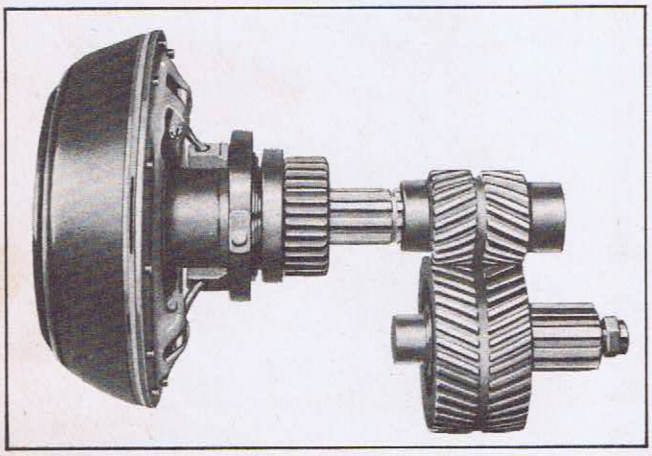


**FIG. 49—POWER FLOW FORWARD DRIVE OF TYPE "B" REVERSE GEAR.**

*In Reverse Drive* the forward clutch [cone (15)] is entirely clear and by-passed. The reverse clutch [assembly (110)] is engaged. Only the reverse gearing is functioning.

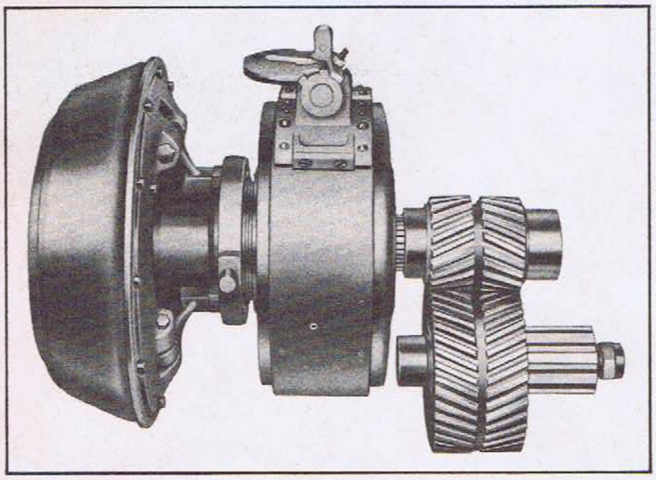


**FIG. 50—POWER FLOW REVERSE DRIVE OF TYPE "B" REVERSE GEAR.**

*In Neutral*—When the control lever is put in neutral position, the forward clutch and the reverse clutch are both disengaged. The forward driven cone (15) is not turning. However, since the cover (9) always turns with the engine, the gear (37)—keyed to the cover hub—turns the gear cage (73) at half engine speed, rolling it in differential fashion around the gear splined to the shaft (36).

*The Forward Clutch* comprises three power transmission members: (a) Case (outer driving cone). (b) Plate assembly (inner driving cone). (c) Cone subassembly (driven cone); hereinafter known as: Outer Driving Cone, Inner Driving Cone, and Driven Cone, respectively.

*When the Forward Clutch* is engaged, the toggles clamp the double-faced driven cone (15) between the inner and outer driving cones (16) and (11). The engine torque is then transmitted through the driven cone (spline-mounted on the drive shaft) direct through the drive shaft to the reduction gears, if used, by-passing all other gears and bearings.

When disengaging the clutch, the control lever is returned to its neutral position and two cone release devices become operative: (a) The spring release (34) in the forward end of the drive shaft (36) separates the driven cone (15) from the outer driving cone (11). (b) The three springs (48), nesting in the clutch assembly, retract the inner driving cone (16). The driven cone (15) is thereby positively positioned with maximum clearance when not engaged. *The only adjustments necessary are those made when the clutch is assembled.*

*The Reverse Clutch* (110) (brake band) clamps the gear cage (73) holding it stationary. The gear (37)—keyed to the hub of the clutch cover (9)—rotates the longer pinions (74) in the opposite direction. The longer pinions turn the shorter pinions (92) in the direction of the engine rotation. The shorter pinions turn the gear (81)—splined to the drive shaft (36)—opposite to engine rotation.

**LUBRICATION**—The oiling system of the S-N Reverse and Reduction Gear is self-contained; that is, all parts are lubricated through the normal functioning of the unit.

Inspect oil level daily before starting the engine. Bear in mind that when a reduction gear is used that about 15 minutes are required after stopping for the oil to level off between the two units. Do not check oil level, therefore, for at least 15 minutes after a run.

Maintain oil level to "H" mark on gauge.

Use the same grade of oil as required by the engine. S.A.E. viscosity between 20 and 50 is preferable. Drain the oil after 300 hours of operation.

An oil capacity chart below shows the oil capacity for both the "LOW" and "HIGH" marks on the bayonet oil gauge for the various reduction gears used with the two S-N reverse gears 3745-5 and 3755-6 for single engine installations; also, for the reverse gears 3755-3 and 3755-7 used with twin engine installations. The accompanying diagram, Fig. 51, illustrates the association of the various reduction gear units with the mating reverse gear, as well as the gear reduction for each.

The oil capacity and oil gauge (dip stick) markings vary with the angle of installation, also with the different models of gears.

Oil gauges are marked on single engine unit S-N reverse-reduction gears at the factory. All **gauge markings for twin engine units** should be made after the unit has been installed. Put in the amount of oil required for the low mark on the gauge, then run the engines idle in forward positions. After running 15 minutes, stop the engines and put the low mark on the gauge. After the low marking on the gauge has been made, add one-half (½) quart of oil to the gear in case of gear number 3755-3, or one (1) quart in case of gear number 3755-7. Start the engines and run idle in forward position 15 minutes, then stop and put full markings on gauge.

| S-N Reverse Gear Model | Reduction Gear Model | Installation Angle of Unit | Oil Capacity —Low Mark | Oil Capacity —High Mark | Single or Twin Installation |
|---|---|---|---|---|---|
| 3745-5 | 2045-1 & 5 | — | 5 | 6 | Single |
| 3745-5 | 2045-7 | — | 6½ | 7½ | Single |
| 3755-6 | 2055-1 & 5 | — | 6 | 7 | Single |
| 3755-6 | 2055-7 | — | 7 | 8 | Single |
| 3755-3 | Diesel | 0°-4° | 3½ | 4 | Twin |
| | | 5°-10° | 5½ | 6 | |
| 3755-7 | Diesel | 0°-4° | 4 | 5 | Twin |
| | | 5°-10° | 6 | 7 | |

*Oil Capacity Chart S-N Reverse Gears for Twin Engine and Reverse-Reduction Gears for Single Engine Installations.*

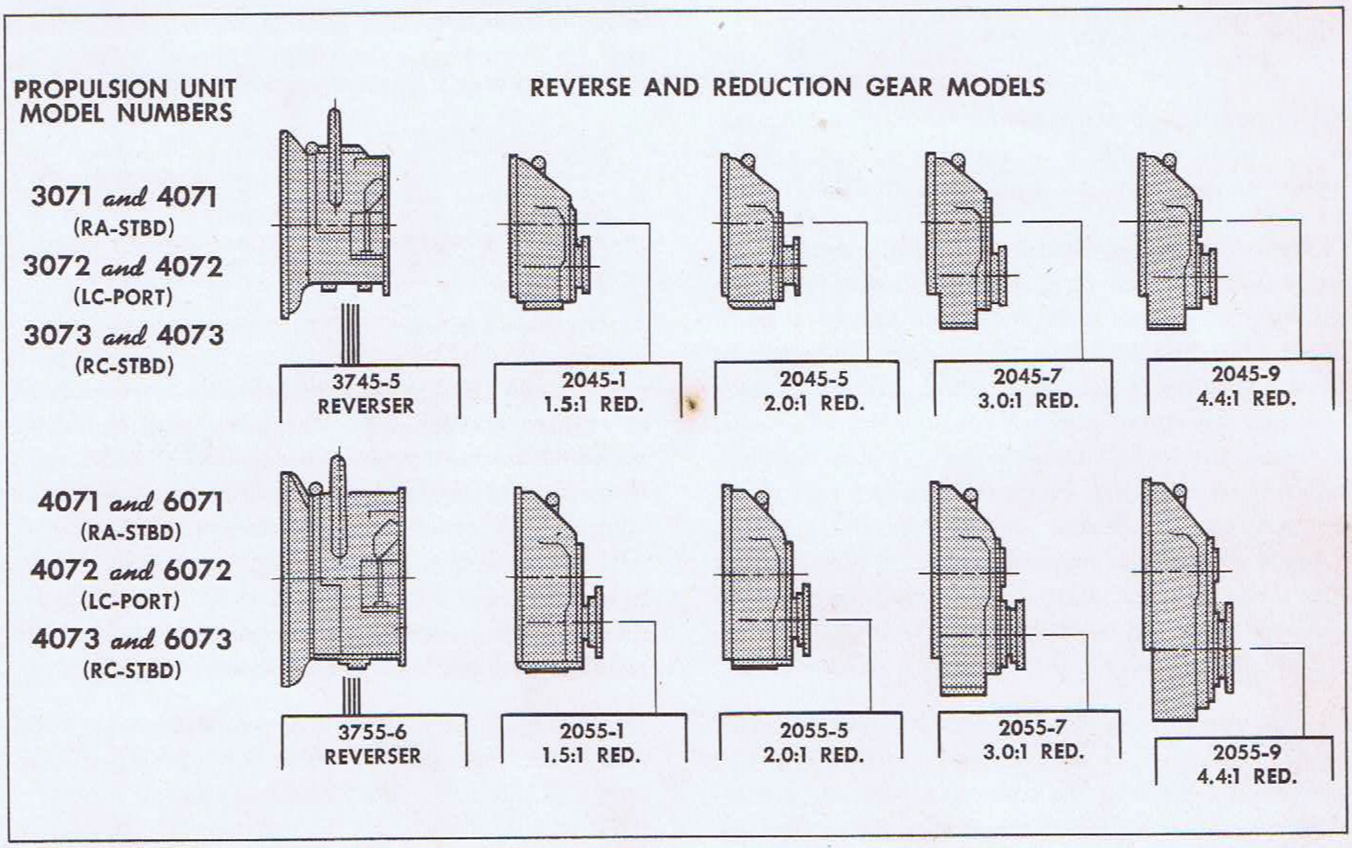



FIG. 51—OIL CAPACITY DIAGRAM FOR SINGLE ENGINE UNIT INSTALLATION USING S-N REVERSE-REDUCTION GEARS.

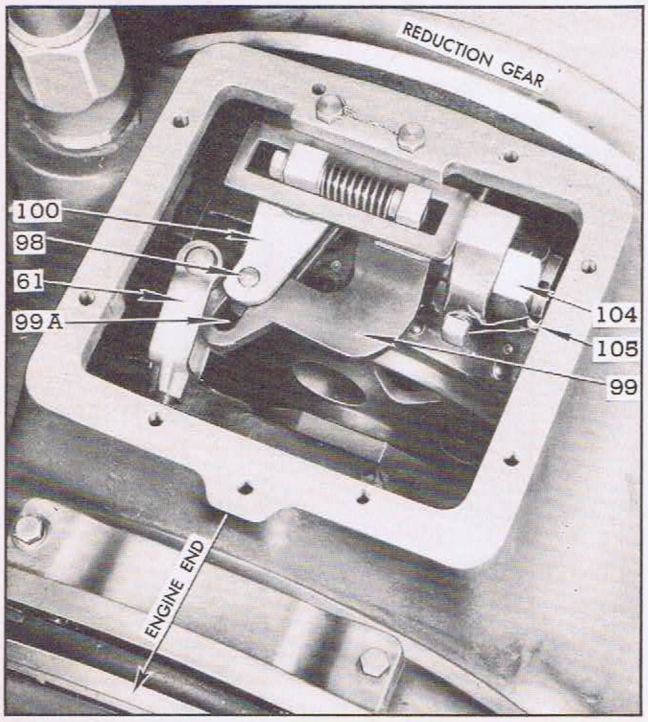



**FIG. 52—REVERSE CLUTCH (BRAKE BAND) AND YOKE LINKAGE IN FORWARD POSITION.**

98. Pin—Brake Cam Toggle.
99. Arm—Brake Cam Toggle.
99a. Arm Slot.
100. Toggle—Brake Cam.
104. Nut—Toggle Shaft.
105. Cotter Pin—Toggle Shaft Nut.

**ADJUSTMENTS**—Before attempting to adjust the reverse clutch or the yoke linkage, disconnect the remote control—if used—from the hand control lever.

*I. Forward Clutch.* The forward double cone clutch requires no adjustment. It is spring loaded for its life and not subjected to undue wear unless abused. Slipping the clutch, riding the clutch or faulty remote control linkages cause 90% of clutch failures. If, after long use, the spring pressure drops so that the clutch no longer carries full load and the clutch surfaces are still in good condition, the initial pressure may again be restored by placing $\frac{1}{16}''$ thick washers in the plunger holes in the pressure plate (14) ahead of the plungers (18). This simple remedy may be repeated a second time and is positive assurance that full life of the clutch facings will be available. (See Fig. 48.)

*II. Reverse Clutch.* The reverse clutch is carried on torque springs and is accurately centralized and positioned at all times. To adjust the clutch for normal wear, put the hand lever in neutral position. Remove wire and loosen setscrew (119).

Tighten the nut (104) one castellation at a time (see Figs. 11 and 12). It is sufficiently tight when the clutch in reverse position holds the gear cage stationary under full load and power. There must be no slippage. However, the adjustment must not be so tight that the control lever cannot lock the clamping mechanism. After adjustment is made, engage in reverse, tighten setscrew (119) and secure with wire. If used, always disconnect the remote control linkages and test adjustment with the hand control lever.

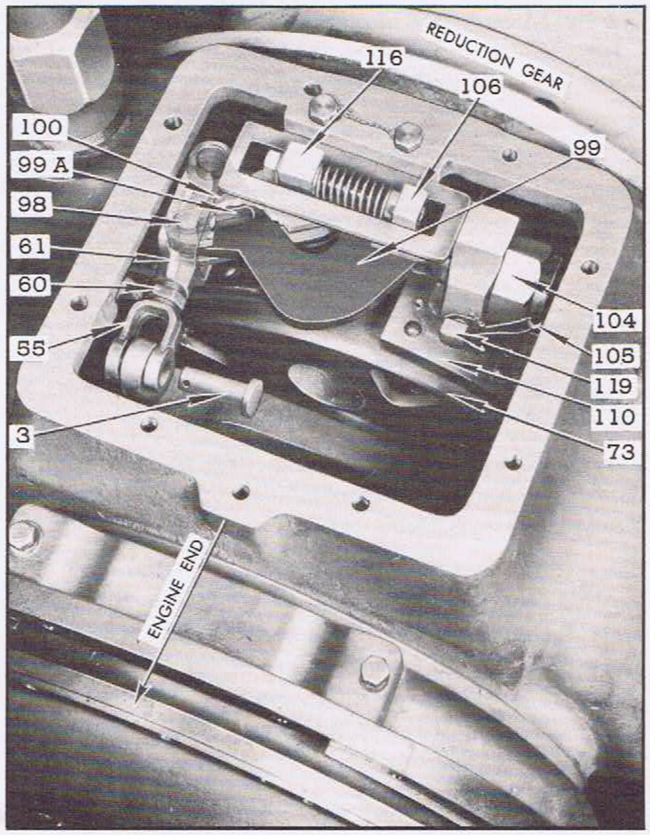



**FIG. 53—YOKE LINKAGE AND REVERSE CLUTCH IN FORWARD DRIVE NEUTRAL POSITION.**

3. End Pin—Operating Lever Yoke.
8. Brake Lever.
55. Yoke End—Brake Lever to Brake Yoke.
60. Jam Nut—Adjusting Yoke.
61. Yoke—Brake Adjusting.
73. Reverse Gear Cage.
98. Pin—Brake Cam Toggle.
99. Arm—Brake Cam Toggle.
99a. Arm Slot.
100. Toggle—Brake Cam.
104. Nut—Toggle Shaft.
105. Cotter Pin—Toggle Shaft Nut.
106. Pin—Brake Cam Toggle Arm.
110. Band Assembly.
116. Stud—Brake Cam.
119. Set Screw.

*III. Yoke Linkage.* After the reverse gear has been attached to the engine, refer to Fig. 53 for part numbers and adjust the yoke linkage as follows:

1. Remove cotter pin (4) from operating yoke lever pin (3) which attaches yoke end (55) to brake lever (8). (See Fig. 48.)

2. Move the hand control lever (1) forward until it meets the first slight resistance of the forward clutch spring release and hold it at this point, i.e., the forward drive neutral point.

3. Move the yoke linkage—parts (55) and (61), together with arm (99)—backward until the cam pin (98) is against the forward end of the slot (99a) in arm (99). (Further movement would begin to clamp the band.) This is the reverse clutch neutral point. (See Fig. 53.)

4. Loosen nut (60) and adjust yoke (61) to such length that holes in yoke end (55) align with hole in lever (18)—meanwhile holding the control lever at its neutral point as indicated in "2", above.

5. Insert lever pin (3). Test the control lever action forward and reverse.

   a. The clutch control action must lock both in forward and reverse positions.

   b. The clutch band must not "cramp." If band "cramps", adjust the yoke linkage one-half turn at a time to relieve any "cramping".

   c. There must be ample linkage clearance and no "striking" at any point against the housing.

6. When the adjustments are correct, tighten nut (60) on yoke end (55), then insert and spread cotter in pin (3).

*IV. Remote Controls.* Faulty remote controls will shorten clutch life. Regular care and regular checking of remote control linkages is good insurance. After the hand control lever action and the reverse clutch have been adjusted, attach and check the action of the remote controls. The controls must (a) lock the clutch engagement but not "ride the clutch"; (b) and must *not* slip the clutch when backed off by holding the clutch in partial engagement. **Do not use an over-locking type remote control with S-N gears.**

## TWIN ENGINE REDUCTION GEARS

Fig. 10, page 7, illustrates the application of a Reduction Gear Unit to a twin, six-cylinder Marine Propulsion Unit and Fig. 54 the construction of the Reduction Gear Unit itself.

A reverse gear—mechanically the same as the one described on page 36 for single engine units—incorporating forward and reverse clutches, is sandwiched between each of the two engines and the common reduction gear unit. These reverse gears are bolted to the engine flywheel and flywheel housing, also to the bell housings of the reduction gear.

The splined shaft of each reverse gear unit drives a herringbone pinion (31) of the reduction gear unit which in turn mesh with a common main driven gear (2) as shown in Fig. 54.

Each pinion (31) is mounted on two single-row ball bearings. The forward bearing is carried in the clutch housing (34), the aft bearing in a pinion bearing retainer (99).

Two single-row ball bearings (23) carried in the gear housing (1), support the forward end of the main driven gear hub (4) and take the thrust of the propeller. A single-row ball bearing (13) carried in a retainer (10), supports the aft end of the main driven gear hub. A flanged coupling (19) splined and locked to the aft end of the main driven gear hub, affords a means of attaching the propeller shaft coupling. Six special machined bolts with hole-to-hole fit, retain the main driven gear (2) to its hub (4).

Endwise motion of the main driven gear is prevented by locking the two forward ball bearings to the gear hub with a plate and in the housing with a thrust cover (24). The outer race of the aft driven gear bearing is free to float endwise in its carrier. A ring (3), set in the I.D. of the driven gear rim, is conducive to more quiet gear action.

Gear box lubricating oil is cooled by the circulation of raw (sea) water through a manifold in the lower portion of the oil pan. Raw water enters at the aft side and at each end of the water manifold, and is drawn from two openings at the forward side of the manifold by the two raw water pumps on the engines. A welded partition in the oil pan separates the water manifold from the upper oil reservoir.

**LUBRICATION**—Oil is supplied to the gear box through a filler at the top of the case, the cover of which provides breathing action for the enclosure. An oil bayonet shows the oil level in the housing.

To prevent oil churning, an oil pan, with an opening in the bottom to the main oil supply in the oil pan, surrounds the lower portion of the driven gear where

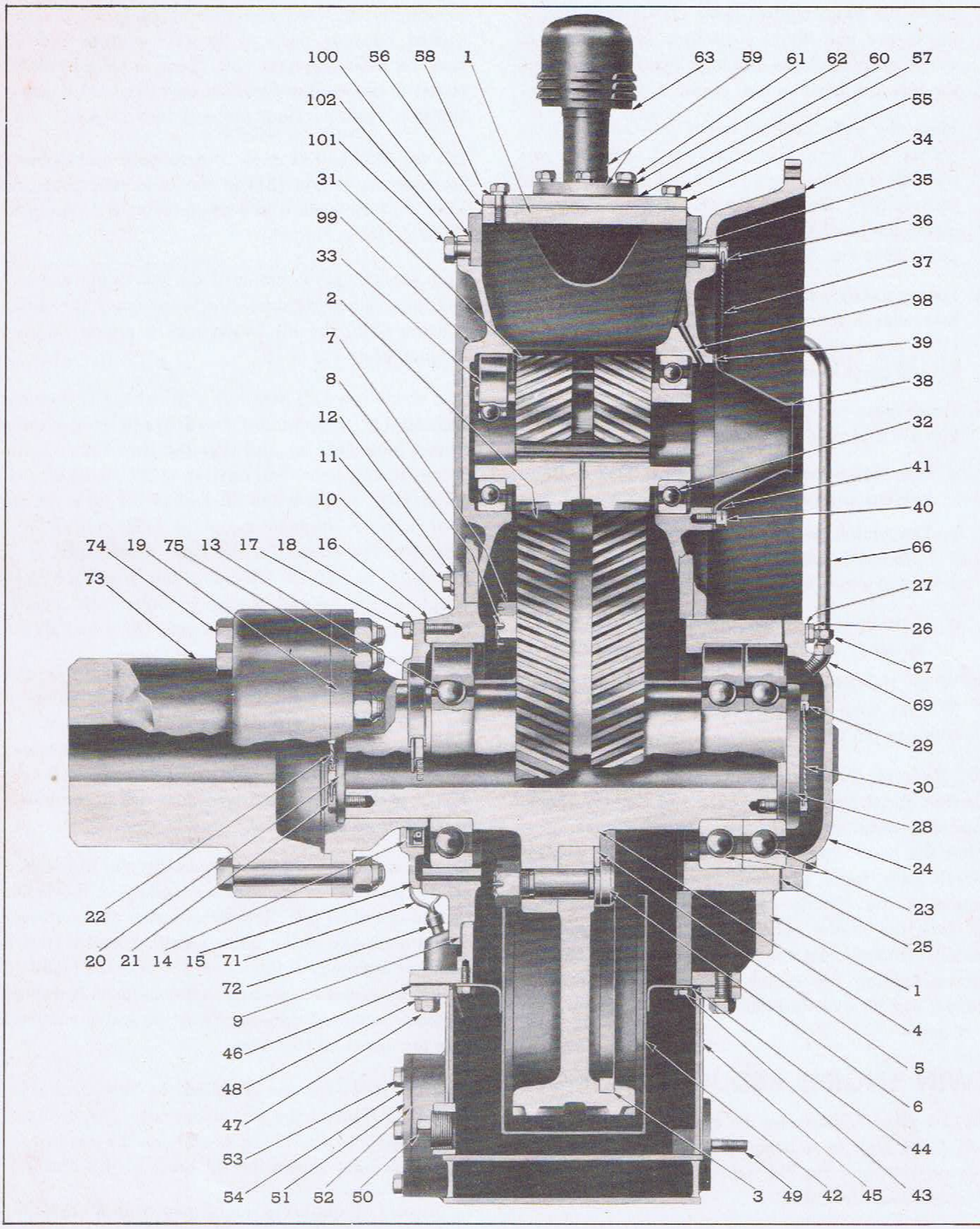



**FIG. 54—TWIN ENGINE REDUCTION GEAR ASSEMBLY.**

the teeth of the lower portion of the gear are always submerged and carry the oil to the upper pinion teeth. Oil is thrown from the two upper pinions (31) into a reservoir at the top of the gear housing between the two pinions. Openings near the top and at each end of the reservoir, spill oil onto the gear teeth and back into the housing. A pipe entering the forward side of the upper oil reservoir conducts lubricant to the driven gear forward ball bearing compartment for bearing lubrication.

Engine oil is used in the reduction gear box. Use 18 U.S. quarts for refill after draining. Maintain oil to FULL mark on bayonet oil gauge.

## FRONT END POWER TAKE-OFF

*Description*—Either a direct drive, 35 HP rating, Model 5168191, or a 3.0:1 reduction gear, Model 5168192, front end power take-off with 60 HP rating, as illustrated in Figs. 55 and 56 are available as accessory equipment on Marine Propulsion units.

Both the direct drive and the reduction gear front end power take-off units attach to the front end of the engine crankshaft in the same manner. A rubber hub coupling keyed and locked to the crankshaft carries a clutch driving adapter to which the power take-off clutch driving plate (25) is bolted. Surrounding the clutch and driving parts is a second power take-off front end adapter (housing) that is bolted to the engine cylinder block end plate (141) at the aft end and to the power take-off unit at the forward end (see Fig. 56).

Drive from the engine crankshaft is taken through a powerful dry-disc clutch, the outer driving plate (25) of which is keyed and locked to the power take-off unit clutch shaft (16). When the clutch is engaged, the over-center action of the four sets of links (36) and levers (33) locks the center driving plate (26) between the outer and inner plates (25) and (27). Thus power is transmitted to the clutch shaft.

On both power take-off units the clutch end of the clutch shaft pilots into the crankshaft coupling through a ball bearing, shielded on the clutch side, thus excluding pilot bearing grease from the clutch compartment.

On the direct drive power take-off unit, the outer end of the clutch shaft is carried on taper roller bearings (55) and (56) with an adjustable retainer (59). On the reduction gear unit, the outer end of the clutch shaft is mounted on a double-row ball bearing which is locked in the reduction gear housing.

Fig. 56 illustrates the drive from the pinion—integral with clutch shaft (16)—to the annular power take-off drive gear (63), which is keyed to the power take-off shaft (64). This latter shaft is mounted on a double-row ball bearing at each side of the drive gear (63). The aft bearing (one nearest clutch) is carried in the reduction gear housing (68). The forward bearing is carried in the gear cover plate (69). An oil seal (70), at the power take-off shaft forward bearing, retains lubricant in the gear housing.

**OPERATION**—Clutch operation is by the hand lever (50), yoke (46), sleeve (41), and four pairs of toggle links (36). When the hand lever is moved toward the engine, to the over-center position, yoke (46) moves sleeve (41) toward the clutch. This movement throws the outer fulcrums of links (36) away from the axis of rotation and the levers (33) against the inner clutch driving plate (27) which locks the moving center plate (26) between the outer and inner plates (25) and (27).

**← FIG. 54—TWIN ENGINE REDUCTION GEAR ASSEMBLY.**

1. Gear Housing.
2. Gear—Main Drive.
3. Silencer Ring.
4. Drive Hub.
5. Lock Ring.
6. Bolt—Main Drive Gear.
7. Nut—1-14 Slotted Hex.
8. Cotter Pin.
9. Gasket.
10. Retainer—Gear Housing Hub Bearing.
11. Bolt—Hub to Gear Housing.
12. Lock Washer.
13. Ball Bearing—Main Drive Gear.
14. Oil Seal.
15. Retainer—Oil Seal.
16. Gasket—Oil Seal Retainer.
17. Bolt—Oil Seal Retainer.
18. Lock Washer.
19. Coupling.
20. Retainer—Gear Housing Coupling.
21. Bolt—Retainer.
22. Lockwire.
23. Ball Bearing—Main Drive Gear Thrust.
24. Cover—Thrust Bearing.
25. Gasket—Thrust Bearing Cover.
26. Bolt—Thrust Bearing Cover.
27. Lock Washer.
28. Thrust Plate—Main Drive Gear Bearing.
29. Bolt—Thrust Plate.
30. Lockwire.
31. Pinion—Main Drive.
32. Ball Bearing — Pinion — Front.
33. Ball Bearing — Pinion — Rear.
34. Clutch Housing.
35. Gasket—Clutch Housing to Gear Housing.
36. Bolt—Clutch Housing to Gear Housing.
37. Lockwire.
38. Oil Baffle.
39. Gasket—Oil Baffle.
40. Bolt—Oil Baffle.
41. Lockwire.
42. Trough—Main Drive Gear Oil Pan.
43. Bolt—Trough to Gear Housing.
44. Lock Washer.
45. Oil Pan.
46. Gasket—Oil Pan.
47. Bolt—Oil Pan to Gear Housing.
48. Lock Washer.
49. Stud—Raw Water Outlet.
50. 1" Pipe Plug.
51. Cover—Raw Water Inlet.
52. Gasket—Raw Water Inlet Cover.
53. Bolt—Raw Water Inlet Cover.
54. Lock Washer.
55. Cover—Gear Housing.
56. Gasket—Gear Housing Cover.
57. Bolt—Cover to Gear Housing.
58. Lock Washer.
59. Pipe—Oil Filler.
60. Gasket—Oil Filter Pipe Flange.
61. Bolt—Oil Filler Pipe to Cover.
62. Lock Washer.
63. Breather Assembly—Gear Box.
66. Oil Line—Gear Housing to Thrust Bearings.
67. Nut—Oil Line Flared Tube.
69. Elbow—Oil Line—45°.
71. Oil Gauge Rod Assembly.
72. Guide—Oil Gauge Rod.
73. Flange—Propeller Drive Shaft.
74. Bolt—Propeller Drive Shaft Flange.
75. Nut—Propeller Drive Shaft Flange.
98. Oil Tube—Clutch Housing.
99. Retainer—Pinion Ball Bearing.
100. Gasket—Bearing Retainer.
101. Bolt—Bearing Retainer Attaching.
102. Lock Washer.

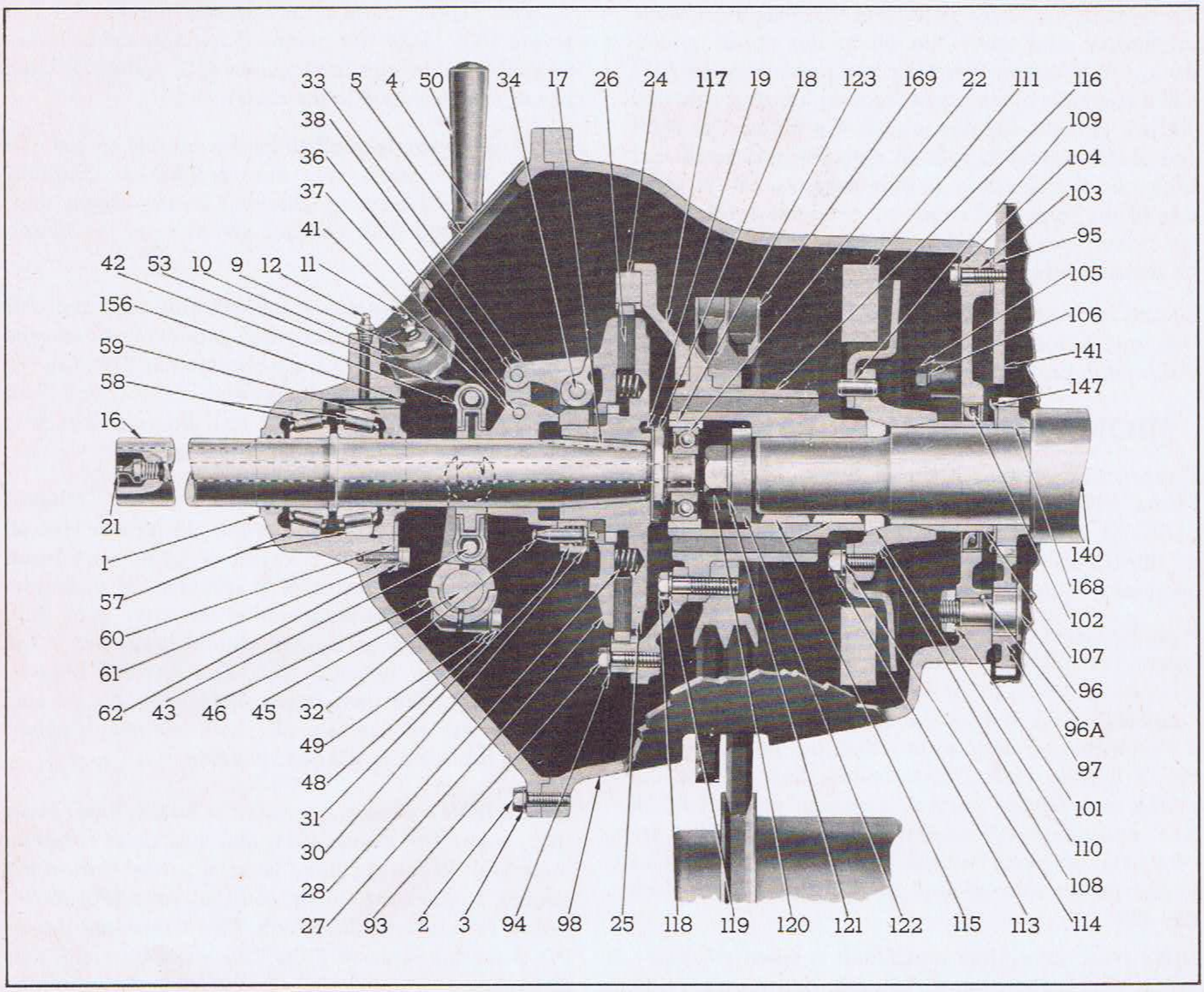



**FIG. 55—DIRECT DRIVE FRONT END POWER TAKE-OFF ASSEMBLY—MODEL 5168191.**

1. Clutch Housing.
2. Bolt—Clutch Housing to Engine.
3. Lock Washer.
4. Cover—Clutch Inspection Hole.
5. Gasket—Clutch Inspection Hole Cover.
9. Nut—Adapter to Housing.
10. Lock Washer.
11. Fitting—1/8" Male Hydraulic (Adapter).
12. Fitting—1/8" Male Hydraulic (Housing).
16. Clutch Shaft.
17. Woodruff Key—Clutch to Shaft.
18. Nut—Clutch Shaft.
19. Lock Washer—Clutch Shaft.
21. Fitting—1/4" Male Hydraulic (Pilot Bearing).
22. Ball Bearing—Clutch Pilot.
24. Ring—Clutch Driving.
25. Plate—Outer (Clutch Driving).
26. Plate—Center (Clutch Driving).
27. Plate—Inner (Clutch Driving).
28. Clutch Spring.
30. Yoke—Clutch Adjusting.
31. Spring—Clutch Adjusting Yoke.
32. Lockpin—Clutch Adjusting Yoke.
33. Lever—Clutch Release.
34. Pin—Clutch Release Lever.
36. Link—Clutch Release Lever.
37. Pin—Clutch Release Lever Link (Inner).
38. Pin—Clutch Release Lever Link (Outer).
41. Sleeve—Clutch Release.
42. Collar Assembly—Clutch Release Sleeve.
43. Bolt—Release Sleeve Collar.
45. Shaft—Clutch Operating.
46. Yoke—Clutch Operating.
48. Bolt—Yoke to Shaft.
49. Lock Washer.
50. Lever—Clutch Hand.
53. Hose—Flexible.
57. Cup—Roller Bearing.
58. Cone—Roller Bearing.
59. Retainer—Clutch Bearing.
60. Retainer Lock Plate.
61. Bolt—Clutch Bearing Retainer Attaching.
62. Lock Washer.
93. Bolt—Clutch Driving Ring to Flywheel.
94. Lock Washer.
95. Gasket—Adapter to Engine.
96. Shaft—Oil Pump Idler Gear.
97. Idler Gear—Oil Pump Assembly.
98. Adapter—Power Take-Off.
101. Nut—Oil Pump Idler Gear Shaft to Adapter.
102. Oil Seal—Power Take-Off Adapter.
103. Bolt—3/8-16 x 2—Power Take-Off Adapter to Engine.
104. Lock Washer.
105. Bolt—1/2-13 x 2 3/4 Power Take-Off Adapter to Engine.
106. Lock Washer.
107. Cone—Vibration Damper (Rear).
108. Hub—Vibration Damper.
109. Pin—Vibration Damper Hub Dowel.
110. Cone—Vibration Damper (Front).
111. Damper Assembly—Heavy Vibration.
113. Bolt—Vibration Damper to Hub.
114. Lock Washer.
115. Woodruff Key—Hub to Crankshaft.
116. Coupling and Flange Assembly.
117. Adapter—Clutch Drive.
118. Bolt—Clutch Drive Adapter to Coupling Flange.
119. Lock Washer.
120. Special Bolt—Coupling Assembly to Crankshaft.
121. Flat Washer—Coupling Assembly to Crankshaft.
122. Special Washer—Coupling Assembly to Crankshaft.
123. Spacer—Clutch Pilot Bearing.
140. Crankshaft.
141. End Plate.
147. Oil Thrower.
156. 1/8" Pipe Plug.
168. Gear—Oil Pump Drive (Crankshaft).
169. Pulley—Accessory Drive (Crank Shaft).

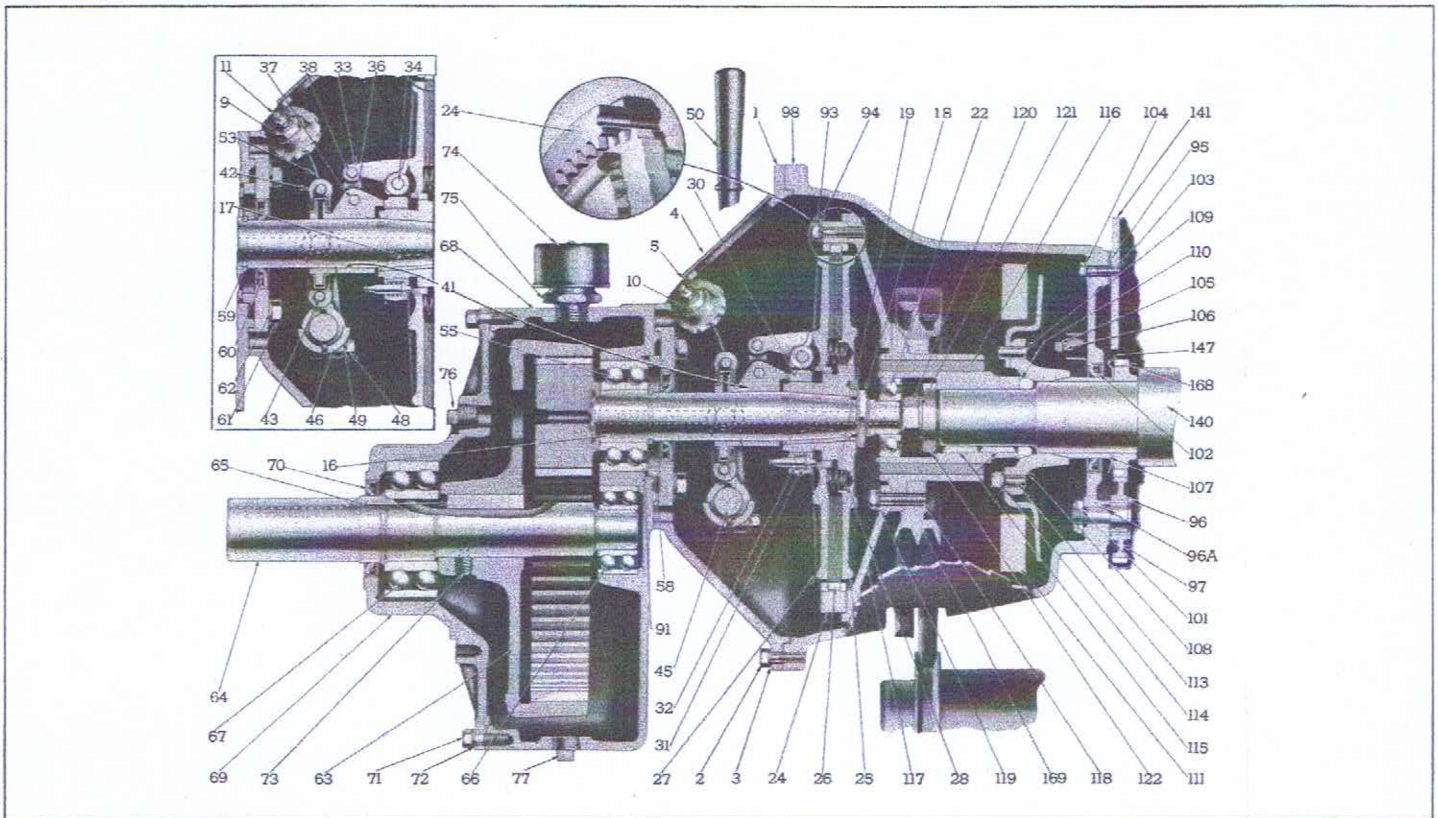



**FIG. 56—REDUCTION GEAR FRONT END POWER TAKE-OFF ASSEMBLY—MODEL 5168192.**

1. Clutch Housing.
2. Bolt—Clutch Housing to Engine.
3. Lock Washer—Clutch Housing to Engine.
4. Cover—Clutch Inspection Hole (Upper).
5. Gasket—Clutch Inspection Hole Cover.
9. Nut—Adapter to Housing.
10. Lock Washer.
11. Fitting—⅛" Male Hydraulic (Adapter).
16. Clutch Shaft.
17. Woodruff Key—Clutch to Shaft.
18. Nut—Clutch Shaft.
19. Lock Washer—Clutch Shaft.
22. Ball Bearing—Clutch Pilot.
24. Ring—Clutch Driving.
25. Plate—Outer (Clutch Driving).
26. Plate—Center (Clutch Driving).
27. Plate—Inner (Clutch Driving).
28. Clutch Spring.
30. Yoke—Clutch Adjusting.
31. Spring—Clutch Adjusting Yoke.
32. Lockpin—Clutch Adjusting Yoke.
33. Lever—Clutch Release.
34. Pin—Clutch Release Lever.
36. Link—Clutch Release Lever.
37. Pin—Clutch Release Lever Link (Inner).
38. Pin—Clutch Release Lever Link (Outer).
41. Sleeve—Clutch Release.
42. Collar Assembly—Clutch Release Sleeve.
43. Bolt—Release Sleeve Collar.
45. Shaft—Clutch Operating.
46. Yoke—Clutch Operating.
48. Bolt—Yoke to Shaft.
49. Lock Washer.
50. Lever—Clutch Hand.
53. Hose—Flexible.
55. Ball Bearing—Clutch Shaft.
58. Spacer—Clutch Bearing.
59. Ring—Clutch Bearing Retaining.
60. Oil Seal—Clutch Housing.
61. Bolt—Clutch Housing to Gear Housing.
62. Lock Washer—Clutch Housing to Gear Housing.
63. Gear—Power Take-Off Drive.
64. Shaft—Power Take-Off Drive.
65. Key—Power Take-Off Drive Shaft.
66. Ball Bearing—Power Take-Off Drive Shaft Pilot.
67. Ball Bearing—Power Take-Off Drive Shaft.
68. Housing—Power Take-Off Reduction Gear.
69. Plate—Power Take-Off Reduction Gear Cover.
70. Oil Seal—Power Take-Off Reduction Gear Cover.
71. Bolt—Reduction Gear Cover Plate Attaching.
72. Lock Washer—Reduction Gear Cover Plate Attaching.
73. Setscrew—Half Dog Point.
74. Breather Cap Assembly.
75. Breather Pipe.
76. ½" Pipe Plug—Cover Plate.
77. ¾" Pipe Plug—Oil Drain.
91. Snap Ring—Clutch Shaft Ball Bearing.
93. Bolt—Clutch Driving Ring to Flywheel.
94. Lock Washer.
95. Gasket—Adapter to Engine.
96. Shaft—Oil Pump Idler Gear.
97. Idler Gear—Oil Pump Assembly.
98. Adapter—Power Take-Off.
101. Nut—Oil Pump Idler Gear Shaft to Adapter.
102. Oil Seal—Power Take-Off Adapter.
103. Bolt—⅜-16 x 2"—Power Take-Off Adapter to Engine.
104. Lock Washer.
105. Bolt—½ x 13 x 2¾"—Power Take-Off Adapter to Engine.
106. Lock Washer.
107. Cone—Vibration Damper (Rear).
108. Hub—Vibration Damper.
109. Pin—Vibration Damper Hub Dowel.
110. Cone—Vibration Damper (Front).
111. Damper Assembly—Heavy Vibration.
113. Bolt—Vibration Damper to Hub.
114. Lock Washer.
115. Woodruff Key—Hub to Crankshaft.
116. Coupling and Flange Assembly.
117. Adapter—Clutch Drive.
118. Bolt—Clutch Drive Adapter to Coupling Flange.
119. Lock Washer.
120. Special Bolt—Coupling Assembly to Crankshaft.
121. Flat Washer—Coupling Assembly to Crankshaft.
122. Special Washer—Coupling Assembly to Crankshaft.
140. Crankshaft.
141. End Plate.
147. Oil Thrower.
168. Gear—Oil Pump Drive (Crankshaft).
169. Pulley—Accessory Drive (Crankshaft).

**LUBRICATION**—*Direct Drive Front End Power Take-Off*—Five places require lubrication on the direct drive front end power take-off unit, each of which should be lubricated when starting the unit for the first time and thereafter at the intervals shown below:

1. *Clutch Throwout Collar*—The throwout collar is lubricated through a pressure fitting at the side of the housing and should be greased every 8 to 10 hours of *engaged* operation. Apply only a small quantity of good quality sodium soap base, short fibre grease, recommended for bearings with operating temperatures of 200° F. Two strokes on a lever type gun or two full turns on the screw type gun should be sufficient.
2. *Pilot Bearing*—The pilot bearing is lubricated through a pressure fitting located in a counterbore at the outer end of the power take-off shaft. A small amount of lubricant should be added after each 50 hours of engine operation. Use the same grease specified above for the throwout collar and apply the same amount.
3. *Outer Roller Bearing*—Grease through the pressure fitting at the bearing with approved ball bearing grease each 50 hours of operation.
4. *Clutch Operating Shaft*—Lubricate through the ball cap oiler at each side of housing with engine oil using hand oil can each 50 hours of operation.
5. *Clutch Mechanism (Toggles)*—Remove hand inspection plate and lubricate toggle joints with engine oil using hand oil can each 50 hours of operation.

