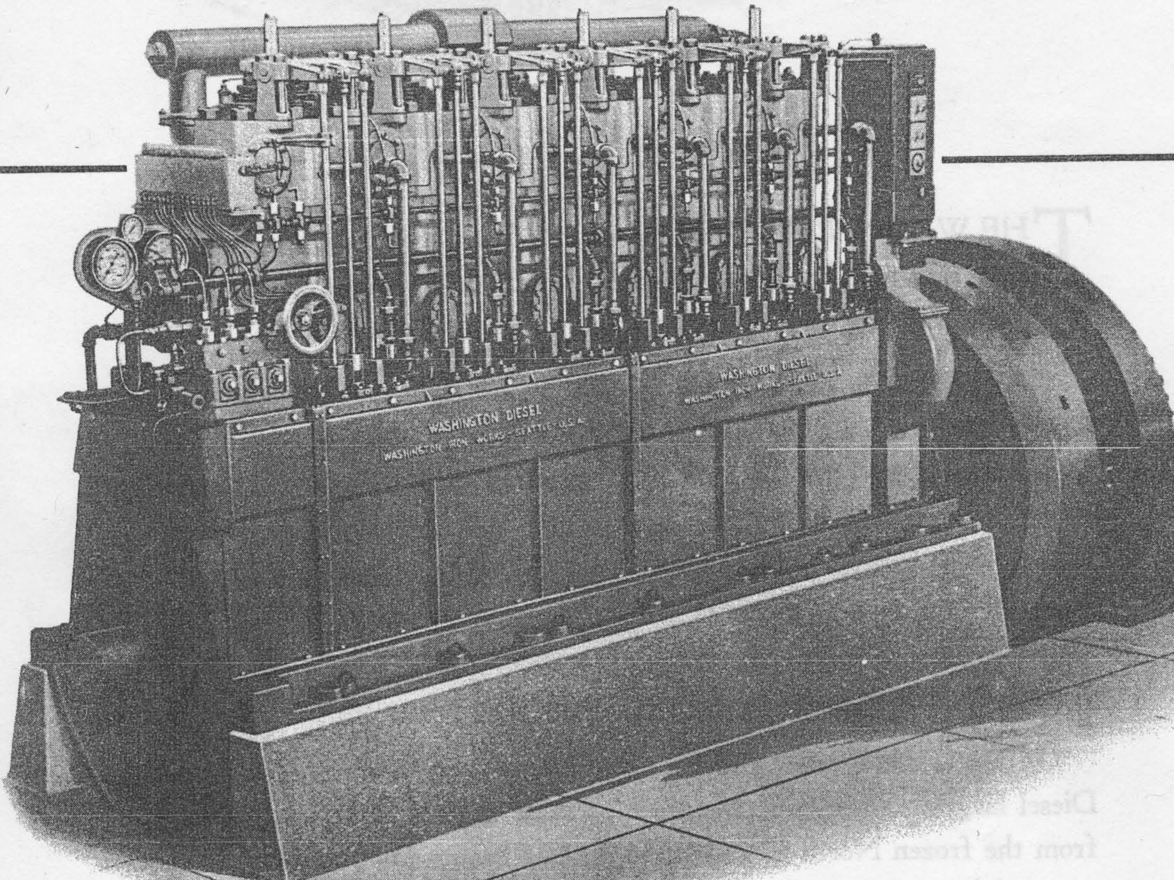
NO. 30-45

PRICE: $1.00

INSTRUCTIONS

FOR

INSTALLATION, CARE AND OPERATION of MARINE AND STATIONARY *Washington Diesel Engines*