**LUBRICATION**—*Reduction Gear Front End Power Take-Off:*

1. *Lubrication of the Clutch Throwout Collar, the Operating Shaft, and the Clutch Mechanism* for the clutch of the reduction gear front end power take-off is the same as for the direct drive shown above.
2. *Clutch Pilot Bearing* is lubricated by removing the plug from the gear cover plate just above the power take-off shaft and installing a pressure fitting into the outer end of the clutch shaft. Lubricate each 50 hours of operation with approved ball bearing grease. One or two strokes with a gun of 2-pound capacity should be sufficient.
3. *Reduction Gear*—Gears and bearing in the reduction gear box are lubricated by splash from the gears. Oil is added through a filler neck at the top of the housing and is carried in the lower portion of the housing to the "Full" level mark shown on the bayonet gauge at the side of the housing. Use transmission lubricant SAE 90 to 110. Check oil level daily. Drain and refill each six months of operation. Capacity to "FULL" mark on bayonet is 2 U.S. quarts. *Do not maintain oil level above "FULL" mark.*

**ADJUSTMENT**—*Clutch*—Clutch adjustment is changed by removing inspection plate (4) and turning the threaded yoke (30) clockwise on the outer driving plate hub (25) to increase or counterclockwise to decrease pressure on center (driving) plate.

Before attempting to turn threaded yoke (30), pull out and free lock pin (32) from plate (27), then turn threaded yoke (30) to successive lock positions of pin (32)—one position at a time—until a good firm pull is required on the hand lever to throw the clutch to the over-center lock position.

## INSTRUMENT PANEL

Any one of four different instrument panels, as shown in Figs. 57, 58, 59, and 60, may be used with the Marine Propulsion Units depending on the installation and the proximity of the panel to the power plant.

The four panels featured in this text include:

1. Mechanical for single engine units.
2. Mechanical for twin engine units.
3. Electrical for single engine units.
4. Electrical for twin engine units.

Mechanical instrument panels are used when the panel is located adjacent to the engine (less than fifteen feet). If the instrument panel is more than fifteen feet from the engine, requiring remote control, the electrical panel is used.

Mounted in each single engine unit panel, both mechanical and electrical, is a tachometer, water temperature gauge, oil temperature gauge, oil pressure gauge and a battery charging ammeter. An additional group of similar instruments is arranged in the instrument panel for the twin engine units.

While the instruments in the electrical instrument panel have the same name, they are a different type than those in the mechanical panel except the battery charging ammeter which is the same in all panels.

As the name implies, instruments in the electrical instrument panel are electrically controlled and are, therefore, provided with wire terminals as shown in

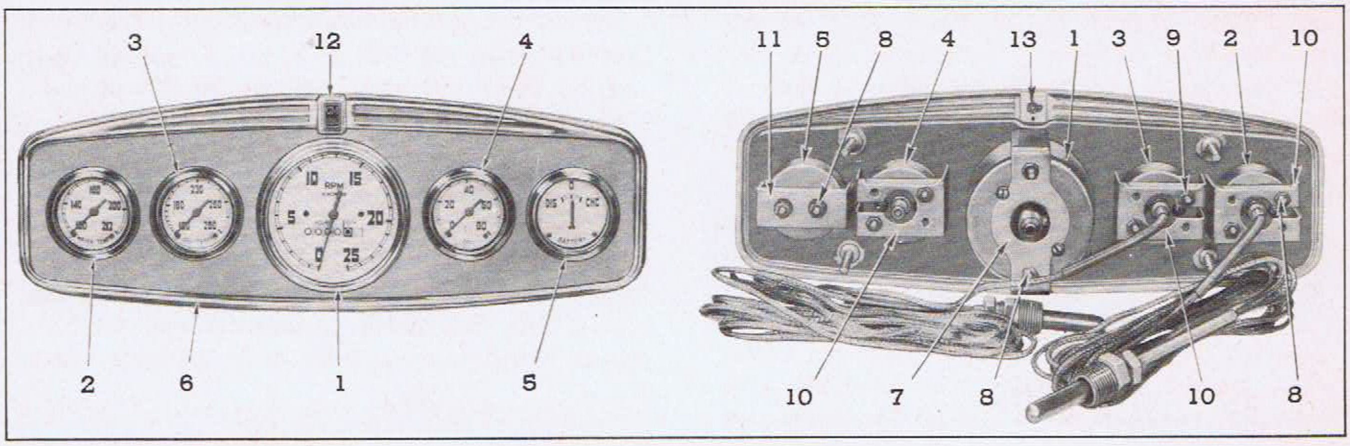



**FIG. 57—MECHANICAL INSTRUMENT PANEL ASSEMBLY FOR SINGLE ENGINE UNIT.**

1. Tachometer Assembly.
2. Gauge—Water Temperature.
3. Gauge—Oil Temperature.
4. Gauge—Oil Pressure.
5. Ammeter—Battery Charging.
6. Mounting Plate Assembly.
7. Mounting Strap—Tachometer.
8. Nut—Mounting Strap Gauges.
9. Lock Washer—Mounting Strap Gauges.
10. Mounting Strap—Temperature Gauges.
11. Mounting Strap—Ammeter.
12. Name Plate.
13. Nut—Name Plate to Panel.

Figs. 59 and 60. Instruments in these panels are energized by the storage batteries and the battery charging generator of the engine unit, wiring diagrams for which are shown on pages 50 and 51.

An instrument panel package is provided with the electrical instrument panels which includes for a single engine unit:

1. *An oil pressure switch* installed in the engine oil gallery to close the electric circuit by the oil pressure as soon as the engine starts.
2. *An oil gauge engine unit* also installed in the engine oil pressure line and electrically connected to the oil pressure gauge in the instrument panel.
3. *Two thermo gauge engine units.* One installed in the water manifold to record engine coolant temperature, the other in the engine oil pan, and immersed in engine oil, to record oil temperature. The former unit is electrically connected to the water temperature gauge and the latter to the oil temperature gauge, both in the instrument panel.

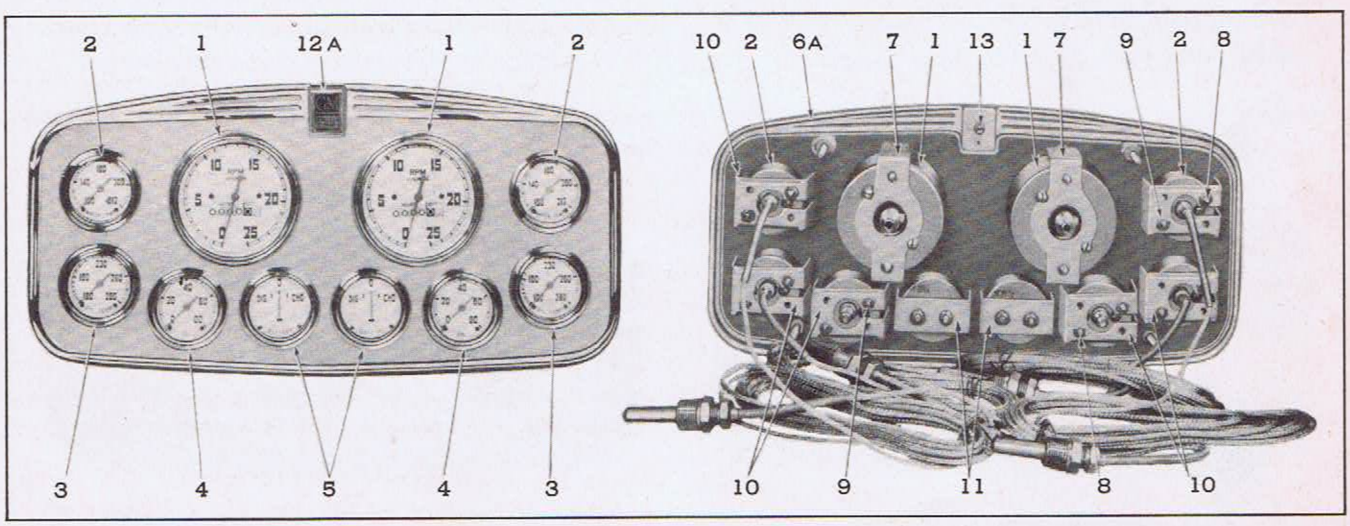



**FIG. 58—MECHANICAL INSTRUMENT PANEL ASSEMBLY FOR TWIN ENGINE UNIT.**

1. Tachometer Assembly—Mechanical.
2. Gauge—Water Temperature.
3. Gauge—Oil Temperature.
4. Gauge—Oil Pressure.
5. Ammeter—Battery Charging.
6a. Mounting Plate Assembly—Instrument Panel.
7. Mounting Strap—Tachometer.
8. Nut—Mounting Strap Gauges.
9. Lock Washer—Mounting Strap Gauges.
10. Mounting Strap—Temperature Gauges.
11. Mounting Strap—Gauges.
12a. Name Plate.
13. Nut—Name Plate to Panel.

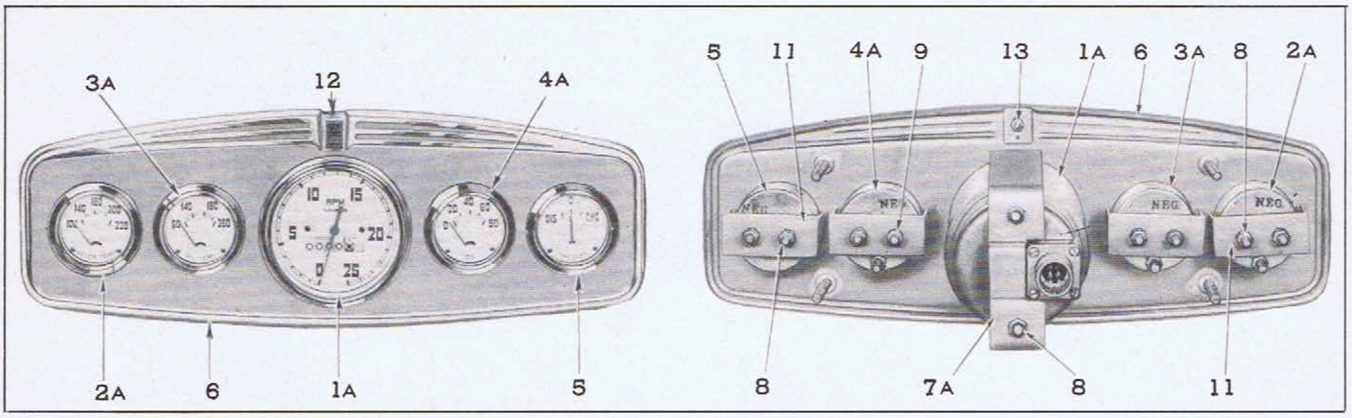



**FIG. 59—ELECTRICAL INSTRUMENT PANEL ASSEMBLY FOR SINGLE ENGINE UNIT.**

1a. Tachometer Assembly—Electric.
2a. Gauge—Water Temperature.
3a. Gauge—Oil Temperature.
4a. Gauge—Oil Pressure.
5. Ammeter—Battery Charging.
6. Mounting Plate Assembly.
7a. Mounting Strap—Tachometer.
8. Nut—Mounting Strap Gauges.
9. Lock Washer—Mounting Strap Gauges.
11. Mounting Strap—Ammeter.
12. Name Plate.
13. Nut—Name Plate to Panel.

4. *A 12 volt drive unit* mechanically driven at one end by a flexible shaft from the engine blower drive shaft and attached to the tachometer in the instrument panel by a cable at the other end.

5. *A shunt assembly* is connected across the ammeter in the battery charging circuit between generator and battery to reduce the charging current to the carrying capacity of the ammeter.

6. *A resistance unit* is wired in series with the oil pressure, the oil temperature, and the water temperature gauges to reduce the battery voltage to the carrying capacity of the three gauges.

7. *A fuse and block assembly* for the 12 volt circuit and two fuses in the 32 volt circuit.

8. Suitable radio shielding to eliminate radio interference.

**The Twin Electrical Instrument Panel** package contains twice the number of the same kind of instruments as the single electrical package except only one battery charging ammeter is used.

**Electrical Instrument Panel Wiring**—A wiring diagram suitable for the single engine electrical instrument panel is shown in Fig. 62 and for twin engines in Fig. 63. Follow the directions carefully when rewiring or checking the wiring of the instrument panels.

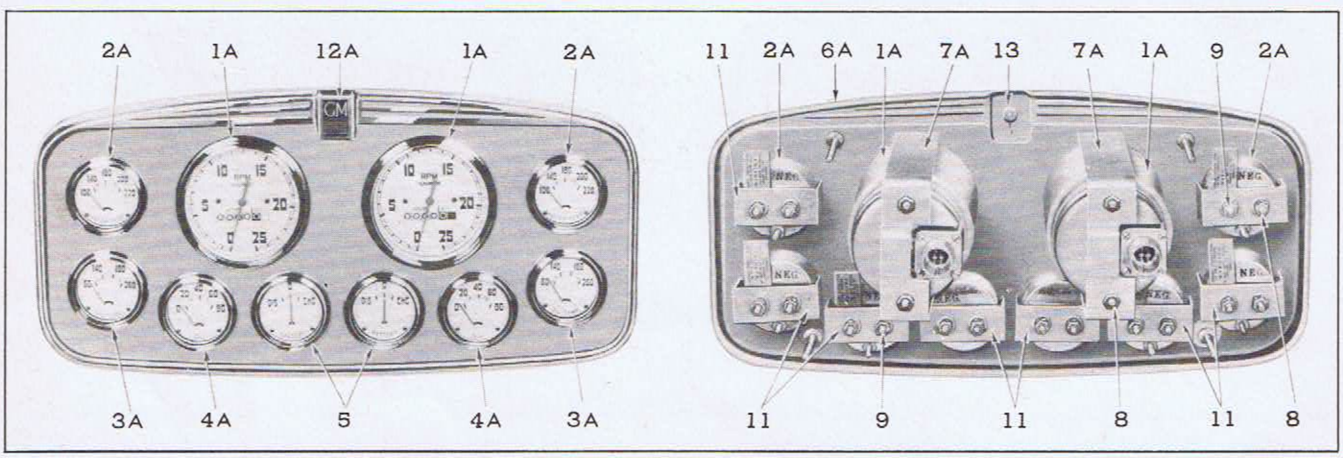



**FIG. 60—ELECTRICAL INSTRUMENT PANEL ASSEMBLY FOR TWIN ENGINE UNIT.**

1a. Tachometer Assembly—Electric.
2a. Gauge—Water Temperature.
3a. Gauge—Oil Temperature.
4a. Gauge—Oil Pressure.
5. Ammeter—Battery Charging.
6a. Mounting Plate Assembly—Instrument Panel.
7a. Mounting Strap—Tachometer.
8. Nut—Mounting Strap Gauges.
9. Lock Washer—Mounting Strap Gauges.
11. Mounting Strap—Gauges.
12a. Name Plate.
13. Nut—Name Plate to Panel.

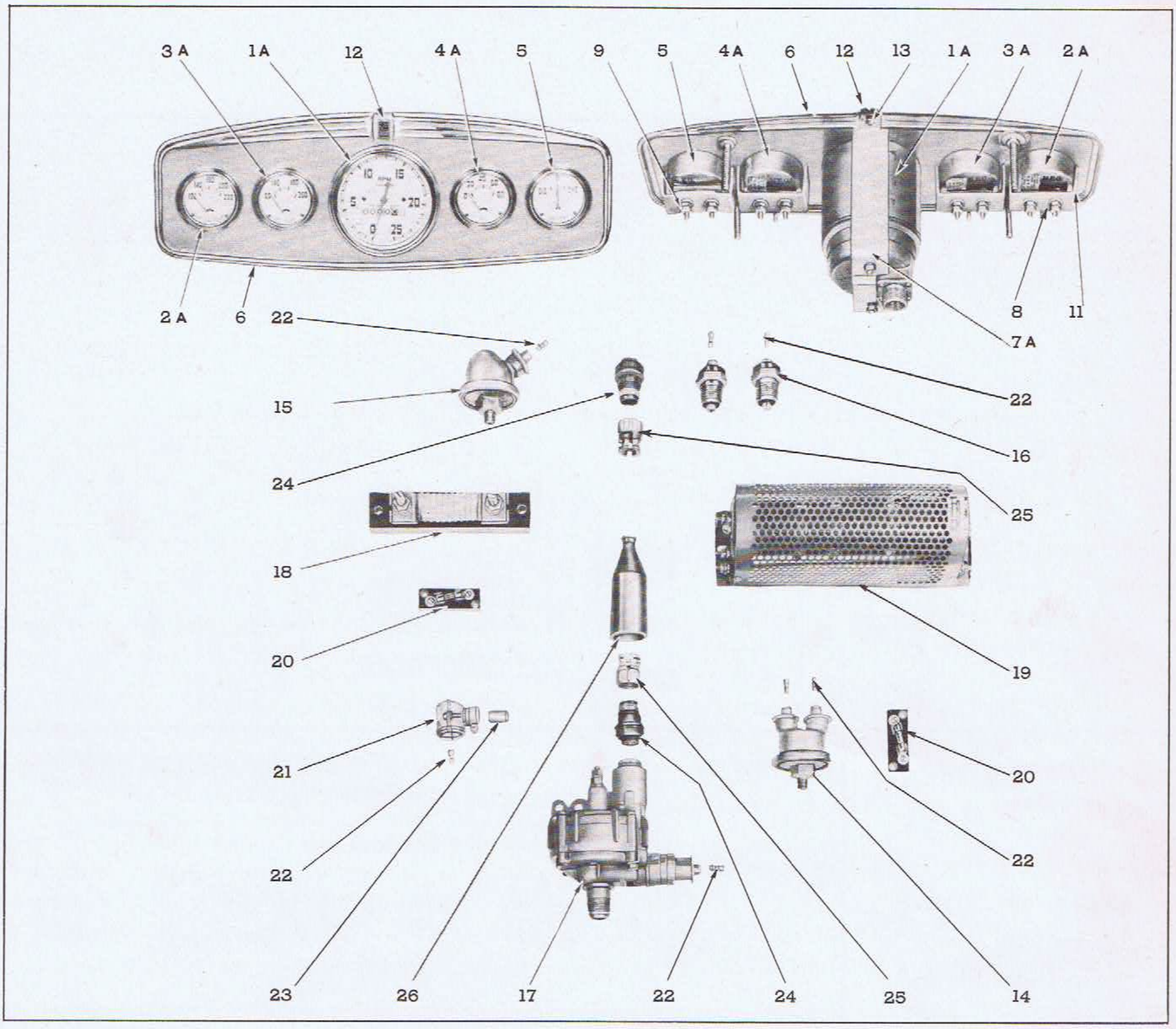



**FIG. 61—PARTS USED WITH SINGLE ENGINE UNIT ELECTRICAL INSTRUMENT PANEL BUT APART FROM THE INSTRUMENT PANEL PROPER.**

14. Switch—Oil Pressure.
15. Gauge—Engine Unit Oil.
16. Gauge—Engine Unit Thermo.
17. Drive Unit—12 Volt.
18. Shunt Assembly.
19. Resistance Assembly.
20. Fuse and Block Assembly.
21. Shield—Radio.
22. Terminal.
23. Bushing—Adapter.
24. Plug—Connector.
25. Clamp Assembly.
26. Boot.

See pages 50 and 51 for wiring diagrams on single and twin engine electrical panels.

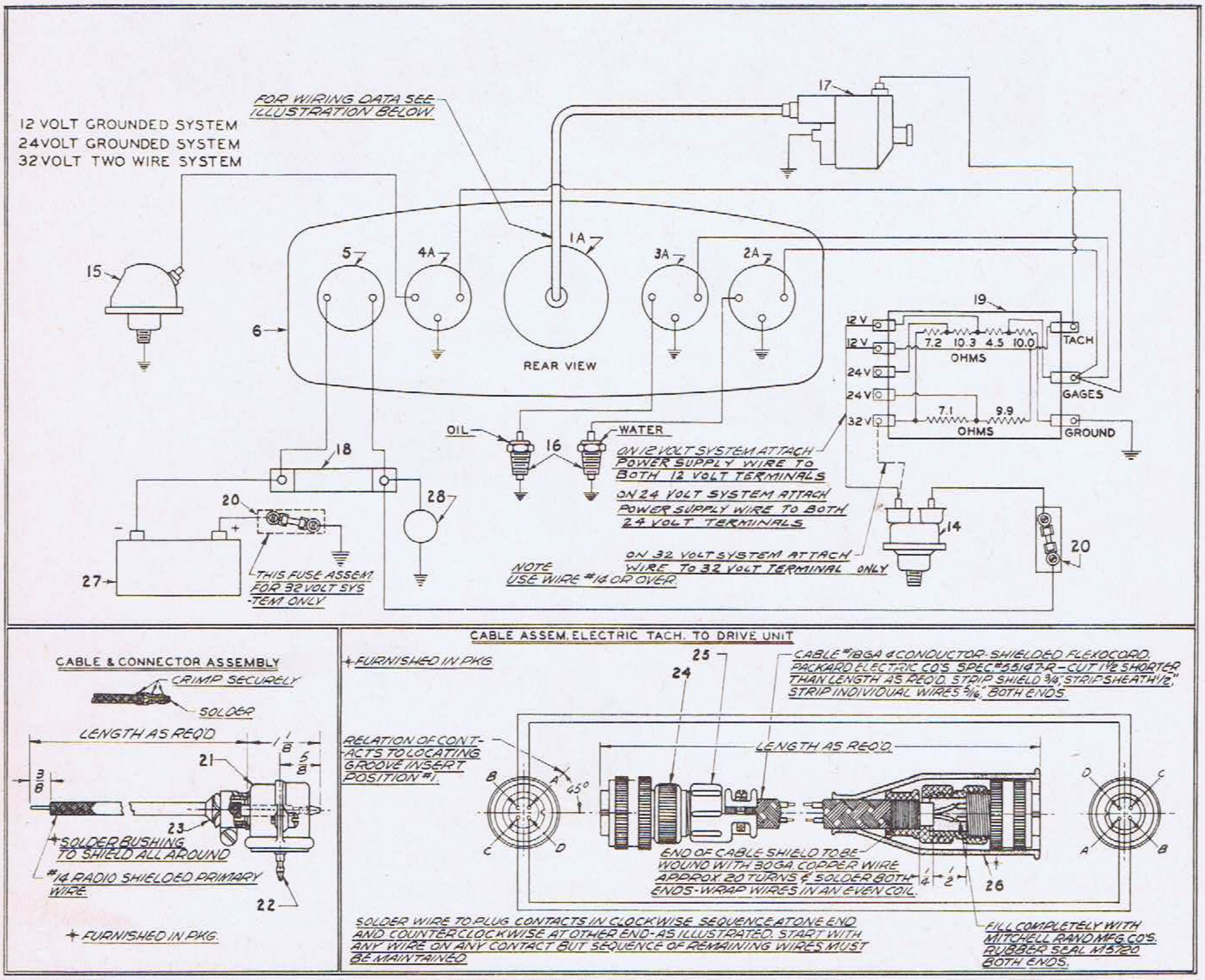



**FIG. 62—WIRING DIAGRAM—ELECTRICAL INSTRUMENT PANEL FOR SINGLE ENGINE UNIT.**

1a. Tachometer Assembly—Electric.
2a. Gauge—Water Temperature.
3a. Gauge—Oil Temperature.
4a. Gauge—Oil Pressure.
5. Ammeter—Battery Charging.
6. Mounting Plate Assembly.
14. Switch—Oil Pressure.
15. Gauge—Oil Pressure—Engine Unit.
16. Gauge—Oil and Water Temperature—Engine Unit.
17. Drive Unit—12 Volt.
18. Shunt Assembly.
19. Resistance Assembly.
20. Fuse and Block Assembly.
21. Shield—Radio.
22. Terminal.
23. Bushing—Adapter.
24. Plug—Connector.
25. Clamp Assembly.
26. Boot.
27. Battery—Storage.
28. Battery Charging Generator.

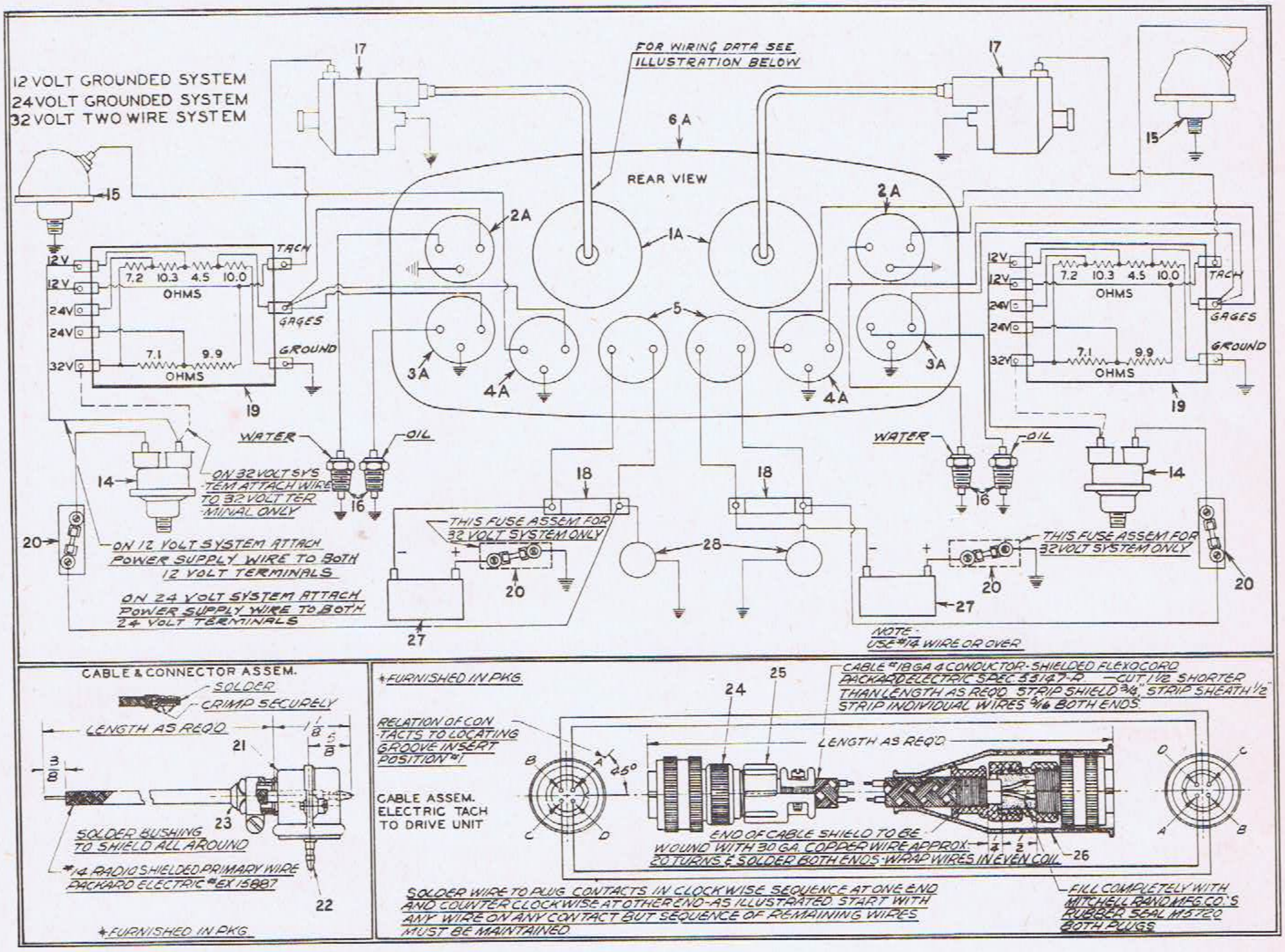


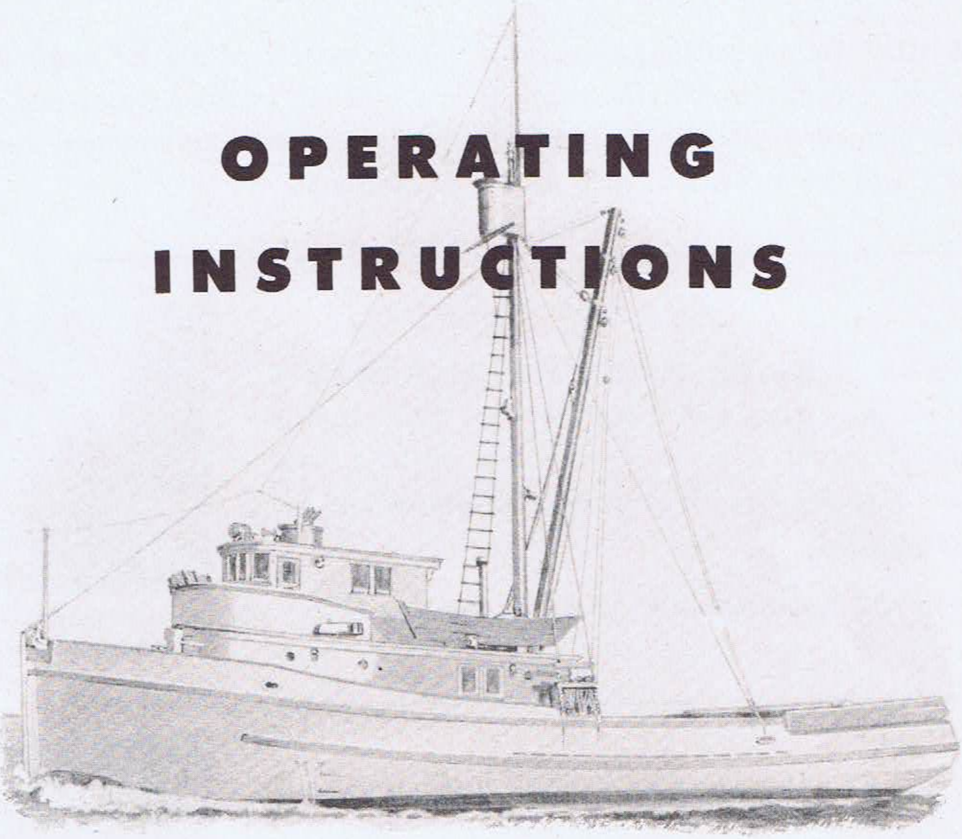

**FIG. 63—WIRING DIAGRAM—ELECTRICAL INSTRUMENT PANEL FOR TWIN ENGINE UNIT.**

1a. Tachometer Assembly—Electric.
2a. Gauge—Water Temperature.
3a. Gauge—Oil Temperature.
4a. Gauge—Oil Pressure.
5. Ammeter—Battery Charging.
6a. Mounting Plate Assembly—Instrument Panel.
14. Switch—Oil Pressure.
15. Gauge—Oil Pressure—Engine Unit.
16. Gauge—Oil and Water Temperature—Engine Unit.
17. Drive Unit—12 Volt.
18. Shunt Assembly.
19. Resistance Assembly.
20. Fuse and Block Assembly.
21. Shield—Radio.
22. Terminal.
23. Bushing—Adapter.
24. Plug—Connector.
25. Clamp Assembly.
26. Boot.
27. Battery—Storage.
28. Generator—Battery Charging.

# SECTION III

## Operating Instructions

# OPERATING INSTRUCTIONS



**The instructions on the following pages for operation of the Series 71 diesel propulsion units are divided into groups under the following headings:**

- **A. Preparation for Starting**
- **B. Starting**
- **C. Running**
- **D. Stopping**
- **E. Storing**

**CAREFUL OPERATING, TOGETHER WITH THOROUGH AND REGULAR MAINTENANCE, PAYS DIVIDENDS IN LOW-COST DEPENDABLE SERVICE.**

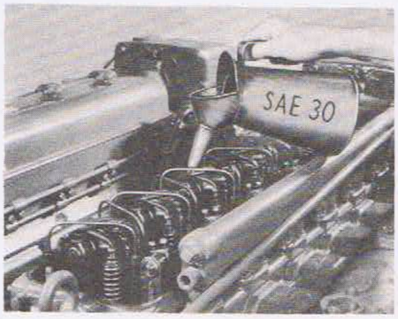
# A—PREPARATION FOR STARTING

Before the first start after installation or a major overhaul, perform *all* of the operations listed below. For routine (daily) starting, carry out the checks and operations listed in *italics.*

**A1 INSTALLATION**—Before starting a newly installed engine, check the installation against the data printed in Section II. Make sure the engine will be provided with an ample supply of air for combustion. Check the fuel oil, cooling water and exhaust piping for correct arrangement and tight, leak-proof joints.

**A2 VALVE AND INJECTOR OPERATING MECHANISM**—Remove valve rocker cover and pour two or three quarts of engine lubricating oil over rockers, valve springs, and push rods. Allow time for this oil to drain into crankcase before performing item A3.

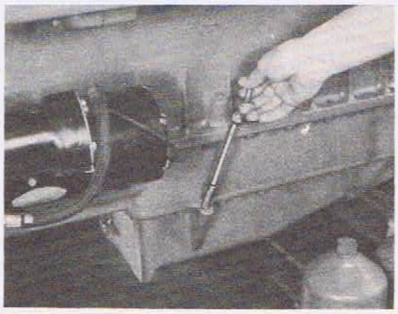
See "Lubricating Oil Requirements", Page 1, Section IV.




LUBRICATE VALVE OPERATING MECHANISM

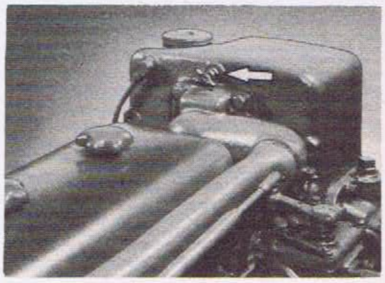
**A3 ENGINE CRANKCASE**—*Check the oil level on the dip stick. Remove the dip stick; wipe the end with a clean rag and re-insert to take level reading. Keep oil level to FULL mark on stick.*

*Use only "Heavy-Duty" detergent type lubricating oils as specified under "Lubricating Oil Requirements" on Page 1, Section IV. SAE 30 above 32°F.; SAE 20, 32° F. to 0° F.; SAE 10 below 0° F.*



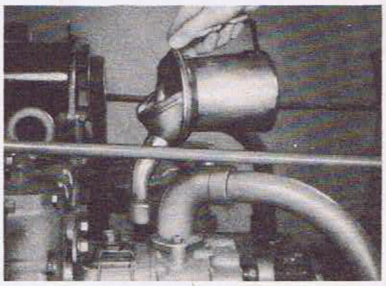
CHECK LEVEL


ADD OIL



VENT VALVE


FILL COOLING SYSTEM



PRIME RAW WATER PUMP

**A4 COOLING SYSTEM**—Close drain cocks in both fresh and raw water systems.

Open air vent on thermostat housing and remove filler cap from expansion tank. *Fill cooling system with clean soft water or a protecting solution of non-evaporating type antifreeze if the engine will be exposed to below freezing temperatures. Liquid level in expansion tank should be kept at about two inches below the filler neck. When using water alone in the cooling system, a reputable brand rust inhibitor may be used to help retard formation of scale and rust.* Close air vent after filling system.

Remove plug in housing of raw water pump and fill reservoir with water. (Prime raw water pump).

Open cocks in raw water piping between hull and pump.

**A5 FUEL TANKS**—Make sure fuel tanks are free of dirt, water or any foreign matter; then fill tanks with clean high-speed diesel fuel. See "Fuel Oil Requirements", Page 2, Section IV.

**A6 FUEL SYSTEM**—To insure prompt starting, the supply side of the fuel system should be practically filled with fuel. When fuel tank is above the primary filter level, remove a vent plug in the cover of the filter and allow the shell to fill with fuel from the tank. When fuel tank is below the filter level, drop the filter shell down from the cover and pour in fuel to fill. Replace shell and tighten retaining bolt. Secondary fuel filter may also be filled by removing the shell from the cover and pouring in fuel.

NOTE: The fuel system of a new engine is filled with a special rust preventive liquid before leaving the factory. If this fluid is still present when preparing to start, priming should be unnecessary. The engine may be started and run on this special fluid until the specified fuel circulates through the system.

PRIME PRIMARY FILTER

PRIME SECONDARY FILTER

---

**A7 REVERSE AND REDUCTION GEARS**—

**Twin Disc Reverse Gears**

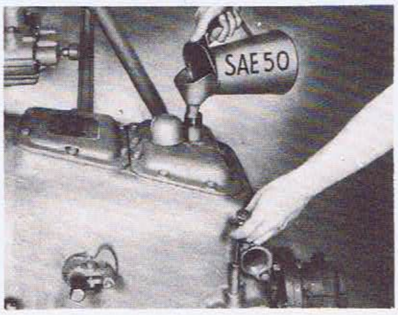
*Check oil level on dip stick and keep filled to HIGH mark. Use only premium grade motor oil of SAE-50 viscosity.*

**S-N Reverse Gears**

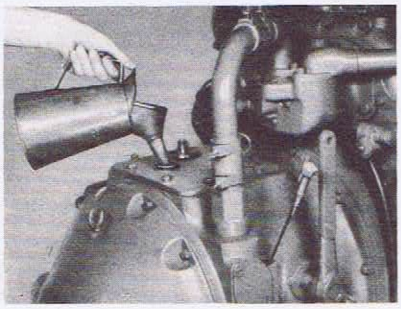
Check oil level on dip stick and keep filled to HIGH mark. The same oil used in the engine crankcase may be used in all S-N reverse gear assemblies. Do not use oil of a viscosity rating lower than SAE-20 or higher than SAE-50.

NOTE 1: The dip stick in S-N reverse gear assemblies on twin engine units are not marked when the units leave the factory. See "Lubrication, S-N Reverse Gears", page 38, Section I for proper marking of dip sticks.

NOTE 2: When an S-N reduction gear assembly is combined with the S-N reverse gear, allow 15 minutes for oil to level off between the two housings before taking final reading on dip stick.




TWIN DISC REVERSE GEAR—
CHECK AND FILL



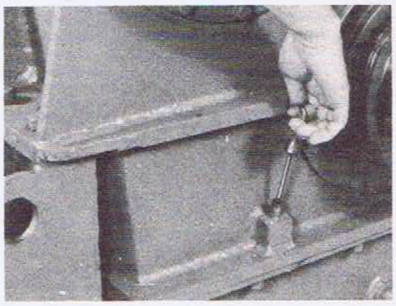
S-N REVERSE GEAR—
CHECK AND FILL

---

**Twin Engine Reduction Gears**

Check oil level on dip stick and keep filled to HIGH mark.

The same oil used in the engine crankcase may be used in this gear box—SAE-30.

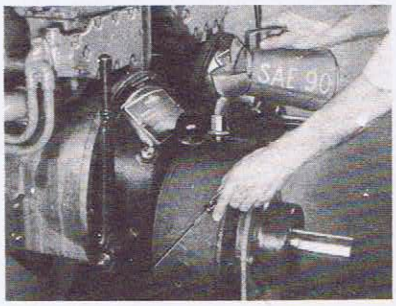


TWIN ENGINE REDUCTION GEAR—CHECK LEVEL

**60 H. P. Front Power Take-off Reduction Gear**

Check lubricant level on dip stick and keep filled to HIGH mark.

Use only a high quality transmission lubricant with a viscosity rating of SAE-90 to SAE-110.




60 H.P. FRONT P.T.O.—CHECK AND FILL

---

**A8 STORAGE BATTERY**—Battery should be fully charged and the electrolyte level should be about ⅜" above the plates. Add only clean distilled water to each cell as required. Check all cable connections for tightness; then coat post and cable end with heavy grease to keep air away from the bare metal.

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**A9 LUBRICATION FITTINGS**—Refer to "Lubrication and Preventive Maintenance", Page 3, Section IV, and lubricate all points other than those mentioned here as instructed. Make sure that initial lubrication of all moving parts will be adequate.

---

**A10 FINAL CHECK OF ENGINE**—Remove all tools, rags, and unnecessary equipment and make sure nothing is blocking the flow of air at the intake to the blower. DISENGAGE CLUTCH OR CLUTCHES and set throttle in STOP position, (check cam on top of governor—See "D2"—to verify throttle setting) then press starting switch and allow starting motor to crank engine over a few turns. Observe entire installation carefully while cranking. If there are no unusual noises or vibrations, and everything seems "ship-shape", the engine should be ready to start and run.

---

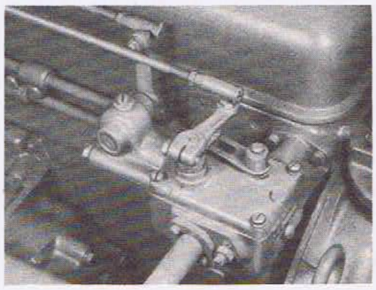
# B – STARTING

**B1** Carry out the instructions under "Preparation for Starting", performing *all* the operations for the first start after installation or a major overhaul and only those operations *printed in italics* for a routine start. Be sure the shifting lever on each reverse gear is in NEUTRAL position.

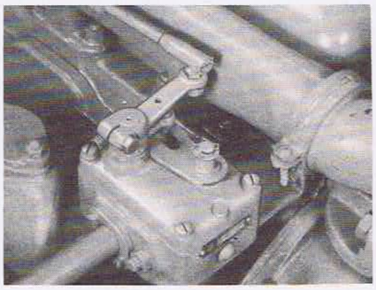
**B2 THROTTLE AND STARTING MOTOR SWITCH**—Set throttle in starting position and check levers at governors to make sure throttle is properly connected. The illustrations show governor controls in correct position for starting.

Crank engine by pressing on starting motor switch.

CAUTION: Avoid overheating starting motor. Do not operate for more than 30 seconds at a time.



STARTING POSITION—
VARIABLE SPEED GOVERNOR



STARTING POSITION—
LIMITING SPEED GOVERNOR

**B3 USE OF AIR HEATER FOR COLD WEATHER STARTING**—At air temperatures below 40° F., a special air heater may be used to assist in starting. See "Cold Weather Starting", Page 10, for complete description of air heater.

(a) Set throttle in starting position.

(b) Turn on air heater switch.

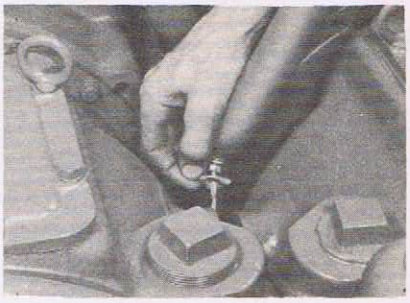
(c) Engage starting motor and at the same time operate the air heater pump plunger with slow, firm strokes at a rate of about 5 strokes in ten seconds.

(d) When engine will run alone, regulate throttle for about half-speed and push plunger of pump way in.

(e) Turn off air heater ignition switch.

**B4 OIL PRESSURE**—Immediately after starting, check oil pressure on gauge. If no pressure shows after 10 to 15 seconds, shut down engine and investigate lubrication system.

**B5 WARM UP PERIOD**—Allow engine to run at about 1200 r.p.m. for five minutes before applying load. If necessary, load may be applied without warm-up.



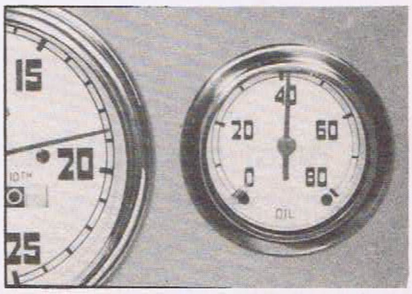
CHECK RAW WATER FLOW

**B6 COOLING SYSTEM**—Check to see that water is being discharged from raw water pump. This may be done by opening a cock in the pump discharge pipe. If water is not flowing, stop engine immediately and locate the trouble.

**B7 CHECK FOR WATER, FUEL AND LUBE OIL LEAKS**—With the engine running at operating temperature and before getting under way, look the unit over carefully for leaks in the water, fuel, or lube oil systems. Tighten joints where necessary to prevent waste and help keep engine room clean.

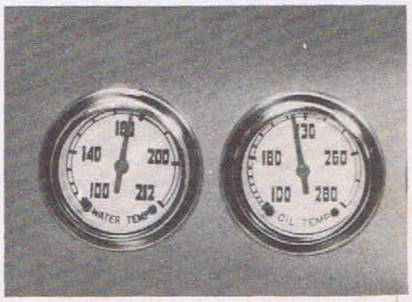
# C—RUNNING

**C1 ENGAGE CLUTCH**—With engine running at idle speed, shift reverse gear into either forward or reverse position. All clutches should move into the over-center, engaged position with a strong, noticeable snap. Throttle engine to idle speed before changing direction of propeller rotation.




NORMAL PRESSURE AT FULL SPEED

**C2 OIL PRESSURE**—Observe oil pressure regularly on gauge. If pressure falls below 20 lbs. at operating speed, an investigation should be made. Four pounds pressure is satisfactory at idle speed.

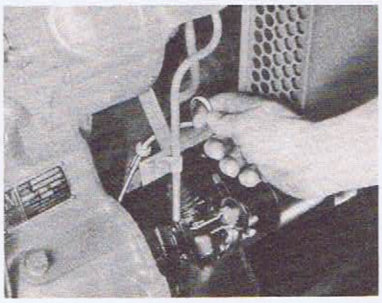


NORMAL OIL AND WATER TEMPERATURES

**C3 TEMPERATURES**—With engine WARMED and running under normal conditions, water temperature should average between 160° and 180° F. with corresponding oil temperature between 215° and 235° F. Any large variations from these temperatures should be investigated.

**C4 OIL AND WATER LEVELS**—After 8 to 10 hours of operation, shut down engine and check level of oil in crankcase. Engine should be stopped about 5 minutes before reading level on dip stick. Add oil if necessary to bring level to HIGH mark on stick. See "Lubricating Oil Requirements", Page 1, Section IV for correct lubricating oil to use.

Remove cap from expansion tank to check level of water in fresh water cooling system. Level should be to top of tank with engine at operating temperature. Add clean, soft water as required.



CHECK OIL LEVEL

**C5 MAINTENANCE** — Refer to "Lubrication and Preventive Maintenance", Page 3, Section IV and carry out those operations that apply for the number of hours the unit has been in operation:

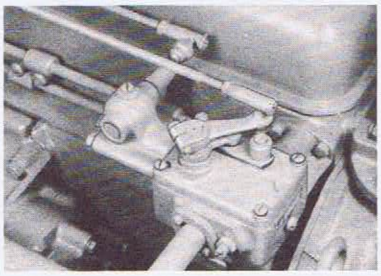
Example: If unit has been in operation 500 hours, perform those operations listed under "After Each 500 Hours of Operation".

# D – STOPPING

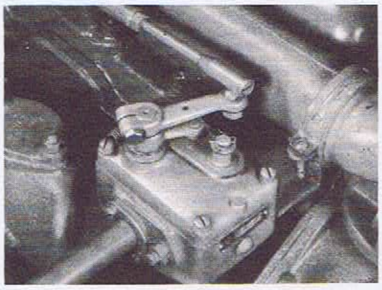
**D1 CLUTCH**—Reduce engine speed to idle and shift clutch or clutches to NEUTRAL position.

**D2 THROTTLE** — If possible, set throttle at about half speed and allow engine to run without load for about 5 minutes before shutting down. If some time, at low engine speed, is required to get boat into berth, this operation will take the place of half speed running before shut down.

Move throttle to NO FUEL position to shut down engine.



NO FUEL POSITION—
VARIABLE SPEED GOVERNOR



NO FUEL POSITION—
LIMITING SPEED GOVERNOR

**D3 CLEAN ENGINE** — Clean the outside of the engine, wiping off all dirt, oil and grease. Keep the engine clean and make service operations more pleasant.

**D4 MAINTENANCE**—Refer to "Lubrication and Preventive Maintenance", Page 3, Section IV and perform all operations required daily—check oil levels, water level, and fill fuel tanks. Also perform all operations required for the number of hours engine has been in operation. Take care of any repairs or adjustments indicated as necessary by operation during the run just completed.

# E – STORING

When the engine is to be stored or removed from operation for a six month period or less, special precautions should be taken to protect the unit against rust accumulation, corrosion on the wearing surfaces, and gumming in the fuel system. The parts requiring attention and the recommended preparations to use are shown in the chart below.

**TEMPORARY STORAGE (SIX MONTHS OR LESS)**

| SYSTEM | SPECIFICATIONS | REMARKS |
|---|---|---|
| Lubrication System | SAE 30-above 32° F.<br>SAE 20-32° F, to 0° F.<br>SAE 10-below 0° F.<br>See "Lubricating Oil Requirements", Page 1, Section IV. | 1 Drain crankcase.<br>2 Renew Lube Oil filter elements.<br>3 Replace drain plug securely.<br>4 Fill crankcase with new clean oil.<br>NOTE: Do not use any special rust-proofing oils, solvents, or flushing oils in crankcase. |
| Transmission Assembly | Twin Disc Reverse Gear—SAE 50.<br>S-N Reverse Gear—same as engine. Never less than SAE 20.<br>Twin Reduction Gear—same as engine.<br>Twin Disc F.P.T.O. Reduction—SAE 90-110 Transmission Lubrication. | 1 Drain transmission case.<br>2 Replace drain plug securely.<br>3 Fill transmission with new clean oil. |
| Fuel System | Part No. 5192065 | 1 Drain fuel tank completely.<br>2 Fill fuel tank with 3 gals. Part number 5192065, special rust-proofing fuel.<br>3 Clean primary fuel strainer.<br>Renew secondary fuel filter element.<br>5 Run engine for two minutes at no load, approximately 400 r.p.m. NOTE: Do not drain fuel system after run. |
| Cooling System | | 1 Drain all cooling water from system.<br>2 Leave drain cocks and vent valves *open*. |
| Engine Exterior | | 1 Clean entire exterior of engine with Fuel Oil and wipe or blow dry.<br>2 Time injectors and lash exhaust valves—See Sec. IV.<br>3 Protect all exposed Ferrous Parts with a thin coat of commercial rust preventive.<br>4 Insert a strip of grease-proof paper approximately 2" wide between each V-belt pulley to prevent rubber from bonding to pulley.<br>5 Close all engine openings with masking tape, cardboard, plywood, or metal covers. |
| Electrical | | 1 Remove battery from engine and store in a warm, dry place.<br>2 Fill battery with distilled water and have fully charged before storing. |

**Engines prepared in this manner may be put into service immediately after removal of the covers, filling the cooling system and the fuel tank. No flushing or any other preparation is required.**

**When longer periods of storage are required, consult the Manufacturer.**

# COLD WEATHER STARTING

When starting an internal combustion engine in cold weather, a large part of the energy of combustion is absorbed by the pistons, cylinder walls, cooling water, and in overcoming friction.

Under extremely low outside temperatures, the cold oil in the bearings and between the pistons and cylinder walls creates very high friction and the effort to crank the engine is much greater than when the engine is warm.

In the Diesel engine, the only means of igniting the fuel sprayed in the combustion chamber is the increased temperature due to compressing the air.

This temperature becomes high enough under ordinary operating conditions, but may not be sufficiently high at extremely low outside temperatures to ignite the charge.

Under these unusually cold conditions, therefore, some external means of warming the in-going air may be necessary.

To assist in engine starting under low temperature conditions, an air heater assembly—described below and illustrated in Fig. 1—has been provided.

## AIR HEATER FOR COLD WEATHER ENGINE STARTING

The air heater shown in Fig. 1 preheats the in-going charge of air to the cylinders sufficiently to insure an engine start at freezing temperatures, providing the lubricating oil in the engine is of the viscosity recommended for winter use, so that sufficiently high engine cranking speeds are possible with fully charged batteries. One heater unit is provided on the engine.

**DESCRIPTION**—The air heater is essentially a small, pressure oil burner with electric ignition, very similar in principle to the burners now common in domestic furnaces. The burner proper is mounted in the engine air box, obtaining the necessary air for combustion from the charging blower, and discharging the products of combustion and the directly flame-heated air into the engine cylinders with practically no heat loss. This results in an immediate response of the engine.

The device consists of two assemblies. One unit comprises the pressure pump and ignition switch and is mounted conveniently in the control panel. The other unit contains the nozzle, filter, ignition coil and ignition points, and replaces one of the hand hole cover plates on the cylinder block. The pump is intended to supply fuel under pressure to the burner unit where the charge is filtered before reaching the discharge nozzle. The suction side of the pump is connected to the fuel tank. The switch is connected in the line between the negative terminal of the starting battery and one terminal of the ignition coil on the burner, the other terminal of the coil (primary) being grounded.

The pump plunger, when not in use, is held in the "IN" position by a simple spring and ball mechanism and may be released by pulling the plunger out from the panel.

The pump plunger is so proportioned that a firm pressure (10 lbs. or over) on the knob will deliver finely atomized fuel from the nozzle. This fuel can be readily ignited by the spark at the electrodes on the burner. The rate of travel of the plunger on the pumping stroke is determined by the flow of oil from the discharge nozzle and normally takes 3 to 4 seconds per stroke.

**OPERATION**—When starting a cold engine with the air heater, the sequence of operation is as follows:

**AIR HEATER INSTRUCTIONS—**

1. Open throttle to "Idle" or "Run" position.
2. Turn switch (23) on instrument panel to starting position.
3. Engage starting motor, simultaneously operating the heater pump plunger in slow, firm strokes at a rate of approximately 5 strokes per 10 seconds.
4. When engine is running, regulate throttle and lock heater pump plunger.
5. Turn off heater ignition switch (23).

Engine usually starts firing during the first or second pumping stroke. At low temperatures, with heavy lubricating oil, the engine may fire for a time with the combined help of the starter and heater before developing sufficient power to run unassisted. Under these conditions, it is advisable to pause briefly at the end of each pumping stroke to allow the engine time to absorb the heat generated.

*Since the air heater acts as a second source of fuel, the engine throttle should be regulated accordingly during this operation.*

*CAUTION: Dependable starting of a Diesel engine by any means can only be obtained with adequate cranking speed. The lubricating oil*

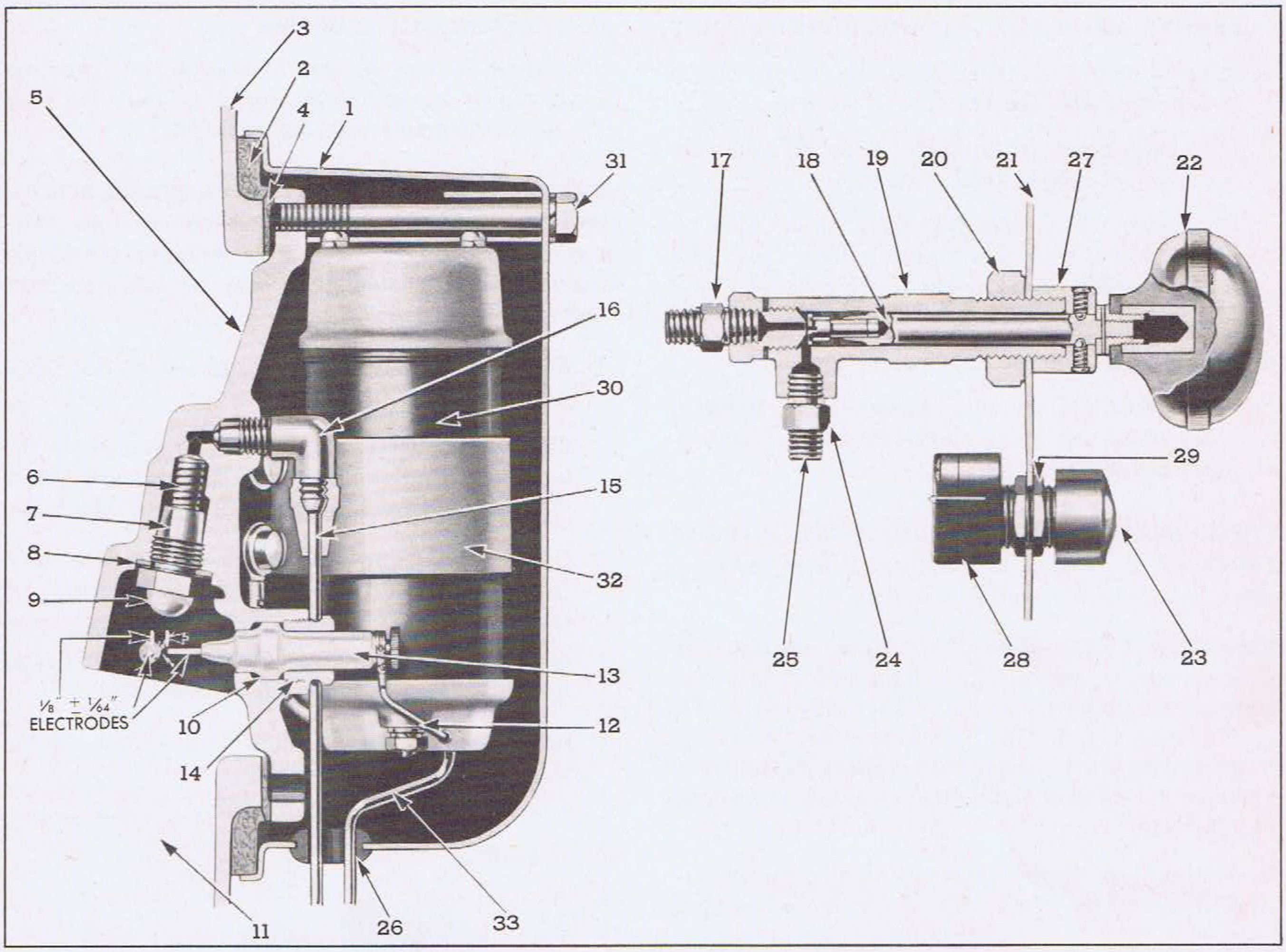



**FIG. 1—AIR HEATER ASSEMBLY.**

1. Cover—Heater Body.
2. Felt Seal.
3. Cylinder Block.
4. Gasket (Cork).
5. Body—Air Heater.
6. Filter Spring.
7. Filter.
8. Washer.
9. Nozzle—Air Heater.
10. Gasket—Air Heater Insulator.
11. Air Box.
12. Lead—High Tension.
13. Insulator Assembly—Electrode.
14. Insulator Nut.
15. Fuel Line.
16. Elbow—Fuel Line.
17. Valve Assembly—Outlet Check.
18. Pump Plunger.
19. Pump Body.
20. Lock Nut.
21. Panel—Control.
22. Pump Knob.
23. Button—Air Heater and Starter Switch.
24. Valve Assembly—Intake.
25. Fuel Supply.
26. Grommet.
27. Plunger Nut.
28. Switch—Air Heater and Starter.
29. Lock Nut.
30. Coil—High Tension.
31. Bolts—Cover-to-Body.
32. Mounting Strap—Coil.
33. Wire—Battery Lead.

*used in cold weather must meet the specifications shown on Page 1, Sec. IV.*

The battery must be kept fully charged and in good condition.

**INSTALLATION**—The general details of the installation of the air heater are shown in Fig. 1. The unit comprising the nozzle, filter, and coil is mounted to the cylinder block in place of the hand hole cover plate. The pressure pump and ignition switch are mounted in the instrument panel, convenient to the engine operator.

Air box drains must be open to avoid fuel accumulating in the air box.

**SERVICE**—If engine fails to start after two or three heater pump strokes, made while cranking the engine with wide open throttle, it is advisable to stop cranking and check for possible causes of failure. Assuming that the engine is in running order and cranking speed is 80 r.p.m. or over, the heater should be investigated for (a) *Failure of Ignition* and (b) *Poor Oil Spray*. To make this investigation, the heater should be removed from its position on the cylinder block and reconnected outside of engine in such a position that the heater operation can be readily observed. To remove the heater from the cylinder block, refer to Figs. 1 and 2 and proceed as follows:

**REMOVE AIR HEATER FROM CYLINDER BLOCK**

1. Remove two bolts (31) attaching cover (1) to heater body (5). See Fig. 1.
2. Lift heater cover (1) off heater body (5) and slide cover down battery lead wire (33).
3. Disassemble fuel line (15) from elbow (16) on heater body, and disconnect battery lead (33) from coil (30). Slide cover (1) off wire (33) and fuel line (15) to heater body (5). Fig. 1.
4. Remove felt seal (2) from heater body.
5. Remove bolt (34) attaching heater body to cylinder block; then, lift heater body (5) away from cylinder block (3).

**CHECK HEATER UNIT—REMOVED FROM CYLINDER BLOCK**—With heater unit removed from cylinder block, it may be checked as follows:

Reassemble heater unit—*away from engine*. Disconnect starting motor wiring from switch on instrument panel. With wiring of air heater only attached to switch, turn switch ON. Coil interrupter should vibrate rapidly and a continuous hot spark should occur between the ignition electrodes. Then turn the heater switch OFF.

A cone-shaped discharge of oil should be emitted from the nozzle (9), Fig. 1, when the pump is operated.

NOTE: These two tests should NOT be made at the same time, as the burner throws a considerable flame and will ignite any surrounding combustible material.

(a) **COIL INTERRUPTER DOES NOT VIBRATE WHEN SWITCH IS CLOSED:**

Check coil points for dirt or carbon and wiring for loose or broken connections. Points may be cleaned with fine sandpaper or a special point file, and should be reset after cleaning to give .018″ gap with the armature or vibrator arm held against the coil body.

(b) **SPARK JUMPS ACROSS PORCELAIN OF ELECTRODE:** Check gap and, if necessary, reset wire electrode to aproximately ⅛″. If gap is correct, then remove porcelain electrode by removing threaded gland and withdrawing electrode assembly. Care should be taken that small copper gasket (10) under the electrode is not dropped out and lost. Porcelain may be cleaned by washing off in gasoline and scraping or sanding off any carbon accumulation. Reassemble as indicated by Fig. 1.

(c) **SPRAY NOZZLE PLUGGED:**

Indicated by excess resistance on pressure pump or by failure of nozzle to "fog" the fuel. Nozzle assembly must be removed.

**REMOVE NOZZLE ASSEMBLY FROM HEATER BODY—HEATER REMOVED FROM CYLINDER BLOCK**—With heater assembly removed from cylinder block, the nozzle and associated parts may be removed from heater body as follows:

1. Again disconnect fuel line and battery lead line connections.
2. Remove insulator and electrode assembly by loosening insulator nut (14), taking care not to lose small copper gasket (10) under electrode.
3. Unscrew fuel line elbow (16) and remove. (See Fig. 2.)
4. Using a screwdriver, remove two screws (43) holding high tension coil strap (32) to air heater body (5). Remove high tension coil (30).
5. Remove screw (40), with wire electrode on tip, from inside of heater body.

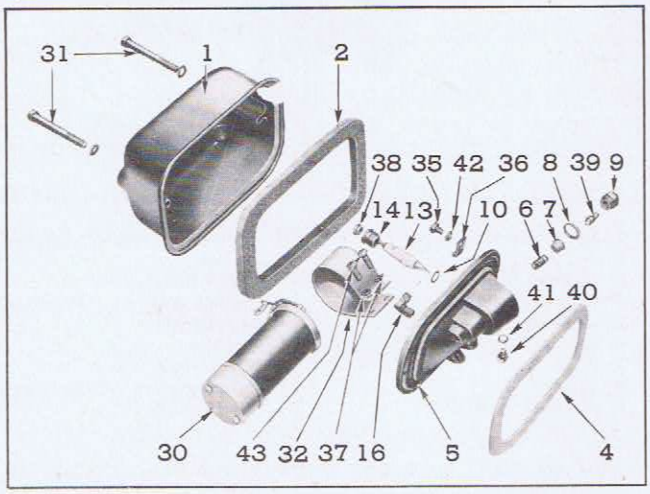



**FIG. 2—AIR HEATER DETAILS AND RELATIVE LOCATION OF PARTS.**

1. Cover—Heater Body.
2. Felt Seal.
4. Gasket (Cork).
5. Body—Air Heater.
6. Filter Spring.
7. Filter.
8. Washer.
9. Nozzle—Air Heater.
10. Gasket—Air Heater Insulator.
13. Electrode.
14. Insulator Nut.
16. Elbow—Fuel Line.
30. Coil—High Tension.
31. Bolts—Cover-to-Heater Body.
32. Mounting Strap—Air Heater Coil.
35. Bolt—Tubing Clip-to-Heater Body.
36. Tubing Clip.
37. Lock Washer—Mounting Strap.
38. Nut—Electrode Post.
39. Swirl Pin.
40. Screw—Air Heater Electrode.
41. Lock Washer—Electrode.
42. Lock Washer—Tubing Clip.
43. Screws — Mounting Strap-to-Body.

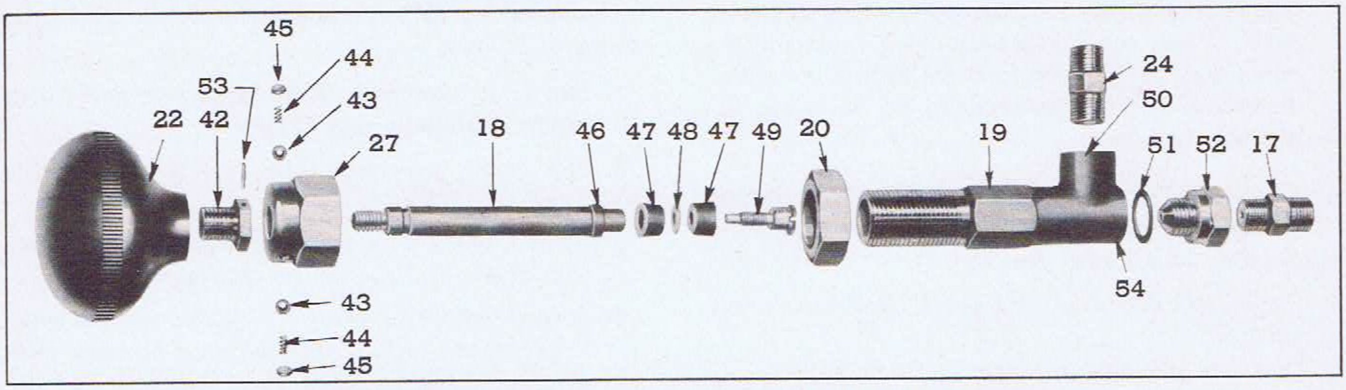



FIG. 3—AIR HEATER PUMP AND RELATIVE LOCATION OF PARTS.

17. Valve Assembly—Outlet Check.
18. Pump Plunger.
19. Pump Body.
20. Lock Nut.
22. Pump Knob.
24. Valve Assembly—Intake.
27. Plunger Nut.
42. Knob Adaptor.
43. Steel Ball.
44. Lock Spring.
45. Expansion Plug.
46. Stop Shoulder—Plunger.
47. Piston Cups.
48. Washer—Piston Separator.
49. Screw—Piston Retaining.
50. Inlet Opening.
51. Gasket—Check Valve Adaptor.
52. Adaptor—Outlet Check Valve.
53. Groove Pin.
54. Outlet Opening.

6. With a thin walled ⅝" socket wrench, remove burner nozzle (9).
7. With a screwdriver, remove swirl pin (39) from nozzle assembly.
8. Jar filter (7) and spring (6) out of heater body.

Wash all parts clean, and dry with compressed air, if possible. DO NOT USE STEEL WIRE OR DRILL TO CLEAN NOZZLE. THE SIZE AND SHAPE OF THE GROOVES AND ORIFICES ARE VERY IMPORTANT AND ANY DAMAGE WILL RENDER NOZZLE USELESS.

**ASSEMBLE HEATER UNIT**—Refer to Fig. 2 for relative location of parts and assemble heater unit as follows:

1. Screw swirl pin (39) into nozzle (9).
2. Insert spring (6) and heater filter (7) in cavity of heater body (5), with washer end of filter out.
3. Position washer (8) against shoulder of nozzle (9) and screw nozzle assembly into heater body.
4. Install electrode screw (40) and lock washer (41) into side of heater body below nozzle.
5. Position coil and mounting strap (32) in place on heater body (5). Secure with screw (43) and lock washer (37). Fasten short wire (12) from coil to electrode (13).
6. Attach fuel line elbow (16) to heater body—large end screws into casting. Tighten elbow until small end points down, in position to connect fuel line.
7. Install insulator gasket (10) on lower shoulder of electrode (13) and assemble electrode into heater body, tightening insulator nut (14) firmly.
8. Set electrode gap at ⅛". (Bend electrode on screw (40) only.)

**ATTACH AIR HEATER ASSEMBLY TO CYLINDER BLOCK**

1. Place cork gasket (4) (dry) on inner face of heater body flange (5) (see Fig. 2).
2. Attach air heater to cylinder block with bolt (34) and lock washer at center of heater body. Tighten firmly, but not too tight.
3. Place felt seal (2), shown in Figs. 1 and 2, around outside edge of heater body and next to cylinder block.
4. Make sure rubber grommet is in place on air heater cover. Thread battery lead (33) and fuel line (15) through grommet and connect lead to coil. Also connect fuel line to elbow.
5. Set heater cover (1), Fig. 1, in place. Adjust felt seal and fasten cover to heater body with two bolts and lock washers.

**PRESSURE PUMP**—Failure of the pressure pump can occur from two causes: (1) *check valves* and (2), *plunger piston cups.*

1. The Suction and Discharge Check Valve Assemblies are threaded into the pump casting. An arrow indicating the direction of flow is stamped on each valve and the suction check valve (½ lb. valve) is marked "½". The check valves are of the spring-loaded-ball type and the parts cannot be disassembled without being damaged. The valves can be cleaned, if necessary, by forcing gasoline through them with any suitable pump.
2. The piston cups are molded from a special oil resistant composition and if they should break or

become worn, they must be replaced by duplicate parts. When any pump parts need replacing the pump may be removed from the instrument panel, disassembled and reassembled by following the instructions below:

**REMOVE HEATER PUMP FROM INSTRUMENT PANEL**—The heater pump may be removed from the instrument panel as follows: (See Fig. 1).

1. Disconnect fuel inlet and outlet lines from pump valves.
2. Unscrew plunger nut (27) and withdraw pump plunger assembly from pump.
3. Loosen lock nut (20) behind instrument panel (21).
4. Lift pump body assembly (19) out of rear of panel.
5. Remove lock nut (20) from pump body.

**INSPECTION—PUMP AND PLUNGER ASSEMBLY**—After removing and thoroughly cleaning in gasoline or fuel oil, examine piston cups carefully for breaks, cracks or evidence of wear. If any of these conditions exist, piston cups must be replaced.

**DISASSEMBLE AIR HEATER PUMP**—Note that when the air heater pump was removed from the panel the plunger assembly was removed from the pump body. Further disassembly of the pump may be carried out as follows: (See Fig. 3).

1. Remove piston retaining screw (49) and piston cups (47) from end of plunger assembly.
2. Remove piston cups (47) and piston separator (48) from retaining screw (49).

   (If any defect is apparent in the plunger nut or lock ball, this assembly can be removed by performing operations 3 to 6, below.)
3. Unscrew knob (22) from plunger assembly.
4. Remove pin (53) from adaptor (42) and unscrew adaptor from plunger (18).
5. Slide plunger nut (27) off end of plunger (18).
6. Steel balls (43) and springs (44) may be removed through the bore of the plunger nut by tapping the nut to dislodge them. The plugs (45) need not be disturbed.
7. Clamp pump body (19) between soft jaws of bench vise and remove inlet (24) and outlet (17)—check valve assemblies.
8. Remove outlet check valve adaptor (52) and gasket (51) from pump body.

**ASSEMBLE AIR HEATER PUMP**—Refer to Fig. 3 for relative location of parts and assemble the air heater pump as follows:

1. Slip one piston cup (47)—large end first—over piston retaining screw (49).
2. Slip piston separator (48) over screw, next to piston cup (47).
3. Slide other piston cup (47)—small end first—over screw and up against separator.
4. Screw retaining screw (49)—with cups and separator attached—into end of pump plunger (46).

   If parts were removed from plunger nut, reassemble as follows:
5. With a pair of small-nose pliers, drop lock springs (44) into holes on inside of plunger nut (27). Then drop steel lock balls (43) into holes on top of springs.
6. With a small screwdriver or similar tool, depress lock balls and slide plunger nut (27)—hex-end first—over small end of plunger.
7. Attach knob adaptor (42) and tighten until pin holes in adaptor and plunger (18) line up. Then insert groove pin (53).
8. Apply non-hardening cement to knob adaptor (42) and securely screw knob (22) on adaptor.
9. Install gasket (51) over shoulder of outlet check valve adaptor (52) and screw adaptor into outlet opening (54) of pump body (19).
10. Install outlet check valve (17) in adaptor (52).

NOTE: This check valve is marked "30" and the arrow, also marked on the valve, should point away from the pump body when assembled.

11. Install inlet check valve (24) in opening (50) (side opening) with arrow on valve directed towards pump body. (*This valve is marked "½"*.)

**ATTACH AIR HEATER PUMP TO INSTRUMENT PANEL**—The air heater pump may be attached to the panel by reversing the sequence of operations for removal and referring to Fig. 1 for a guide, as follows:

1. Screw lock nut (20) onto outer end of pump body (19).
2. Insert threaded end of pump body (19) through hole in instrument panel (21), from rear of panel.
3. Lubricate piston cups and slide plunger assembly (18) into pump body (19), being careful not to damage lips of piston cups. Screw plunger nut (27) onto end of pump body and tighten lock nut (20) against rear face of panel.
4. Attach fuel lines to inlet and outlet connections.

# SECTION IV

## Maintenance

## LUBRICATING OIL REQUIREMENTS FOR GENERAL MOTORS SERIES 71 TWO-CYCLE DIESEL ENGINES

**QUALITY** Lubricating oils for Series "71" Diesel engines must possess high oxidation resistance, low tendency towards formation of carbon deposits and non-corrosiveness to copper-lead bearings.

Commonly quoted inspection data, such as Gravity, Flash and Fire Points, Carbon Residue, etc., do not bear any significance to the performance of the lubricant in an engine.

The operator is, therefore, entirely dependent on the experience and reliability of his oil supplier.

***Satisfactory operation of heavy-duty engines for long periods of time, requires use of the specially compounded "Heavy Duty Lubricants."***

These superior oils provide better lubrication, possess more heat resistance, and counteract sludge formation more efficiently than ordinary motor oils. Their higher initial cost is more than offset by greatly increased life.


Heavy-Duty Lubricants are marketed, by most oil companies, for use in high-speed Diesel and Gasoline engines.

**VISCOSITY**—the recommended viscosity grade for all operating conditions is SAE-30.

Only when prolonged engine exposure to temperatures below freezing is unavoidable, use of the following lighter grades of oil is permissible to facilitate cold starting.

| ATMOSPHERIC TEMPERATURE | VISCOSITY GRADE |
|---|---|
| +32°F to 0°F | SAE—20W |
| Below 0°F | SAE—10W |

**FILTRATION**—Satisfactory engine lubrication requires continuous cleaning of the oil.

Heavy-Duty Lubricants will always appear dark-colored on account of their exceptional ability to keep fine carbon particles in suspension.

Since the oil color can, therefore, not be used any more as an indicator for proper filter action, removal of abrasive dust, metal and carbon must be insured by periodic replacement of the absorption filter elements simultaneously with each oil change.

Engines equipped with full-flow oil strainers require additional cleaning of the edge-type strainer elements at every third oil change.

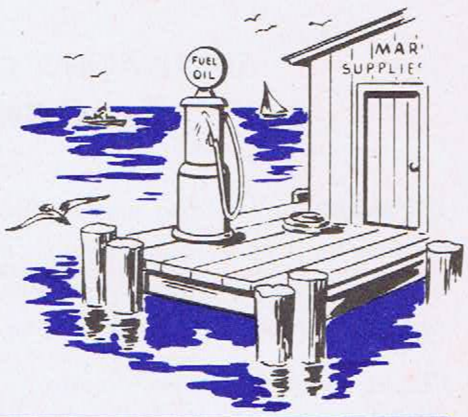
**RENEWAL**—All mineral oils deteriorate in service. To remove the acidic and resinous materials thus formed, the crankcase content must be renewed in regular intervals.

The frequency of these oil changes depends on the quality of the lubricant, the efficiency of filtration, and the severity of service.

When using recognized oils of the "Heavy-Duty" type the interval suggested for changing oil is EVERY 200 HOURS.

Selection of a reliable oil supplier, strict observation of his oil change recommendations and proper filter maintenance serve best to insure trouble-free lubrication.

## FUEL OIL REQUIREMENTS FOR GENERAL MOTORS SERIES 71 TWO-CYCLE DIESEL ENGINES

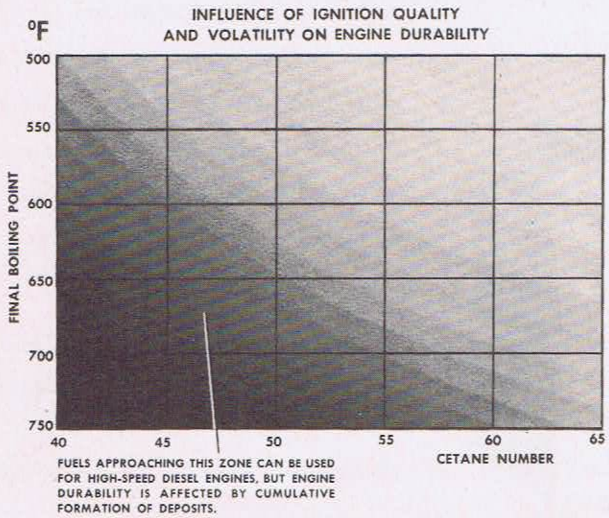



**I.** For satisfactory operation of high-speed Diesel engines over long periods of time, clean, completely distilled petroleum fuel oils must be used.

Suitable fuels range in color from clear white to medium yellow.

**II.** Commercial standards for Diesel fuel oils have not been established.

As a guide for the purchase of suitable fuels, the following specification data are recommended:




| | Summer | Winter | ASTM Test Method Number |
|---|---|---|---|
| Cetane No., minimum | 54 | 50 | D-613 |
| Initial Boiling Point, min. | 325° F | 325° F | D-158 |
| 90% Boiling Point, max. | 625° F | 550° F | D-158 |
| Final Boiling Point, max. | 675° F | 590° F | D-158 |
| Kinematic Viscosity @ 100° F | 1.8-4.5 | 1.8-3.0 | D-445 |
| Total Sulfur Content, max. | .50% | .25% | D-129 |
| Corrosive Sulfur Content | None | None | D-130 |
| Water and Sediment, max. | 0.05% | 0.05% | D-96 |
| Ash, max. | 0.01% | 0.01% | D-482 |
| Carbon Residue, max. (See Note 1) | 0.15% | 0.15% | D-189 |
| Flash Point | See Note 2 | | D-93 |
| Pour Point | See Note 3 | | D-97 |

NOTES 1. Carbon Residue to be determined on 10% distillation residum.

2. The Flash Point of a fuel oil has no influence on its performance in an engine but may have to be specified by the purchaser for storage or legal reasons.

3. The Pour Point of a fuel oil determines its fluidity at low temperatures, but has no other influence on engine operation. To prevent flow restrictions in cold weather, the pour point must be specified at least 10°F below the lowest expected fuel temperature.

**III.** For efficient combustion in high-speed Diesel engines, two fuel properties are of foremost importance: Volatility and Ignition Quality.

The ignitability of fuel oils is expressed in terms of "Cetane Numbers", high values indicating short ignition delay, easy starting and smooth combustion.

The volatility of fuel oils is numerically represented by their boiling temperature range. Low-boiling fuels vaporize more readily and burn more completely than fuels with a higher boiling range.

Since both of these fuel properties influence the combustion process simultaneously, it is advisable to increase the cetane rating and decrease the boiling range if the exhaust condition and internal engine cleanliness seem to call for a combustion improvement.

The inter-relation of these two factors with regard to combustion cleanliness is graphically shown above:

As the ignition quality goes down and the final boiling point rises, the combustion grows increasingly worse. Exhaust smoke, rapid blackening of the lubricating oil, short oil filter life and formation of carbon deposits on piston rings and air intake ports accompany this condition.

Fuels in the dark area of the chart can be burned in Series 71 engines, but their use should be restricted to short periods of time. Satisfactory operation of high-speed engines on these heavy fuels requires frequent dismantling and cleaning of internal engine parts.

**IV.** Suitability of a Diesel fuel depends, to a large extent, on the type of service for which the engine is used.

Stationary engines operated at constant speed are less critical in their fuel volatility requirements than automotive engines which must frequently respond to sudden load changes over a wide range of speeds.

The lighter fuels specified above for winter use may therefore also be employed to advantage all year around on vehicle engines where drastic restrictions are imposed on the exhaust conditions.

**V.** In view of the dominating influence of the fuel on engine performance, high-speed Diesel engine fuels should be procured from a reputable source.

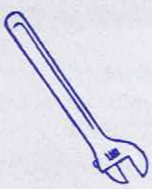
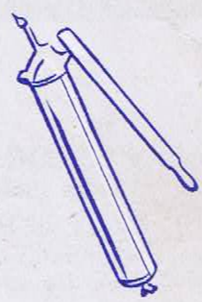
Since quality and suitability of the fuel are responsibilities of the supplier, he should first be consulted if fuel difficulties are experienced.


# LUBRICATION AND PREVENTIVE MAINTENANCE

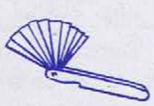
The recommendations made in the following pages for frequency of lubricant application to the various bearings and moving parts of the propulsion unit and its attached accessories are arbitrary figures and may be varied by the judgment of an experienced operator. The inexperienced operator, by following closely these printed instructions, may feel assured that his engine is being well cared for.


## USE ONLY CLEAN LUBRICANTS! ALL GREASES AND OILS SHOULD BE KEPT IN CLOSED CONTAINERS.

### HERE ARE A FEW POINTERS WORTH REMEMBERING IN REGARD TO LUBRICATION OF PARTICULAR ASSEMBLIES.

• **STARTING MOTOR**—The starting motor is used for a very small portion of the engine operating time. Lubricate the bearings sparingly as excess oil leaking into the motor housing can foul up brushes and commutator and permanently damage winding insulation thus causing starting motor failure.




• **CLUTCH PILOT BEARING**—Grease forced into the pilot bearing cavity after the cavity is full will be thrown by centrifugal force of the revolving clutch parts onto clutch facings where it causes slipping and damaging carbon formation. While the pilot bearing **must** have lubrication, **too much** lubrication will result in premature repairs.

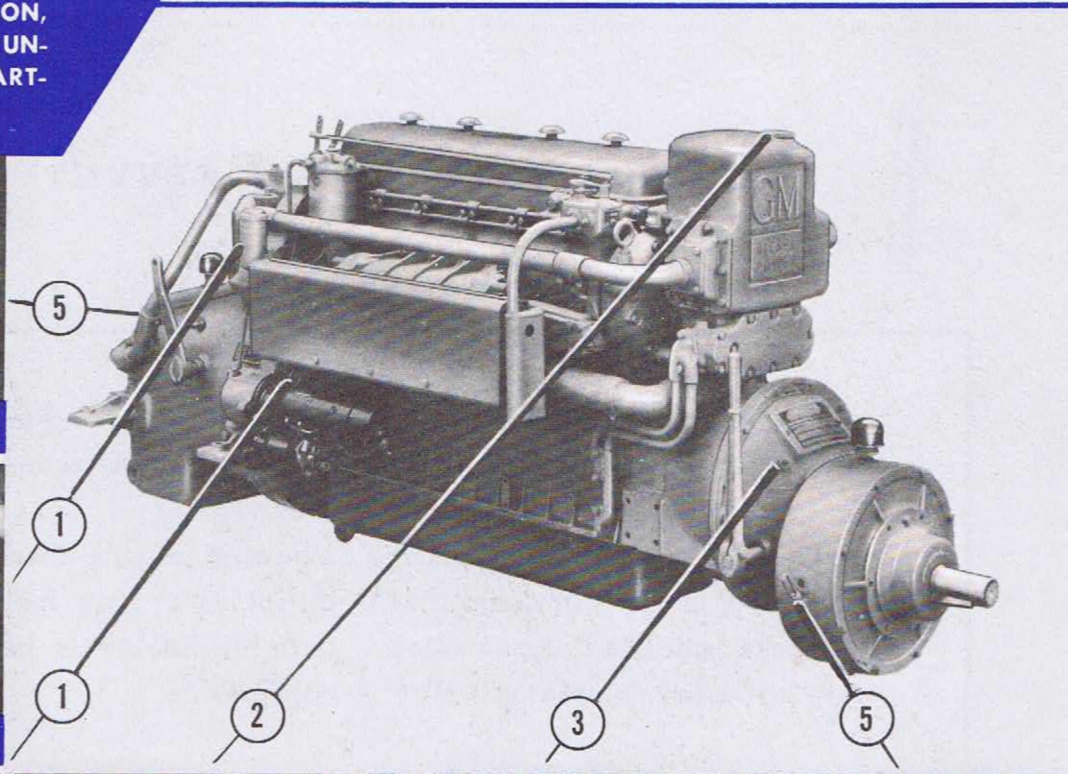

• **BATTERY CHARGING GENERATOR**—Like the starting motor, overlubrication of the battery charging generator can seriously interfere with the electrical function of the machine. Excess oil will coat commutator and damage insulation. While the generator bearings are in use during all engine operating time and require sufficient lubrication, do not flood them with lubricant.

# LUBRICATION AND

**TO INSURE INITIAL LUBRICATION, CARRY OUT THE INSTRUCTIONS UNDER "PREPARATION FOR STARTING", PAGE 2, SEC. III.**

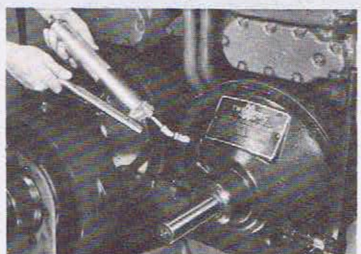
5. CHECK OIL LEVEL, TWIN DISC


1. CRANKCASE, ADD OIL

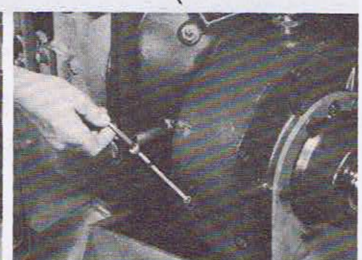



1. CRANKCASE, CHECK OIL LEVEL


2. CHECK WATER



3. GREASE F.P.T.O.



5. CHECK OIL LEVEL 60 H.P.—F.P.T.O.

## *Perform the Following Operations Every 10 Hours During Continuous Operation or Once During Each Day of Intermittent Operation.*

**1. CRANKCASE,** Check lubricating oil level on dip stick.

Check oil level after engine has been stopped for two minutes. Level should be to "FULL" mark on stick. Never let oil level fall below "LOW" mark. Add oil as required. Always use a clean can for handling fluid lubricants.

Use Heavy Duty Detergent Type Diesel Lubricating Oil. (See "Lubricating Oil Specifications", Page 1) S.A.E. 30—Above 32° F.; S.A.E. 20—32° F. to 0° F.; S.A.E. 10—Below 0° F.

**2. FRESH WATER SYSTEM,** Check water level in expansion tank.

Remove filler cap at top of expansion tank and add water as needed. Fill to about 2 inches below filler neck when engine is cold to allow for expansion without overflow. When draining or completely filling cooling system, open the air vent in the top of the thermostat housing just behind expansion tank. Add only fresh soft water or permanent antifreeze solution.

**3. CLUTCH THROWOUT COLLAR,** Lubricate. (This operation applies only to Twin-Disc front power take-off assemblies with the time interval based on period of engagement.)

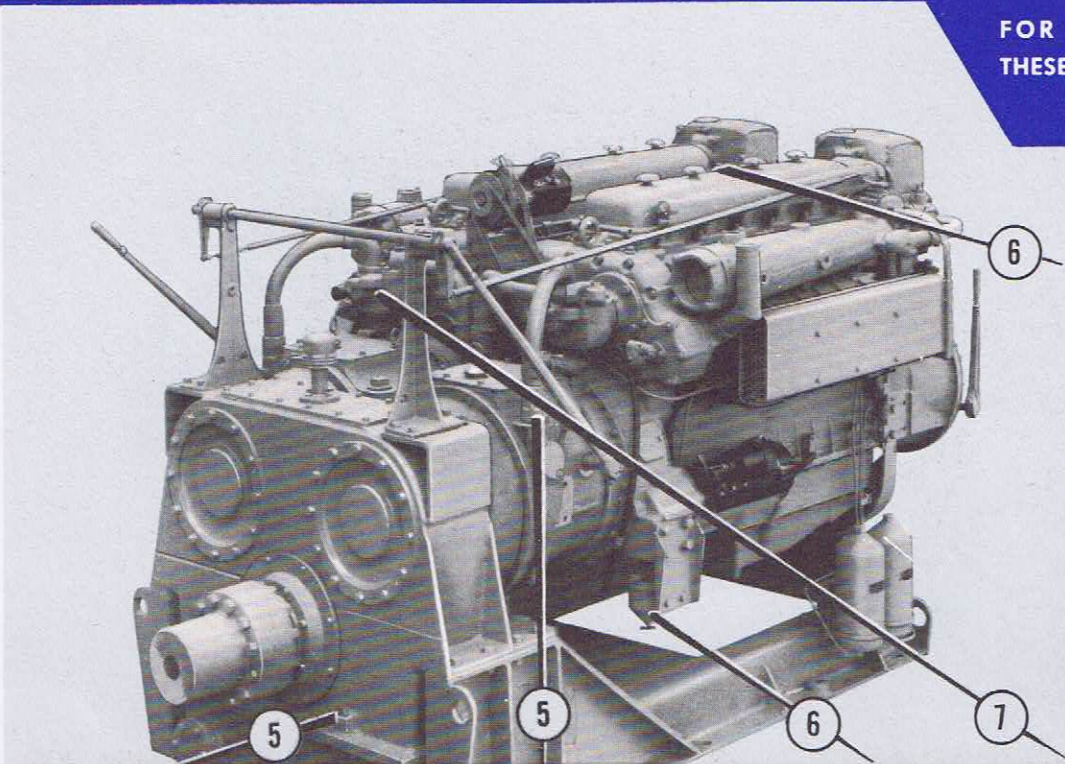
Attach grease gun to fitting and apply a small amount of lubricant. Two strokes of a lever type, or two full turns of screw type hand grease gun should be sufficient.

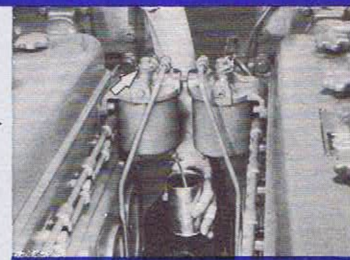
Good quality, sodium soap base, short fibre grease, the same as used on the Twin-Disc reverse gear bearings, may be used.

**4. FUEL TANK,** Check fuel supply and fill tank. (Not illustrated.)

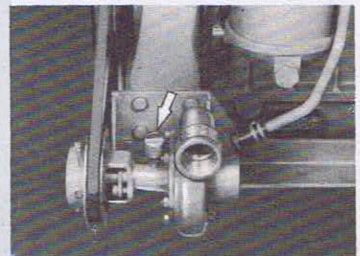
Retard corrosion and scaling inside of fuel tank by

**FOR TWIN ENGINE UNITS, PERFORM THESE OPERATIONS ON EACH ENGINE.**

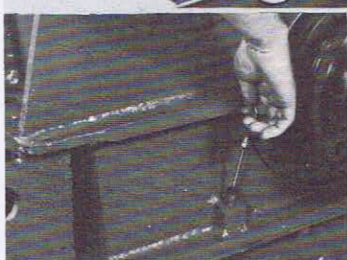


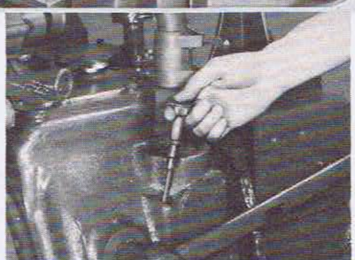
6. SECONDARY FILTER



7. GREASE BILGE PUMP

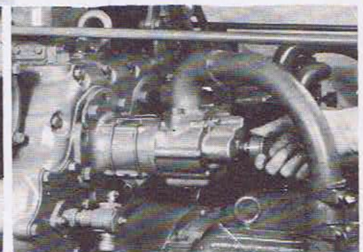


5. CHECK OIL LEVEL, GEAR BOX



5. CHECK OIL LEVEL, SNOW — NABSTEDT

6. PRIMARY FILTER



7. GREASE WATER PUMP

keeping tank as full as possible. Do not let tank empty as starting is difficult after fuel system has been run dry.

Use only Diesel fuel oil of the quality specified on page 2.

**5. REVERSE AND REDUCTION GEARS** (Propulsion and Front Power Take-Off) Check lubricating oil level on dip stick.

Oil level should be to high mark on dip stick with engine stopped. Remove filler cap and add oil if required. On twin engine units, check reverse gear for each engine, also the large reduction gear box.

The same oil used in the engine crankcase may be used in all Snow — Nabstedt reverse and reduction gears and in the large reduction gear box of twin engine units. Oil lighter than S.A.E. 20 viscosity is not recommended for Snow-Nabstedt units.

In Twin-Disc reverse and reduction gear propulsion units, use only a premium grade motor oil of S.A.E. 50 viscosity.

For front power take-off units having a reduction gear, use a good quality transmission lubricant of S.A.E. 90 to 110 viscosity.

**6. PRIMARY AND SECONDARY FUEL FILTERS**, Drain off sediment.

Open drain cock at bottom of each primary and secondary fuel filter and drain off about ¼ pint of fuel and sediment. Loosen vent plug or retaining bolt to improve drainage. Close drains and tighten vent.