Manufactured by

WASHINGTON IRON WORKS

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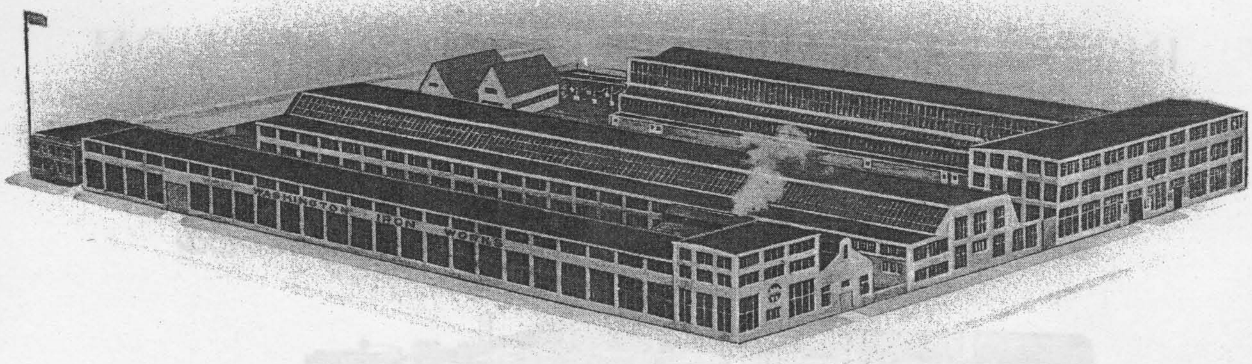
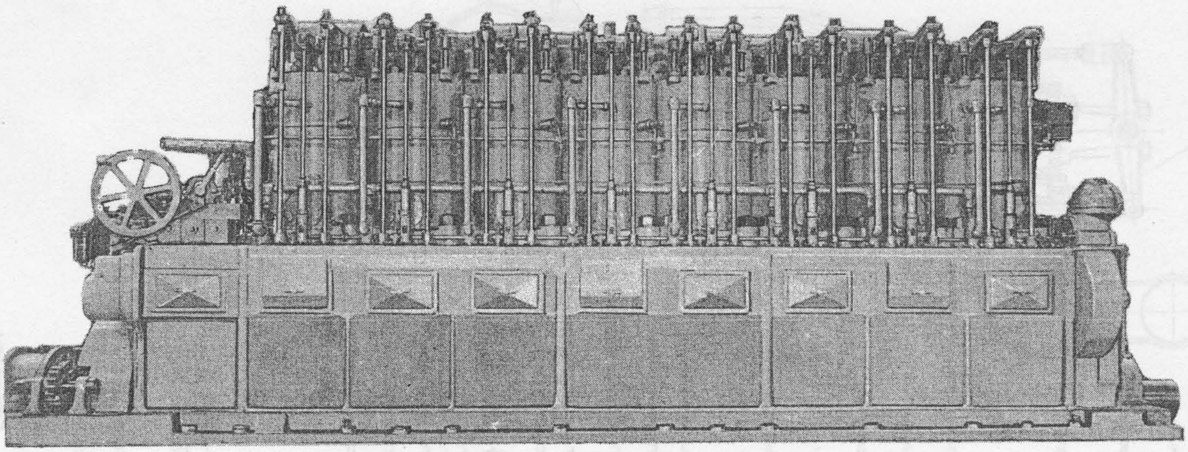


THE WASHINGTON IRON WORKS was established in 1882, and since that time has been in business continuously, manufacturing heavy duty equipment for marine, logging, mining and allied industries.

This splendidly equipped plant covers almost eight acres of ground, has 233,000 sq. ft. of floor space and represents the last word in modern industrial practices. Castings are made in the modern foundry under supervision of a skilled metallurgist. The machine and forge shops are equipped with the finest precision machines available. A trained experienced engineering staff constantly supervises the manufacture of each product. Every phase of the manufacturing of these products receives the same exacting precaution to make sure of flawless quality and fine workmanship.

In 1921, the Washington Iron Works produced the first Washington Diesel Engine. Since then, hundreds of these engines have been in service from the frozen North of Alaska to the hot tropics of the Equator. They are used for main propulsion of ships, driving generators in ships, stationary power plants, powering logging and dredge equipment, in fact, wherever heavy duty, slow speed, dependable Diesel power is required.

The same careful precision and quality is maintained in the manufacture of Washington Diesel Engines as has always been the creed of Washington Iron Works in their other products, thereby assuring more power, greater dependability and longer life.



This book has been prepared to assist owners of all types of Washington Diesel Engines in their installation, operation and repair.

There is no list of part numbers in this book. It has been the experience of the Washington Iron Works that there is less chance of mistake if parts are ordered by name rather than part number only. Drawings are included in this book, giving the part names of practically all of the parts of the engine. On Washington Diesels you will find all parts marked with a part number where it has been possible to do so.