**7. RAW WATER PUMP AND BILGE PUMP**, Turn down grease cup.

Turn grease cup down ½ revolution. Avoid forcing excessive grease into pump.

Use only special water pump grease when filling grease cup.

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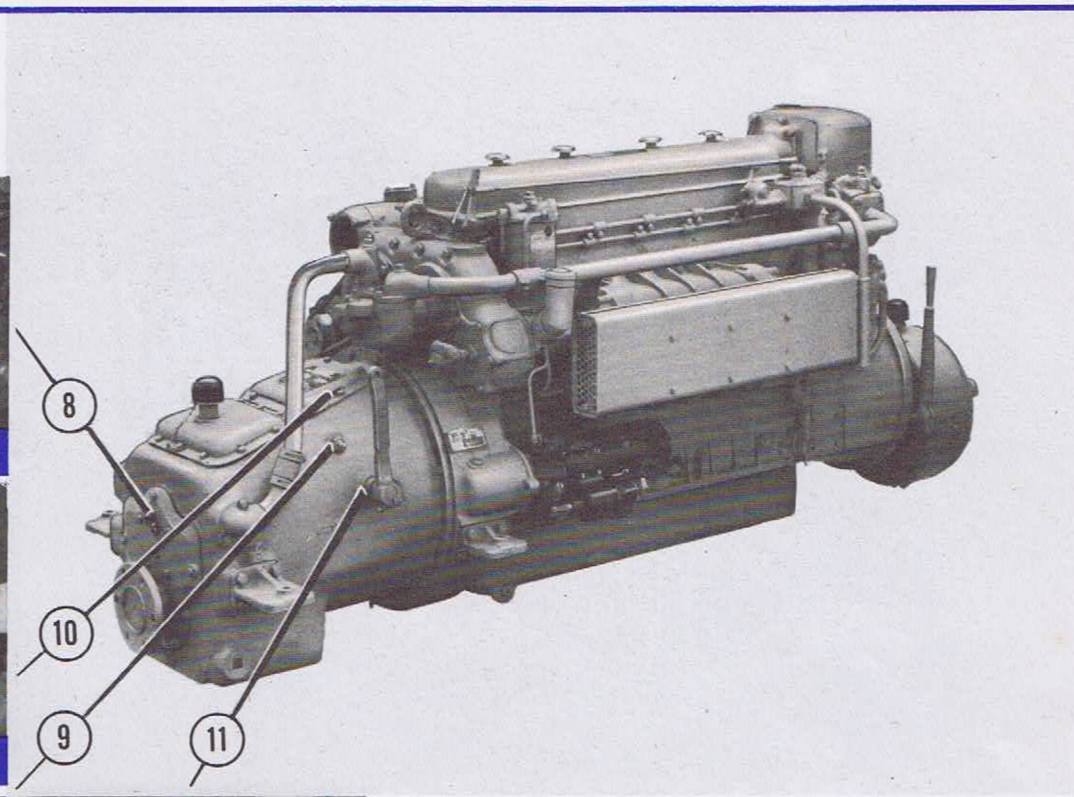
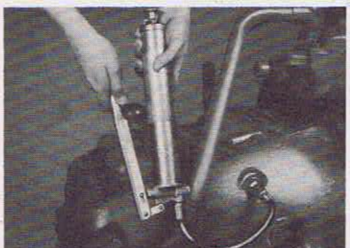
*Continued from page 5*





**8. GREASE PILOT BEARING**


**10. OIL CLUTCH ACTION PARTS**


**9. GREASE THROWOUT BEARING**


**11. OIL OR GREASE REVERSE GEAR OPERATING SHAFT END BEARINGS**

## After Each 24 to 25 Hours of Operation

Perform all 10 Hour Items.

**8. CLUTCH PILOT BEARING**, Lubricate. (This operation applies only to Twin-Disc reverse and reduction gear assemblies.)

Attach grease gun to fitting in end of reverse shaft and apply grease *sparingly.* One or two strokes of a lever type, or two full turns of screw type hand gun should be sufficient.

Use only high grade, 30-35% sodium soap base, short fibre grease that will withstand bearing operating temperatures of 200° F.

**9. CLUTCH THROWOUT BEARING**, Lubricate. (This operation applies only to Twin-Disc reverse and reduction gear assemblies.)

Attach grease gun to fitting at side of gear housing and apply grease *sparingly.* One or two strokes of a lever type, or two full turns of screw type hand gun should be sufficient.

Use only high grade, 30-35% sodium soap base, short fibre grease that will withstand bearing operating temperatures of 200° F.

## After Each 50 Hours of Operation

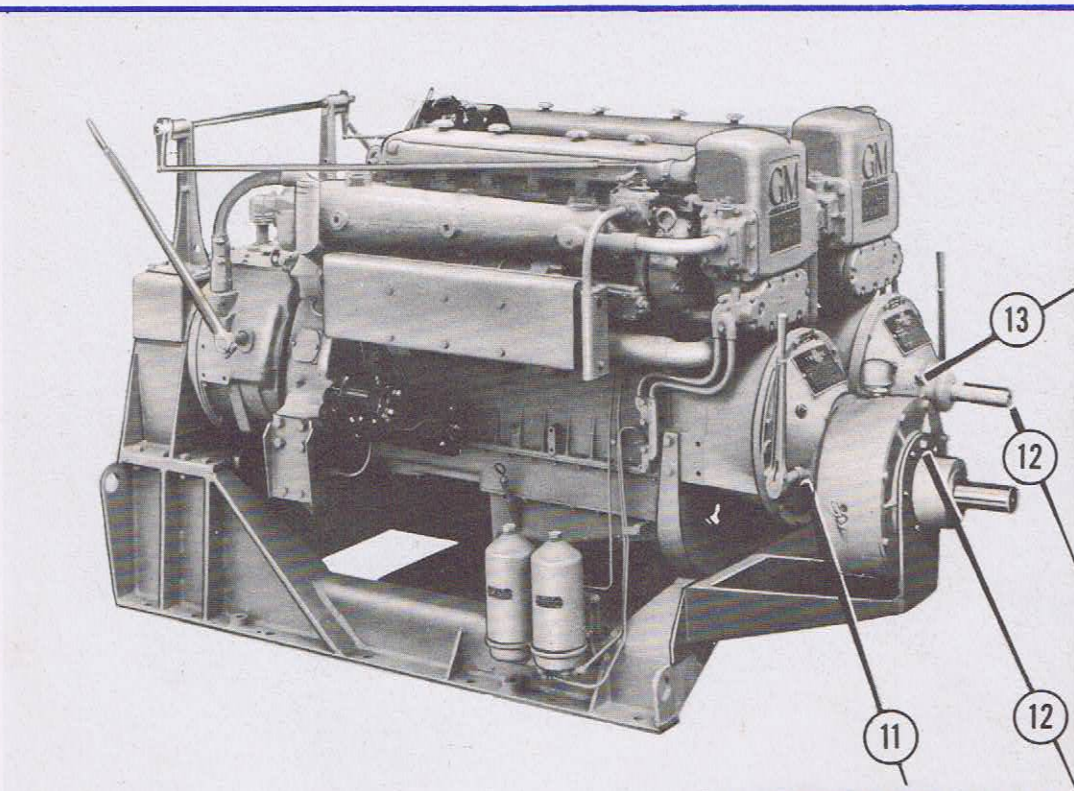
Perform all 25 Hour Items

**10. CLUTCH ACTION PARTS**, Lubricate. (This applies to Twin-Disc Reverse Gear Assemblies Only.)

Remove cover plate from clutch housing and apply a few drops of light engine oil to all pivot pins, rollers, trunnion blocks on ball bearing throwout collar, and the sliding sleeve support.

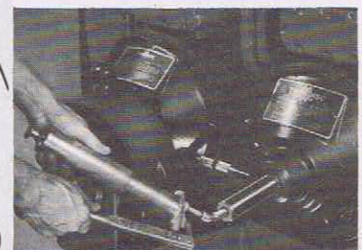
**11. CLUTCH OPERATING SHAFT END BEARINGS**, Lubricate. (This applies to both Twin-Disc Reverse Gear and Front Power Take-Off Assemblies.)

On assemblies provided with hydraulic grease fittings, attach hand gun and apply two or three

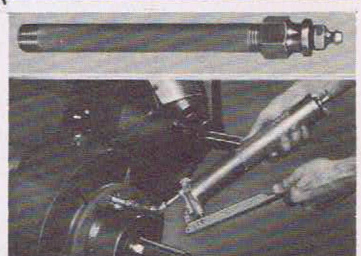




13. GREASE MAIN CLUTCH SHAFT BEARING


12. GREASE PILOT BEARING 35 H.P. —F.P.T.O.


11. OIL FRONT P.T.O. OPERATING SHAFT END BEARINGS


12. GREASE PILOT BEARING 60 H.P. —F.P.T.O

strokes of lubricant. Where a flush type ball fitting is provided, light machine oil may be applied with an oil can. Lubrication will prevent corrosion and keep shaft moving freely in its bearings.

The bearing grease in the gun used on the other fittings will be satisfactory on these shaft end bearings. When using oil, any light, clean, engine oil will be satisfactory.

**12. PILOT BEARING**, Lubricate. (This applies only to Twin-Disc front power take-off units.) Attach hand grease gun to fitting in exposed end of clutch shaft and apply grease *sparingly*. Two strokes of lever type gun should be sufficient. On front power take-off assemblies which incorporate speed reduction gears, a pipe plug must be removed from the reduction gear housing and a ¼″ nipple inserted through the housing and reduction gear webb and threaded into the tapped hole in the end of the clutch shaft. A grease fitting attached to the outer end of the nipple will simplify lubrication. Be sure nipple is packed with grease before counting the *two* gun strokes specified.

Use only high grade, sodium soap base, short fibre grease gun lubricant recommended by its manufacturer for use with antifriction bearings having operating temperatures of 200° F.

**13. FORWARD CLUTCH SHAFT BEARING**, Lubricate. (This applies only to Twin-Disc Direct Drive front power take-off units.)

Attach hand gun to grease fitting in housing just above bearing and pump lubricant into bearing cavity. Three or four strokes on lever type gun should be sufficient. Do not continue to pump after pressure builds up against gun.

Use only high grade, sodium soap base, short fibre grease gun lubricant recommended by its manufacturer for use with antifriction bearings having operating temperatures of 200° F.

*Continued on page 8*

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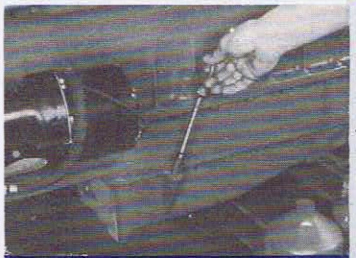
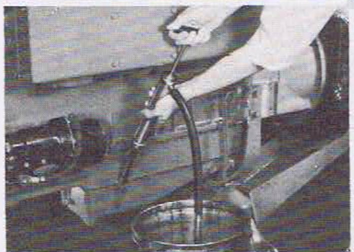
**15.** REFILL

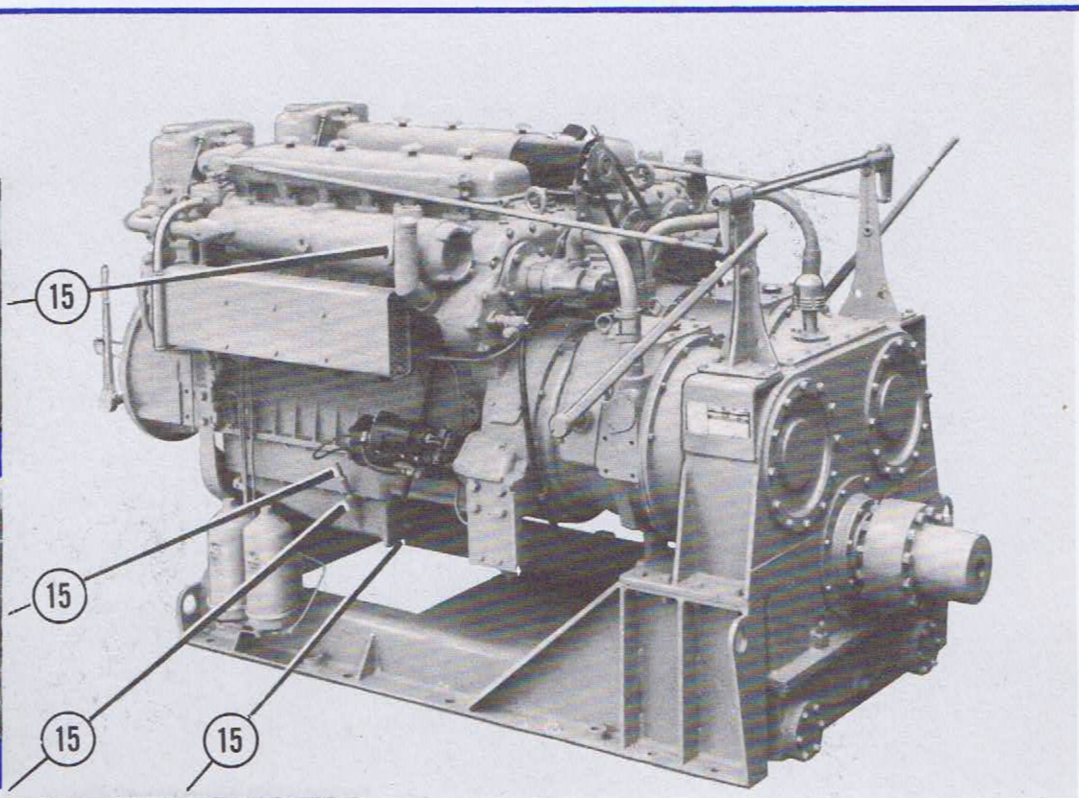


**15.** CHECK LEVEL



**15.** PUMP CRANKCASE

**15.** DRAIN CRANKCASE




## After Each 200 Hours of Operation

Perform All 50 Hour Items

**14.** **ENGINE**, Check all adjustments. (Tune-up.)

Engine tune-up should be carried out 200 hours after initial start or complete overhaul and need only be carried out every 500 hours thereafter or as indicated by functioning of engine.

For correct procedure, refer to "Tune-Up", Page 18.

**15.** **ENGINE CRANKCASE**, Change Oil.

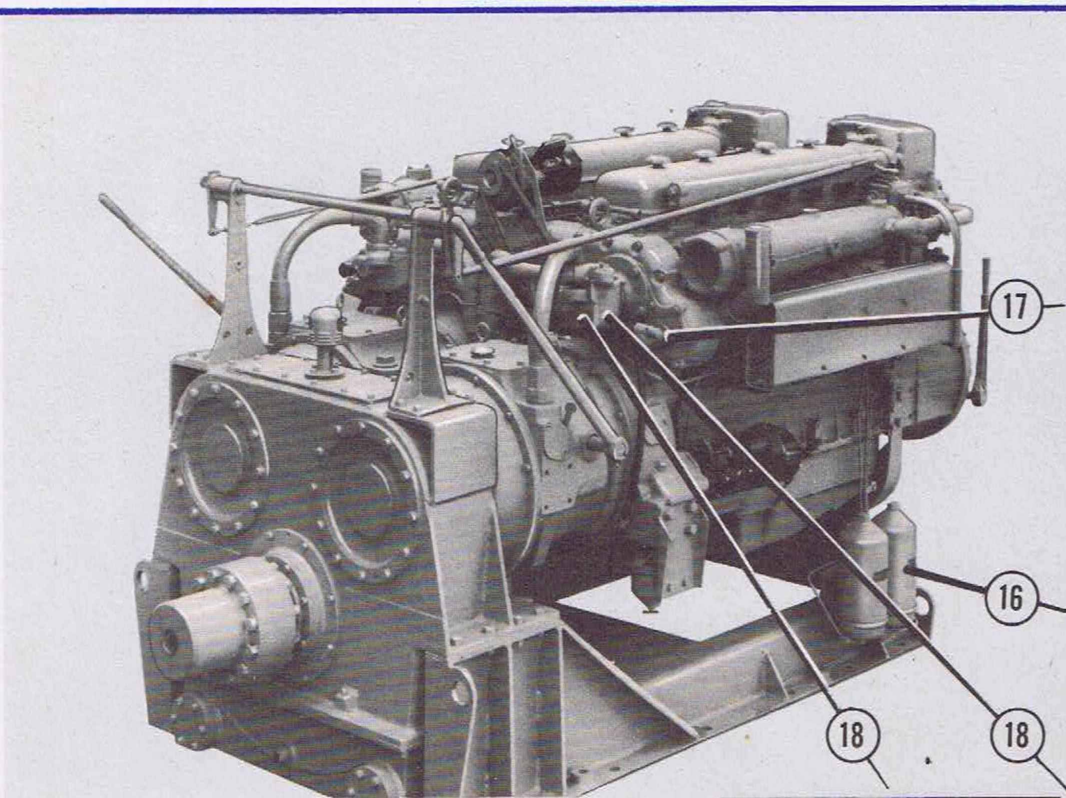
If possible, remove drain plug from oil pan to empty old oil. If this cannot be done, remove the dip stick and attach rubber hose from a sump pump over the end of the dip stick guide tube which extends to the bottom of the oil pan, and holding pump in a near vertical position, suck the old oil out of the pan. Replace element in lubricating oil filter and refill crankcase to "FULL" mark on dip stick.

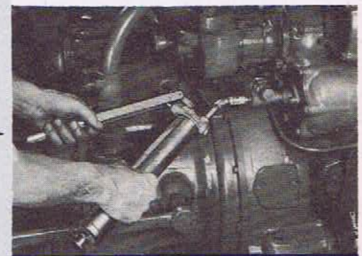
Use only Heavy Duty Detergent Type Diesel Lubricating Oil (See "Lubricating Oil Specifications," Page 1.) S.A.E. 30—above 32° F.; S.A.E. 20—32° F. to 0° F.; S.A.E. 10—Below 0° F.

NOTE: When engine is required to deliver only medium power output, samples of drained Oil may be submitted to the Supplier for testing and for his approval of a longer interval between changes. Be sure to change lubricating oil filter element each time oil is changed.

**16.** **LUBRICATING OIL FILTER**, Change elements.

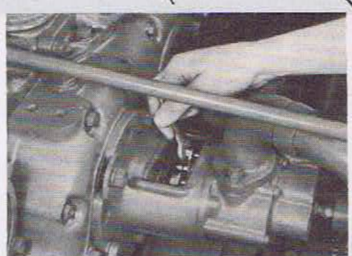
With engine shut down, hold receptacle under filter base and remove drain plug. Loosen retaining bolts to vent shells then remove bolts and lift each shell and element away from base. Discard old elements,



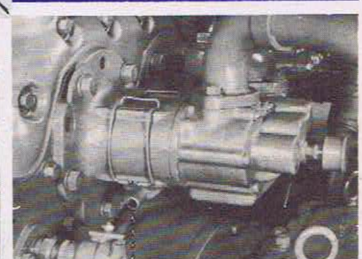



17. GREASE TACHOMETER DRIVE

16. CHANGE FILTER ELEMENT



18. TIGHTEN GLANDS, RAW WATER PUMP



18. CHECK DRIP, RAW WATER PUMP

clean shells in fuel oil, and wipe sediment out of base. With new elements and gaskets in place install shells and tighten retaining bolts. After starting engine, check filter for oil leaks.

Use the element specified on shell of filter. Element package includes new shell-to-base gasket.

**17. TACHOMETER DRIVE ASSEMBLY,** Lubricate.

Attach hand grease gun to fitting and apply a small amount of lubricant. Two or three strokes of lever type gun should be sufficient.

Short fibre, high speed bearing grease is a satisfactory lubricant for the tachometer drive.

External lubrication is necessary only on that type drive assembly provided with a grease fitting.

**18. RAW WATER PUMP,** Check for leaks and tighten packing glands if necessary. (This applies also to bilge pump furnished by engine manufacturer.)

While engine is running, check amount of water leaking past packings on pump shafts and running out through drain. If more than a fast drip, remove drip shield and tighten packing glands evenly until flow is reduced to a slow drip. Replace shield.

When tightening of gland nuts is no longer effective in stopping the leak, it will be necessary to partially disassemble the pump and install new packings.

**19. BATTERY,** Check water level in each cell.

Add distilled, or clean soft water as required to maintain water level about 3/8" above top of plates. If corrosion collects at terminals, clean it off with a wire brush and coat terminal and cable end with grease to keep air away from the metal.

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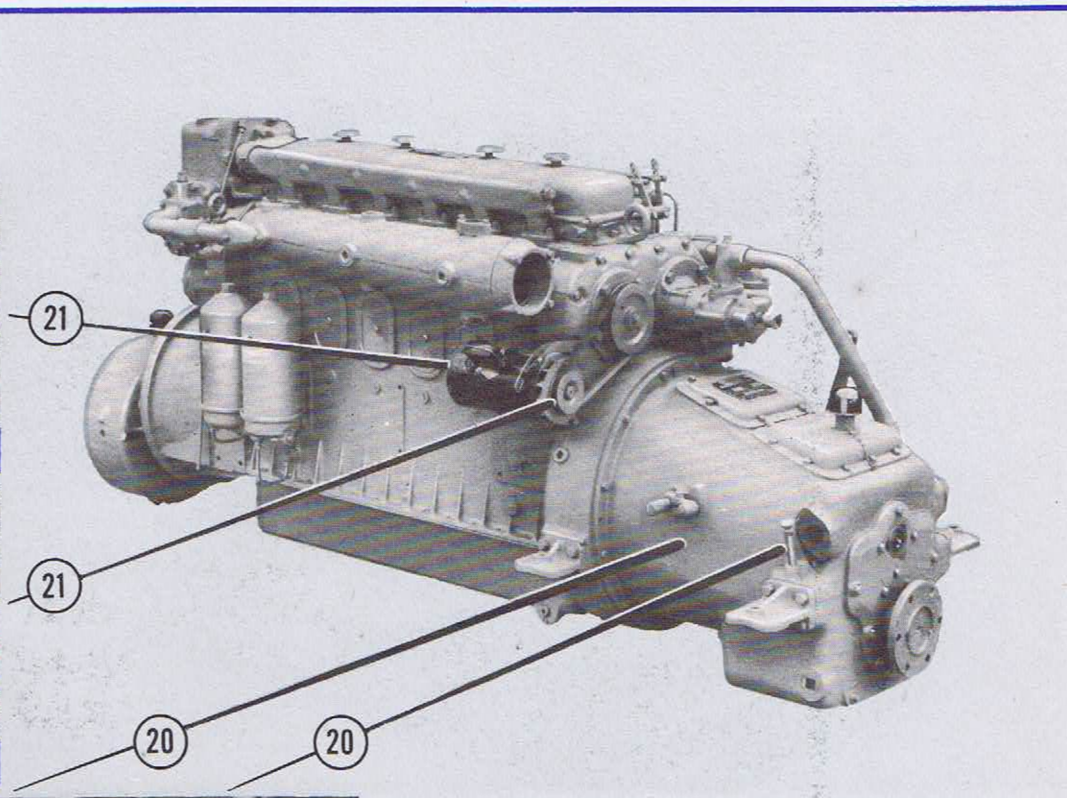
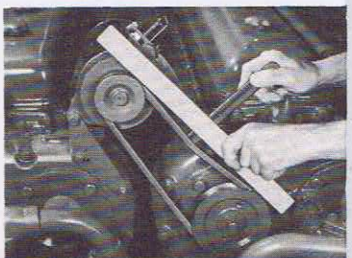
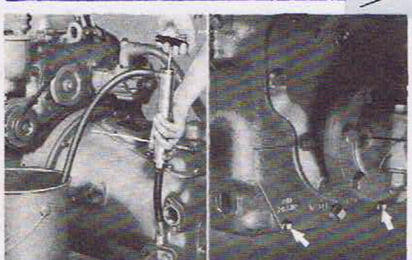



**21.** OIL OR GREASE GENERATOR



**21.** CHECK BELT TENSION



**20.** TWIN DISC, DRAIN


**20.** TWIN DISC, FILL AND CHECK

## After Each 300 Hours of Operation

Perform All 50 Hour Items

### 20. REVERSE AND REDUCTION GEAR, Change Oil.

#### *On Twin-Disc Assemblies*

It is possible to remove the used lubricant from the gear housing in two ways: (1) Remove the pipe plugs from the holes marked "Oil Drain" which are located at the aft end of the housing just below the propeller shaft. (2) Remove the bayonet oil gauge and, using a sump pump and a piece of 5/8" I.D. rubber hose fitted tightly over the end of the oil gauge tube, pump the oil up from the bottom of the housing.

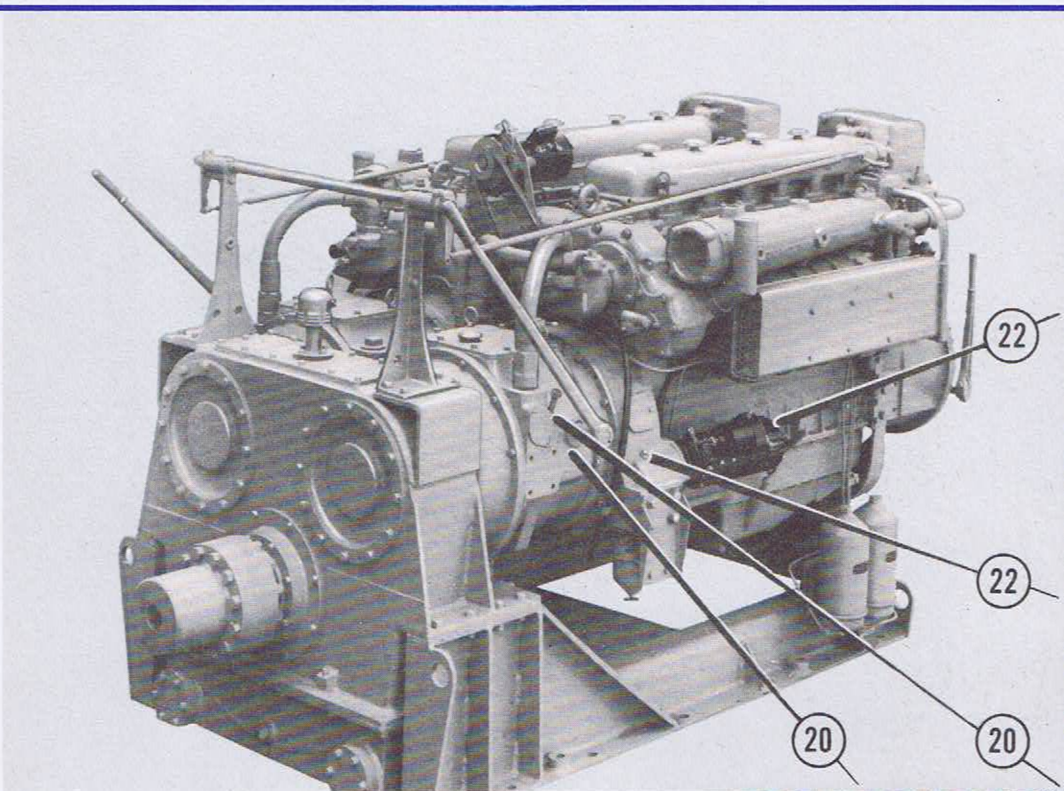
Replace drain plug, if removed, and refill with premium grade motor oil of *S.A.E. 50 viscosity.* Fill to high mark on dip stick. Check level with engine stopped.

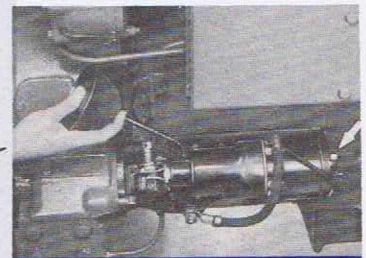
#### *On Snow-Nabstedt Assemblies*

Remove 3/4" pipe plug at bottom of housing and drain out old oil. When the reduction gear housing extends below the reverse gear housing, a 3/4" pipe plug at the bottom rear face of the reduction gear housing must also be removed for a complete drain.

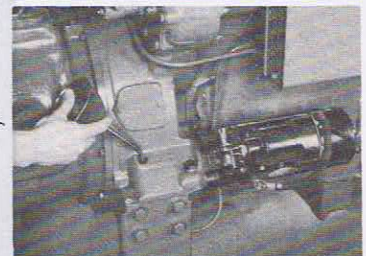
After replacing drain plugs, refill housing to bring level up to high mark on the dip stick. When a reduction unit is combined with the reverse unit, allow 15 minutes for oil to level off between the two housings.

The same oil used in the engine crankcase may be used in all Snow—Nabstedt units. However, oil with a viscosity rating between S.A.E. 20 and S.A.E. 50 is preferable.

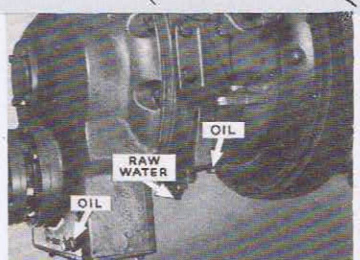


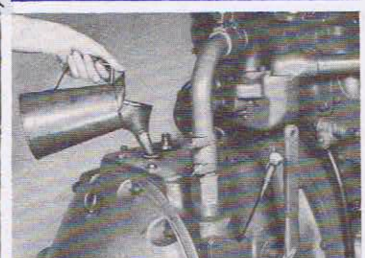
**22.** EXPOSED OILERS



**22.** DRIVE END OILER




**20.** SNOW—NABSTEDT, DRAIN



**20.** SNOW — NABSTEDT, FILL AND CHECK

## 21. BATTERY CHARGING GENERATOR, Lubricate and check belt tension.

Generators provided with *oilers* should have the oil wells filled to the level of the oil hole with a light grade of engine oil (S.A.E. 30).

On generators provided with *grease cups,* turn the cup down one full turn. Grease cups should be filled with a quality grade of short fibre ball bearing grease having a melting point of 200° F. The relief holes in the grease passages should be kept open at all times so excess lubricant will not be forced out onto the commutator.

NEVER PUT OIL OR GREASE ON THE COMMUTATOR. DO NOT LUBRICATE GENERATOR WHILE IT IS IN OPERATION.

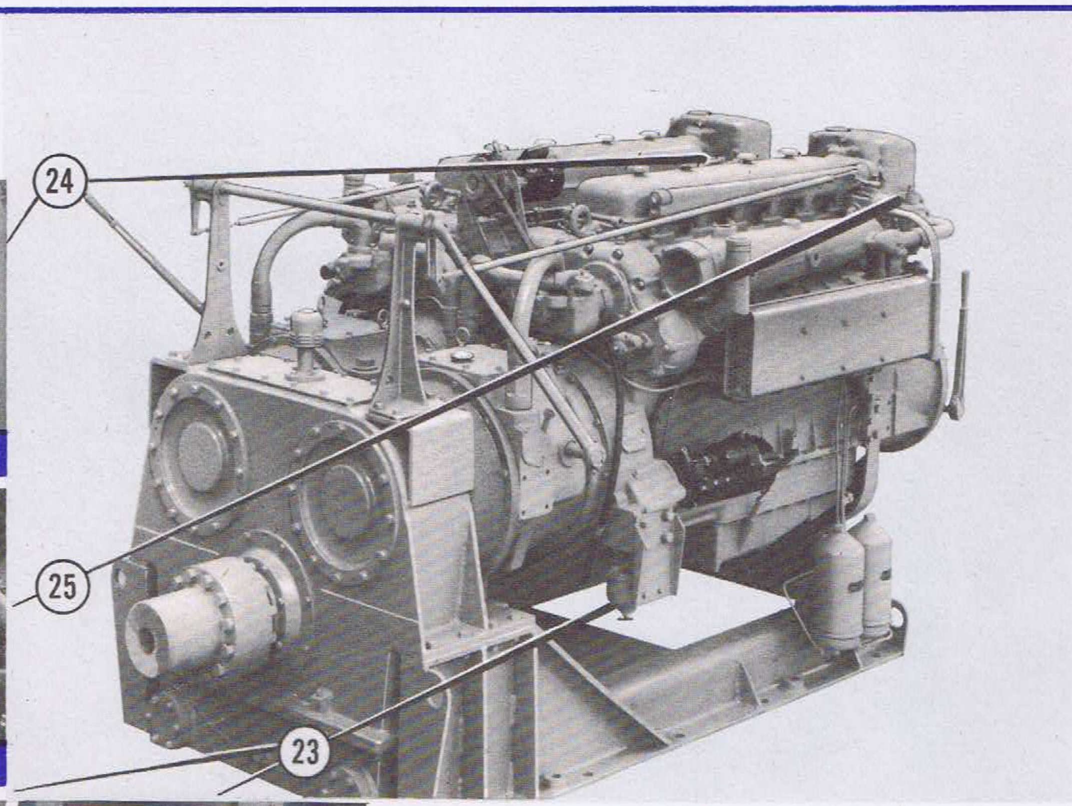
Correct belt tension is important to belt and bearing life. The belt should never be loose enough to allow slippage but should not be so tight as to cause excessive side thrust on the generator bearing. The belt should be kept free from oil and grease. Always replace worn belts with a new one of the part number specified for your engine model.

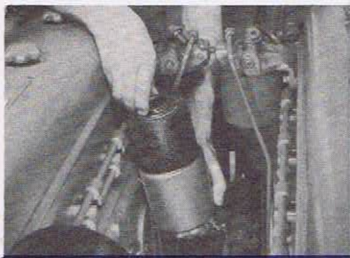
## 22. STARTING MOTOR, Lubricate.

The three plain bearings with hinge cap oilers should have 8 to 10 drops of light engine oil. (S.A.E. 30.) It is necessary to remove the pipe plug in the flywheel housing to expose the oiler at the drive end of the motor. With this pipe plug removed, and using a suitable oil can, lubricate the cranking motor drive with 3 or 4 drops of the same light oil.

*Continued on page 12*

*Continued from page 11*

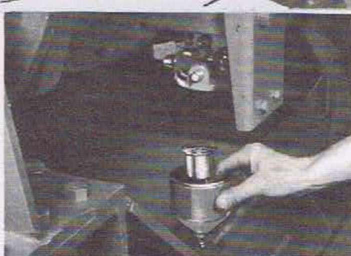


24. CHANGE ELEMENT, SECONDARY FILTER


25. INSPECT ELECTRODES

23. CLEAN PRIMARY FILTER



23. REMOVE PRIMARY FILTER

## After Each 500 Hours of Operation

Have The 200 Hour Items Been Repeated?

**23. PRIMARY FUEL FILTER**, Clean element.

With engine stopped, loosen top retaining bolt and remove filter shell and element. Wash filter discs thoroughly in clean fuel oil using a *soft bristle brush* if necessary. Wash out filter bowl and re-assemble using new gaskets. After starting engine, check for leaks.

**24. SECONDARY FUEL FILTER**, Replace element.

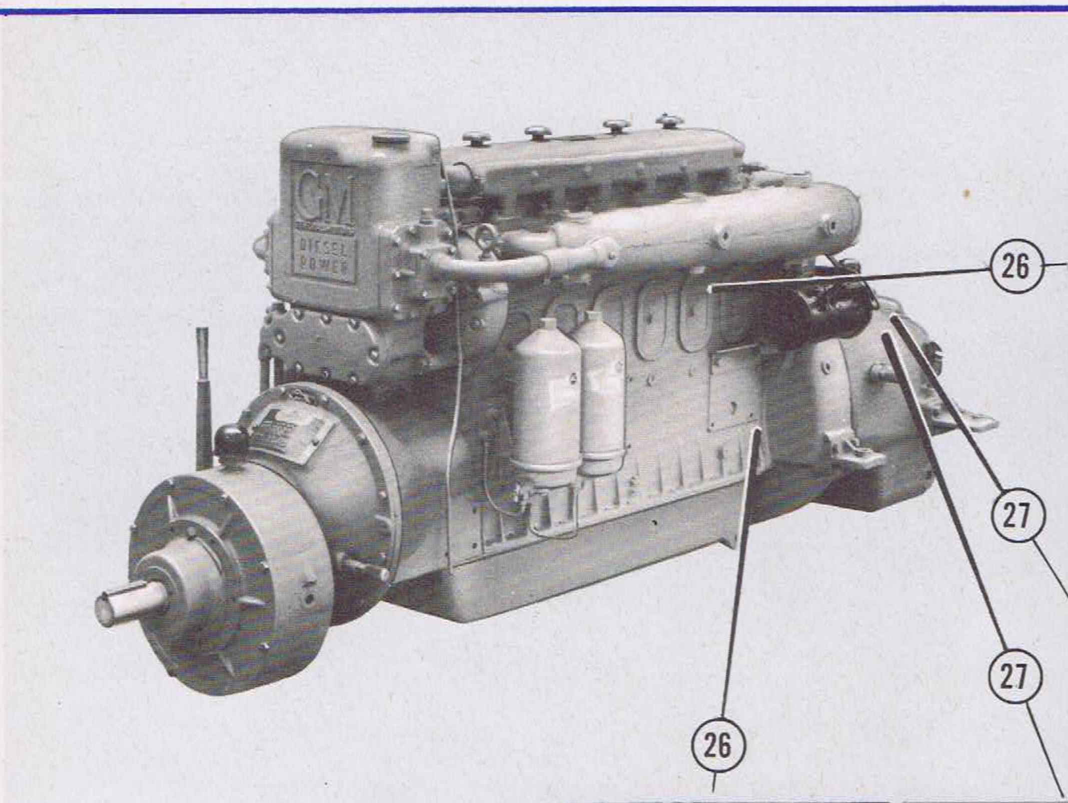
With engine stopped, loosen bottom nut and remove filter shell together with center stud and element. Wash shell in clean fuel and discard old element and gaskets. Using new element of the type and number specified on shell and the new gaskets provided in the element package, reassemble the filter. With engine running, check for leaks.

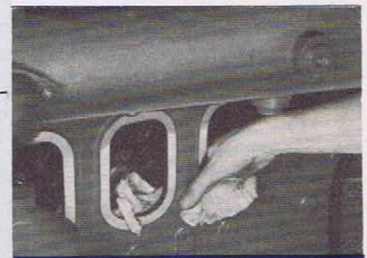
**25. HEAT EXCHANGER**, Check electrodes.

Remove electrodes from heat exchanger inlet and outlet flange at front of engine. If only slightly coated, clean down to zinc with a wire brush. If badly corroded, replace with a new electrode.

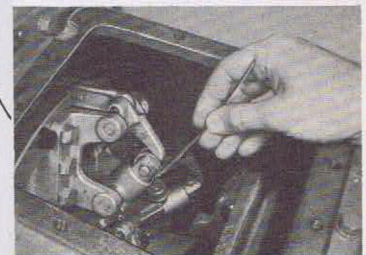
**26. AIR BOX DRAINS**, Check air flow through drain.

Each engine has two air box drain tubes located near the bottom of the cylinder block and venting to atmosphere. These drains *must* be open. With

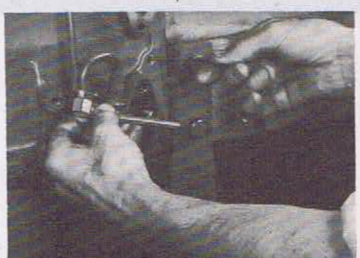


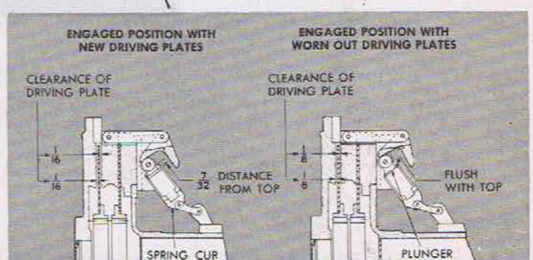
26. WIPE OUT AIR BOX



27. INSPECT CLUTCH



26. CLEAN DRAINS




27. POSITION OF PLUNGER IN CUP

engine running, hold a finger at the drain opening to check for air stream. If drains are plugged, remove fittings from block and clean with a wire. Also clean opening just inside of block. After cleaning drains, shut down engine and remove hand hole covers, then, with clean rags, wipe air box floor as dry and clean as possible. Replace hand hole covers before starting.

**27.** **CLUTCH** (Twin Disc Reverse Gear), Inspect for wear.

The simplest means of checking the relative wear on the clutch friction surfaces and determining whether the driving plates need replacing, is to remove the housing cover and check the position of the plunger in the engaging mechanism. The illustration shows the position of the plunger in the spring cup when driving plates are new and worn out. Clutch must be engaged when making this inspection.

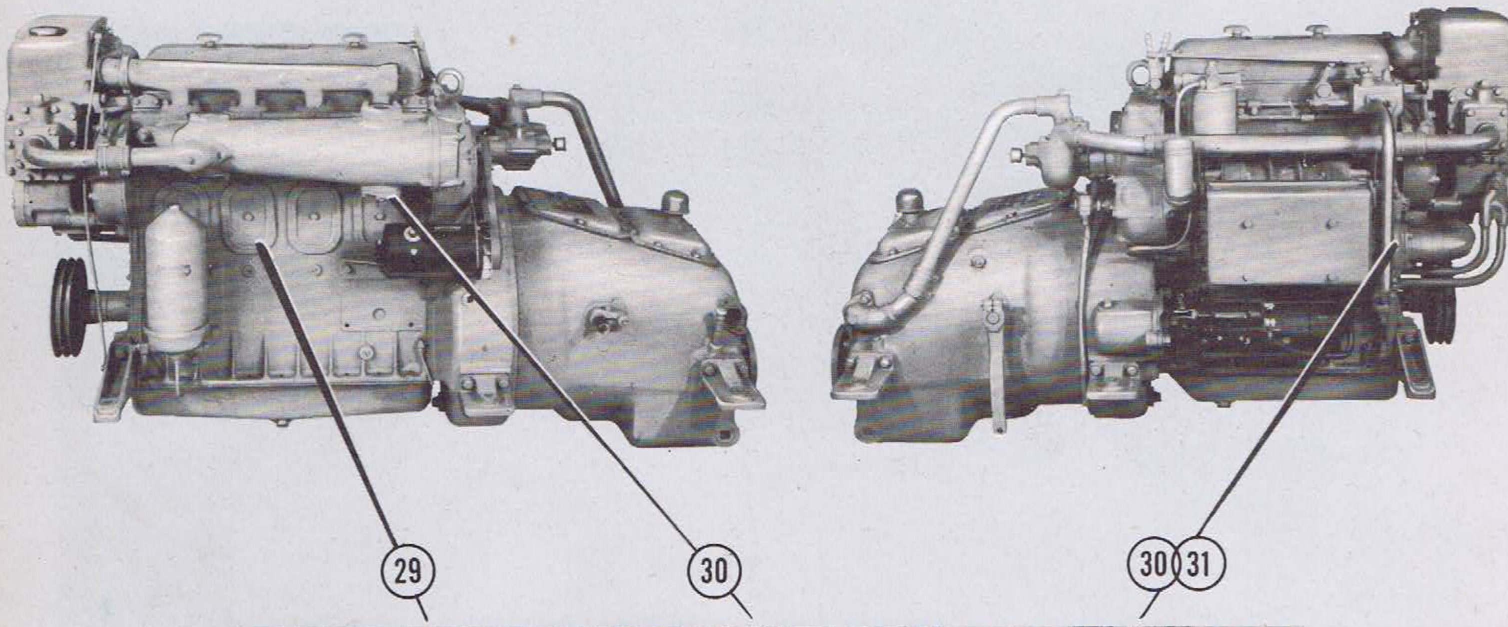
**28.** **ENGINE**, Check all adjustments. (Tune-Up.)

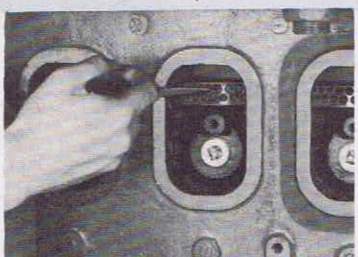
Engine tune-up should be carried out 200 hours after initial start or complete overhaul (see item 14, page 8) and at 500 hour intervals thereafter or as indicated by functioning of engine.

For correct procedure, refer to "Tune-Up", Page 18.

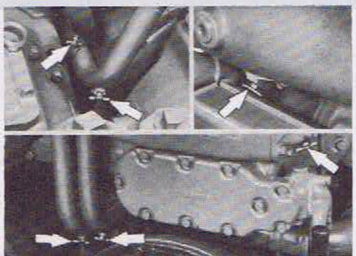
*Continued on page 14*

*Continued from page 13*

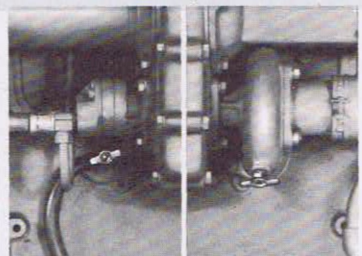


29. INSPECT RINGS AND PORTS



30. RAW WATER DRAINS



30. and 31. FRESH WATER DRAINS

## After Each 1000 Hours of Operation

Perform All 500 Hour Items

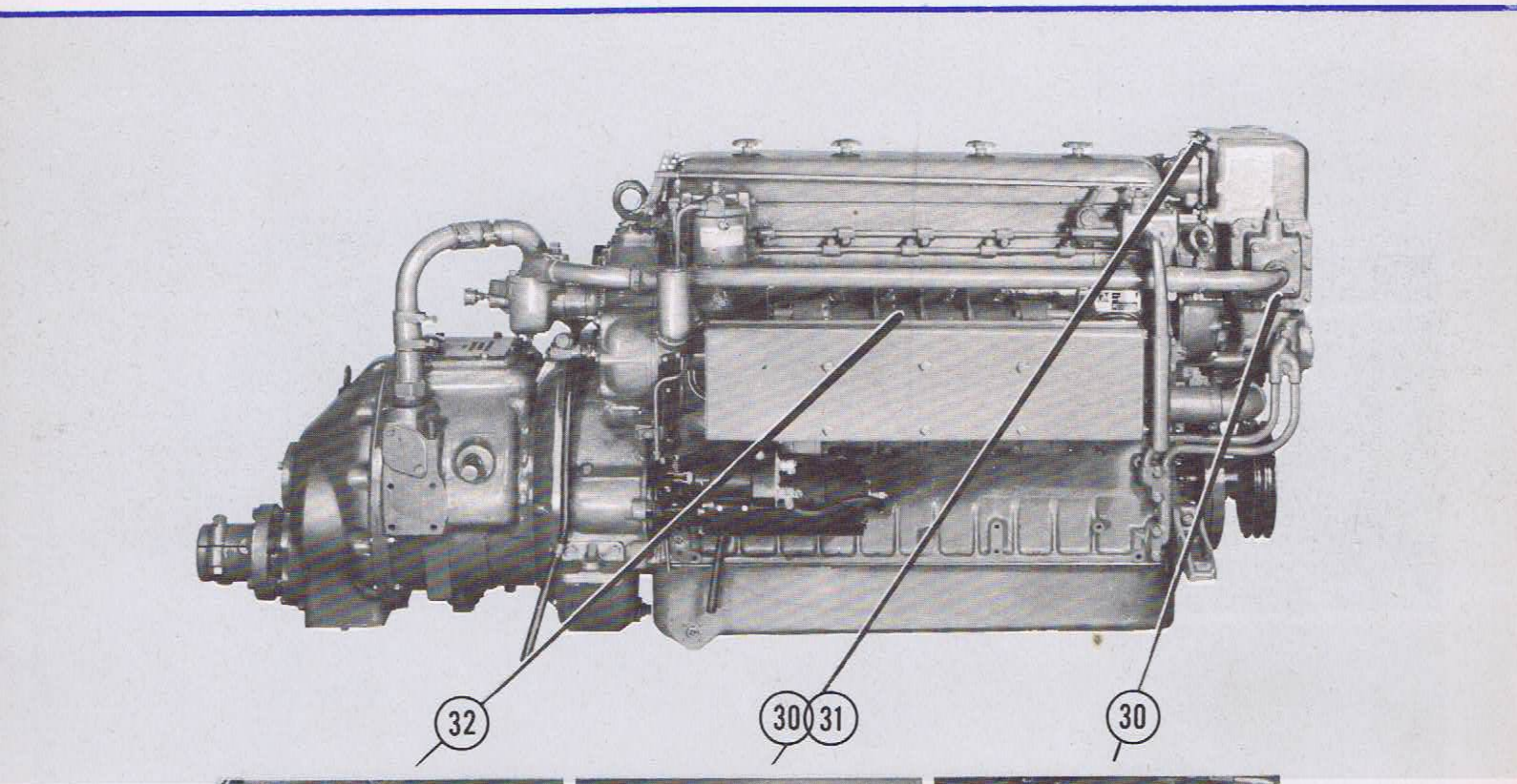
**29.** CYLINDER LINER PORTS, Inspect and clean if necessary.