When ordering parts be sure to give the following:

1. ***Engine Number***
2. ***Name of the Part***
3. ***Number of the Part***
   (Get number, if possible, from old part)

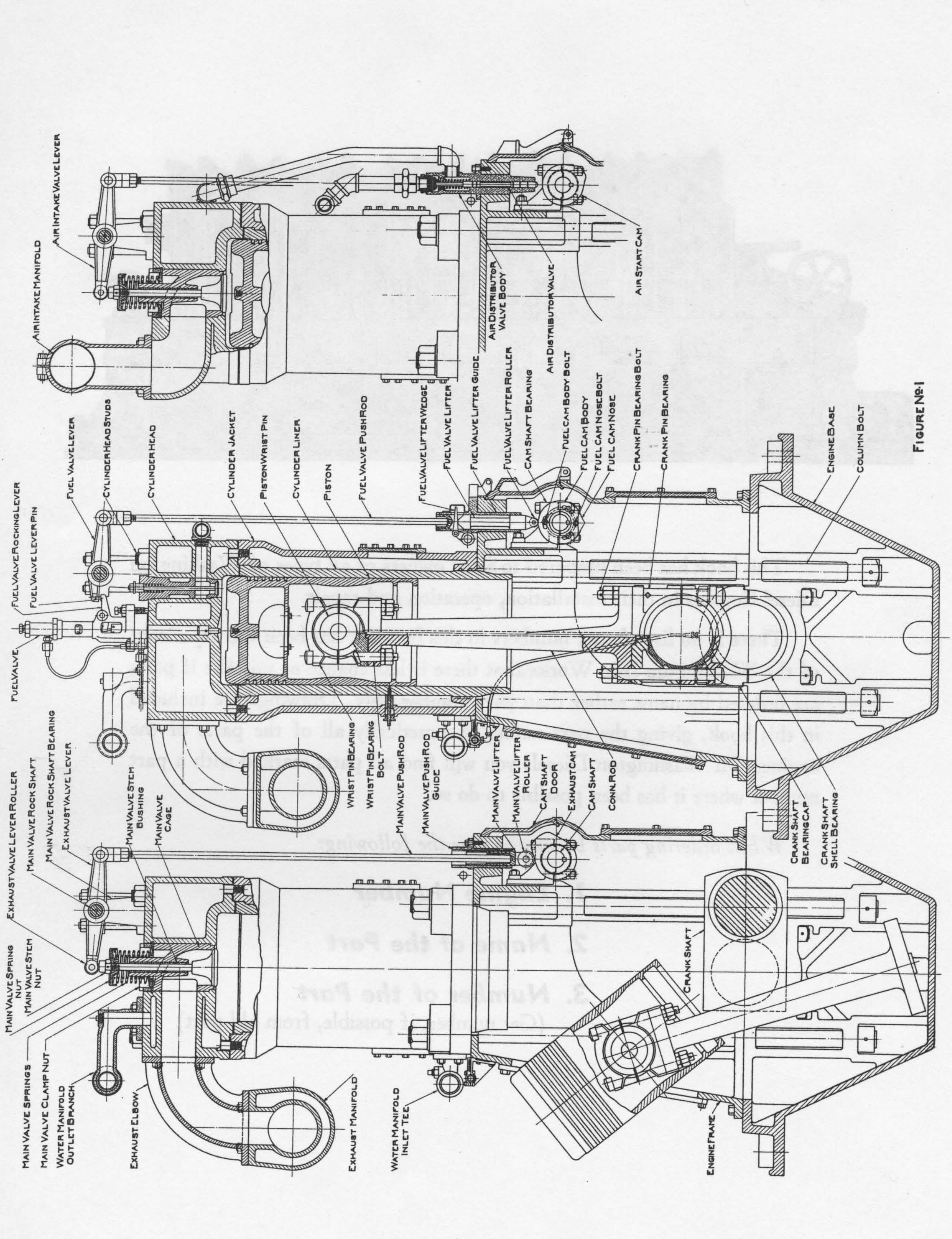

AIR INTAKE MANIFOLD
AIR INTAKE VALVE LEVER
AIR DISTRIBUTOR VALVE BODY
AIR DISTRIBUTOR VALVE
AIR START CAM
FUEL VALVE ROCKING LEVER
FUEL VALVE LEVER PIN
FUEL VALVE LEVER
CYLINDER HEAD STUDS
CYLINDER HEAD
CYLINDER JACKET
PISTON WRIST PIN
CYLINDER LINER
PISTON
FUEL VALVE PUSH ROD
FUEL VALVE LIFTER WEDGE
FUEL VALVE LIFTER
FUEL VALVE LIFTER GUIDE
FUEL VALVE LIFTER ROLLER
CAM SHAFT BEARING
FUEL CAM BODY BOLT
FUEL CAM BODY
FUEL CAM NOSE BOLT
FUEL CAM NOSE
CRANK PIN BEARING BOLT
CRANK PIN BEARING
ENGINE BASE
COLUMN BOLT
FUEL VALVE
EXHAUST VALVE LEVER ROLLER
MAIN VALVE ROCK SHAFT
MAIN VALVE ROCK SHAFT BEARING
EXHAUST VALVE LEVER
MAIN VALVE STEM BUSHING
MAIN VALVE CAGE
WRIST PIN BEARING
WRIST PIN BEARING BOLT
MAIN VALVE PUSH ROD
MAIN VALVE PUSH ROD GUIDE
MAIN VALVE LIFTER
MAIN VALVE LIFTER ROLLER
CAM SHAFT DOOR
EXHAUST CAM
CAM SHAFT
CONN. ROD
CRANK SHAFT BEARING CAP
CRANK SHAFT SHELL BEARING
CRANK SHAFT
MAIN VALVE SPRING NUT
MAIN VALVE STEM NUT
MAIN VALVE SPRINGS
MAIN VALVE CLAMP NUT
WATER MANIFOLD OUTLET BRANCH
EXHAUST ELBOW
EXHAUST MANIFOLD
WATER MANIFOLD INLET TEE
ENGINE FRAME

FIGURE No. 1

GENERAL CHARACTERISTICS
FEATURES OF CONSTRUCTION

Heavy Duty Type

These engines are of rugged construction with all wearing surfaces exceptionally large to insure long life.

Cold Starting

The engine starts cold from the heat of compression only, without the use of torches or electric plugs. Engine starts easily on low starting air pressure of 125 to 300 lbs.

Fuel Injection

Fuel injection is by simple hydraulic pressure, without the use of high pressure air. The use of the airless fuel system greatly simplifies the engine and insures quick starting at all times since the cooling effect of injection air is done away with.

Low Cylinder Compression

Cylinder compression is from 360 lbs. to 450 lbs. per square inch, depending upon the size and model of engine.

Conservative Rating

The engine has large cylinder size per rated horsepower; will develop full power continuously without overheating, and will pull large overloads when necessary.

Simple and Accessible

Washington Diesel engines are carefully built of the best materials with simplicity and accessibility as the key features of the design.

Cylinders

Cylinders are fitted with removable liners, or bushings, of special hard close-grained cast iron of exceptional wear resisting qualities. A large water-jacket is provided with clean-out doors for each cylinder.

Valves

Removable and interchangeable large-sized inlet and exhaust valves may be cleaned and ground without removing the cylinder head. Engines of small bores have valves in the head. The exhaust valves on large engines are water-cooled.

Main Bearings

Large removable main bearing shells are used. On the older engines the main bearings are square set shells which can be shimmed up for re-alignment of the crankshaft. Large size engines have square set plates into which are fitted roll-out shells.

Frame

Open side main frame is completely enclosed with oil-tight cover plates.

Pistons

Pistons are removable from bottom of cylinder through large inspection doors in engine frame without removing the cylinder heads.