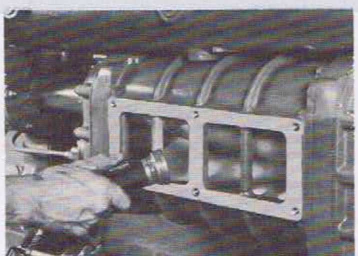
Remove handhole covers at side of block and inspect liner ports. Also insert a narrow screwdriver through ports and press in on piston rings to determine if they are stuck in their grooves or broken. If liner ports are more than 30% choked with carbon or if rings are stuck or broken, the cylinder head should be removed, ports should be cleaned and rings replaced. This is a job for a qualified mechanic!

**30.** HEAT EXCHANGER, Inspect. Remove and clean if necessary.

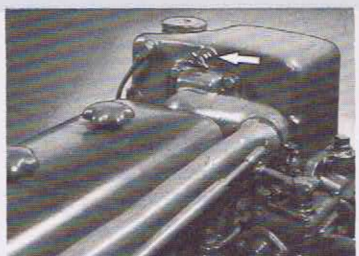
Drain fresh and raw water cooling systems then disconnect the raw water pipe at the **outlet** side of the heat exchanger and remove the heat exchanger retaining cover. If the core shows a considerable amount of scale or coating, **loosen** the cover retaining bolts at the **inlet** side of the heat exchanger to relieve the pressure of the annular seals against the nipple end of the core. Pulling on the core flange at the outlet side, remove the heat exchanger from the housing.

The core should be cleaned immediately after removal to prevent drying and hardening of the deposits. Cleaning may be done by immersing the core in a scale solvent consisting of one-third (1/3) muriatic acid and two-thirds (2/3) water to which has been added one-half (1/2) pound of oxalic acid to each two-and-one-half (2 1/2) gallons of solution.

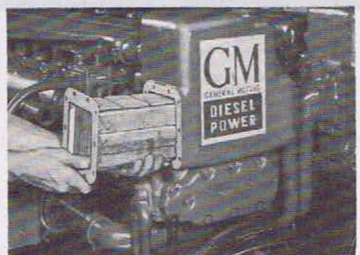


**32.** INSPECT BLOWER



**30. and 31.** VENT VALVE




**30.** REMOVE HEAT EXCHANGER

Remove core when foaming and bubbling stops. This usually takes from thirty (30) to sixty (60) seconds. Flush thoroughly with clean hot water under pressure.

After cleaning, replace the core, using new gaskets at the flange on the outlet side. Flush and refill cooling system as directed in Item 31. Check prime at raw water pump before starting.

## 31. FRESH WATER COOLING SYSTEM, Drain, flush, and refill.

This operation may be carried out in conjunction with inspection and cleaning of the heat exchanger. After the cooling system has been assembled, add radiator flushing compound to the fresh water system as directed on the compound container. When flush is completed, drain and refill the system with fresh soft water or antifreeze solution. A reputable rust inhibitor may be added to the cooling water when antifreeze is not used. When draining or refilling system, open the vent valve at top of thermostat housing. Close valve before operating engine.

## 32. BLOWER, Inspect for wear and leaking oil seals. Clean silencer screens.

*With engine stopped,* remove silencer. Clean screens. Inspect blower for scoring on rotors, housing, or end plates. Check for leaks at rotor shaft oil seals, which will be indicated by a film of oil on the end plate radiating away from the seals. If scoring or leaking seals is discovered, the blower should be removed and repaired before the condition becomes too serious. This is a job for a qualified mechanic.

*Continued on page 16*

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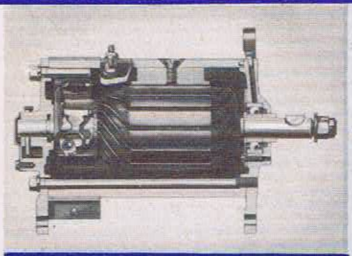
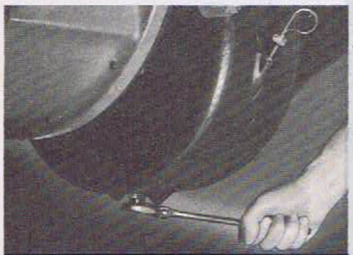
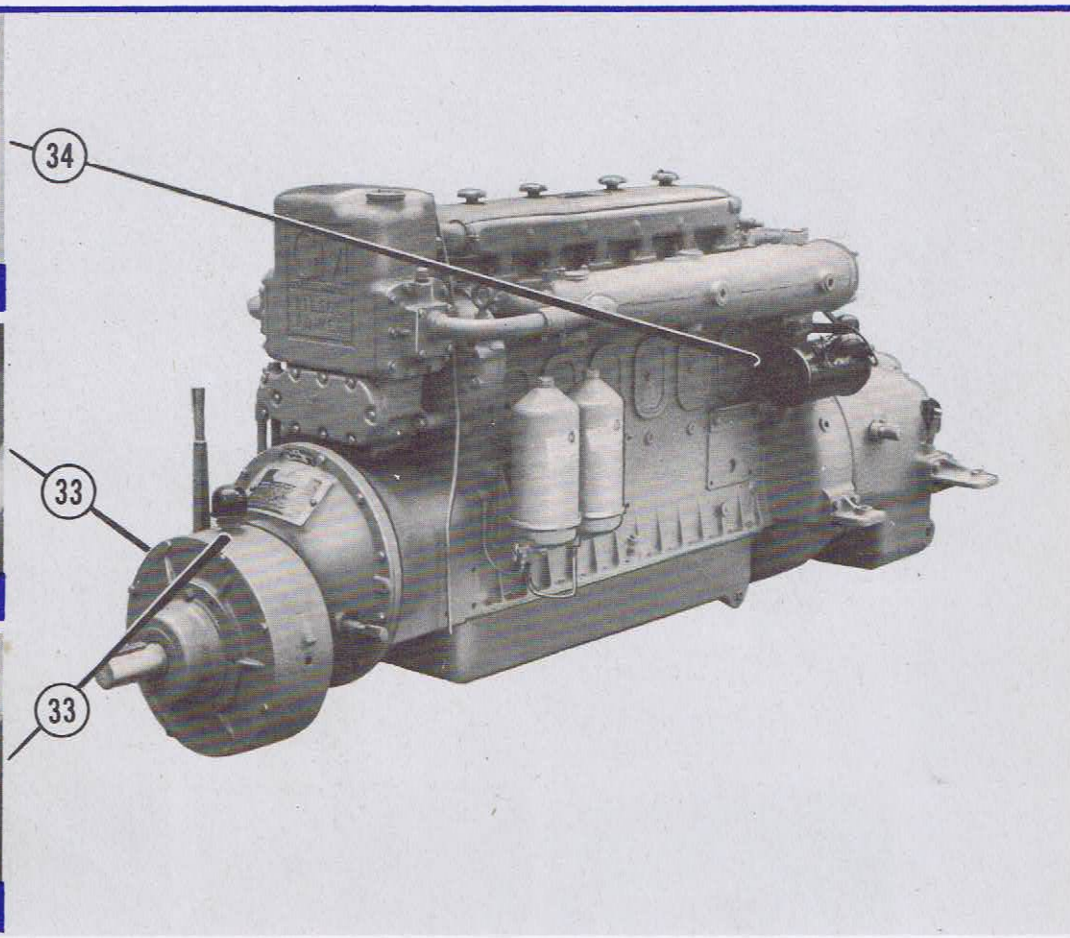


34. GENERATOR CROSS SECTION



33. DRAIN


33. FILL AND CHECK




## After Each 2000 Hours of Operation

Perform All 1000 Hour Items

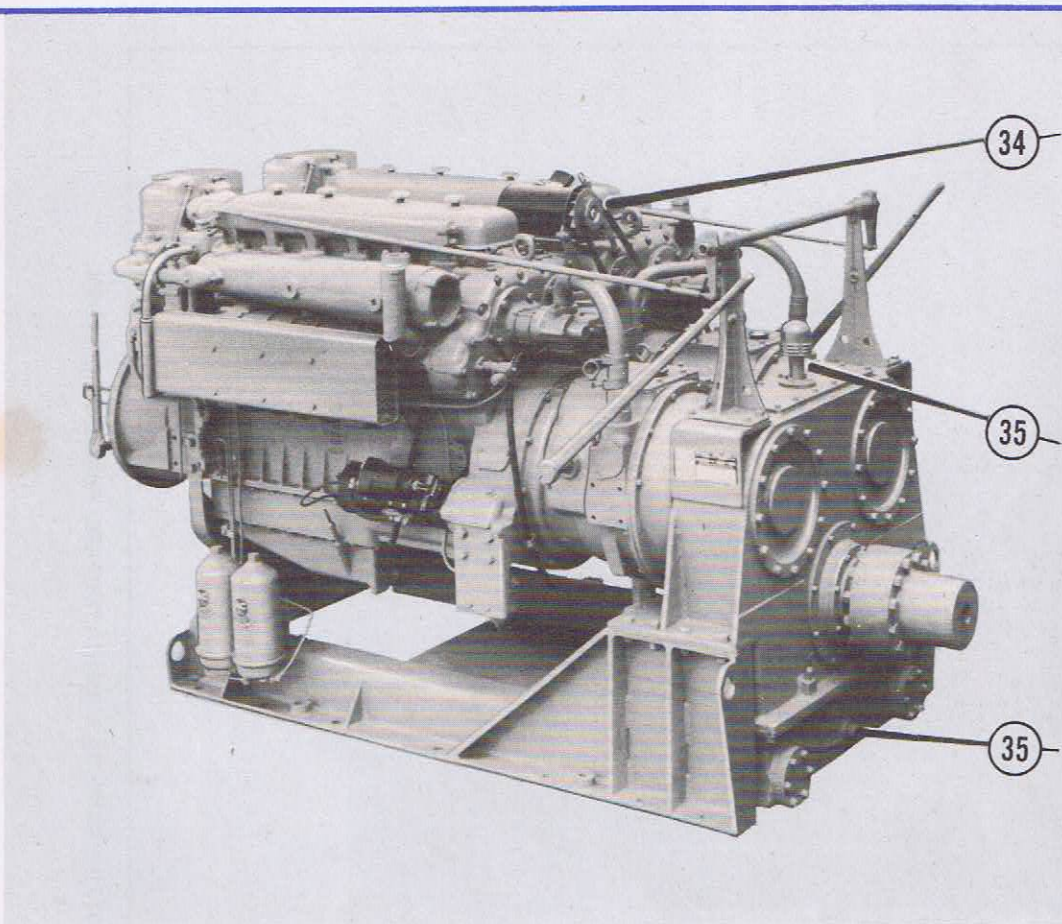
**33.** FRONT POWER TAKE-OFF WITH REDUCTION GEAR (60 H.P.), Change oil.

Remove pipe plug at bottom of gear housing to drain old lubricant. Replace plug and add new oil through filler neck at top of housing to bring level to high mark on dip stick.

Use only good quality transmission lubricant of S.A.E. 90 to 110 viscosity.

**34.** BATTERY CHARGING GENERATOR, Inspect and recondition.

Remove the generator from the engine, disassemble, and thoroughly clean the various subassemblies and parts in carbontetrachloride or gasoline. (Do not use fuel oil or soak insulated parts in solvent.) Any parts showing excessive wear or damage should be repaired or replaced. Internal and external wiring connections should be checked and any loose or corroded joints made clean and tight. Use only rosinflux for soldered connections. Brushes should be examined to see that they are seating well and do not stick in their holders. Replace worn brushes. New brushes may be seated by use of a bedding stone. **Never use emery cloth to seat brushes or clean commutator.** If the commutator is rough, out of round, or has high mica, put armature in a lathe and take a light cut on commutator to remedy the condition. Undercut the mica.




**34.** GENERATOR


**35.** REFILL

**35.** DRAIN

**35.** **REDUCTION GEAR BOX** (Twin Engine Units Only), Change oil.

Remove drain plug located just below the propeller shaft coupling and allow old oil to drain from housing. When empty, replace plug and add oil through filler neck at top of housing to bring level to high mark on dip stick.

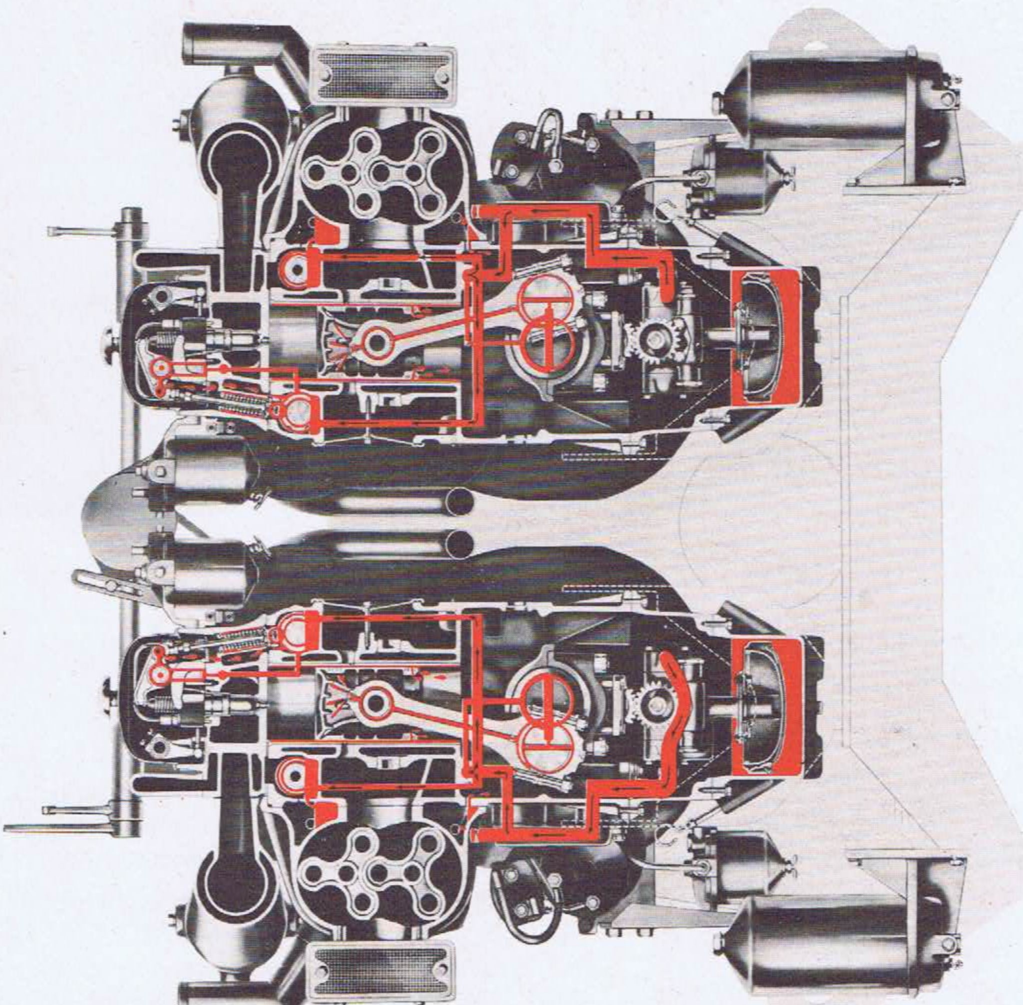
The same oil used in the engine crankcase may be used in this gear box. However, a heavy duty detergent type diesel lubricating oil is not necessary. Any reputable, premium quality, motor oil of S.A.E. 30 viscosity (S.A.E. 20 below 32° F.) will be satisfactory.

## *After Each 2500 to 3000 Hours of Operation*

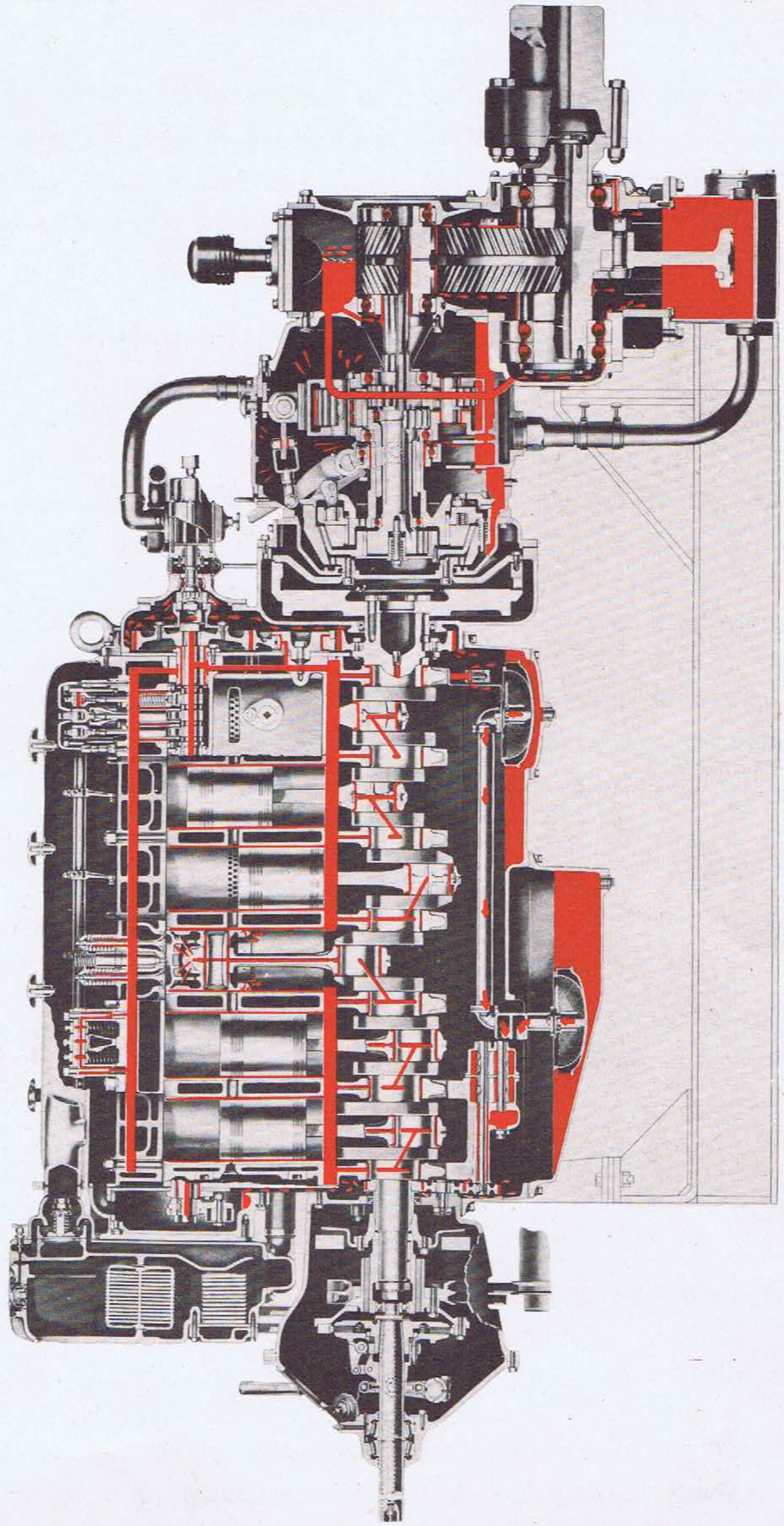
**36.** **ENGINE**, Recondition completely. (The period between engine reconditionings may be extended far beyond 3000 hours through good engine care and desirable operating conditions.)

Complete reconditioning should include full disassembly of the engine, thorough cleaning, inspection, reconditioning or replacement of all worn parts, and careful assembling using all new seals and gaskets. Accurate adjustments of valves, injectors, and governor must be made after assembly and before starting.

Your dealer is the best qualified agency to do this job.



END SECTION OF TWIN ENGINE UNIT SHOWING DISTRIBUTION OF LUBRICATING OIL THROUGH ENGINES.



SIDE SECTION OF TWIN ENGINE UNIT SHOWING LUBRICATING OIL DISTRIBUTION THROUGH ENGINE, REVERSE GEAR, AND REDUCTION GEAR.

## ENGINE TUNE-UP PROCEDURE

From time to time the operator will be called upon to make certain checks and adjustments on the engines. As for example: check, and perhaps change, the valve lash or check the governor adjustments at certain intervals as called for under "Lubrication and Preventive Maintenance", page 3. Items falling within the scope of the operator and discussed in this section are:

I. Check and, if necessary, time fuel injector.

II. Check and, if necessary, adjust valve lash.

III. Check and, if necessary, position injector control racks (includes governor spring gap setting).

IV. Cut out each injector in turn to check for erratic firing or loss of power.

If injectors are found to be operating at full efficiency further work is unnecessary and the tune-up may be considered completed. If one or more injectors are found in need of servicing, the tune-up will continue thus:

V. Remove Injectors.

VI. Install Injectors.

Having now disturbed the valve and injector operating mechanism and throttle adjustments, it becomes necessary to again:

a. Time Injectors.

b. Adjust Valve Lash.

c. Position Injector Control Racks.

d. Check Throttle Adjustments.

Complete instructions for carrying out the above operations appear on the following pages. *Study these instructions carefully before attempting the work.*

## I. TIME FUEL INJECTORS

To insure fuel delivery to the cylinder at just the correct moment, the plunger follower of each injector must be adjusted to a definite position in relation to the injector body. If injectors are not properly "timed", engine operation will be "ragged" and power output will be reduced.

The injectors should be timed as follows:

1. Shut down engine and leave throttle control set in the "STOP" position.
2. Remove valve rocker cover.
3. Turn engine over with a bar and socket or with the starting motor until the exhaust valves of the cylinder to be timed are fully open. By taking the injectors in firing order, all may be timed by turning the crankshaft only *one* full revolution.

NOTE: When cranking the engine by hand (using a wrench on the retaining bolt at the front of the crankshaft), always turn it in a clockwise direction regardless of the engine's normal rotation. If the engine rotation is left-hand or *counterclockwise* (looking at water tank end), the firing order will be reversed when turning crankshaft *clockwise*.

4. Place the stem of the *correct* injector timing gauge (2), tool number J-1242 or J-1853, into the timing gauge hole bored in the top of the injector body.

| Injector Identification Tag | Gauge No. | Timing Dimension |
|---|---|---|
| Red 50 or Blue 60 | J-1242 | 1.484″ |
| Green 80 | J-1853 | 1.460″ |

5. As illustrated in Fig. 1, adjust the position of the injector rocker arm (4) by means of the threaded adjustment on the upper end of the push rod (6) until the lowest surface of the timing gauge head (2), when rotated, will *just* pass over the top surface of the plunger follower guide (3). Tighten the lock nut on the push rod and recheck the setting. Timing gauge must be held perpendicular to top surface of the injector body.

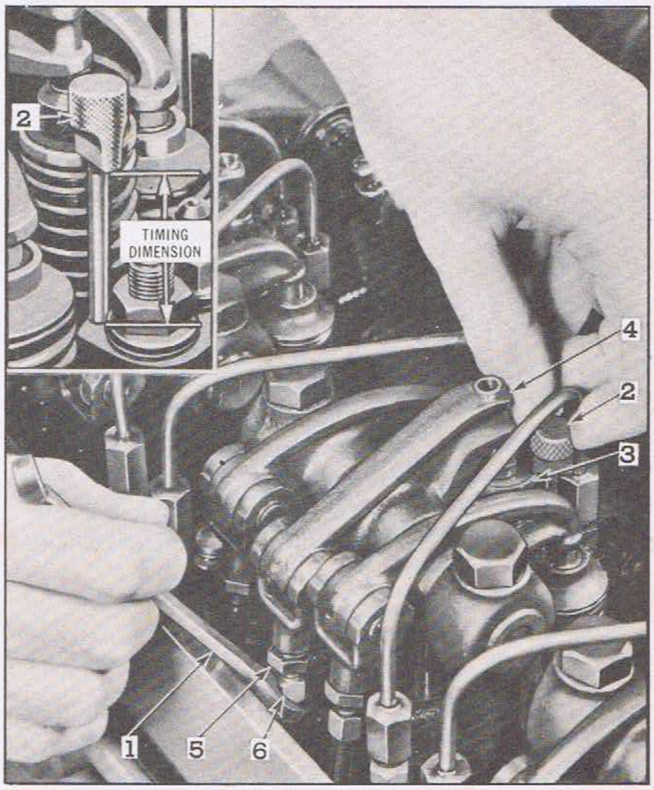



**FIG. 1—TIMING FUEL INJECTORS**

1. Push Rod Adjusting Wrench.
2. Timing Gauge.
3. Injector Follower Guide.
4. Injector Rocker Arm.
5. Lock Nut—Push Rod.
6. Push Rod—Injector.

## II. ADJUST VALVE LASH

**(CLEARANCE BETWEEN VALVE STEM AND ROCKER)**

Correct clearance between valve stem and valve operating rocker is especially important in a diesel engine because of the high compression pressure developed. Too little clearance will cause a loss of compression, a missing cylinder, and eventually, burned valves and valve seats. Too much clearance results in noisy operation of the engine, especially in the idling range.

The two valves over each cylinder of the Series 71 Diesel, open and close simultaneously to allow escape of exhaust gases. Consequently, all valves are adjusted to the same lash—.012″ *with engine at operating temperature.* This clearance is correct when an .011″ feeler will "GO" between valve stem and rocker and a .013″ feeler will "NO GO" between valve stem and rocker.

When cylinder head has been removed, or valve rocker mechanism disturbed, lash valves to .015″ with engines cold before starting by following the procedure outline in steps 2 and 3 below. After

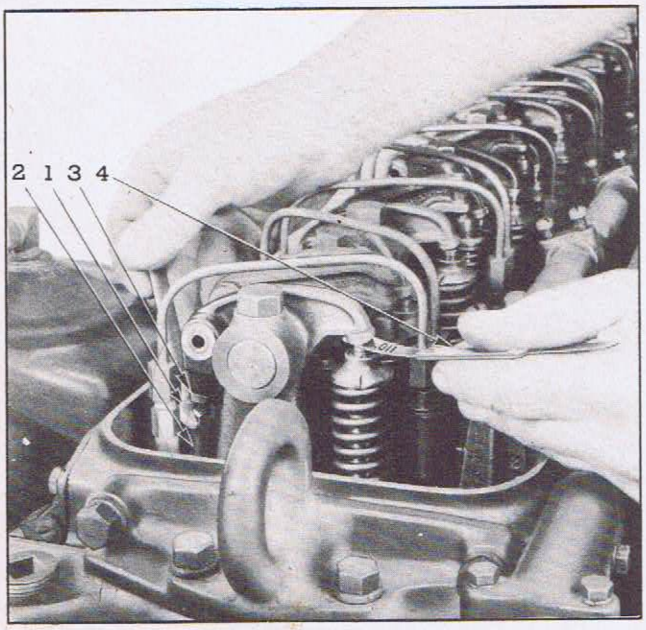



**FIG. 2—ADJUSTING VALVE CLEARANCE**

1. End Wrench—5/16″.
2. Push Rod.
3. Push Rod Lock Nut.
4. Feeler Gauge.

starting and warming up engines to operating temperatures, readjust valve clearance to .012″ hot (.011″ GO, .013″ NO GO).

Adjustment of valve lash may be carried out as follows:

1. Shut down engine and leave throttle set in "STOP" position. Remove valve rocker cover.

2. Using a bar and socket on the front of the crankshaft or the starting motor, turn the engine until the *injector rocker arm* on the cylinder to be checked is fully depressing the injector plunger. Valves on this cylinder are now fully closed and in proper position for checking lash.

NOTE: When cranking the engine by hand (using a wrench on the retaining bolt at the front of the crankshaft), always turn it in a clockwise direction regardless of the engine's normal rotation. If the engine rotation is left-hand or *counterclockwise* (looking at water tank end), the firing order will be reversed when turning crankshaft *clockwise*.

3. Refer to Fig. 2 and loosen lock nut (3) just below the end clevises on each of the two valve push rods. Insert .011″ feeler of gauge KMO-233-B (4) between end of valve stem and rocker and adjust clearance to a light contact with the feeler by turning push rod clockwise to increase clearance and counterclockwise to decrease clearance. Holding push rod from rotating, remove .011″ feeler and try gap with .013″ feeler. .013″ ribbon should be "NO GO". While still holding push rod, tighten lock nut and recheck lash with the two feeler ribbons to .011″ "GO", .013″ "NO GO".

4. Repeat steps 2 and 3 for the two valves on each cylinder. By taking cylinders in firing order, all can be checked while turning crankshaft only one revolution.

NOTE: Whenever a push rod has been disconnected from the push rod clevis, the rod must be screwed back into the clevis until push rod end touches rocker arm before the valve lash is checked. If this is not done, the piston may hit the head of the valve when the engine is being turned, owing to the small clearance between the valves and piston head at the piston upper position.

Before replacing the rocker cover, open the fuel supply valve, start the engine and inspect fuel line connections for leaks as diluting the lube oil with fuel oil may damage engine bearings.

## III. POSITION INJECTOR CONTROL RACKS

After injectors have been installed in the engine, the control racks must be correctly positioned so that all cylinders carry an equal share of the load and so that the injector racks are in correct relationship with the governor. The amount of fuel injected into each cylinder is controlled by the position of the injector rack. The maximum amount of fuel is injected when the racks are all the way IN, and no fuel is injected when the racks are all the way OUT.

Two different conditions will arise when it will be necessary to position the injector control racks.

CONDITION I applies when one injector has been replaced and the engine was in good operating condition previous to such replacement. In this event, the valves should be lashed, injector timed, and the rack positioned on the cylinder involved to correspond with that of the other racks.

CONDITION II applies when more than one injector has been replaced; also, when cylinder head has been removed or the valve gear disturbed. For this condition, valves should be lashed, injectors timed, and racks positioned on all cylinders.

I. POSITION INJECTOR CONTROL RACK WHEN ONLY ONE INJECTOR HAS BEEN REPLACED.

If the remaining injectors or governor adjustments have not been disturbed, and the engine was in good working order otherwise, proceed as follows to position the injector rack:

1. Back off several turns (at least four) on both adjusting screws (11) and (12) in rack control lever (8) at the injector being adjusted. (See Figs. 4 and 5.)

2. Hold the other injector racks all the way IN (full fuel position) by means of the governor control lever (1) as shown in Fig. 4 and adjust rack control lever (8) to the full IN position by slowly turning down inner adjusting screw (11) until injector rack can just be felt striking "bottom" and *just before* the racks of the other injectors start moving *out. Guard against moving the other injector racks OUT when positioning this one rack. Tighten outer screw (12) and then check as outlined in item 3 below.*

3. While still holding the racks all the way IN by means of the governor control lever (1), check rack coupling (10) of injector in question for looseness with the finger tips and compare with other injectors.

   Adjust rack coupling to the same degree of looseness as that felt at the other couplings by turning inner and outer screws (11) and (12) a very small amount.

II. POSITION INJECTOR CONTROL RACKS WHEN MORE THAN ONE INJECTOR HAS BEEN REPLACED IN THE ENGINE.

*When more than one injector has been replaced* in the engine, all injector racks must be correctly positioned so that each cylinder carries an equal share of the load and so that the injector racks are in correct relationship with the governor.

Since the governor spring mechanism is connected to the injector rack control tube through a link, *the governor spring plunger gap must be correctly set for the type of governor used to obtain full engine power.*

Four stops are involved in this case to position the injector control racks. They are:

A. *Make preliminary rack setting so engine can be safely started and run.*

B. *Set the governor spring gap to obtain full engine power.*

C. *Position Injector Racks to Full Fuel Position (Engine Not Running).*

D. *Set Governor Idling Speed.*

**A. Preliminary Positioning of Injector Control Rack Before Starting Engine**—Immediately following the installation of injectors, they should be timed and the valves lashed. (See page 21.)

Injector racks must then be approximately positioned to permit starting and stopping of engine. This is accomplished as follows:

1. Turn inner and outer adjusting screws on all injector rack control levers to equal depth. Tighten screws.

2. Hold governor control lever in the "stop" position (governor control link connected). Each injector rack must extend approximately $\frac{27}{32}''$ from injector body. (See Fig. 3.) This measurement assures engine shut down.

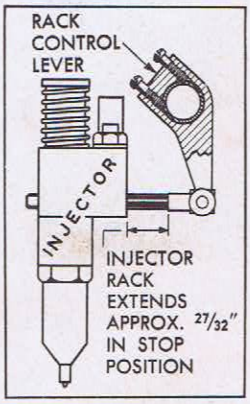



**FIG. 3—RACK STOP POSITION.**

**B. Governor Spring Gap Setting**—With valves properly lashed and injectors timed, refer to page 28 for gap setting instructions on limiting speed type governors or to page 29 for gap setting instructions on variable speed type governors.

**C. Position Injector Racks to Full Fuel Position (Engine Not Running) (Limiting and Variable Speed Governors).**

1. After setting the governor spring gap, refer to Fig. 4 and set the injector rack on No. 1 cylinder by backing out governor buffer screw (4) until it projects about ⅝" from the governor housing.

2. Back off several turns on both adjusting screws (11) and (12) of all rack control levers (8). Outer screw (12) on No. 1 lever should be backed off several additional turns. Be sure *all* levers are free to rotate on shaft.

3. ON THE LIMITING SPEED TYPE GOVERNOR:

   (a) Turn down inner adjusting screw (11) on No. 1 injector rack control lever (8) until screw bottoms.

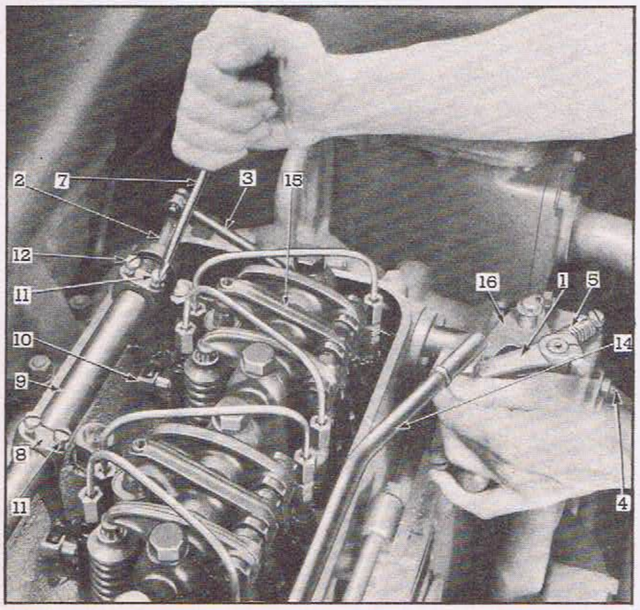



**FIG 4—POSITIONING RACK OF NO. 1 INJECTOR ON ENGINE EQUIPPED WITH LIMITING SPEED TYPE GOVERNOR.**

1. Governor Control Lever.
2. Control Tube Lever.
3. Control Link.
4. Buffer Screw.
5. Cam Spring.
7. Screwdriver.
8. Rack Control Lever.
9. Control Tube.
10. Injector Rack.
11. Adjusting Screw—Inner.
12. Adjusting Screw—Outer.
14. Throttle Control Rod.
15. Injector Rocker Arm.
16. Cam.

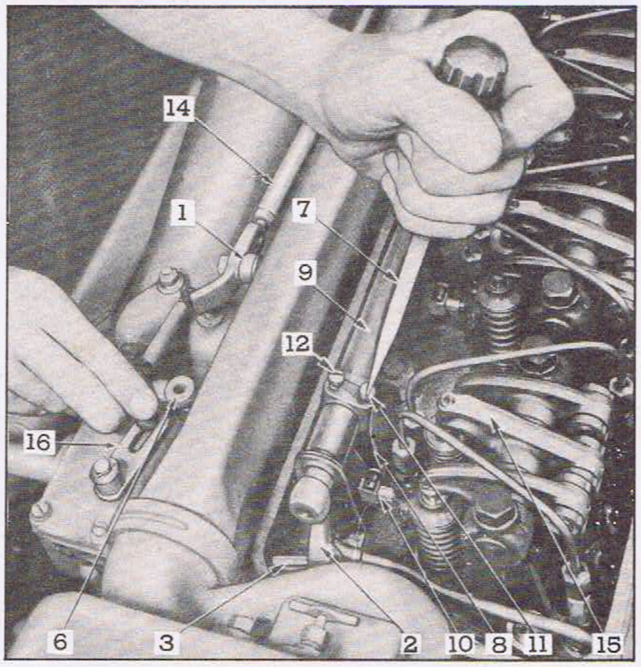



**FIG. 5—POSITIONING RACK OF NO. 1 INJECTOR ON "TWIN" ENGINE EQUIPPED WITH VARIABLE SPEED TYPE GOVERNOR.**

1. Speed Control Lever.
2. Control Tube Lever.
3. Control Link.
6. Governor Control Lever.
7. Screwdriver.
8. Rack Control Lever.
9. Control Tube.
10. Injector Rack.
11. Adjusting Screw—Inner.
12. Adjusting Screw—Outer.
14. Throttle Control Rod.
15. Injector Rocker Arm.
16. Slotted Cam.

(b) Move governor control lever (1) toward full open position. Do not force it past the point at which resistance to movement suddenly increases, but hold it at this point, pressing lightly toward FULL OPEN position.

(c) Back off inner adjusting screw (11) which will allow governor control lever (1) to move toward FULL OPEN position. Continue backing out screw until governor control lever (1) just "bottoms" at end of governor cam (16).

3a. ON THE VARIABLE SPEED TYPE GOVERNOR:

(a) Secure the speed control lever (1) in the FULL OPEN position (all the way back) as shown in Fig. 5. Place control lever (6) in the OFF position.

(b) Turn down inner adjusting screw (11) on No. 1 injector rack control lever (8) until screw "bottoms".

(c) Move the governor control lever (6) toward the RUN position at the end of the governor cam (16) as shown in Fig. 5. Do not force it past the point at which resistance to movement suddenly increases, but hold it at this point, pressing lightly toward the RUN position.

(d) Back off the inner adjusting screw (11) on No. 1 injector rack control lever which will allow the control lever (6) to move toward the RUN position. Continue backing out screw until the control lever (6) just "bottoms" at the end of the governor cam.

(e) Turn down *outer* adjusting screw (12) to lock rack control lever (8) in position. Tighten inner adjusting screw (11). This should accomplish the desired setting of No. 1 injector rack control lever (8).

(f) Check the adjustment by holding the governor control lever (6) in the RUN position (to aft end of slot in cam (16), as shown in Fig. 5), then note rotary movement of No. 1 injector rack to rack control lever (8).

1. If a light pressure of the finger tip shows the rack to be tight, and the governor control lever (6) is free to travel to the extreme end of the slot in the governor cam (16) without encountering any step-up in resistance, *the rack control lever (8) has been properly adjusted.*
2. If a light pressure of the finger tip shows the injector rack to be tight and the governor control lever (6) is not free to travel to the extreme end of the slot in cam (16), unless the step-up in resistance is overcome, the rack is too tight and the adjustment should be corrected by loosening the inner screw slightly and tightening the outer screw.
3. If a light pressure of the finger tip causes the rack coupling to rotate, the rack is too loose and the adjustment should be corrected by loosening the outer screw slightly and tightening the inner screw. *Once set, do not change the adjustment on No. 1 cylinder rack when adjusting the remaining injector racks.*

4. *Adjust Remaining Racks to FULL FUEL Position—Both Governors—by:*
   (a) Secure the governor control lever (6) in the RUN position.
   (b) Adjust No. 2 injector rack by turning down inner adjusting screw (11) while finger tip is touching No. 2 injector rack coupling. When coupling loses its rotary movement, tighten outer screw (12) and relock with inner screw (11).
   (c) Compare No. 2 and No. 1 rack couplings with finger tip for tightness or looseness. If No. 1 rack feels loose, No. 2 rack is too tight. If No. 2 rack feels loose, it should be tightened. Always correct the condition by adjusting the No. 2 rack.
   (d) When No. 2 rack coupling feels the same as No. 1, repeat procedure (b) and (c) on the remaining injector racks. That is, compare No. 3 rack with No. 1, etc.
   (e) Reconnect linkage to the governor control lever (6).

**D. Set Idle Speed** and buffer screw as outlined on page 29 for limiting speed type governors and on page 30 for variable speed type governors.

## IV. CUTTING OUT INJECTORS

**(TRACING A MISSING CYLINDER)**

One erratic or missing cylinder on a six-cylinder or twin engine unit is not easily detected when the engine is working at operating speeds. A periodic check of the injectors carried out as outlined below will show the presence and location of minor injector troubles which may sometimes be "cleared" without removing the injector. A missing cylinder that is detected early and corrected may save costly repairs that can result from complications should the condition be allowed to continue.

To detect a missing or erratic cylinder:

1. Start engine and run until water and oil temperatures come up to the point reached during normal operation.
2. Stop engine and remove valve rocker cover. Unless exhaust valve lash is known to be correct, check the clearance on all valves and adjust to .012″ (.011″ "GO"—.013″ "NO GO"). See page 21 for correct procedure.
3. Start engine and run at idle speed. If possible, have clutch engaged so engine will be under load.
4. Hold injector plunger of No. 1 cylinder down with a screwdriver as shown in Fig. 6, thus putting the injector out of operation. At the same time, note the tachometer for any difference in engine speed. If the cylinder is misfiring or the injector is not functioning properly, there will be no change in speed when the injector is put out of action. If the

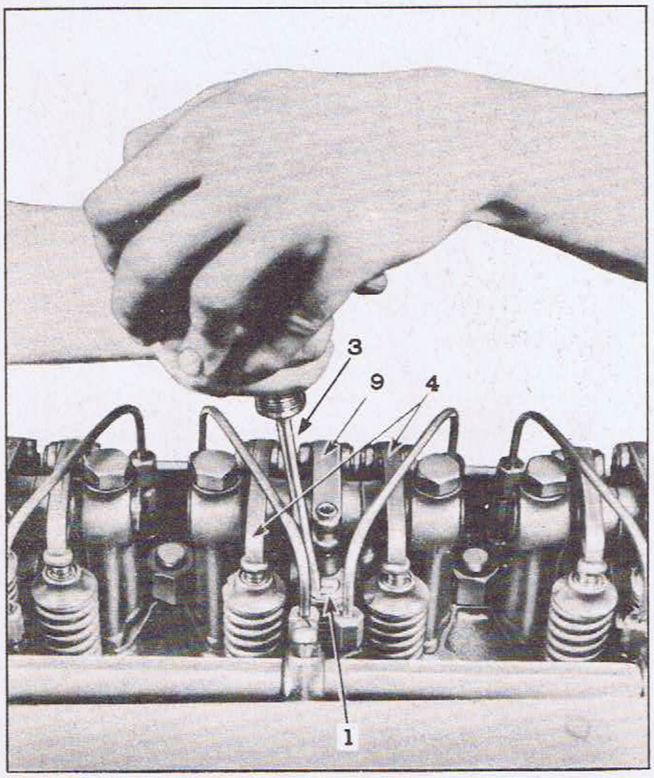



**FIG. 6—DEPRESSING INJECTOR FOLLOWER WITH SCREWDRIVER.**

1. Follower—Injector Plunger.
3. Screwdriver.
4. Arms—Valve Rocker.
9. Arm—Injector Rocker.

injector has been functioning properly, there will be a decrease in engine speed. Cutting out the cylinder in the manner described is similar to short-circuiting a spark plug on a gasoline engine.

5. If cylinder No. 1 proves to be firing properly, repeat the same procedure successively on all other cylinders until all have been tested.

6. If an injector is found to be firing poorly or not at all it may sometimes be "cleared" without removing by proceeding as follows:

   a. Keep engine running at idle speed (NO LOAD).

   b. Loosen both inner and outer adjusting screws (11 and 12, Fig. 4) on rack control lever of injector in question.

   c. Hold injector rack way in (full fuel position) for an instant. If the injector "comes in", detonation will be heard, indicating a heavy fuel charge.

   d. Stop engine and reposition control rack. (See page 22.)

7. If the injector cannot be "cleared" by the procedure outlined in item 6, it must then be removed and replaced with one known to be in good condition. Refer to the instructions below for removing and installing injectors.

## V. REMOVE AN INJECTOR

When necessary, a fuel injector may be removed for inspection, repair, or replacement by following the procedure outlined below:

1. Close fuel supply valve, if fuel level is above injectors.

2. Remove valve rocker cover.

3. Refer to Fig. 7 and remove fuel lines (1) from both the injector (2) and the fuel connectors (3).

NOTE: Immediately after removal of the fuel lines from an injector, the two fuel feed fittings should be protected with the shipping cap, part number 5226414, to prevent dirt entering the injector.