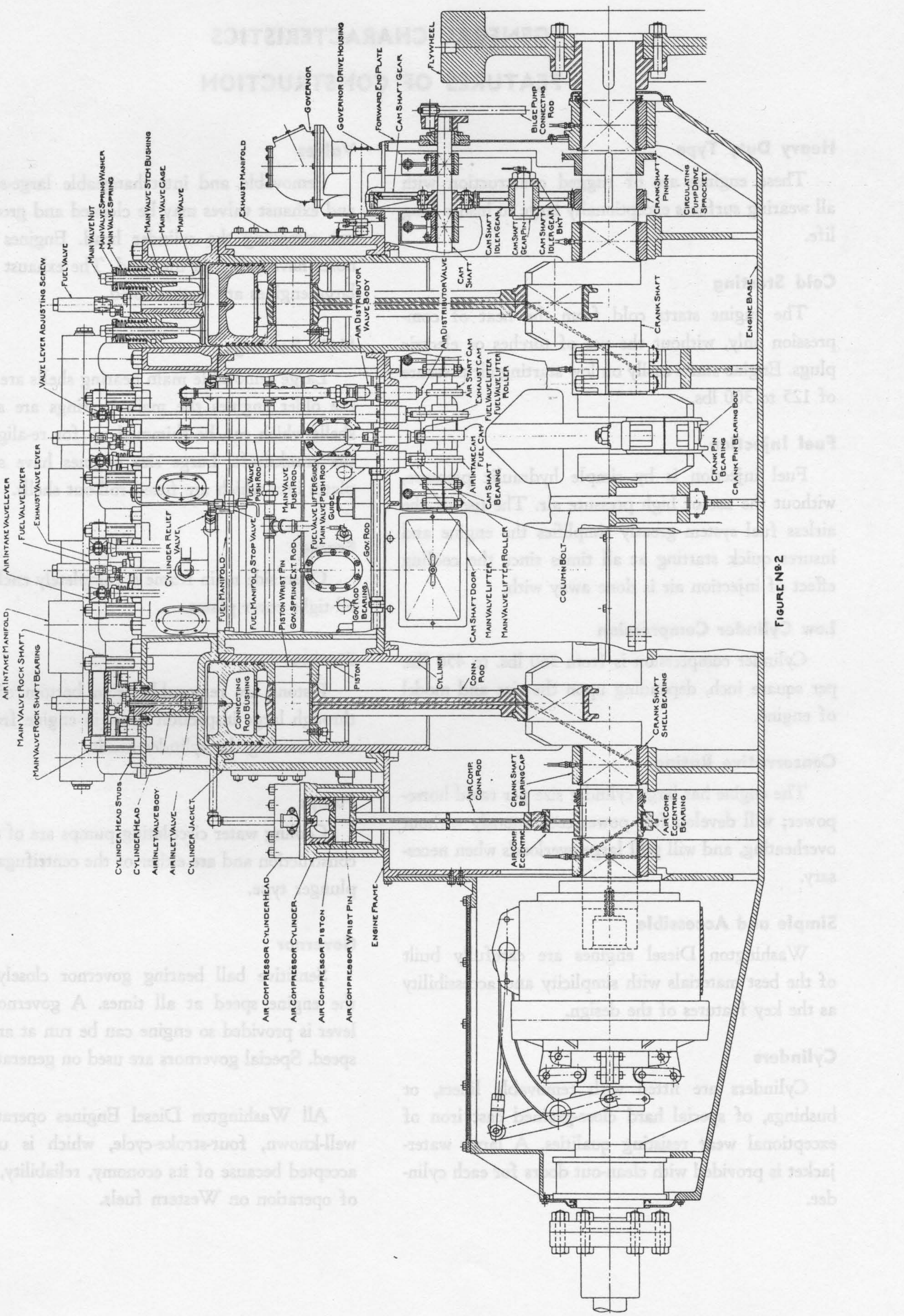
Pumps

Cooling water circulating pumps are of all-bronze construction and are either of the centrifugal, gear or plunger type.

Governor

Sensitive ball bearing governor closely controls the engine speed at all times. A governor control lever is provided so engine can be run at any desired speed. Special governors are used on generator drives.

All Washington Diesel Engines operate on the well-known, four-stroke-cycle, which is universally accepted because of its economy, reliability, and ease of operation on Western fuels.


Flywheel
Forward End Plate
Cam Shaft Gear
Governor Drive Housing
Governor
Exhaust Manifold
Bilge Pump Connecting Rod
Crank Shaft Pinion
Circulating Pump Drive Sprocket
Cam Shaft Idler Gear
Cam Shaft Idler Gear Pin
Cam Shaft Idler Gear Bkt
Main Valve Nut
Main Valve Spring Washer
Main Valve Spring
Main Valve Stem Bushing
Main Valve Gage
Main Valve
Fuel Valve
Valve Lever Adjusting Screw
Air Distributor Valve
Cam Shaft
Crank Shaft
Engine Base
Air Distributor Valve Body
Air Start Cam
Exhaust Cam
Fuel Valve Lifter Roller
Air Intake Cam
Fuel Cam
Cam Shaft Bearing
Crank Pin Bearing
Crank Pin Bearing Bolt
Air Intake Valve Lever
Fuel Valve Lever
Exhaust Valve Lever
Cylinder Relief Valve
Fuel Manifold
Fuel Manifold Stop Valve
Fuel Valve Push Rod
Main Valve Push Rod
Fuel Valve Lifter Guide
Main Valve Push Rod Guide
Gov. Rod
Gov. Rod Bearing
Piston Wrist Pin
Gov. Spring Ext. Rod
Main Valve Lifter Roller
Cam Shaft Door
Main Valve Lifter
Column Bolt
Air Intake Manifold
Main Valve Rock Shaft
Main Valve Rock Shaft Bearing
Piston
Cylinder
Conn. Rod
Connecting Rod Bushing
Crank Shaft Shell Bearing
Cylinder Head Studs
Cylinder Head
Air Inlet Valve Body
Air Inlet Valve
Cylinder Jacket
Air Comp. Conn. Rod
Crank Shaft Bearing Cap
Air Comp. Eccentric
Air Comp. Eccentric Bearing
Air Compressor Cylinder Head
Air Compressor Cylinder
Air Compressor Piston
Air Compressor Wrist Pin
Engine Frame
FIGURE No. 2

GENERAL INSTRUCTIONS

Freezing Temperatures

Should there be the possibility of the engine temperature falling below the freezing point while the engine is standing idle, precautions should be taken to see that engine and all piping is thoroughly drained to prevent freezing.

Fuel Oil

The Washington Diesel permits a wide selection of fuels for successful operation. The following points should be considered in selecting a fuel:

1. The fuel must be free from water and dirt. *More engine trouble and shut-down-time can be traced to water and dirt in fuel than any other cause.*

2. It is important that the fuel selected has sufficient body to properly lubricate the fuel pump plungers and valves, since these parts obtain their lubrication from the fuel itself.

3. The fuel must flow freely at the prevailing temperatures.

The various large petroleum companies are co-operating with the Diesel engine manufacturers at all times to produce fuels that are most suitable. We may say, in general, that any fuel oil manufactured by a reputable company and classified as a refined DIESEL FUEL OIL, (not crude oil) may be used, providing it has a gravity 24 deg. to 32 deg. Baume.

Lubricating Oil

We advise that a good quality oil manufactured by a reliable refiner be used. The best oil will be found cheapest over a longer period of operation. Generally, a good oil of an S.A.E. 40 rating is best for the engine. DE 30

The oil should be changed after about 200 to 350 (256 hrs) hours of operation and replaced with new oil. However, where it has been well filtered during running of engine it may be used longer. The temperature of the oil in the crankcase should be checked occasionally to see that it does not exceed approximately 130 deg. F. Any excessive rise in temperature usually indicates trouble, improper functioning of oil cooler or engine cooling system, mechanical parts not being properly lubricated, etc., or an inferior grade of oil. The amount of oil in the engine service or sump tank should be checked regularly (each 8 hrs and at starting) to insure there being an adequate amount of oil in the engine system at all times.

If an engine is to be let standing idle for some time, it is very important that old lubricating oil should not be left in the engine. Remove the old oil, clean the engine carefully and re-fill with new oil, running the engine for 10 or 15 minutes to be sure the new oil is well circulated in the system. Old oil may contain some fuel and water which will etch cylinder walls and bearings. If possible, it is a good idea to turn the engine over at least two revolutions once a week.

Engine Overload

The Washington Diesel Engine is designed to pull its full-rated horsepower continuously, with a large overload capacity that can be called upon when necessary. This overload capacity should be kept in reserve for emergency use, and then only used intermittently.