4. If necessary, crank the engine with the starter, or by hand, until the three rocker arm clevis pins—at outer end of rocker arms are in line.

NOTE: When cranking the engine by hand (using a wrench on the retaining bolt at the front of the crankshaft), always turn it in a clockwise direction regardless of the engine's normal rotation. If the engine rotation is right-hand or *counterclockwise* (looking at water tank end), the firing order will be reversed when turning crankshaft *clockwise.*

5. Loosen the two rocker arm bracket bolts (4) holding the brackets to the cylinder head (5) and swing the rocker arm assembly over away from valves and injector.

6. Remove injector hold-down stud nut (8), special washer (9) and injector clamp (7).

7. Using Tool J-1227-1, as illustrated in Fig. 7, pry injector from its seat.

8. Lift injector from seat; at the same time disengage the control rack linkage.

## VI. INSTALL AN INJECTOR

Supplied with an injector that has been tested and is known to be in first-class condition, refer to Fig. 7 and proceed to install it as outlined below.

1. Inspect the bore in the cylinder head into which injector is to be inserted. The inside of the copper tube should be clean; free from dirt, grit, oil or any particles which might keep the injector from sealing tight against the copper tube. The tube may be wiped clean with a cloth wrapped around a wood stick. Particular attention should be given to the beveled area just above the hole for the injector spray tip. At this point the seal is formed that keeps compression pressure from escaping around the injector.
2. Set the injector into the tube with dowel of injector body entering into the small dowel hole in cylinder head and with the operating lug on the rack control lever engaging the coupling slot at the end of the injector rack.
3. Position injector clamp (7) over stud with forked end resting on injector body.
4. Set special washer (9) over stud with curved surface next to clamp and replace nut (8).

   CAUTION: 1. Be careful not to overstress clamp when tightening nut. If torque wrench is available, a 20 to 25 pound reading on the wrench is satisfactory; otherwise, use 40 pounds pull on a 6″ wrench.

   CAUTION: 2. Injector rack must move freely after tightening nut.
5. Swing valve rocker assembly back into position and tighten bracket bolts (4).
6. Replace fuel lines (1).
7. Set operating lever on top of governor to the "STOP" position, thus throwing injector control tube and injector racks into the "NO FUEL" position. (Injector racks way out.) Adjust screws (11) and (12), Fig. 4, in rack control lever (8) of the injector, or injectors, just installed to bring the inner shoulder of the rack coupling (10) approximately $\frac{11}{32}$″ distance from the injector body. This distance should be the same on all injectors, the one, or ones, just installed as well as the ones that have not been removed.
8. Valve lash on cylinders where the rocker mechanism was disturbed should be given a preliminary setting of .015″ and then reset to .012″ (.011″ "GO"—.013″ "NO GO") after engine has been started and reaches operating temperature. (See page 21.) Adjust the timing of the new injector with correct timing gauge as outlined on page 21. If adiustment of valve clearance and injector timing was not carried out on all cylinders just before replacing the injector, proceed now to adjust valve lash and time injectors on the entire engine as outlined on page 21.
9. Open fuel supply valve if it was closed. Do not replace valve rocker cover until after engine has been started and all fuel line connections have been checked for leaks.
10. Proceed to position injector control rack or racks as outlined on page 22.

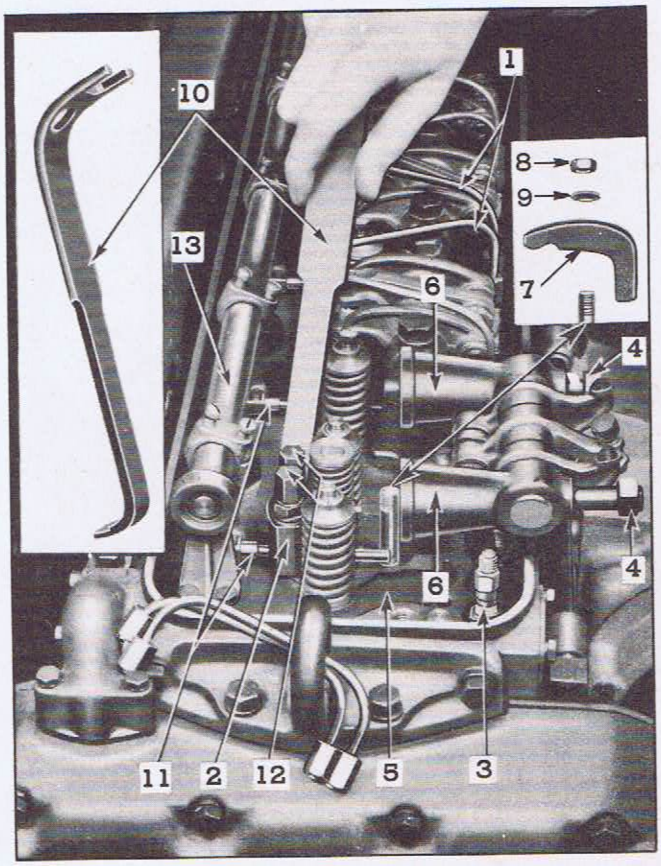



FIG. 7—REMOVING INJECTOR FROM CYLINDER HEAD WITH TOOL J-1227-1.

1. Fuel Lines.
2. Injector.
3. Fuel Connectors.
4. Bolts—Rocker Arm Shaft Bracket-to-Cylinder Head.
5. Cylinder Head.
6. Brackets—Rocker Arm Shaft.
7. Clamp—Injector Hold-down.
8. Nut—Injector Hold-down Stud.
9. Washer—Injector Hold-down Clamp.
10. Injector Removing Tool—J-1227-1.
11. Injector Control Rack.
12. Shipping Cap, No. 5226414.
13. Injector Control Tube.

## GOVERNOR ADJUSTMENTS

### Limiting Speed Type Governor

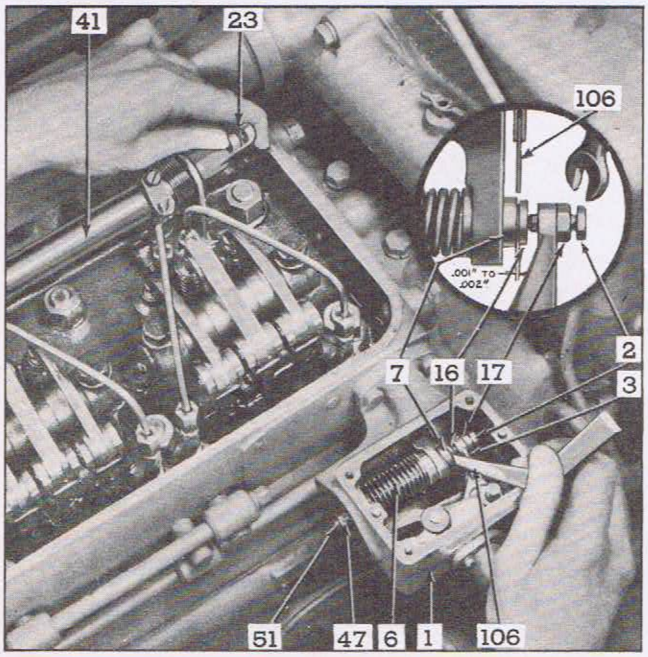



**FIG. 8—MEASURING GOVERNOR LOW-SPEED SPRING PLUNGER GAP.**

1. Housing—Governor Control.
2. Screw—Low Speed Spring Gap Adjusting.
3. Lever—Operating.
6. Spring—High Speed.
7. Plunger—Governor Spring.
16. Cap—Low Speed Spring.
17. Lock Nut—Low Speed Spring Gap Adjusting Screw.
23. Lever—Control Tube.
41. Tube—Injector Control.
47. Lock Nut—Low Speed Spring Screw.
51. Screw—Low Speed Adjusting.
106. Feeler Gauge.

•

When working on a *twin engine unit* equipped with limiting speed type governors, refer to "Throttle Controls—Twin Engine Units with Limiting Speed Governors", page 34, before proceeding with the governor adjustments.

•

There are four adjustments to be checked on the limiting speed type mechanical governor. The four adjustments in the order of their checking and setting are as follows:

I. Adjust gap between low speed spring cap and high speed spring plunger.

II. Adjust engine idling speed to 500 r.p.m.

III. Adjust buffer spring tension for limiting travel of differential lever toward the "stop" position.

IV. Adjust load limit screw, if one was furnished and if installation requires limiting the maximum engine output.

The engine maximum speed is determined by the characteristics of the governor high speed spring and cannot be increased except through the use of shims. (See "Set Governor No Load Top Speed", page 34.)

**I. Governor Spring Plunger Gap Adjustment.** After checking valve lash, timing injectors, and giving injector racks a preliminary positioning to assure engine "shut down", refer to Fig. 8 and adjust plunger gap as follows:

1. Remove the governor spring cover at the rear of the governor control housing (1) and set the low-speed adjusting screw (51) so that it projects ⅛" to $\frac{3}{16}$" from the lock nut (47).

2. Remove the governor cover and the link between the governor and the injector control tube (41).

3. Start the engine and with the aid of a helper, regulate the speed by hand operation of the injector control tube lever (23), as shown in Fig. 8.

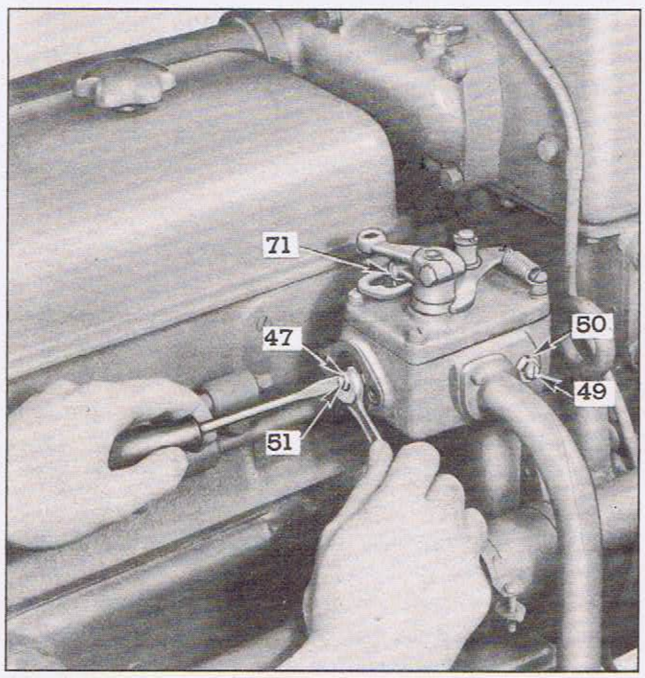



**FIG. 9—GOVERNOR IDLE-SPEED ADJUSTMENT.**

47. Lock Nut—Low Speed Adjusting Screw.
49. Buffer Screw.
50. Lock Nut—Buffer Screw.
51. Screw—Low Speed Adjusting.
71. Pin in Idle Notch (engine running).

*As the governor is now disconnected, care must be taken not to over-speed the engine.*

4. Keep the engine running between 700 and 1000 r.p.m. and set the low-speed spring gap adjusting screw (2) so that the gap between the low-speed spring cap (16) and the governor spring plunger (7) is only .001″ to .002″. This may be measured with a .0015″ or .002″ feeler gauge (106) inserted between cap (16) and plunger (7). Tighten lock nut (17) each time before checking above setting.

5. Stop engine and replace control link and the governor cover.

6. After adjusting the spring plunger gap, the injector racks must be positioned to establish correct relationship between governor and injectors. (See "Position Injector Control Racks", page 22.)

NOTE: The low speed adjustment cover removed from the rear of the governor control housing need not be replaced until after the following (Low Speed) adjustment is made.

**II. Idle Speed Adjustment**—The desirable idling speed of these marine engines is approximately 500 r.p.m. Even though the low-speed adjustment is set at the factory before the engine is shipped, it may be desirable either to raise or lower the idling speed of the engine, in which case the adjustment is made as follows: The engine should be running at operating temperature while making this adjustment.

(a) Remove low-speed adjustment screw cover at rear side of governor control housing (unless previously taken off for adjusting the low-speed plunger gap).

(b) Loosen lock nut (50) and turn buffer screw (49) out until screw projects ⅝″ beyond lock nut. (Fig. 9.) Set throttle control lever in idling position and start engine. If engine "gallops" or "rolls", after it has become thoroughly warm, gradually turn buffer spring screw (49) IN to contact differential lever until "roll" disappears, or nearly so. If engine doesn't "roll", leave buffer screw backed out until after low-speed adjustment has been completed.

(c) Loosen lock nut (47) on low-speed adjusting screw (51).

(d) Adjust screw IN (clockwise) for higher, and OUT (counter clockwise) for lower speed.

(e) Again check buffer spring adjustment, and re-adjust idle speed if necessary.

(f) Tighten idle adjusting screw lock nut (47) and replace cover and gasket over low speed adjusting screw.

**III. Buffer Spring Adjustment**—To adjust, after the screw has been backed out as directed for the low speed adjustment, turn screw IN until engine idling speed is increased slightly (not to exceed 20 r.p.m.), thus insuring spring contact with the differential lever. Secure lock nut (50).

**IV. Load Limit Screw Adjustment**—Some mechanical governors are equipped with this screw, others are not. If so equipped, its purpose is to stop the injector racks at any desired position before maximum fuel position has been reached. If loading conditions on engine are such that maximum rack opening is inadvisable, adjust load limit screw as follows:

(a) With load limit screw backed out and engine running with the desired maximum load, turn in load limit screw until it *just* contacts the governor differential lever. This will be just before the injector racks start to move out (toward the NO FUEL position).

(b) Tighten lock nut.

## Adjustments—Variable Speed Type Governor

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When working on a *twin engine unit* equipped with variable speed governors, refer to "Throttle Controls—Twin Engine Units with Variable Speed Governors", page 31, before proceeding with the governor adjustments.

●

There are four adjustments to be checked on the variable speed type mechanical governor. The four adjustments, in the order of their checking and setting, are as follows:

I. Adjust the gap between the spring plunger and the spring plunger guide.

II. Adjust engine idling speed to 500 r.p.m.

III. Adjust buffer spring tension for limiting travel of the differential lever toward the "stop" position.

IV. Adjust load limit screw, if one is furnished, and if installation requires limiting the maximum engine output.

**I. Governor Spring Plunger Gap Adjustment**—After checking valve lash, timing injectors, and giving injector racks a preliminary positioning to assure

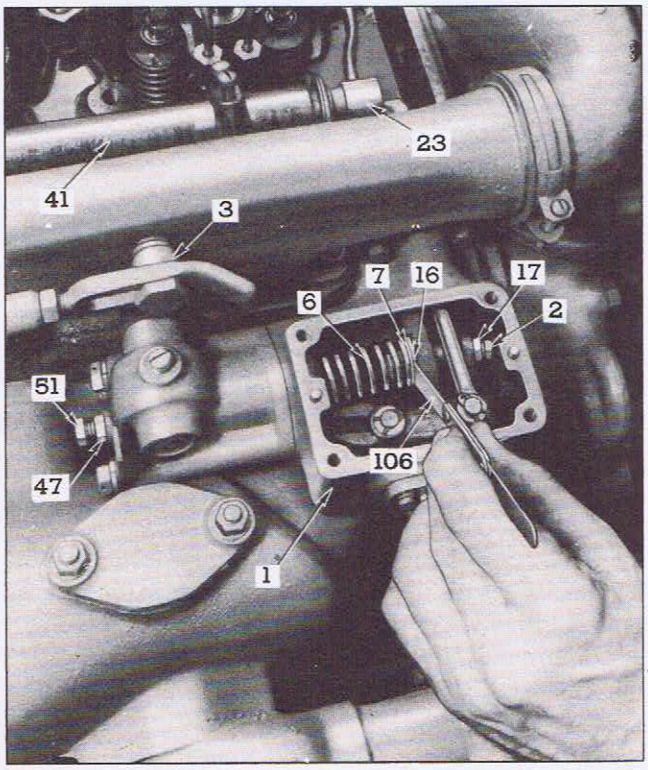



**FIG. 10—ADJUSTING SPRING PLUNGER GAP ON VARIABLE SPEED GOVERNOR.**

1. Housing—Governor Control.
2. Screw—Gap Adjusting.
3. Lever—Speed Control.
6. Governor Spring.
7. Plunger—Governor Spring.
16. Guide—Governor Spring Plunger.
17. Lock Nut—Adjusting Screw.
23. Lever—Control Tube.
41. Tube—Injector Control.
47. Lock Nut—Idle Speed Screw.
51. Screw—Idle Speed Adjusting.
106. Feeler Gauge.

engine "shut down", as outlined on pages 22 and 23, refer to Fig. 10 and adjust plunger gap as follows:

1. With engine stopped, disconnect linkage to the governor control lever (6), Fig. 5, and remove governor control housing cover assembly.
2. Secure the speed control lever (3) in the maximum speed position—all the way back.
3. With a feeler gauge, check clearance between shoulder of spring plunger (7) and plunger guide (16). This clearance should measure from .005" to .007".
4. If clearance is correct, install control housing cover and proceed to adjust idle and buffer screws. If adjustment of the gap is required, loosen gap adjusting screw lock nut (17) and turn gap adjusting screw (2) as required to establish clearance within the correct dimensions of .005" to .007". Tighten lock nut and recheck gap.
5. Replace control housing cover.
6. After adjusting the spring plunger gap, the injector racks must be positioned to establish correct relationship between governor and injectors. (See "Position Injector Control Racks," page 22.)

**II. Idle Speed Adjustment—**

1. Back out buffer screw (49), Fig. 9, until it projects ⅝" from side of governor control housing.
2. If load limit screw is used in governor housing, back screw out all the way.
3. With governor control lever (6), Fig. 5, in RUN position and speed control lever (1) in approximately half-speed position—slightly forward of vertical—start and warm engine up to operating temperature.
4. Set the governor speed control lever (1) in the IDLE position—all the way ahead—with control lever (6) still in RUN position.
5. If engine idle speed is unsatisfactory, loosen lock nut (47), Fig. 10, and turn adjusting screw (51) IN to increase or OUT to decrease engine speed. Tighten lock nut.

**III. Buffer Spring Adjustment**—(Engine running at correct idle speed).

1. To adjust buffer spring screw after it has been backed out as directed for the idle speed adjustment, turn screw IN until engine idle speed is increased slightly (not to exceed 20 r.p.m.) over the 500 r.p.m. idle speed. This will insure buffer spring contact with the governor differential lever. Tighten buffer screw lock nut.

**IV. Load Limit Screw Adjustment**—(Engine stopped.) Some mechanical governors are equipped with this screw, others are not. If so equipped, its purpose is to stop the injector racks at any desired position before maximum fuel position has been reached. If loading conditions on engine are such that maximum rack opening is inadvisable, adjust load limit screw as follows:

(a) With load limit screw backed out and engine running with the desired maximum load, turn in load limit screw until it just contacts the governor differential lever. This will be just before the injector racks start to move out (toward the NO FUEL position).

(b) Tighten lock nut.

## THROTTLE ADJUSTMENTS—TWIN ENGINE UNITS

Each Twin Marine Unit consists of two Diesel engines driving a common gear box. The object of the throttle adjustment is to cause each of the two engines to carry its share of the total load. If the throttle mechanism is set so that one engine reaches full throttle before the other is allowed to reach this setting, the total output of the twin unit will be reduced.

As pointed out under "Throttle Control", page 24, Sec. I, either variable speed or limiting speed type governors may be used on the Twin Marine Units.

Owing to the somewhat different design and characteristics of the two governors, somewhat different **throttle adjustments** are required for each type. For the sake of clearness, the complete adjustment for each governor type is given below together with separate adjustments diagrams.

**THROTTLE ADJUSTMENTS WITH VARIABLE SPEED GOVERNORS** are divided into the three following groups:

I. Adjustments of individual governors before installing the equalizer (cross) link.

II. Adjustments of governor speed lever control linkage.

III. Adjustment of equalizer link between the two engines.

NOTE: Before any governor adjustments are attempted: (a) lash engine valves to .011" "GO"—.013" "NO GO" Hot as outlined on page 21; (b) Time injectors as outlined on page 21; (c) position injector racks as outlined on page 22 unless these three adjustments are known to be satisfactory.

**I. Individual Governor Adjustments**—Each Variable Speed Governor is adjusted *individually* for four adjustments with the equalizer (cross) link (45) disconnected between the two engines. The four adjustments are:

1. Set gap between the spring plunger and the spring plunger guide to .005" to .007".
2. Set engine idling speed to 500 r.p.m.
3. Set buffer spring tension to limit travel of the differential lever toward the "STOP" position.
4. Set load limit screw, if one is furnished, and if installation requires limiting the maximum engine output.

Each of the above adjustments are described on page 29 under "Variable Speed Type Governor."

**II. Adjustments of Governor Speed Lever Control Linkage—With Engines Stopped**—After adjusting the individual governors and connecting both speed lever links (24), refer to Fig. 11 and adjust the speed lever control linkage as follows:

1. Set the throttle control cross shaft (1) so that throttle control levers (5) are in a vertical position. At "A-A" in Fig. 11. In this position, the detent ball (50) will drop into position in lever (5).
2. Adjust turnbuckles (19) on the throttle control tubes (21) so there is 1/8" between the forward end of the slot in throttle control link (24) and the bolt (25) in the speed control lever (23). This insures that when the master throttle is returned to "IDLE" (detent position) each governor is free from the throttle linkage.
3. Move the master throttle (2) until the "B" engine link (24) just barely starts to pick up the governor speed lever (23). Lock the master throttle in this position.
4. Adjust the turnbuckle (19) on the throttle control tube (21) for the "D" engine until its link (24) starts to pick up its speed lever, then take not less than 1/4 nor more than 1/2 additional shortening turns on the turnbuckle (19) for the "D" engine only. Tighten lock nuts (20) at turnbuckles on both throttle control tubes.

**III. Adjustment of Equalizer Link Between the Two Engines—With Engines Stopped**—With equalizer link (45) and cover (48) in place between the two engines; also, after adjusting the individual governors and the speed lever control linkage, refer to Fig. 11 and adjust the length of link (45) as follows:

1. Back out equalizer spring adjusting screw (37) so there is a definite clearance between the screw and the free end of the equalizer spring (35).
2. Loosen lock nut at turnbuckle (47) on equalizer link for "B" engine and remove pin (40) that connects link (46) to lever (31).
3. Set equalizer link lever (31) at "B" engine so that its clevis pin (40) center is directly over the center of the injector rack control tube (33) as shown at "B-B", Fig. 11. Set equalizer link lever (44) at "D" engine so that its clevis pin center is directly beneath the center of its injector rack control tube.
4. Adjust the length of link (46) so that pin (40) at the "B" engine can just be slipped in place with

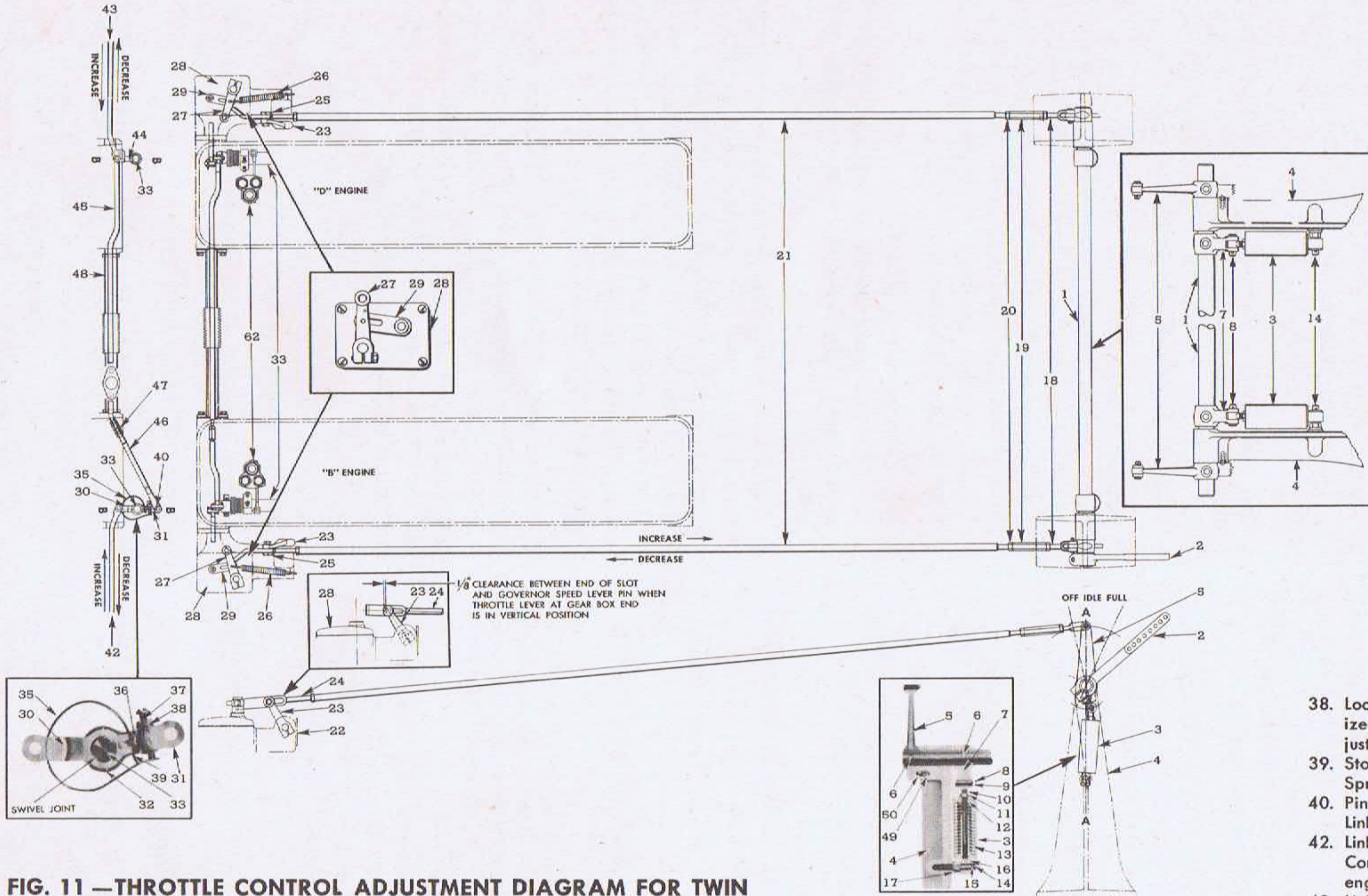



**FIG. 11 —THROTTLE CONTROL ADJUSTMENT DIAGRAM FOR TWIN ENGINES USING VARIABLE SPEED GOVERNORS.**

1. Cross Shaft—Throttle Control.
2. Lever—Master Throttle Control.
3. Booster.
4. Bracket—Throttle Control Support.
5. Lever—Throttle Control.
6. Pin—Throttle Booster Lever to Shaft.
7. Lever—Throttle Booster.
8. Pin—Booster to Throttle Booster Lever.
9. Cotter Pin—Booster Lever Pin.
10. Rod—Adjuster—Booster.
11. Lock Nut—Booster Adjuster Rod.
12. Nut—Booster Spring Adjusting.
13. Spring—Booster Compression.
14. Stud—Booster Support.
15. Cotter Pin—Booster Support Stud.
16. Washer—Booster Stud Support (Outer).
17. Washer—Booster Stud Support (Inner).
18. Clevis—Throttle Control Tube.
19. Turnbuckle—Throttle Control Tube.
20. Lock Nut—Throttle Control Tube.
21. Tube—Throttle Control.
22. Clip—Speed Control Lever Retaining Spring.
23. Lever—Speed Control.
24. Link—Throttle Control to Governor.
25. Bolt—Link to Speed Control Lever.
26. Spring—Stop Lever Retracting.
27. Lever—Governor Control.
28. Governor.
29. Control Cam.
30. Lever—Injector Control Tube.
31. Lever—Equalizer Link.
32. Pin—Injector Control Tube Lever to Control Tube.
33. Tube—Injector Rack Control.
35. Spring—Equalizer.
36. Screw—Equalizer Spring to Lever.
37. Screw—Equalizer Spring Adjusting.
38. Lock Nut—Equalizer Spring Adjusting Screw.
39. Stop—Equalizer Spring.
40. Pin—Equalizer Link to Lever.
42. Link—Governor Control (for "B" engine).
43. Link—Governor Control (for "D" engine).
44. Lever—Equalizer Link and Control Tube (for "D" engine).
45. Link—Equalizer (Long).
46. Link—Equalizer (Short).
47. Turnbuckle—Equalizer Links.
48. Cover Tube—Equalizer Link.
49. Spring—Throttle Control Lever Stop.
50. Ball—Throttle Control Lever Stop Spring.
62. Injector.

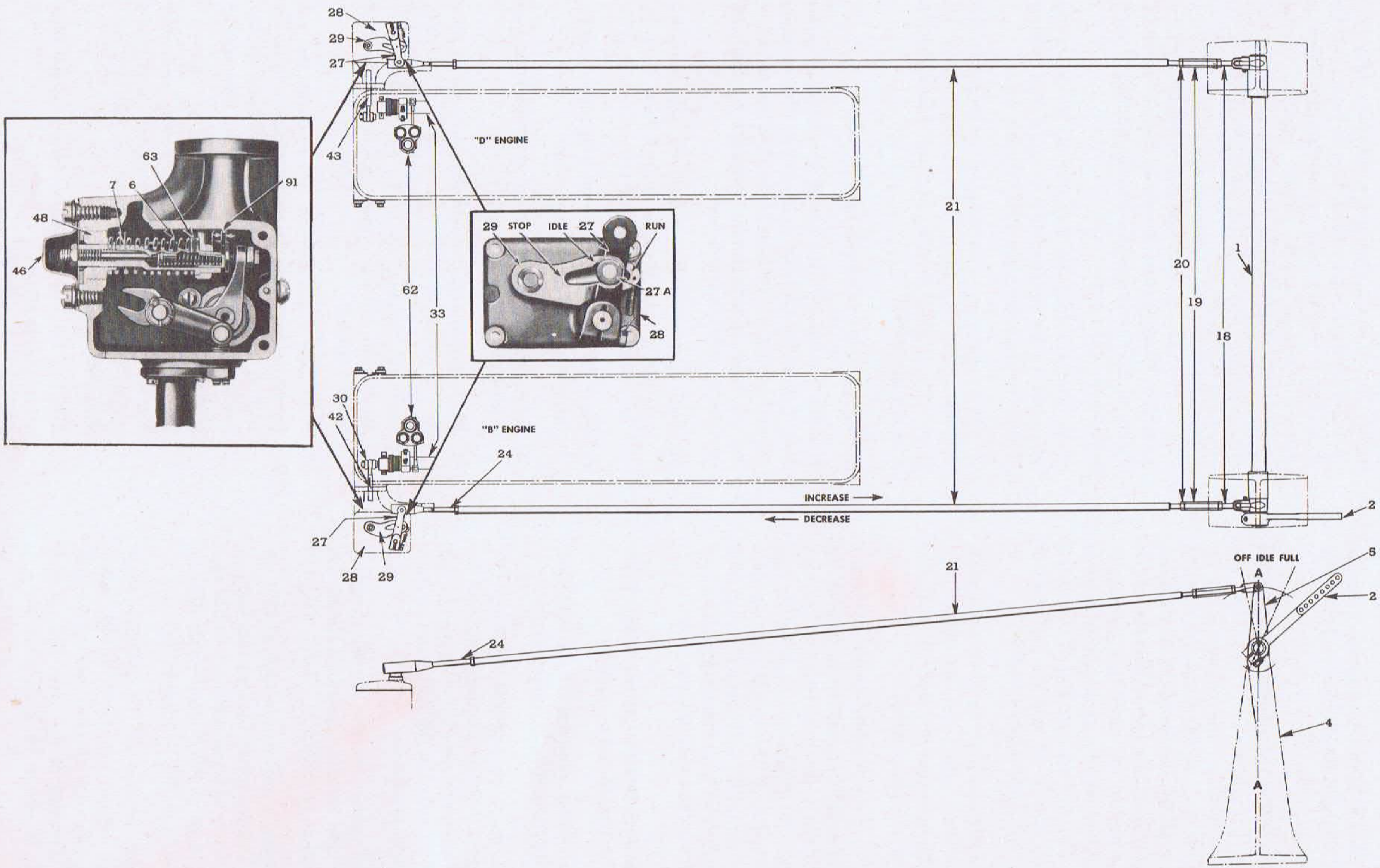



**FIG. 12—THROTTLE CONTROL ADJUSTMENT DIAGRAM FOR TWIN ENGINES USING LIMITING SPEED GOVERNORS.**

1. Cross Shaft—Throttle Control.
2. Lever—Master Throttle Control.
4. Bracket—Throttle Control Support.
5. Lever—Throttle Control.
6. Spring—High-Speed.
7. Spring Plunger.
18. Clevis—Throttle Control Tube.
19. Turnbuckle—Throttle Control Tube.
20. Lock Nut—Throttle Control Tube.
21. Tube—Throttle Control.
24. Link—Throttle Control to Governor.
27. Lever—Governor Control.
27a. Lever—Throttle Control.
28. Governor.
29. Control Cam.
30. Lever—Injector Control Tube.
33. Tube—Injector Rack Control.
42. Link—Governor Control (for "D" engine).
43. Link—Governor Control (for "B" engine).
46. Cover—Low-Speed Adjusting Screw.
48. Nut—High-Speed Spring Retaining.
62. Injector.
63. Shims.
91. Low-Speed Spring Gaps.

levers (31) and (44) held in the positions given in item "3" above. Tighten turnbuckle lock nut and install cotter pin.

5. Check as follows: Rotate the injector rack control tube (33) of the "D" engine until the cross link clevis pin is directly under the center of the injector control tube; i.e., on an imaginary vertical line passing through the center of the two pieces. Holding this position, check to see that the clevis pin on the other end of the cross link is directly over the center of the injector rack control tube of the "B" engine. *Careful adjustment of the cross link length, as closely as can be judged by the eye, is essential to proper operation.*

6. Set the master throttle so that the governor speed control levers (23) are approximately vertical, in which position the governor springs will push the injector rack in to full fuel position.

7. Carefully screw in the equalizer spring adjusting screw (37) in the equalizing link lever (31) at the "B" engine until the screw just touches the free end of the spring (35). Tighten lock nut (38) and check the adjustment. If the mechanism is correctly adjusted, spring (35) will touch the stop (39) and the adjusting screw (37) simultaneously, with all slack taken out of the cross link pin joints.

**THROTTLE ADJUSTMENTS WITH LIMITING SPEED TYPE GOVERNORS may be carried out as follows:**

1. Adjust governor spring plunger gap as outlined on page 28, for limiting speed type governor.

2. Position injector racks as outlined on page 22. Note: It is important that the governor gap and injector rack adjustments on all engines be as nearly identical as possible so that each engine will pull its share of the load.

3. With engines stopped, set the throttle control cross shaft (1) so that throttle control levers (5) are in a vertical position as shown at "A-A", Fig. 12.

4. With engines stopped, adjust turnbuckles (19) on the two throttle control tubes (21) so that pins in throttle control levers (27a) at governor cover rest against the shoulders of the control cams (29) in the "IDLE" position at the two governors.

5. Now move master throttle (2) to "FULL" open position, at which setting the pin in throttle lever (27a) at both governors should *just* strike the extreme end of the slot in the cam (29) at the "RUN" position. If either or both pins do not reach end of slot in cams, adjust turnbuckles (19) to bring about this condition. The linkage must be so adjusted that the pins in the throttle levers at governor covers reach "RUN" position in the control cam at exactly the same time. *Do not put any strain in the throttle linkage when making this adjustment.*

6. Start and warm up both engines to operating temperature. Move master throttle to "IDLE" position. Declutch both engines and set idling speed of each engine to 500 r.p.m.

   Note: Engines may be brought up to operating temperature by declutching engines and setting throttle to approximately 1200 engine r.p.m.

   If quick warm-up is attempted by turning the propeller, the ship must be securely tied to the dock with no loose lines or floating obstructions to foul the propeller.

7. **Set Governor No Load Top Speed.**

   Usually the top no load speed is set the same on both governors of twin units before the engines leave the factory. If check as outlined below shows top no load speeds to be different on the two governors, correct as follows:

   (a) With both engines warmed up, stop engines and disconnect throttle control tube (21) for "B" engine by removing pin at clevis (18).

   (b) Start "D" engine, declutch and move master throttle to "FULL" open position.

   (c) Note and record maximum no load speed as indicated by tachometer.

   (d) Stop engine and connect throttle control tube for "B" engine and disconnect "D" engine.

   (e) Start "B" engine, declutch, and with master throttle in "FULL" open position, note and record speed.

   (f) If no load speeds of the two engines are not the same, increase the speed of low engine by adding shims (63) (part No. 5150947), between the high speed spring (6) and the spring plunger (7) as shown in Fig. 12.

   To add shims, remove low-speed adjusting screw cover (46), back out nut (48) and place shims between inner end of spring and shoulder on plunger.

   Add one shim at a time and check speed after each shim is added.

**8. Synchronize Engine Speeds at No Load.** Speeds of the two engines must be synchronized to obtain, as nearly as possible, the same no load speeds in the range just below the rated load speed by adjusting the linkage to each governor. Thus, a unit rated at 1850 r.p.m. should have the engines synchronized at 1700-1800 r.p.m. *Synchronize as follows:*

(a) With engines warmed up, declutch both engines and move master throttle to such position that speed of "B" engine is 1750 r.p.m. as recorded by the speedometer. *Lock the master throttle in this position.*

(b) Note speed of the "D" engine. If the speeds of the two engines are not the same, loosen the two lock nuts at turnbuckle (19) on the "D" engine, and by adjusting turnbuckle, shorten throttle tube (21) to increase or lengthen to decrease engine speed.

(c) Unlock and move master throttle to "FULL" open position. In the "FULL" open position, without strain on the throttle linkage, the pins in throttle control levers (27a) at the governor covers of both engines should be within $\frac{1}{16}$" of the same distance from the end of the slot in cam (29). If the levers are not within this limit, the chances are that the governor gaps or the injector rack adjustments are not identical on the two engines and should be rechecked.

The governor with the pin closest to the end of the cam slot may have a "close" gap or the governor with the pin farthest from the end of the cam slot may have the injector racks too "tight". If adjustments are necessary, recheck engine speeds after making adjustments.

## TROUBLE SHOOTING

The satisfactory performance of a Diesel engine depends on two items of foremost importance:

1. The presence of sufficiently high compression pressure.
2. The injection of the proper amount of fuel at the right time.

The first one of these items depends almost entirely on pistons, piston rings, and valves with their operating mechanism; the second item depends on the injectors and their operating mechanism.

Lack of engine power, uneven running, excessive vibration, and a tendency to stall when idling may be caused either by a compression loss or faulty injector action.

Some of the more common difficulties that would hamper engine operation and the suggested remedies are reviewed below:

### I. ENGINE FAILS TO START AT TEMPERATURES ABOVE FREEZING (32° F.)

1. Throttle not in starting position or improperly adjusted.

   CORRECTION: Check throttle adjustment and open throttle. (See Throttle Adjustment, under "Tune-up Procedure", page 31).

2. Fuel tank empty.

3. Fuel supply valves closed.

4. Fuel supply insufficient.

   CORRECTION: Check fuel oil filters for choked elements and admission of air. Check for dirt or chips in fuel lines. Check for choked injector filters. See if fuel pump is working properly. (Consult your Diesel dealer on major repair operations).

5. Water in air box (possible after installing a cylinder head).

   CORRECTION: Dry air box through hand holes with compressed air or clean rags. Also check air box drains. (See "Lubrication and Preventive Maintenance", page 12).

6. Low compression pressure.

   CORRECTION: Check compression pressure. (See "Checking Compression Pressure", below).

7. Blower rotors not revolving.

   CORRECTION: Inspect for broken blower rotor drive shaft or any other damaged parts of blower drive mechanism. (Consult your Diesel dealer on major repair operations).

8. Improper engine timing. (After an engine overhaul).

   CORRECTION: Inspect for proper timing by marks on gear train. (Consult your Diesel dealer on major repair operations).

**II. UNEVEN RUNNING AND EXCESSIVE VIBRATION.**

1. Faulty injector timing or injector rack setting.

   CORRECTION: See "Time Injectors" and "Position Injector Racks" under "Engine Tune-up Procedure", page 20.

2. Fuel supply insufficient.

   CORRECTION: See Item 4, under I, "Engine Fails to Start", above.

3. Hunting governor.

   CORRECTION: Remove bind from injector rack operating mechanism, from linkage between governor and injector control tube, and in the governor itself. (Consult your Diesel dealer on major repair operations).

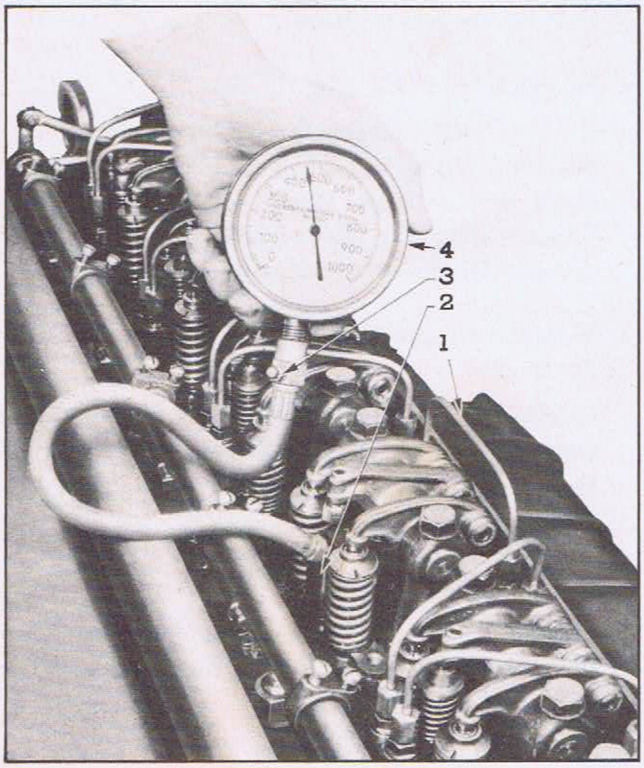



**FIG. 13—CHECKING COMPRESSION PRESSURE WITH TOOL J-1319-A.**

1. Fuel Jumper.
2. Compression Adaptor Fitting.
3. Bleed Valve.
4. Gauge.

4. Cooling water temperature too low.

   CORRECTION: Inspect thermostat for water leaks past the thermostat.

5. Valves in bad condition.

   CORRECTION: Check compression pressure as described in Item "7" below.

6. One or more cylinders cutting out.

   CORRECTION: **Tracing a Missing Cylinder.** If the cutting out of a cylinder is suspected, refer to page 25 and perform the operations outlined there to find the faulty cylinder.

   (a) If the valve springs in the faulty cylinder are satisfactory, remove the fuel injector as outlined in "Engine Tune-up Procedure" page 26, and replace with a new one.

   (b) If the replacement of the injector has not corrected the difficulty, the compression pressure of the cylinder in question should be checked. Check compression pressure as outlined below referring to Fig. 13.

**7. Checking Compression Pressure.**

   (a) Remove valve rocker cover.

   (b) Start on No. 1 cylinder and remove fuel lines from both injector and fuel connectors.

   (c) Remove the injector from the No. 1 cylinder and install the pressure gauge J-1319-A, Fig. 14, the same as the injector was installed. (See "Remove and Install Injector" under "Engine Tune-up Procedure", page 26.

   (d) Use one of the two fuel lines as a "jumper" connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.

   (e) Start engine, run at approximately 500 r.p.m., and take readings on the gauge.

   **Do not take compression pressure by cranking engine with the starter.**

   (f) Perform this same operation on each cylinder in turn. The compression pressure on any one cylinder should not drop more than 25 pounds below the reading on the other cylinders, as for example.

| Cylinder | Gauge Reading |
|---|---|
| 1 | 415 lbs./sq. in. |
| 2 | 450 lbs./sq. in. |
| 3 | 445 lbs./sq. in. |
| 4 | 450 lbs./sq. in. |
| 5 | 445 lbs./sq. in. |
| 6 | 450 lbs./sq. in. |

Note that the compression pressure in No. 1 cylinder falls considerably below the pressure in the five other cylinders, indicating compression leak in No. 1 cylinder.

In such cases, remove the cylinder head, inspect valve seats, valve stems for sticking and cylinder head gasket for leaks. If these parts are found to be satisfactory, the leak is probably past the piston due to insufficient sealing of the piston rings.

To inspect the piston rings thoroughly, the piston must be removed from the engine. (Consult your Diesel dealer on major repair operations).

**8. Air in Fuel System.**

CORRECTION:

(a) Disconnect the fuel return line and run engine, and observe if air bubbles are discharged with fuel. This can best be done by submerging the end of the pipe in an open can of fuel.

(b) Remove one fuel pipe to injector at end of engine which is highest, if standing uneven, and install combination sight glass and pressure gauge fixture. Air bubbles will show up in the sight glass.

(c) If air is present, inspect all fuel line connections from the suction side of fuel pump to the fuel tank. Inspect for cracked tubing flared ends. Inspect primary filter gaskets and vent valves. Inspect for holes chafed through fuel suction line. Inspect for cracks arising from screwing fittings in too tight at fuel pump and filter.

## III. ENGINE STALLS FREQUENTLY.

1. Cooling water temperature too low.

   CORRECTION: Inspect thermostat for water leaks past the thermostat.

2. One or more cylinders cutting out.

   CORRECTION: See "Tracing a Missing Cylinder", Item 6, under "II. Uneven Running and Excessive Vibration", above.

3. Hunting governor.

   CORRECTION: Remove bind from injector rack operating mechanism, from linkage between governor and injector control tube and in the governor itself. (Consult your Diesel dealer on major repair operations).

4. Choked fuel oil filters.

   CORRECTION: Clean strainer in primary filter and change element in secondary filter. (See "Lubrication and Preventive Maintenance", page 12.

5. Unsatisfactory injectors.

   CORRECTION: See "Remove Injector" and "Install Injector" under "Engine Tune-up Procedure", page 27.

6. Improper governor adjustment and/or governor linkage incorrectly set.

   CORRECTION: See "Governor Adjustments" and "Throttle Adjustments" under "Engine Tune-up Procedure", pages 28 and 31.

7. Air in fuel system.

   CORRECTION: See "Air in Fuel System", Item 8, under "II. Uneven Running and Excessive Vibration", above.

## IV. LOSS OF POWER.

1. Injector racks not properly positioned.

   CORRECTION: See "Position Injector Control Racks", under "Engine Tune-up Procedure", page 22.