The life of the engine is shortened, and repair costs greatly increased, by a great many operators who insist on overloading their engines, merely because the engine is capable of pulling this added load with apparent ease.

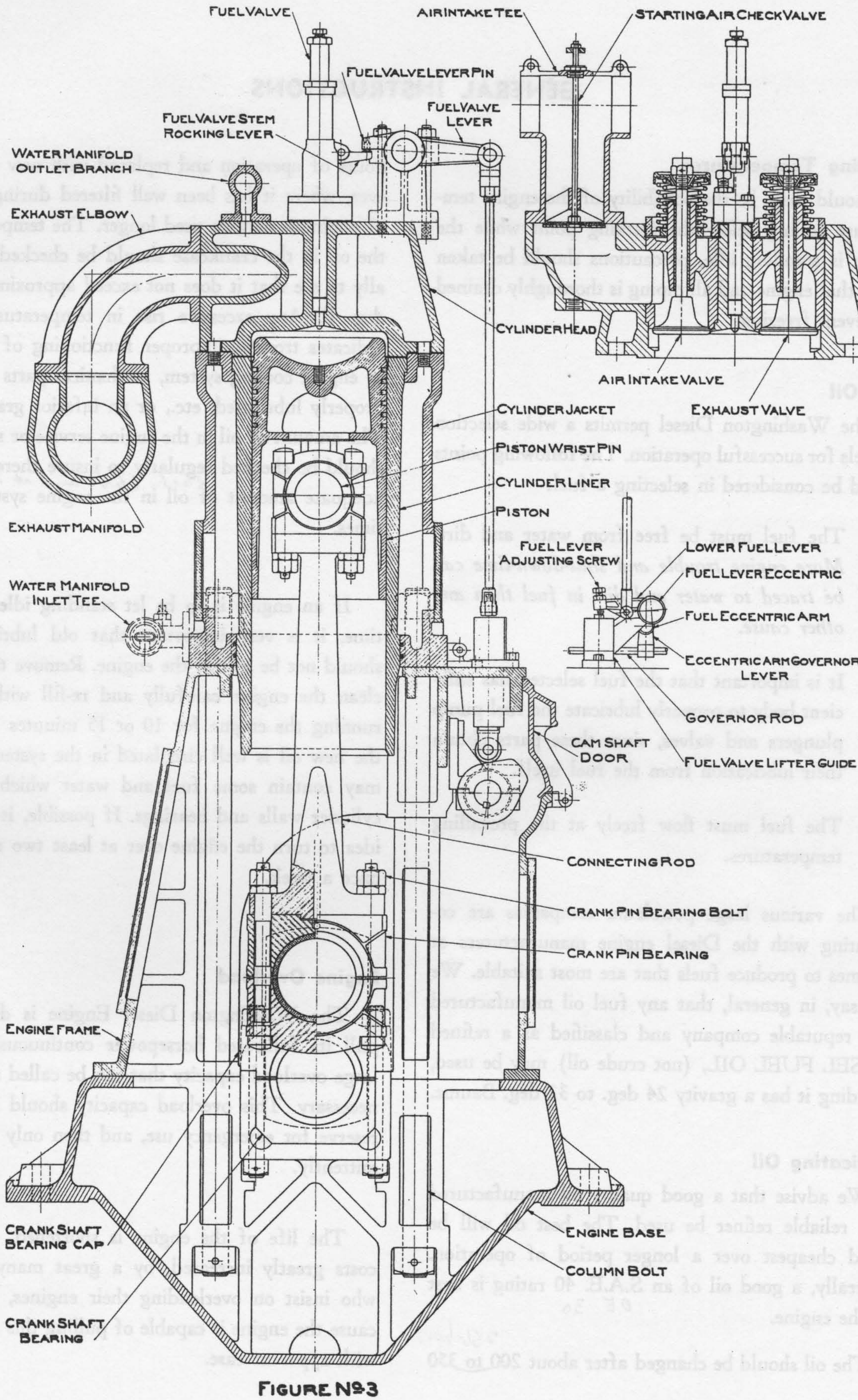

FUEL VALVE
AIR INTAKE TEE
STARTING AIR CHECK VALVE
FUEL VALVE LEVER PIN
FUEL VALVE LEVER
FUEL VALVE STEM ROCKING LEVER
WATER MANIFOLD OUTLET BRANCH
EXHAUST ELBOW
CYLINDER HEAD
AIR INTAKE VALVE
EXHAUST VALVE
CYLINDER JACKET
PISTON WRIST PIN
CYLINDER LINER
PISTON
EXHAUST MANIFOLD
FUEL LEVER ADJUSTING SCREW
LOWER FUEL LEVER
FUEL LEVER ECCENTRIC
WATER MANIFOLD INLET TEE
FUEL ECCENTRIC ARM
ECCENTRIC ARM GOVERNOR LEVER
GOVERNOR ROD
CAM SHAFT DOOR
FUEL VALVE LIFTER GUIDE
CONNECTING ROD
CRANK PIN BEARING BOLT
CRANK PIN BEARING
ENGINE FRAME
ENGINE BASE
CRANK SHAFT BEARING CAP
COLUMN BOLT
CRANK SHAFT BEARING

FIGURE Nº 3

OPERATOR'S INSTRUCTIONS

Preparing to Start Engine

First, start the auxiliary air compressor and put 250 lbs. of air pressure in each air tank. Clean off the engine and oil all small parts and see that everything, including the main valves, governor, etc., is working freely. Fill the engine base to the top of the strainer in the crank pit with a good grade of Diesel engine lubricating oil. Fill the mechanical oiler on the engine. Engines equipped with a strainer or filtering tank should be filled about two-thirds full of the same oil, making sure that the gate valve in the suction line of the lubricating oil pump is open. Give the mechanical oiler a few turns by hand to fill the lines. When starting for the first time after a long lay-up, it is a good plan to put about a half cupful of lubricating oil in each cylinder. This lubricates and seals the piston rings, insuring good compression.

Next, check to see that all the fuel valves are shut off, then open the snifters, or cylinder relief valves and bar the engine over *at least two complete revolutions* so as to be sure that everything is in order, nothing fouls and there is no water in cylinders.