2. Faulty injector timing.

   CORRECTION: See "Time Fuel Injectors", under Engine Tune-up Procedure", page 21.

3. One or more cylinders cutting out.

   CORRECTION: See "Tracing a Missing Cylinder", Item 6, under "Uneven Running", page 36.

4. Fuel supply insufficient.

   CORRECTION: See Item 4, under "I. Engine Fails to Start", page 35.

5. Choked fuel oil filters.

CORRECTION: Clean strainer in primary filter and change element in secondary filter. (See "Lubrication and Preventive Maintenance", page 12.

6. Air in fuel system.

CORRECTION: See "Air in Fuel System", Item 8, under "II. Uneven Running and Excessive Vibration", page 37.

7. Unsatisfactory injectors.

CORRECTION: See "Remove Injector" and "Install Injector", under "Engine Tune-up Procedure", pages 26 and 27.

8. Improper governor adjustment and/or governor linkage incorrectly set.

CORRECTION: See "Governor Adjustments" and "Throttle Adjustments", under "Engine Tune-up Procedure", page 31.

9. Loss of compression.

CORRECTION: See "Check Compression Pressure", Item 7, under "II. Uneven Running and Excessive Vibration", page 36.

10. Fuel tank air vent plugged.

**V. SMOKY EXHAUST.**

A. BLACK SMOKE.

1. Poor grade of fuel.

CORRECTION: See "Fuel Oil Specifications", page 2.

2. Injector timing late.

CORRECTION: See "Time Fuel Injectors", under "Engine Tune-up Procedure", page 21.

3. Unsatisfactory injector.

CORRECTION: See "Remove Injector" and "Install Injector", under "Engine Tune-up Procedure", pages 26 and 27.

4. Air box hand hole cover plate gasket ruptured.

CORRECTION: Replace gasket.

5. Air ports in cylinder liners choked.

CORRECTION: Remove cylinder head and force carbon from ports into air box with pointed stick. Clean air box with dry rags. Check air box, drain pipes and elbows for stoppage. (Consult your Diesel dealer on major repair operations).

6. Obstructions in blower air intake.

CORRECTION: Remove air silencer; then inspect and clean screen between silencer and blower.

B. BLUE SMOKE.

1. Injector racks not properly positioned.

CORRECTION: See "Position Injector Control Racks", under "Engine Tune-up Procedure", page 22.

2. One or more cylinders cutting out.

CORRECTION: See "Tracing a Missing Cylinder", Item 6, Under "II. Uneven Running and Excessive Vibration", page 36.

3. Lubricating oil in combustion chambers.

(a) Piston rings worn or stuck or oil rings incorrectly assembled.

CORRECTION: Remove pistons and piston rings, clean pistons and ring grooves, replace piston rings.

(b) Oil leaks in blower housing or air box because of leaky blower to cylinder block gasket or leaky blower oil seals.

CORRECTION: Renew gasket or oil seals. (Consult your Diesel dealer on major repair operations).

4. Engine temperature too low.

CORRECTION: Check thermostat for water leaks past thermostat. Disregard blue smoke until engine warms up to at least 140° F. water temperature.

**VI. ENGINE DETONATES.**

A hard, metallic knock indicates detonation in one or more cylinders and the engine should be immediately stopped to prevent serious damage due to the excessive pressures accompanying detonation.

5. Choked fuel oil filters.

CORRECTION: Clean strainer in primary filter and change element in secondary filter. (See "Lubrication and Preventive Maintenance", page 12.

6. Air in fuel system.

CORRECTION: See "Air in Fuel System", Item 8, under "II. Uneven Running and Excessive Vibration", page 37.

7. Unsatisfactory injectors.

CORRECTION: See "Remove Injector" and "Install Injector", under "Engine Tune-up Procedure", pages 26 and 27.

8. Improper governor adjustment and/or governor linkage incorrectly set.

CORRECTION: See "Governor Adjustments" and "Throttle Adjustments", under "Engine Tune-up Procedure", page 31.

9. Loss of compression.

CORRECTION: See "Check Compression Pressure", Item 7, under "II. Uneven Running and Excessive Vibration", page 36.

10. Fuel tank air vent plugged.

## V. SMOKY EXHAUST.

### A. BLACK SMOKE.

1. Poor grade of fuel.

CORRECTION: See "Fuel Oil Specifications", page 2.

2. Injector timing late.

CORRECTION: See "Time Fuel Injectors", under "Engine Tune-up Procedure", page 21.

3. Unsatisfactory injector.

CORRECTION: See "Remove Injector" and "Install Injector", under "Engine Tune-up Procedure", pages 26 and 27.

4. Air box hand hole cover plate gasket ruptured.

CORRECTION: Replace gasket.

5. Air ports in cylinder liners choked.

CORRECTION: Remove cylinder head and force carbon from ports into air box with pointed stick. Clean air box with dry rags. Check air box, drain pipes and elbows for stoppage. (Consult your Diesel dealer on major repair operations).

6. Obstructions in blower air intake.

CORRECTION: Remove air silencer; then inspect and clean screen between silencer and blower.

### B. BLUE SMOKE.

1. Injector racks not properly positioned.

CORRECTION: See "Position Injector Control Racks", under "Engine Tune-up Procedure", page 22.

2. One or more cylinders cutting out.

CORRECTION: See "Tracing a Missing Cylinder", Item 6, Under "II. Uneven Running and Excessive Vibration", page 36.

3. Lubricating oil in combustion chambers.

(a) Piston rings worn or stuck or oil rings incorrectly assembled.

CORRECTION: Remove pistons and piston rings, clean pistons and ring grooves, replace piston rings.

(b) Oil leaks in blower housing or air box because of leaky blower to cylinder block gasket or leaky blower oil seals.

CORRECTION: Renew gasket or oil seals. (Consult your Diesel dealer on major repair operations).

4. Engine temperature too low.

CORRECTION: Check thermostat for water leaks past thermostat. Disregard blue smoke until engine warms up to at least 140° F. water temperature.

## VI. ENGINE DETONATES.

A hard, metallic knock indicates detonation in one or more cylinders and the engine should be immediately stopped to prevent serious damage due to the excessive pressures accompanying detonation.

Detonation is caused by the presence of fuel or lubricating oil in the air charge of the cylinders during the compression stroke.

CORRECTION: The engine should be checked for:

1. Leaky injectors. Locate bad cylinders by cutting out injectors, one at a time, as in "Tracing a Missing Cylinder", page 36. When bad cylinder is located, install a replacement injector.

2. Crankcase dilution due to fuel leaks at fuel oil connectors or fuel pipes at cylinder head.

   CORRECTION:

   (a) Inspect all fuel oil connections for leaks and tighten.

   (b) Inspect air box and blower for presence of oil. Clean air box and inspect and clean air box drains and drain pipe elbows.

   (c) Drain and refill crankcase with specified oil.

   (d) Inspect piston rings, first through ports in cylinder liners. If rings are stuck in grooves or broken, they must be changed. (Consult your Diesel dealer on major repair operations.)

3. Leaky blower housing gasket.

   CORRECTION: Replace gasket.

4. Leaky blower oil seals.

   CORRECTION: Change seals (Consult your Diesel dealer on major repair operations.

5. Plugged air box drains.

   CORRECTION: Remove air box drain pipes and elbows. Clean both pipes and elbows on inside. Remove hand hole covers and clean air box with dry rags. Open holes to drains.

### VII. LACK OF LUBRICATING OIL PRESSURE.

1. Oil supply in crankcase low, allowing pump to suck air.

   CORRECTION: Fill crankcase.

2. Crankcase oil diluted with fuel oil.

   CORRECTION: Check odor of crankcase oil for fuel oil. Drain and refill crankcase with specified lubricant if fuel oil is detected. Check and tighten all fuel oil connections at cylinder head.

3. Use of improper lubricant.

   CORRECTION: See "Lube, Oil Specifications", page 1.

4. Wear on main or connecting rod bearings.

   CORRECTION: Inspect all crankshaft bearings. (Consult your Diesel dealer on major repair operations.)

5. Lubricating oil pump relief valve (valve in pump) sticking.

   CORRECTION: Clean oil pump and valve. Examine oil in crankcase for dirt and sludge. Change oil if conditions warrant change. Clean oil pipes. (Consult your Diesel dealer on major repair operations).

6. Oil cooler choked.

   CORRECTION: Clean oil cooler. (Consult your Diesel dealer on major repair operations).

7. Oil pump screen choked.

   CORRECTION: Clean screen and change lube oil if necessary.

8. Oil pump drive inoperative.

   CORRECTION: Inspect pump drive.

9. Oil pump lines and oil galleries choked, improperly tightened or ruptured gaskets at joints.

   CORRECTION: Choked lines are the result of very dirty and sludged oil. For a badly sludged condition, engine should be torn down, oil galleries and pipes thoroughly cleaned, parts washed and inspected and engine rebuilt. (Consult your Diesel dealer on major repair operations).

### VIII. ENGINE RUNS UNEVENLY OR STOPS FREQUENTLY.

1. Water in fuel.

   CORRECTION: Drain water from fuel tank. Drain filters. Fill filters with clean fuel. Disconnect fuel return line and allow engine to run and discharge fuel into an outside container until fuel system is purged of water.

2. Low fuel pressure.

   CORRECTION: See Item 4, under "I. Engine Fails to Start", page 35.

## CHECKING ELECTRICAL STARTING SYSTEM

### Grounded System

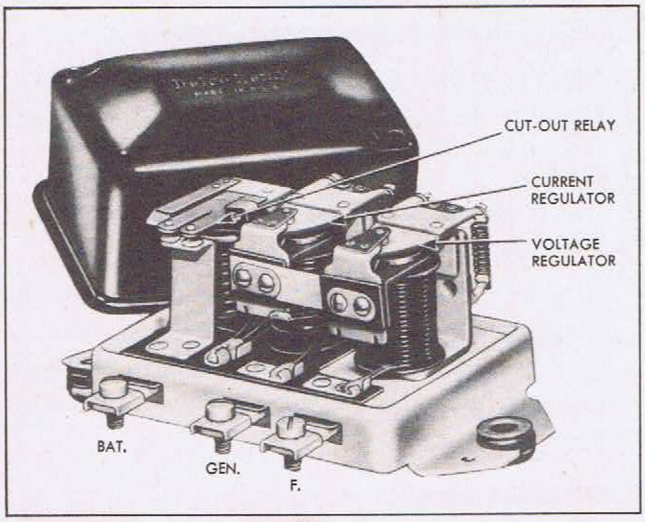



**FIG. 14—CURRENT AND VOLTAGE REGULATOR ASSEMBLY.**

**QUICK CHECKS TO DETERMINE IF GENERATOR AND REGULATOR ASSEMBLY ARE OPERATING NORMALLY.**

The following checks can be made to determine whether or not the units in the electrical starting system are operating normally. If not, the checks will indicate whether the generator or regulator is at fault, then proper corrective measures may be taken.

**CASE No. 1—A Fully Charged Battery and Low Charging Rate Indicates Normal Voltage Regulator Operation.**

To check the current regulator:

1. Use the cranking motor with the throttle set in the NO FUEL position for about 15 seconds.
2. Then with the engine running at a medium speed, turn on air heater ignition coil switch and any lights and note *quickly* on the ammeter, the generator output, which will be the *value for which the current regulator is set.*
3. Now turn off air heater switch and lights, and allow the engine to continue running.
4. As soon as the generator has replaced in the battery the current used in cranking, the voltage regulator, if operating normally, will taper the output down to a few amperes.

**CASE No. 2—A Fully Charged Battery and a High Charging Rate.** It must be remembered in analyzing trouble of this nature that the charging rate at any given voltage depends as much on battery temperature as on battery specific gravity. The charging rate to a fully charged *hot* battery may be greater than that obtained with a cool battery which has a fairly low specific gravity. If, considering the battery tempera-

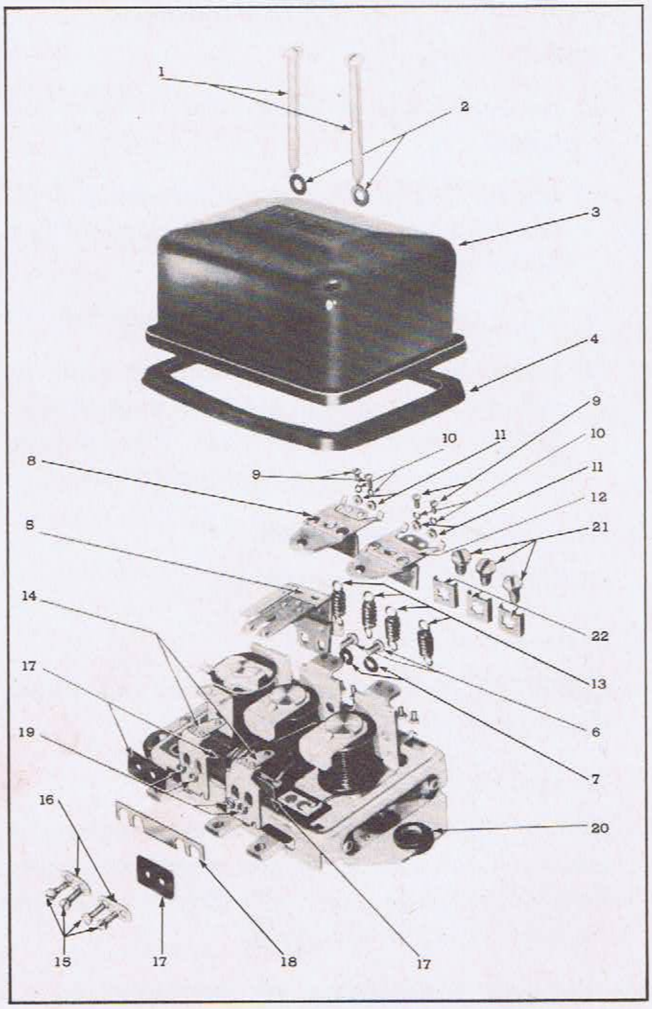


**FIG. 15—TYPICAL CURRENT AND VOLTAGE REGULATOR DETAILS AND RELATIVE LOCATION OF PARTS.**

1. Cover Screw.
2. Washer.
3. Regulator Cover.
4. Cover Gasket.
5. Relay Armature.
6. Armature Screw.
7. Lockwasher.
8. Current Regulator Armature.
9. Armature Screw.
10. Lockwasher.
11. Nut.
12. Voltage Regulator Armature.
13. Armature Spring.
14. Contact Point and Support.
15. Screw.
16. Lockwasher.
17. Insulated Washer.
18. Connector Strap.
19. Insulated Bushing.
20. Base Grommet.
21. Terminal Screw.
22. Terminal Clamp.

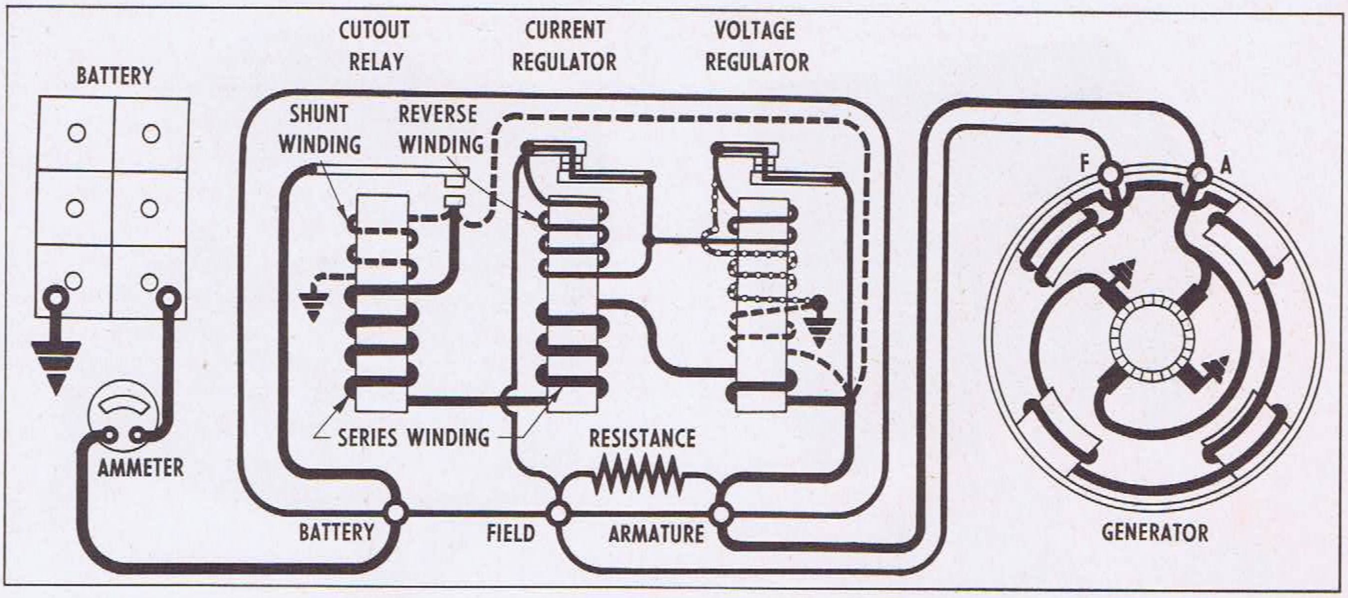



FIG. 16—DELCO-REMY HEAVY-DUTY THREE-UNIT REGULATOR WIRING DIAGRAM FOR GROUNDED SYSTEM.

ture and specific gravity, the charging rate is excessive, proceed as follows to determine reason:

1. Disconnect the field "F" terminal lead from the regulator. This opens the generator field circuit and the output should normally drop off. If it does not, the generator field circuit is grounded either internally or in the external wiring.

2. If the output drops to zero with the "F" terminal lead disconnected, the trouble has been isolated in the regulator.

3. Reconnect the "F" terminal lead, remove the regulator cover (3), Fig. 15, and depress the voltage regulator armature (12) manually to open the points.

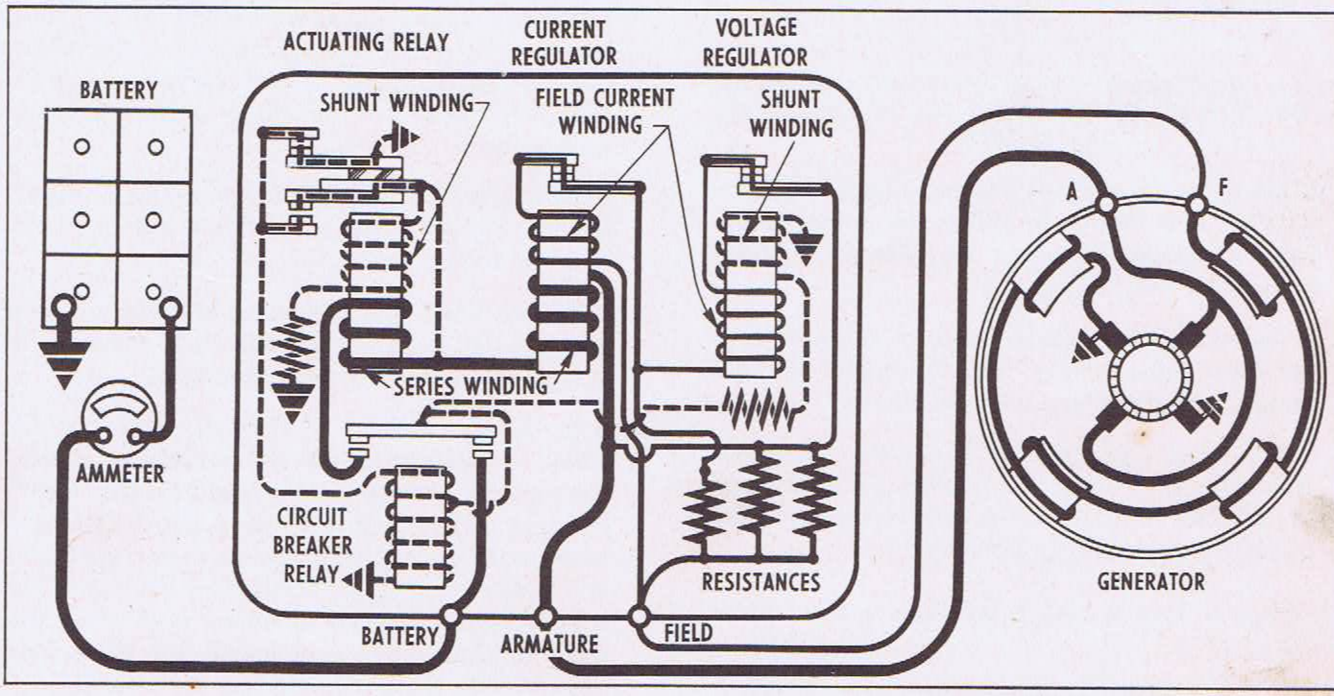



FIG. 17—DELCO-REMY HEAVY-DUTY FOUR-UNIT REGULATOR WIRING DIAGRAM FOR GROUNDED SYSTEM.

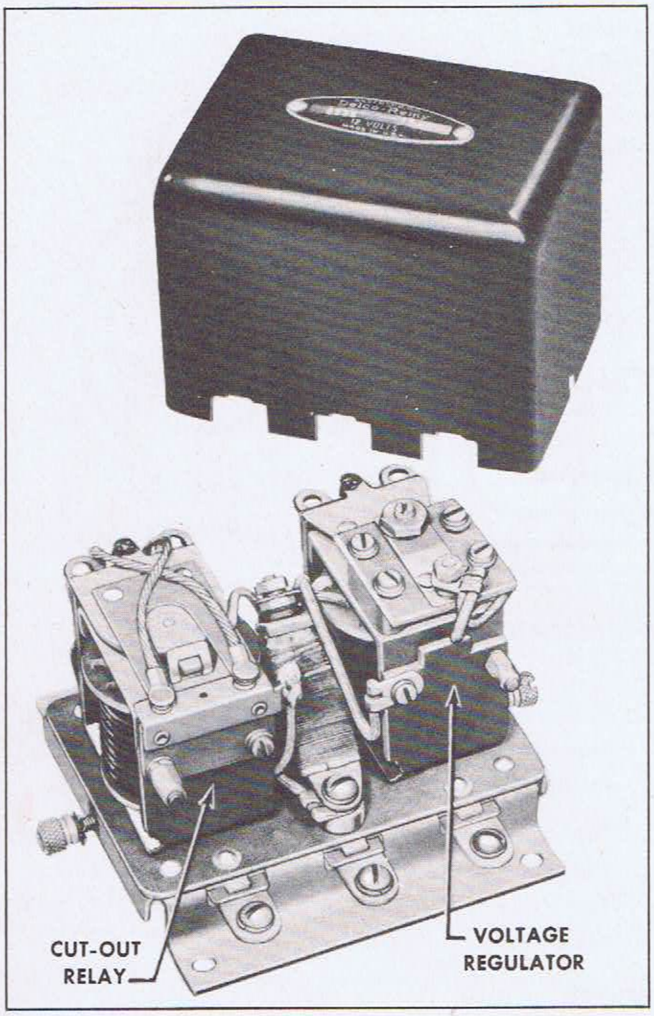



FIG. 18—DELCO-REMY HEAVY-DUTY TWO-UNIT REGULATOR WITH COVER REMOVED SO THE TWO UNITS CAN BE SEEN.

4. If the output now drops off, the voltage regulator unit has been failing to reduce the output as the battery came up to charge, and voltage regulator adjustment is indicated.

5. If separating the voltage regulator contacts does not cause the output to drop off, inspect the field circuit, within the regulator, for shorts.

   Pay particular attention to the bushings (19) and insulators (17) under the contact point supports of the two regulator units, and make sure the insulators are correctly assembled.

**CASE No. 3—With a Low Battery and a Low or No Charging Rate.**

1. Check the circuit for loose connections, frayed or damaged wires. High resistance resulting from these conditions will prevent normal charge from reaching the battery. If the wiring is in good condition, then either the regulator or generator is at fault.

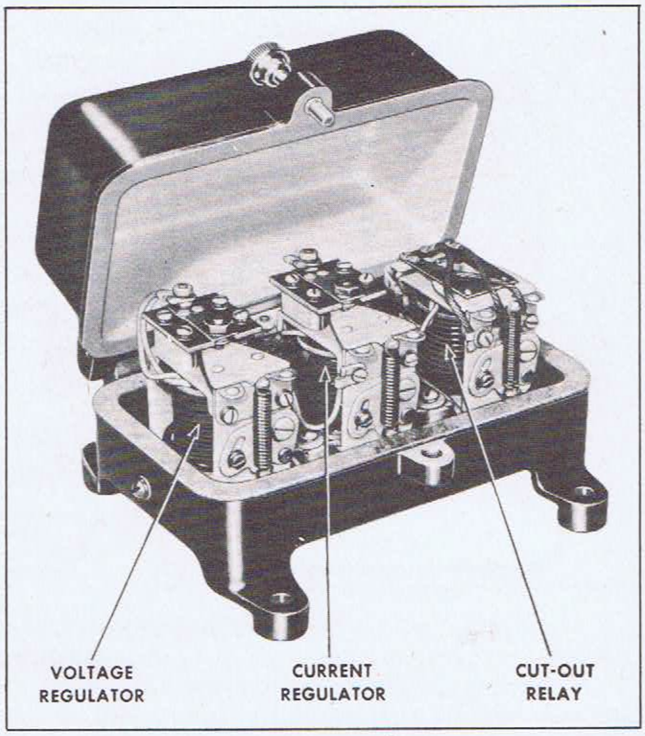



FIG. 19—DELCO-REMY HEAVY-DUTY THREE-UNIT REGULATOR WITH HINGE COVER.

2. Ground the "F" terminal of the regulator temporarily and increase generator speed to determine which unit needs attention. *Use care to avoid excessive speed, since under these conditions the generator may produce a dangerously high output.*

3. If the output does increase, the regulator needs attention. Check for dirty or oxidized contact points, or a low voltage setting.

4. If the generator output remains at a few amperes with the "F" terminal grounded, the generator is at fault and should be checked further.

5. If the generator does not show any output at all, either with or without the "F" terminal grounded, *very quickly* disconnect the lead from the "GEN" terminal of the regulator and strike it against a convenient ground with the generator operating at a medium speed. If a spark does not occur, the trouble has now been definitely isolated in the generator and repair is indicated. If a spark does occur, likely the generator output can build up, but the cutout relay is not operating to permit the current to flow to the battery, due to burned points,

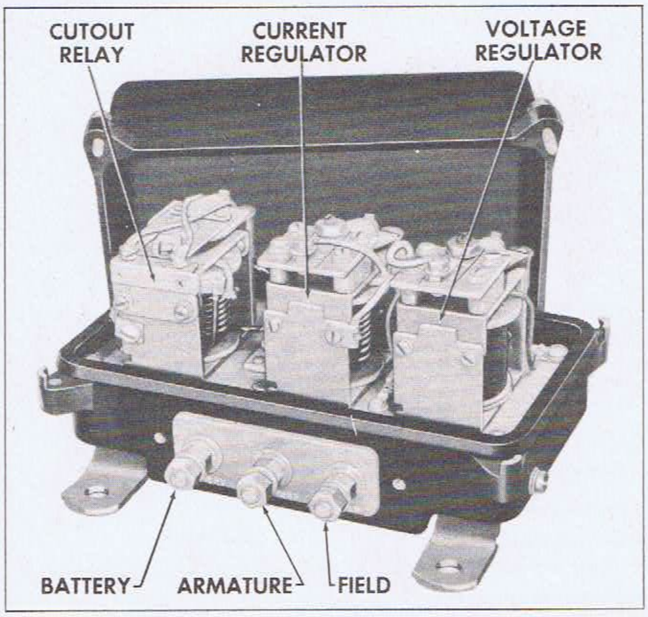



FIG. 20—DELCO-REMY HEAVY-DUTY THREE-UNIT REGULATOR WITH COVER REMOVED.

points not closing, open shunt winding, ground high voltage setting, or other causes. *Do not operate generator with the "GEN" terminal lead disconnected* for any length of time, since this is "open circuit" operation and the units will be damaged.

***CAUTION: A burned resistance unit, regulator winding or fused contacts can result only from OPEN CIRCUIT OPERATION, or extreme resistance in the charging circuit. With these conditions, check all wiring before reinstalling regulator.***

DO NOT RUN OR TEST GENERATOR ON OPEN CIRCUIT. TO DO SO WILL DESTROY REGULATOR OR GENERATOR.

IF NECESSARY TO REMOVE THE BATTERIES WHILE THE ENGINE IS OPERATING AND THE GENERATOR IS TURNING, THE FIELD TERMINAL ON THE GENERATOR MUST BE DISCONNECTED TO SAFEGUARD GENERATOR AND REGULATOR AGAINST BURNING OUT.

## Insulated System

**QUICK CHECKS OF GENERATOR AND REGULATOR.**

The following checks can be made to determine whether or not the units in the electrical starting system are operating normally. If not, the checks will indicate whether the generator or regulator is at fault; then proper corrective measures may be taken.

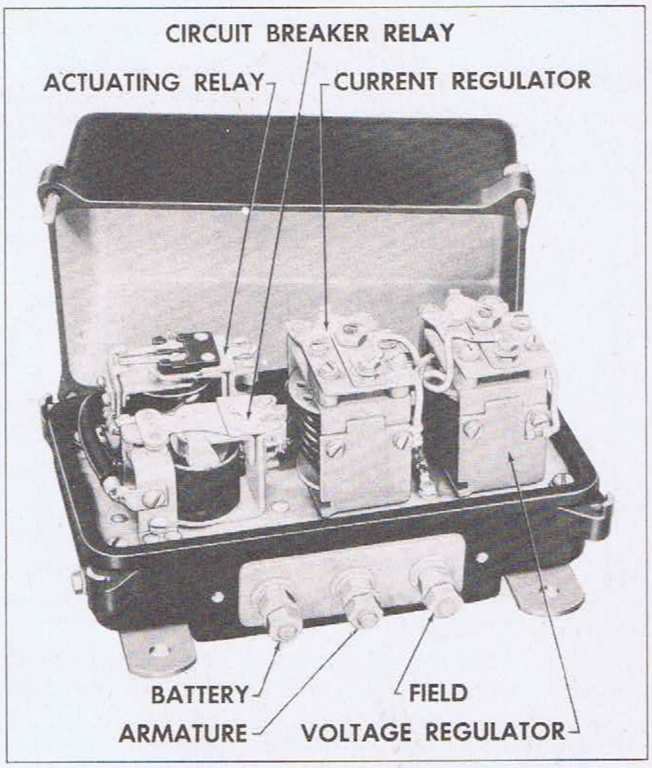



FIG. 21—DELCO-REMY HEAVY-DUTY FOUR-UNIT REGULATOR WITH COVER REMOVED.

**CASE No. 1—A Fully Charged Battery and Low Charging Rate Indicates Normal Voltage Regulator Operation.**

To check the current regulator:

1. Use the cranking motor with the throttle set in the NO FUEL position for about 15 seconds.

2. Then with the engine running at a medium speed, turn on air heater ignition coil switch and any lights and note *quickly* on the ammeter, the generator output, which will be the *value for which the current regulator is set.*

3. Now turn off air heater switch and lights, and allow the engine to continue running.

4. As soon as the generator has replaced in the battery the current used in cranking, the voltage regulator, if operating normally, will taper the output down to a few amperes.

**CASE No. 2—A Fully Charged Battery and a High Charging Rate.** This indicates that the voltage regulator is not reducing the generator output as it should. A high charging rate to a fully charged battery will damage the battery and the accompanying high voltage is very injurious to all electrical equipment.

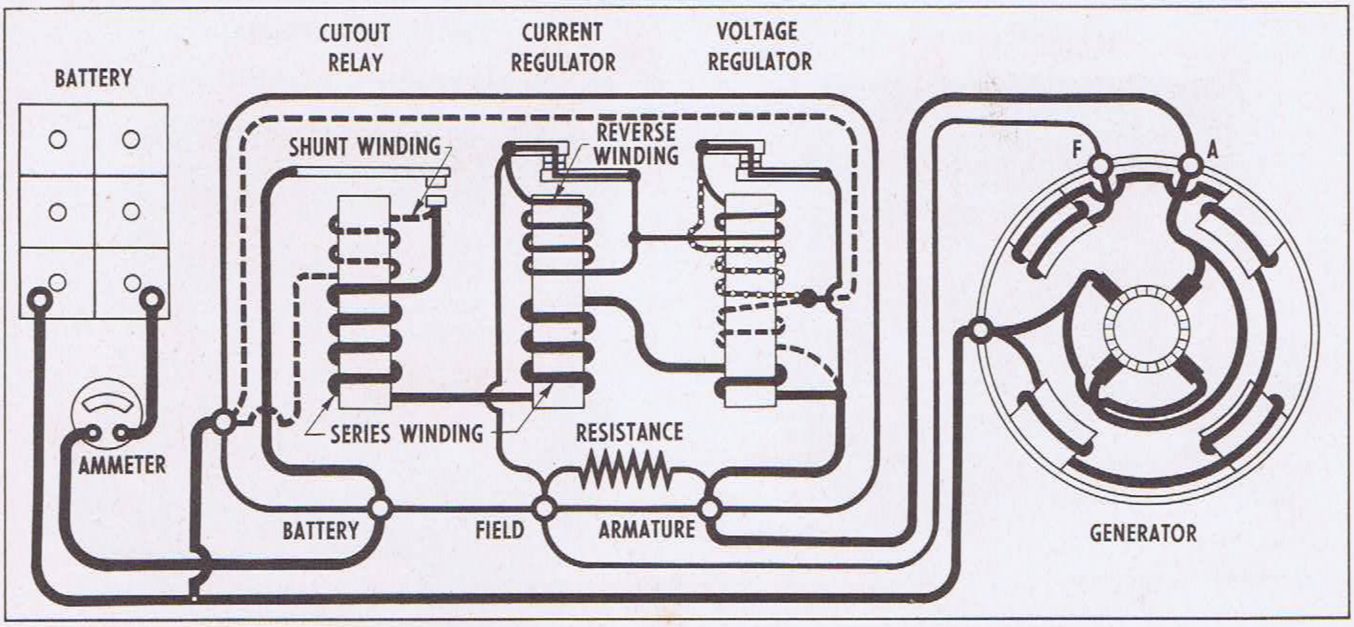



FIG. 22—DELCO-REMY HEAVY-DUTY THREE-UNIT REGULATOR WIRING DIAGRAM FOR INSULATED SYSTEM.

This operating condition may result from:

1. Improper voltage regulator setting.
2. Defective voltage regulator unit.
3. Short circuit between the charging circuit and field circuit, either in the generator, regulator, or wiring.
4. High temperature which reduces the resistance of the battery to charge so that it will accept a high charging rate even though the voltage regulator setting is normal.

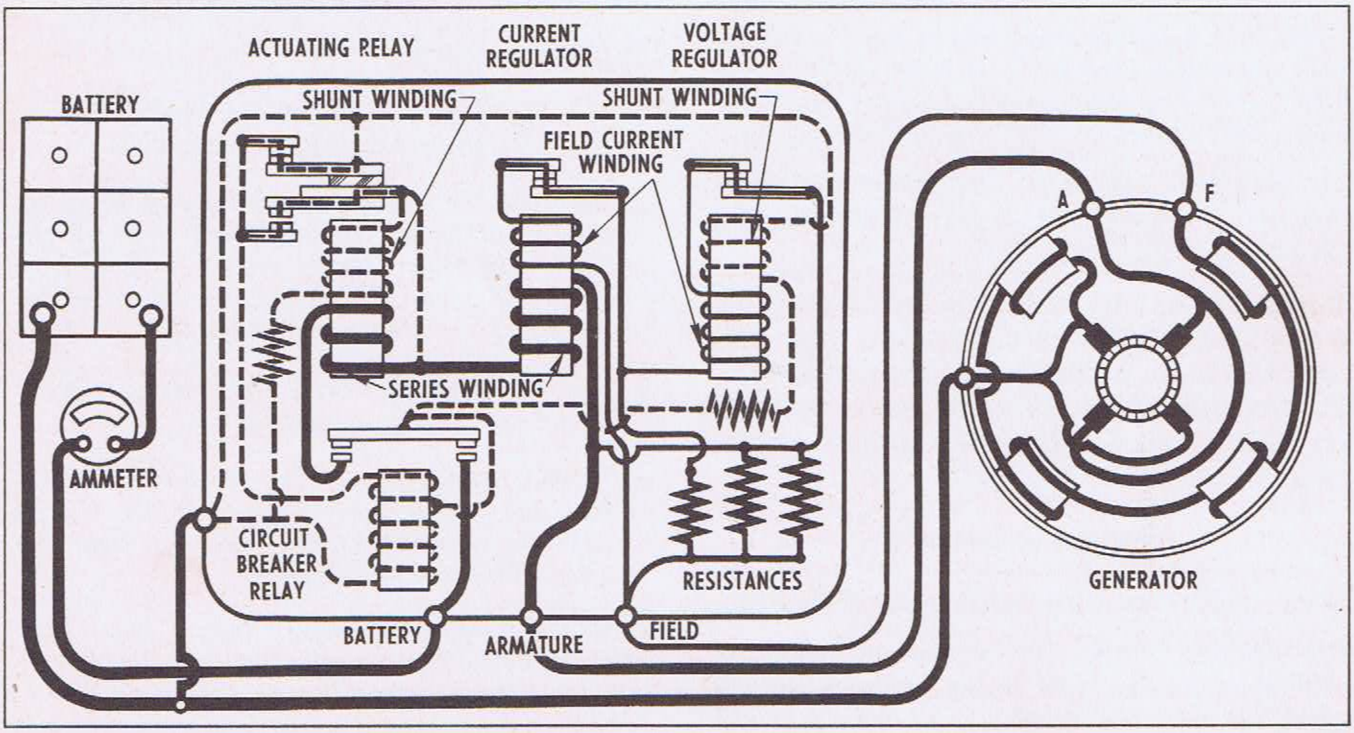



FIG. 23—DELCO-REMY HEAVY-DUTY FOUR-UNIT REGULATOR WIRING DIAGRAM FOR INSULATED SYSTEM.

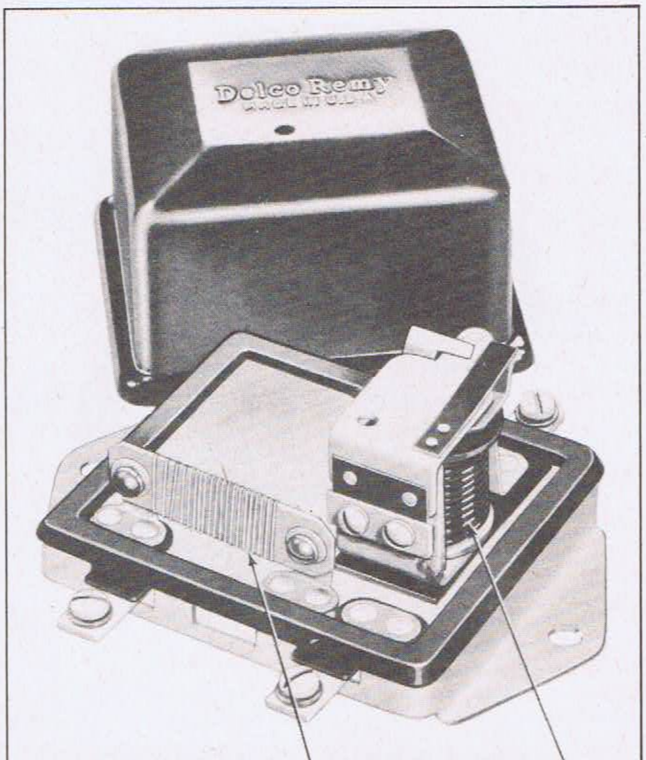



FIG. 24—DELCO-REMY CUTOUT RELAY WITH FIXED GENERATOR FIELD RESISTANCE.

If the trouble is not due to high temperatures, determine the cause of trouble by disconnecting the lead from the regulator field terminal with the generator operating at medium speed. If the output remains high, the generator is at fault. If the output drops off, the regulator is at fault and it should be inspected for high setting or short circuits.

**CASE No. 3—With a Low Battery and a Low or No Charging Rate.** This condition could be due to loose connections, frayed or damaged wires, low regulator setting, oxidized regulator contact points, or defects within the generator. If the condition is not caused by loose connections, frayed or damaged wires, proceed as follows to locate the cause of trouble.

To determine whether the generator or regulator is at fault, bridge the regulator armature and field terminals momentarily with a jumper lead with the generator operating at medium speed. If the output does not increase, the generator is probably at fault.

If the generator output increases, the trouble is due to:

1. A low voltage (or current) regulator setting.

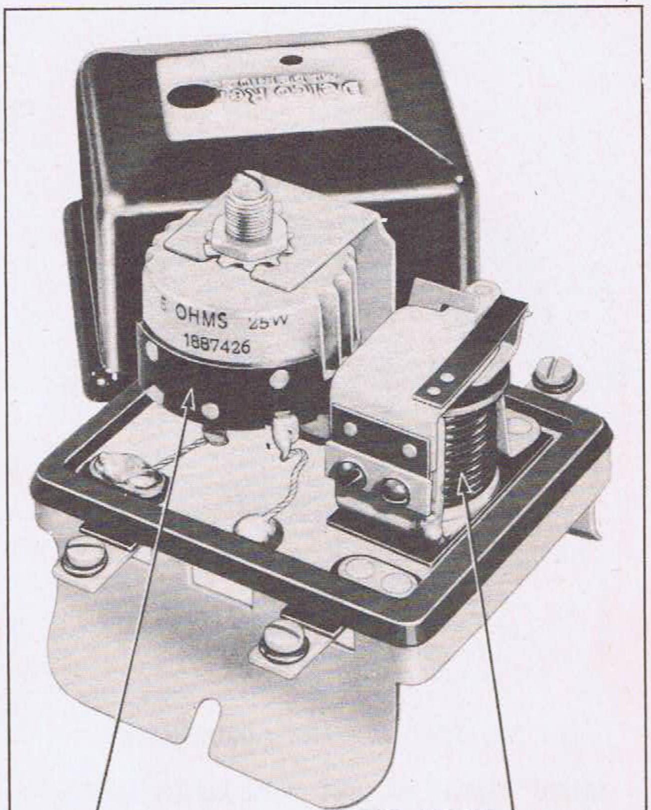



FIG. 25—DELCO-REMY CUTOUT RELAY WITH VARIABLE GENERATOR FIELD RESISTANCE.

2. Oxidized regulator contact points which insert excessive resistance in the generator field circuit so that output remains low.

3. Generator field circuit open within the regulator, either at the connections or in the regulator windings.

## Cutout Relays

### QUICK CHECKS OF GENERATOR AND CUTOUT RELAY

The cutout relay is used with both the third brush and shunt generator, with or without voltage control or regulation. It closes the circuit between the generator and the battery when the generator voltage has built up to a value sufficient to force a charge into the battery. The cutout relay opens the circuit when the generator slows or stops and current begins to flow back from the battery into the generator.

For the engine models covered by this manual, a special type cutout is employed using a fixed or variable generator field resistance as a means of controlling generator output which is additional to that provided by the generator third brush adjustment.

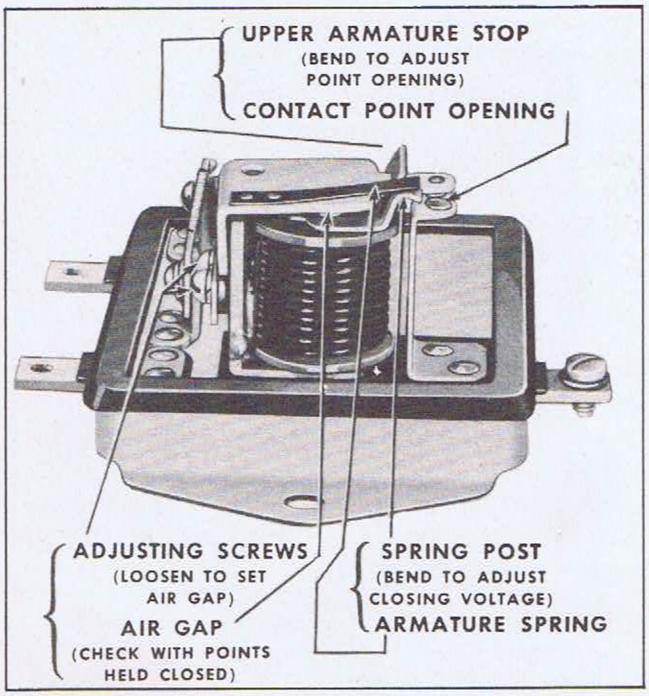



FIG. 26—CUTOUT RELAY ADJUSTMENTS.

## CUTOUT RELAY CHECKS AND ADJUSTMENTS

Three checks and adjustments are required on the cutout relay: air gap, point opening and closing voltage. The air gap and point opening are checked and adjusted with the battery disconnected.

**Air Gap**—Measure the air gap between the armature and the center of the core with the points held closed. To adjust the air gap, loosen the two screws at the back of the relay and raise or lower the armature as required. See Fig. 27.

Settings are as follows:

12 volt grounded
Regulator Part No. 005849
Air Gap—.045 inches

12 volt insulated
Regulator Part No. 005907
Air Gap .015 inches

**Point Opening**—Measure the point opening with the contact points open and adjust by bending the upper armature stop. See Fig. 28.

12 volt grounded
Regulator Part No. 005849
Point Opening—.015 inches

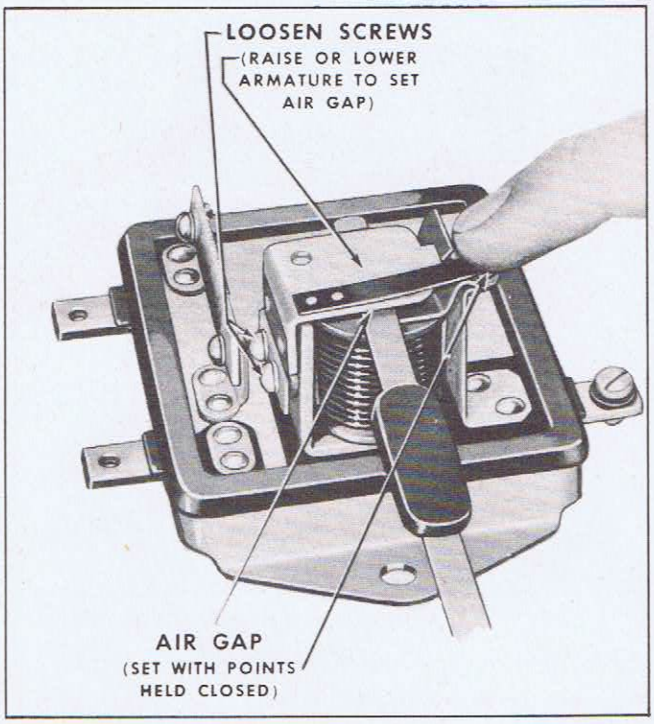



FIG. 27—CUTOUT RELAY AIR GAP CHECK AND ADJUSTMENT.

12 volt insulated
Regulator Part No. 005907
Point Opening—.020 inches

**Closing Voltage** (Grounded System)—To check the closing voltage of the cutout relay, connect a voltmeter between the *GEN* terminal of the relay and the relay base, as shown in Fig. 30. Gradually increase the generator speed and note the voltage at which the cutout relay operates. To adjust the closing voltage, bend the spring post as shown in Fig. 29. Bend the spring post up to increase the spring tension and raise the closing voltage or bend down to reduce the closing voltage.

12 volt grounded
Regulator Part No. 005849
Closing Voltage 12.0 volts max.

**Closing Voltage** (Insulated System)—To check the closing voltage of the cutout relay, connect a voltmeter between the *GEN* terminal of the relay and the plus terminal. Gradually increase the generator speed and note the voltage at which the cutout relay operates. To adjust the closing voltage, bend the spring post as shown in Fig. 29. Bend the spring post up to increase the spring tension and raise the closing voltage or bend down to reduce the closing voltage.

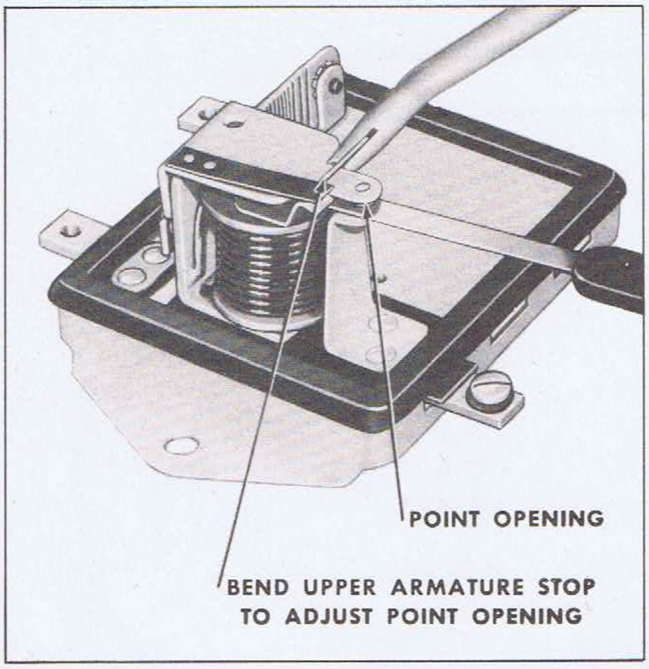



FIG. 28—CUTOUT RELAY POINT OPENING CHECK AND ADJUSTMENT.

12 volt insulated
Regulator Part No. 005907
Closing Voltage 13.2 to 14.0

**Generator Output**—To determine if generator can produce specified output, the resistance must be out of the generator field circuit so that the full output as determined by generator speed and third brush position will be obtained. To check the output of the generator, connect the voltmeter between the *GEN* terminal of the relay and the relay base (insulated system connect voltmeter between *GEN* terminal and plus terminal of relay) and connect an ammeter into the circuit at the *BAT* terminal of the relay as shown in Fig. 30. With the generator at operating temperature, note the output as indicated on the ammeter and the voltage. The output must be checked at the proper voltage, as indicated on the generator name plate. If the battery is in a charged condition, the approximately correct voltage will be attained. If the battery is discharged, it will be necessary to insert a ¼ ohm variable resistance into the charging circuit in series with the ammeter and cut in resistance until the voltage increases to the specified value.

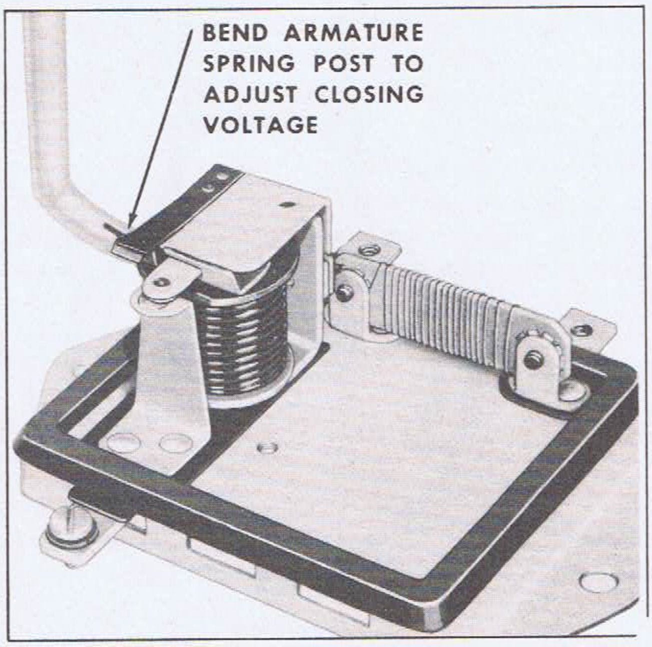



FIG. 29—ADJUSTING CUTOUT RELAY CLOSING VOLTAGE.

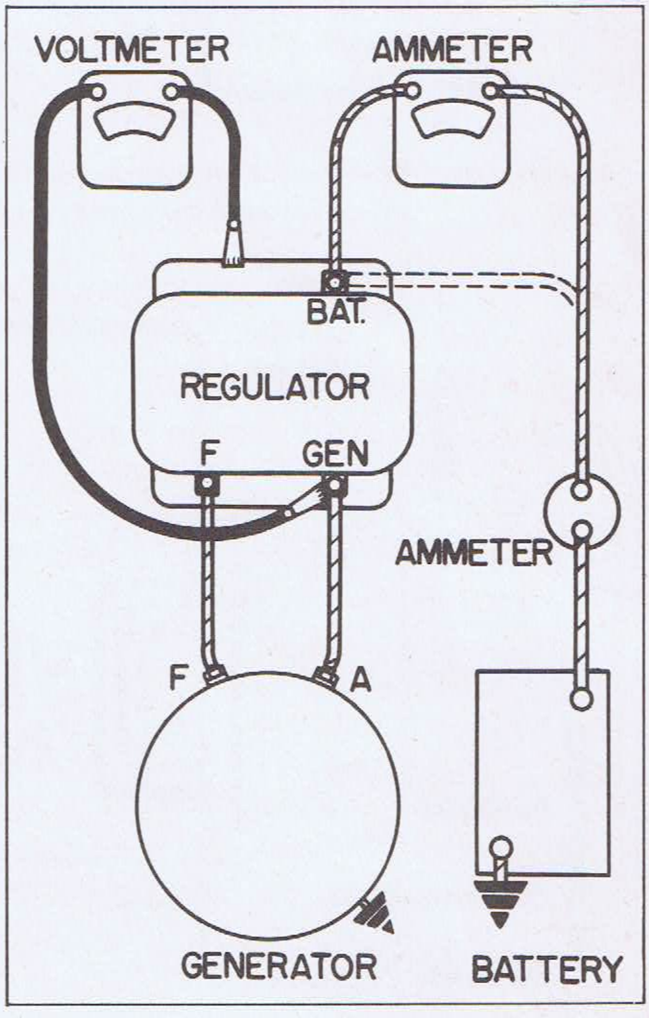



FIG. 30—METER CONNECTIONS TO CHECK CUTOUT RELAY CLOSING VOLTAGE AND GENERATOR OUTPUT.

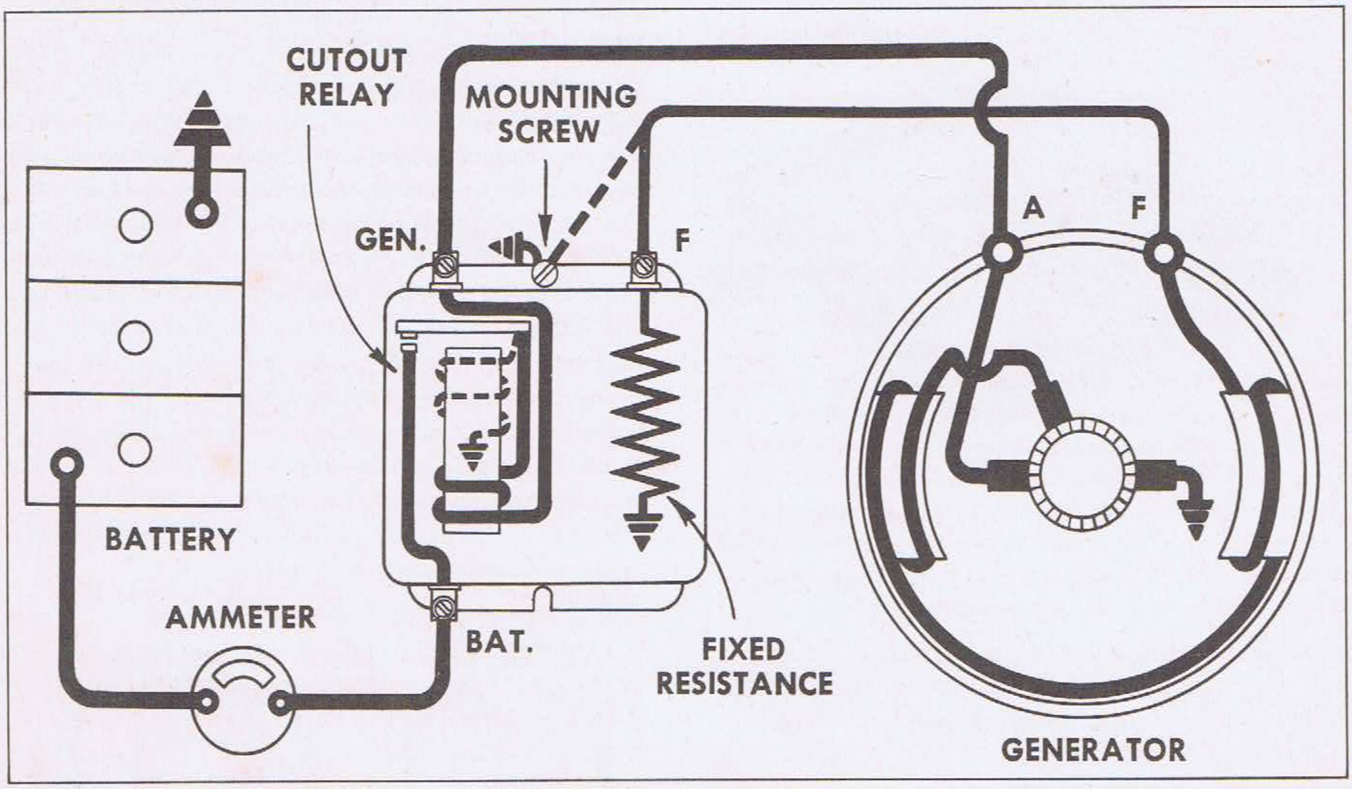



FIG. 31—WIRING DIAGRAM OF CUTOUT RELAY WITH FIXED RESISTANCE.

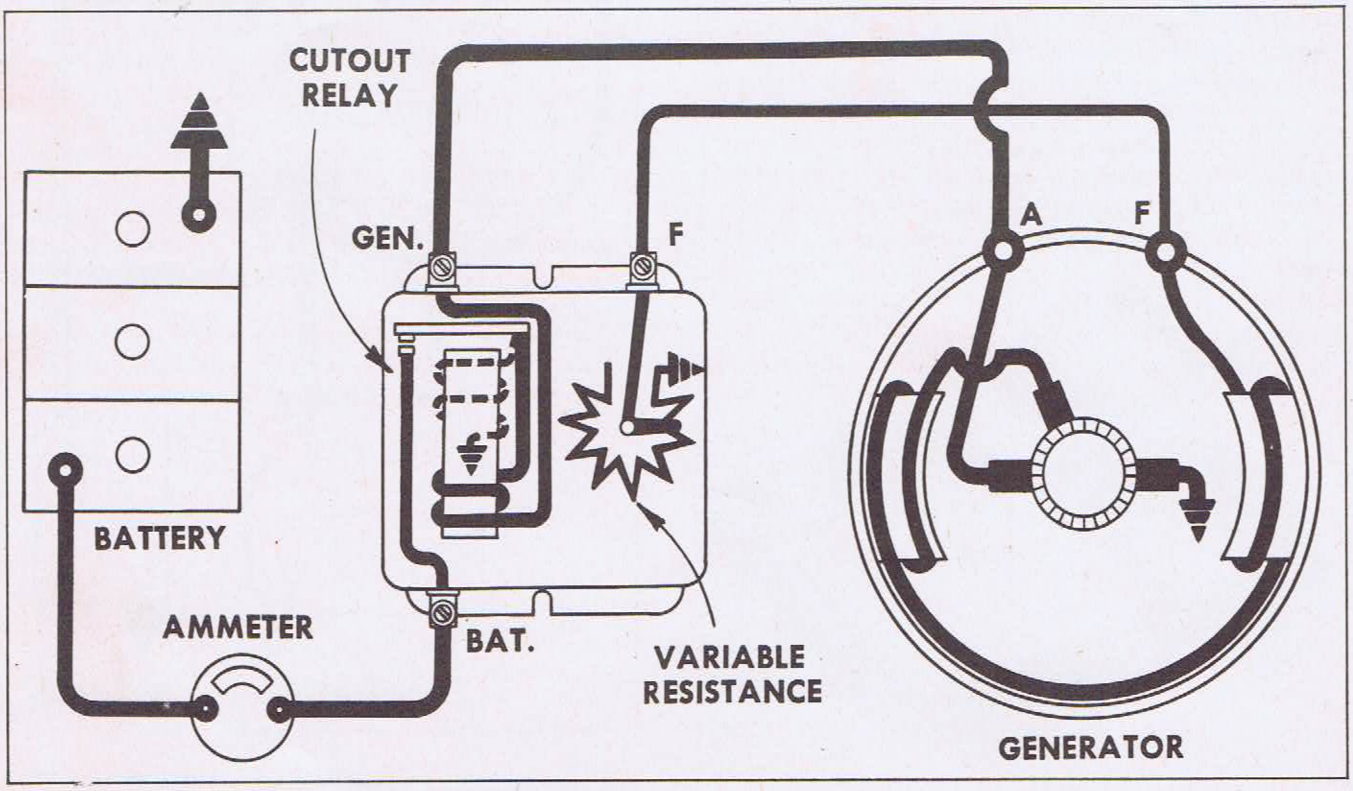



FIG. 32—WIRING DIAGRAM OF CUTOUT RELAY WITH VARIABLE RESISTANCE.

Adjustment of the third brush will alter generator output. Moving the third brush toward its adjacent main brush in the direction of armature rotation will increase generator output while moving the third brush in the opposite direction will reduce output.

The generator must be at operating temperatures when the output is checked. If the generator is cold, it should be operated for 10 to 15 minutes in order to make sure that it attains operating temperatures.

**Adjusting Variable Resistance**—The connection in Fig. 30 (meter connections to check cutout relay closing voltage and generator output) can also be used to measure generator output while readjusting the variable field resistance on those applications so equipped. This adjustment should be such as to permit the generator to produce sufficient current to take care of load requirements (up to rated capacity of generator) without producing excessive current which would cause battery overcharge

If the generator operates long hours with little or no load, the output should be reduced so the battery is supplied only an ampere or two. If the current requirements are increased (by addition of lights, more frequent starts, etc.) the output can be increased by adjusting the variable resistance.

Periodic checking of the battery provides a good indication of whether the variable resistance is properly adjusted. If the battery is gassing freely, has a high specific gravity reading (1.275 to 1.300) and requires frequent addition of water to maintain the electrolyte level above the plates, battery overcharge is being experienced and the output of the generator should be reduced somewhat by adjusting the variable resistance. If the battery specific gravity is low, indicating a partly discharged battery, then the variable resistance should be adjusted to permit increased generator output. Failure of the generator output to increase to its rated maximum requires checking of the generator.

**Repolarize Generator After Relay or Generator Check**—After the generator is reinstalled on the engine, or at any time that generator or regulator test has been made, the generator must be repolarized to make sure that it has the correct polarity with respect to the system. *This must be done before the engine is started.* Two different procedures of polarizing the generator must be used, depending on the type of generator. *Be sure to determine which type the generator is so the correct procedure can be followed.*

PROCEDURE FOR TYPE WITH FIELD EXTERNALLY GROUNDED: Connect a jumper lead momentarily between the generator and battery terminals of the cutout relay. This allows a momentary surge of current to flow through the generator which correctly polarizes it.

PROCEDURE FOR TYPE WITH FIELD INTERNALLY GROUNDED: Disconnect the lead from the "F" terminal of the generator, and then momentarily connect between this terminal and the insulated battery terminal with a jumper lead. (On insulated systems, connect momentarily from generator "F" terminal to each battery terminal in turn. Current will flow from one battery terminal only.) This allows a flash of current to flow through the generator field windings which correctly polarizes the generator. The other method of polarizing generators should not be used on heavy duty units, since the armature resistance is low, and a high current will flow, causing damage.

***NEVER OPERATE THE GENERATOR ON OPEN CIRCUIT. TO DO SO WILL ALLOW IT TO BUILD UP A DANGEROUSLY HIGH VOLTAGE WHICH WILL PROBABLY RESULT IN COMPLETE GENERATOR FAILURE.***

Never adjust generator to an output above the specified maximum as this would overload the generator and cause Generator Failure.

# SECTION V

## Miscellaneous

# USEFUL INFORMATION

## DECIMAL EQUIVALENTS

| 1/4 | 1/8 | 1/16 | 1/32 | 1/64 | Decimal |
|---|---|---|---|---|---|
| | | | | 1/64 | .015625 |
| | | | 1/32 | | .03125 |
| | | | | 3/64 | .046875 |
| | | 1/16 | | | .0625 |
| | | | | 5/64 | .078125 |
| | | | 3/32 | | .09375 |
| | | | | 7/64 | .109375 |
| | 1/8 | | | | .125 |
| | | | | 9/64 | .140625 |
| | | | 5/32 | | .15625 |
| | | | | 11/64 | .171875 |
| | | 3/16 | | | .1875 |
| | | | | 13/64 | .203125 |
| | | | 7/32 | | .21875 |
| | | | | 15/64 | .234375 |
| 1/4 | | | | | .25 |
| | | | | 17/64 | .265625 |
| | | | 9/32 | | .28125 |
| | | | | 19/64 | .296875 |
| | | 5/16 | | | .3125 |
| | | | | 21/64 | .328125 |
| | | | 11/32 | | .34375 |
| | | | | 23/64 | .359375 |
| | 3/8 | | | | .375 |
| | | | | 25/64 | .390625 |
| | | | 13/32 | | .40625 |
| | | | | 27/64 | .421875 |
| | | 7/16 | | | .4375 |
| | | | | 29/64 | .453125 |
| | | | 15/32 | | .46875 |
| | | | | 31/64 | .484375 |
| 1/2 | | | | | .5 |

| 1/4 | 1/8 | 1/16 | 1/32 | 1/64 | Decimal |
|---|---|---|---|---|---|
| | | | | 33/64 | .515625 |
| | | | 17/32 | | .53125 |
| | | | | 35/64 | .546875 |
| | | 9/16 | | | .5625 |
| | | | | 37/64 | .578125 |
| | | | 19/32 | | .59375 |
| | | | | 39/64 | .609375 |
| | 5/8 | | | | .625 |
| | | | | 41/64 | .640625 |
| | | | 21/32 | | .65625 |
| | | | | 43/64 | .671875 |
| | | 11/16 | | | .6875 |
| | | | | 45/64 | .703125 |
| | | | 23/32 | | .71875 |
| | | | | 47/64 | .734375 |
| 3/4 | | | | | .75 |
| | | | | 49/64 | .765625 |
| | | | 25/32 | | .78125 |
| | | | | 51/64 | .796875 |
| | | 13/16 | | | .8125 |
| | | | | 53/64 | .828125 |
| | | | 27/32 | | .84375 |
| | | | | 55/64 | .859375 |
| | 7/8 | | | | .875 |
| | | | | 57/64 | .890625 |
| | | | 29/32 | | .90625 |
| | | | | 59/64 | .921875 |
| | | 15/16 | | | .9375 |
| | | | | 61/64 | .953125 |
| | | | 31/32 | | .96875 |
| | | | | 63/64 | .984375 |
| 1 | | | | | 1. |

## WEIGHTS AND MEASURES

### Measures of Length

1 mile = 1,760 yards = 5,280 feet.
1 yard = 3 feet = 36 inches. 1 foot = 12 inches.

The following measures of length are also used occasionally:
1 mil = 0.001 inch. 1 fathom = 2 yards = 6 feet.
1 rod = 5.5 yards = 16.5 feet. 1 hand = 4 inches. 1 span = 9 inches.

### Surveyor's Measure

1 mile = 8 furlongs = 80 chains. 1 furlong = 10 chains = 220 yards.
1 chain = 4 rods = 22 yards = 66 feet = 100 links. 1 link = 7.92 inches.

### Nautical Measure

1 league = 3 nautical miles.
1 nautical mile (knot) = 6080.26 feet = 1.1516 statute mile.
One degree at the equator = 60 nautical miles = 69.168 statute miles.
360 degrees = 21,600 nautical miles = 24,874.5 statute miles = circumference of earth at the equator.

### Square Measure

1 square mile = 640 acres = 6,400 square chains.
1 acre = 10 square chains = 4,840 square yards = 43,560 square feet.
1 square chain = 16 square rods = 484 square yards = 4,356 square feet.
1 square rod = 30.25 square yards = 272.25 square feet = 625 square links.
1 square yard = 9 square feet. 1 square foot = 144 square inches.
An acre is equal to a square, the side of which is 208.7 feet.

### Measures Used for Diameters and Areas of Electric Wires

1 circular inch = area of circle 1 inch in diameter = 0.7854 square inch.
1 circular inch = 1,000,000 circular mils.
1 square inch = 1.2732 circular inch = 1,273,239 circular mils.
A circular mil is the area of a circle 0.001 inch in diameter.

### Cubic Measure

1 cubic yard = 27 cubic feet. 1 cubic foot = 1,728 cubic inches.

The following measures are also used for wood and masonry:
1 cord of wood = 4 x 4 x 8 feet = 128 cubic feet.
1 perch of masonry = 16½ x 1½ x 1 foot = 24¾ cubic feet.

### Shipping Measure

For measuring entire internal capacity of a vessel:
1 registor ton = 100 cubic feet.

For measurement of cargo:
1 U.S. shipping ton = 40 cubic feet = 32.143 U.S. bushels = 31.16 Imperial bushels.
1 British shipping ton = 42 cubic feet = 33.75 U.S. bushels = 32.72 Imperial bushels.

### Dry Measure

1 bushel (U.S. or Winchester struck bushel) = 1.2445 cubic foot = 2150.42 cubic inches.
1 bushel = 4 pecks = 32 quarts = 64 pints.
1 peck = 8 quarts = 16 pints. 1 quart = 2 pints.
1 heaped bushel = 1¼ struck bushel. 1 cubic foot = 0.8036 struck bushel.
1 British Imperial bushel = 8 Imperial gallons = 1.2837 cubic foot = 2218.19 cubic inches.

## WEIGHTS AND MEASURES

### Liquid Measure

1 U.S. gallon = 0.1337 cubic foot = 231 cu. inches = 4 quarts = 8 pints.
1 quart = 2 pints = 8 gills.
1 pint = 4 gills.
1 British Imperial gallon = 1.2003 U.S. gallon = 277.27 cubic inches.
1 cubic foot = 7.48 U.S. gallons.

### Old Liquid Measure

1 tun = 2 pipes = 3 puncheons.
1 pipe or butt = 2 hogsheads = 4 barrels = 126 gallons.
1 puncheon = 2 tierces = 84 gallons.
1 hogshead = 2 barrels = 63 gallons.
1 tierce = 42 gallons.
1 barrel = 31½ gallons.

### Apothecaries' Fluid Measure

1 U.S. fluid ounce = 8 drams = 1.805 cubic inch = 1/128 U.S. gallon.
1 fluid dram = 60 minims.
1 British fluid ounce = 1.732 cubic inch.

### Avoirdupois or Commercial Weight

1 gross or long ton = 2,240 pounds.
1 net or short ton = 2,000 pounds.
1 pound = 16 ounces = 7,000 grains.
1 ounce = 16 drams = 437.5 grains.

The following measures for weight are now seldom used in the United States:
1 hundred-weight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundred-weights); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

### Troy Weight

Used for Weighing Gold and Silver

1 pound = 12 ounces = 5,760 grains.
1 ounce = 20 pennyweights = 480 grains.
1 pennyweight = 24 grains.
1 carat (used in weighing diamonds) = 3.086 grains.
1 grain troy = 1 grain avoirdupois = 1 grain apothecaries' weight.

### Apothecaries' Weight

1 pound = 12 ounces = 5,760 grains.
1 ounce = 8 drams = 480 grains.
1 dram = 3 scruples = 60 grains.
1 scruple = 20 grains.

### Measures of Pressure

1 pound per square inch = 144 pounds per square foot = 0.068 atmosphere = 2.042 inches of mercury at 62° F. = 27.7 inches of water at 62° F. = 2.31 feet of water at 62° F.

1 atmosphere = 30 inches of mercury at 62° F. = 14.7 pounds per square inch = 2,116.3 pounds per square foot = 33.95 feet of water at 62° F.

1 foot of water at 62° F. = 62.355 pounds per square foot = 0.433 pound per square inch.

1 inch of mercury at 62° F. = 1.132 foot of water = 13.58 inches of water = 0.491 pounds per square inch.

### Miscellaneous

1 great gross = 12 gross = 144 dozen.
1 gross = 12 dozen = 144 units.
1 dozen = 12 units.
1 score = 20 units.
1 quire = 24 sheets.
1 ream = 20 quires = 480 sheets.
1 ream printing paper = 500 sheets.

A gallon of water (U.S. standard) weighs 8½ pounds and contains 231 cubic inches.

A cubic foot of water contains 7½ gallons, 1,728 cubic inches, and weighs 62½ pounds at a temperature of about 39° Fahrenheit. The weight changes slightly above and below this temperature.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434.

Steam rising from water at its boiling point (212° F.) has a pressure equal to that of the atmosphere at sea level (14.7 pounds per square inch).

## METRIC CONVERSION TABLES

The unit of length in the metric system, the meter, is intended to be 1 ten-millionth part of the distance from the equator to the pole. The original meter is a platinum bar made in 1799 and kept in the archives of the French Republic. Refinements in the measuring of the earth's surface since then have shown that only a very slight discrepancy exists between the actual and the intended length.

The meter is divided into 10 equal parts, decimeters; each of these into 10 centimeters, and each centimeter into 10 millimeters. A millimeter, therefore, is 1 thousandth part of a meter.

Simultaneously with the meter bar a platinum weight was constructed, as nearly as possible equal to the mass of a cube of pure water at 4° C. and whose side is one decimeter. The weight is called the kilogram and equals 1,000 units or grams.

The volume of one kilogram of pure water at the temperature of maximum density (4° C.) and under a pressure of 76 cm. of mercury is called the liter and is the unit of capacity in the metric system.

The metric units of length, mass and capacity are subdivided decimally, the Latin prefixes of deci, centi and milli being used to indicate the order of the divisions, while the Greek prefixes deka, hecto, kilo and myria, are used to indicate the order of multiplication of the units by 10.

| U. S. TO METRIC | METRIC TO U. S. |
|---|---|
| **LINEAR** | |
| 1 inch = .0254000 meters. | 1 meter = 39.3700 inches. |
| 1 foot = .304800 meters. | 1 meter = 3.28083 feet. |
| 1 yard = .914400 meters. | 1 meter = 1.09361 yards. |
| 1 mile = 1609.35 meters. | 1 kilometer = .62137 miles. |
| = 1.60935 kilometers. | |
| **SQUARE** | |
| 1 sq. inch = 6.452 sq. centimeters. | 1 sq. centimeter = .1550 sq. inches. |
| 1 sq. foot = 9.290 sq. decimeters. | 1 sq. meter = 10.7640 sq. feet. |
| 1 sq. yard = .836 sq. meters. | 1 sq. meter = 1.196 sq. yards. |
| **CUBIC** | |
| 1 cu. inch = 16.387 cu. centimeters. | 1 cu. centimeter = .0610 cu. inches. |
| 1 cu. foot = .02832 cu. meters. | 1 cu. meter = 35.314 cu. feet. |
| 1 cu. yard = .765 cu. meters. | 1 cu. meter = 1.308 cu. yards. |
| **WEIGHT** | |
| 1 grain = 64.7989 milligrams. | 1 milligram = .01543 grains. |
| 1 avoirdupois ounce = 28.3495 grams. | 1 kilogram = 15432.36 grains. |
| 1 troy ounce = 31.10348 grams. | 1 hectogram = 3.5274 avoirdupois ounces. |
| 1 avoirdupois pound = .45359 kilograms. | 1 kilogram = 2.20462 avoirdupois pounds. |
| **CAPACITY** | |
| 1 fluid dram = 3.70 cu. centimeters. | 1 milliliter = .27 fluid drams. |
| 1 fluid ounce = 29.57 milliliters. | 1 centiliter = .338 fluid ounces. |
| 1 quart = .94636 liters. | 1 liter = 1.0567 quarts. |
| 1 gallon = 3.78544 liters. | 1 hectoliter = 26.417 gallons. |
| **PRESSURE** | |
| 1 pound per square inch = .0703 kilograms per square centimeter. | 1 kilogram per square centimeter = 14.22 pounds per square inch. |

## EQUIVALENT VALUES

### Electrical Units

1 kilowatt = 1000 watts
1 kilowatt = 1.3414 horsepower
1 kilowatt = 44,260 foot-pounds per minute
1 kilowatt = 56.89 British thermal units per minute
1 horsepower = 745.7 watts
1 horsepower = 33,000 foot-pounds per minute
1 horsepower = 42.41 British thermal units per minute
1 British thermal unit = 778.26 foot-pounds
1 British thermal unit = 0.2930 watthour
1 joule = 1 watt-second.

### Miscellaneous

Kilogram-meter = 7.234 foot-pounds
1 foot-pound = 0.1383 kilogram-meter
1 metric horsepower = 0.9863 horsepower
1 horsepower = 1.014 metric horsepower
1 Liter per second = 2.119 cubic feet per minute
1 Liter per second = 15.85 U.S. gallons per minute
1 Angstrom unit (used to express wave length of light) = A = $10^{-8}$ centimeters
Absolute temperature (Kelvin scale) = Centigrade temperature + 273.16
Lumen = unit of luminous flux. A one candle power source radiates $4\pi$ lumens.

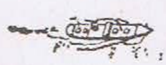
## USEFUL CONVERSION RATIOS

| Multiply | By | To Obtain |
|---|---|---|
| Diam. circle | 3.1416 | Circumference circle |
| Diam. circle | 0.886 | Side of equal square |
| U.S. gallons | 0.8327 | Imperial gallons (British) |
| U.S. gallons | 0.1337 | Cubic feet |
| Inches of mercury | 0.4912 | Pounds per sq. in. |
| Feet of water | 0.4335 | Pounds per sq. in. |
| Cubic feet | 62.428 | Pounds of water |
| U.S. gallons | 8.336 | Pounds of water |
| U.S. gallons | 3.785 | Liters |
| Knots | 1.152 | Miles per hour |
| Inches | 2.540 | Centimeters |
| Yards | 0.9144 | Meters |
| Miles | 1.609 | Kilometers |
| Cubic inches | 16.39 | Cubic centimeters |
| Ounces | 28.35 | Grams |
| Pounds | 0.4536 | Kilograms |
| **To obtain the above** | **Divide by** | **Starting with the above** |

## WORLD TIME DIFFERENCE

| Singapore | Tokio | Sidney Port Moresby | Guadalcanal | Attu Dutch Harbor | Pearl Harbor | San Francisco | Denver | Chicago | New York Martinique | Reykjavik | Algiers | Tunis | Paris London | Berlin Rome Cairo | Murmansk Moscow | New Delhi | Chungking |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **11:20** | * 1:00 | * 2:00 | * 3:00 | 6:00 | 6:30 | 9:00 | 10:00 | 11:00 | Noon | **3:00** | **4:00** | **5:00** | **6:00** | **6:00** | **7:00** | **9:30** | **11:00** |
| * 0:20 | * 2:00 | * 3:00 | * 4:00 | 7:00 | 7:30 | 10:00 | 11:00 | Noon | **1:00** | **4:00** | **5:00** | **6:00** | **7:00** | **7:00** | **8:00** | **10:30** | * Mid. |
| * 1:20 | * 3:00 | * 4:00 | * 5:00 | 8:00 | 8:30 | 11:00 | Noon | **1:00** | **2:00** | **5:00** | **6:00** | **7:00** | **8:00** | **8:00** | **9:00** | **11:30** | * 1:00 |
| * 2:20 | * 4:00 | * 5:00 | * 6:00 | 9:00 | 9:30 | Noon | **1:00** | **2:00** | **3:00** | **6:00** | **7:00** | **8:00** | **9:00** | **9:00** | **10:00** | *12:30 | * 2:00 |
| * 4:50 | * 6:30 | * 7:30 | * 8:30 | 11:30 | Noon | **2:30** | **3:30** | **4:30** | **5:30** | **8:30** | **9:30** | **10:30** | **11:30** | **11:30** | *12:30 | * 3:00 | * 4:30 |
| * 5:20 | * 7:00 | * 8:00 | * 9:00 | Noon | **12:30** | **3:00** | **4:00** | **5:00** | **6:00** | **9:00** | **10:00** | **11:00** | * Mid. | * Mid. | * 1:00 | * 3:30 | * 5:00 |
| * 5:20 | * 7:00 | * 8:00 | * 9:00 | Noon | **12:30** | **3:00** | **4:00** | **5:00** | **6:00** | **9:00** | **10:00** | **11:00** | * Mid. | * Mid. | * 1:00 | * 3:30 | * 5:00 |
| 8:20 | 10:00 | 11:00 | Noon | • **3:00** | • **3:30** | • **6:00** | • **7:00** | • **8:00** | • **9:00** | Mid. | 1:00 | 2:00 | 3:00 | 3:00 | 4:00 | 6:30 | 8:00 |
| 9:20 | 11:00 | Noon | **1:00** | • **4:00** | • **4:30** | • **7:00** | • **8:00** | • **9:00** | • **10:00** | 1:00 | 2:00 | 3:00 | 4:00 | 4:00 | 5:00 | 7:30 | 9:00 |
| 9:20 | 11:00 | Noon | **1:00** | • **4:00** | • **4:30** | • **7:00** | • **8:00** | • **9:00** | • **10:00** | 1:00 | 2:00 | 3:00 | 4:00 | 4:00 | 5:00 | 7:30 | 9:00 |
| 10:20 | Noon | **1:00** | **2:00** | • **5:00** | • **5:30** | • **8:00** | • **9:00** | • **10:00** | • **11:00** | 2:00 | 3:00 | 4:00 | 5:00 | 5:00 | 6:00 | 8:30 | 10:00 |
| Noon | **1:40** | **2:00** | **3:40** | • **6:40** | • **7:10** | • **9:40** | • **10:40** | • **11:40** | 12:40 | 3:40 | 4:40 | 5:40 | 6:40 | 6:40 | 7:40 | 10:10 | 11:40 |
| **12:20** | **2:00** | **3:40** | **4:00** | • **7:00** | • **7:30** | • **10:00** | • **11:00** | Mid't | 1:00 | 4:00 | 5:00 | 6:00 | 7:00 | 7:00 | 8:00 | 10:30 | Noon |
| **1:50** | **3:30** | **4:30** | **5:30** | • **8:30** | • **9:00** | • **11:30** | 12:30 | 1:30 | 2:30 | 5:30 | 6:30 | 7:30 | 8:30 | 8:30 | 9:30 | Noon | **1:30** |
| **4:20** | **6:00** | **7:00** | **8:00** | • **11:00** | • **11:30** | 2:00 | 3:00 | 4:00 | 5:00 | 8:00 | 9:00 | 10:00 | 11:00 | 11:00 | Noon | **2:30** | **4:00** |
| **4:20** | **6:00** | **7:00** | **8:00** | • **11:00** | • **11:30** | 2:00 | 3:00 | 4.00 | 5:00 | 8:00 | 9:00 | 10:00 | 11:00 | 11:00 | Noon | **2:30** | **4:00** |
| **5:20** | **7:00** | **8:00** | **9:00** | Mid. | 12:30 | 3:00 | 4:00 | 5:00 | 6:00 | 9:00 | 10:00 | 11:00 | Noon | Noon | **1:00** | **3:30** | **5:00** |
| **5:20** | **7:00** | **8:00** | **9:00** | Mid. | 12:30 | 3:00 | 4:00 | 5:00 | 6:00 | 9:00 | 10:00 | 11:00 | Noon | Noon | **1:00** | **3:30** | **5:00** |
| **5:20** | **7:00** | **8:00** | **9:00** | Mid. | 12:30 | 3:00 | 4:00 | 5:00 | 6:00 | 9:00 | 10:00 | 11:00 | Noon | Noon | **1:00** | **3:30** | **5:00** |
| **5:20** | **7:00** | **8:00** | **9:00** | Mid. | 12:30 | 3:00 | 4:00 | 5:00 | 6:00 | 9:00 | 10:00 | 11:00 | Noon | Noon | **1:00** | **3:30** | **5:00** |
| **5:20** | **7:00** | **8:00** | **9:00** | Mid. | 12:30 | 3:00 | 4:00 | 5:00 | 6:00 | 9:00 | 10:00 | 11:00 | Noon | Noon | **1:00** | **3:30** | **5:00** |
| **6:20** | **8:00** | **9:00** | **10:00** | 1:00 | 1:30 | 4:00 | 5:00 | 6:00 | 7:00 | 10:00 | 11:00 | Noon | **1:00** | **1:00** | **2:00** | **4:30** | **6:00** |
| **7:20** | **9:00** | **10:00** | **11:00** | 2:00 | 2:30 | 5:00 | 6:00 | 7:00 | 8:00 | 11:00 | Noon | **1:00** | **2:00** | **2:00** | **3:00** | **5:30** | **7:00** |
| **8:20** | **10:00** | **11:00** | * Mid. | 3:00 | 3:30 | 6:00 | 7:00 | 8:00 | 9:00 | Noon | **1:00** | **2:00** | **3:00** | **3:00** | **4:00** | **6:30** | **8:00** |
| **11:20** | * 1:00 | * 2:00 | * 3:00 | 6:00 | 6:30 | 9:00 | 10:00 | 11:00 | Noon | **3:00** | **4:00** | **5:00** | **6:00** | **6:00** | **7:00** | **9:30** | **11:00** |

International Date Line



★ Indicates following day—due to crossing of International Date Line.

● Indicates previous day—due to crossing of International Date Line.

### WORLD TIME DIFFERENCE

New York (Eastern), Chicago (Central), Denver (Western), San Francisco (Mountain), represent the four time zones of the United States.

To use this table read from top to bottom—Example: 5:00 P.M. Tuesday in Chicago would be 9:00 A.M. in Guadalcanal Wednesday (following day).

Light face print is A.M. **Bold face print is P.M.**

United States is based on War Time. Alaska and Hawaiian Islands are based on War Time. Rome based on Daylight Saving Time. London based on Double Summer Time. Berlin and Paris based on Berlin Summer Time.

All other mentioned localities are based on Standard Time and local corrections if any should be made.

Editor's Note: This table is based upon the latest authoritative information available but due to changing seasonal and wartime conditions this information **may need local corrections.**

## SALT WATER

The *composition* of salt water varies at different parts of the world, but usually contains the following to every 100 parts:

| | | | |
|---|---|---|---|
| Pure water | 96.2 | Sulphate of lime | .08 |
| Common salt | 2.71 | Sulphate of magnesium | .12 |
| Magnesium chloride | .54 | Calcium bicarbonate | .01 |
| Magnesium bromide | .01 | Organic matter | .33 |

As the composition varies, so does the specific gravity and weight per cubic foot. The figures given below are commonly accepted values.

1 cu. ft. of salt water = 64 lb.

35 cu. ft. of salt water = 1 ton (2,240 lb.)

1 U.S. gallon of salt water = 8.58 lb.

1 Imperial gallon of salt water = 10.27 lb.

Water is at its *maximum density* at 39.1° F. or 4° C. The boiling point of fresh water at sea level is 212° F. and of salt water 213.2. Fresh water freezes at 32° F. or 0° C.; salt water freezes at a lower temperature. As hot water cools down from the boiling point, it contracts and becomes more dense until it reaches 39.1° F. (0° C.) at which temperature it has reached maximum density. As it continues to cool from 39.1° F. to the freezing point, 32° F. (0° C.) it expands again.

## FRESH WATER

| | | |
|---|---|---|
| One Imperial gallon | = | 277.27 Cubic inches |
| One Imperial gallon | = | .16 Cubic feet |
| One Imperial gallon | = | 10.00 Lb. |
| One Imperial gallon | = | 4.54 Liters |
| One Imperial gallon | = | 1.20 U.S. gallons |
| One U.S. gallon | = | 231 Cubic inches |
| One U.S. gallon | = | .134 Cubic feet |
| One U.S. gallon | = | 8.33 Lb. |
| One U.S. gallon | = | .83 Imperial gallons |
| One U.S. gallon | = | 3.8 Liters |
| One pound of water | = | 27.74 Cubic inches |
| One pound of water | = | .083 U.S. gallons |
| One pound of water | = | .10 Imperial gallons |
| One cwt. of water | = | 11.2 Imperial gallons |
| One cwt. of water | = | 13.44 U.S. gallons |
| One cwt. of water | = | 1.79 Cubic feet |
| One ton of water | = | 35.88 Cubic feet |
| One ton of water | = | 223.60 Imperial gallons |
| One ton of water | = | 268.38 U.S. gallons |
| One ton of water | = | 1000 Liters (approx.) |
| One ton of water | = | 1 Cubic meter (approx.) |
| One cubic inch of water | = | .036 Lb. |
| One cubic inch of water | = | .0036 Imperial gallons |
| One cubic inch of water | = | .0043 U.S. gallons |
| One cubic foot of water | = | .027 Ton |
| One cubic foot of water | = | .55 Cwt. |
| One cubic foot of water | = | 62.42 Lb. |
| One cubic foot of water | = | 6.23 Imperial gallons |
| One cubic foot of water | = | 7.48 U.S. gallons |
| One cubic foot of water | = | 28.31 Liters |
| One cubic foot of water | = | .028 Cubic meters |
| One liter of water | = | .22 Imperial gallons |
| One liter of water | = | .264 U.S. gallons |
| One liter of water | = | 61 Cubic inches |
| One liter of water | = | .0354 Cubic feet |
| One cubic meter of water | = | 220 Imperial gallons |
| One cubic meter of water | = | 264 U.S. gallons |
| One cubic meter of water | = | 1.308 Cubic yards |
| One cubic meter of water | = | 35.31 Cubic feet |
| One cubic meter of water | = | 61024 Cubic inches |
| One cubic meter of water | = | 1000 Kilos |
| One cubic meter of water | = | 1 Ton (Approx.) |
| One cubic meter of water | = | 1000 Liters |
| One Pood | = | 3.6 Imperial gallons |
| One Eimer | = | 2.7 Imperial gallons |
| One Vedros | = | 2.7 Imperial gallons |
| One Miner's inch of water | = | 10 Imperial gallons (Approx.) |
| One column of water 1 foot high | = | .434 Lb. pressure per sq. in. |
| One column of water 1 meter high | = | 1.43 Lb. pressure per sq. in. |
| A pressure of 1 lb. per sq. in. | = | 2.31 Feet of water in height |

In the above, one ton = 2,240 lb.

## WEIGHT AND SIZE OF DIFFERENT STANDARD GALLONS OF FRESH WATER

| | Cubic Inches in a Gallon | Weight of a Gallon in Pounds | Gallons in a Cubic Foot | Weight of a cubic foot of fresh water, English standard, 62.321 lb. avoirdupois. |
|---|---|---|---|---|
| Imperial or English | 277.274 | 10.00 | 6.232102 | |
| United States | 231. | 8.33111 | 7.480519 | |

## THE INTERNATIONAL MORSE CODE OF BLINKER SIGNALS

How to Memorize MORSE CODE:

1. Learn to recognize each symbol as a whole unit, not as a series of separate flashes.

2. Practice timing of dots and dashes. (A dot is represented by a flash of about one-half second duration. A dash, about one and one-half seconds.)

3. Work on the receiving end as much as possible. Remember, if you can receive you can send.

4. After you practice receiving and sending letters, practice with simple words. Hold each letter in mind as it is flashed. Then write it down.

5. To increase your speed, compile a list of simple, frequently used words such as: to, the, are, and, for, etc., and learn to recognize as whole units.

6. Speed and accuracy are essential after you memorize code. Practice often. Standard Navy rate of sending blinker messages is eight words per minute. An expert signalman sends faster.

SIGNALING PROCEDURE

| | |
|---|---|
| Call for unknown ship and general call | AA AA etc. |
| Answering sign | $\overline{\text{TTTTTT}}$, etc. |
| Space sign | II |
| Break sign | $\overline{\text{BT}}$ |
| Erase sign | $\overline{\text{EEEEEEEE}}$, etc. |
| Repeat sign | UD |
| All after (Used when obtaining a repetition) | AA |
| All before (Used when obtaining a repetition) | AB |
| Word or group after (Used when obtaining a repetition) | WA |
| Word or group before (Used when obtaining a repetition) | WB |
| Ending sign | $\overline{\text{AR}}$ |
| From | DE |
| You are correct | C |
| Repeat back | G |
| Message received | R |
| Word (plain language) received | T |
| I am unable to read your message owing to light not being properly trained or light burning badly | W |
| International Code groups follow | PRB |

## INTERNATIONAL MORSE CODE

### TIME OF DASH EQUALS THREE DOTS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A | • — | J | — • — — — | S | • • • | 1 | • — — — — |
| B | — • • • | K | — • — | T | — | 2 | • • — — — |
| C | — • — • | L | • — • • | U | • • — | 3 | • • • — — |
| D | — • • | M | — — | V | • • • — | 4 | • • • • — |
| E | • | N | — • | W | • — — | 5 | • • • • • |
| F | • • — • | O | — — — | X | — • • — | 6 | — • • • • |
| G | — — • | P | • — — • | Y | — • — — | 7 | — — • • • |
| H | • • • • | Q | — — • — | Z | — — • • | 8 | — — — • • |
| I | • • | R | • — • | | | 9 | — — — — • |
| | | | | | | 0 | — — — — — |