Turn the sea cocks, or other valves in the water line, so the circulating pump can furnish water to the engine. See that the day tank is full of clean fuel oil and open the vents at the fuel oil strainer and at the engine to let the air out of the line. Open the fuel valves, pump the fuel pressure up by means of the hand primer, setting the fuel relief valve lever to release 3,000 lbs., then let the air out of the pressure lines to fuel valves by quickly lifting the fuel lever of each cylinder until the fuel pressure drops on the gauge. During priming, be sure that none of the fuel valves are held open by its cam. If the fuel valves have been removed during installation, they must be re-timed by adjusting the fuel push rod, as described in a later part of this book.

Turn the flywheel about 30 deg. past top center on any cylinder to insure that all the fuel valves are closed. Make sure that the compression relief valves on each cylinder are tightly closed. For engines with Bosch or Bendix-Scintilla fuel injection systems, see instructions in another part of this book.

Check the exhaust line to see that there are no obstructions. Having made sure that the lubricating oil, fuel oil, exhaust and cooling water systems are in proper order, the engine is ready to start.

Starting the Engine

The actual starting operation is controlled by a single air valve which automatically admits the starting air to each cylinder at the proper time through the air starting valves in the cylinder heads. When ready to start, make sure the clutch is out so the propeller will not drag; and on common rail injections, see that the shut-off valve to the fuel valve for each cylinder is open two or three turns. Set the governor control for half-speed position, open the air valve until the engine has made three or four revolutions and shut off the air. The engine will start to fire immediately if all the adjustments have been properly made. It is important to shut off the starting air as soon as the engine has made several revolutions. If the starting air valve is held open too long, the cooling effect of the expanding air will hinder starting.

There are only two general causes for an engine failing to start, they are:

(1) The fuel oil is not reaching the cylinder, or

(2) The compression is too low.

For more details on failure of engine to start, refer to section on "Engine Troubles."

Running the Engine

As soon as the engine has started, make sure that there is at least 10 lbs. pressure on the lubricating oil gauge, and the cooling water is circulating properly.

The oil feeds to the cylinders from the mechanical

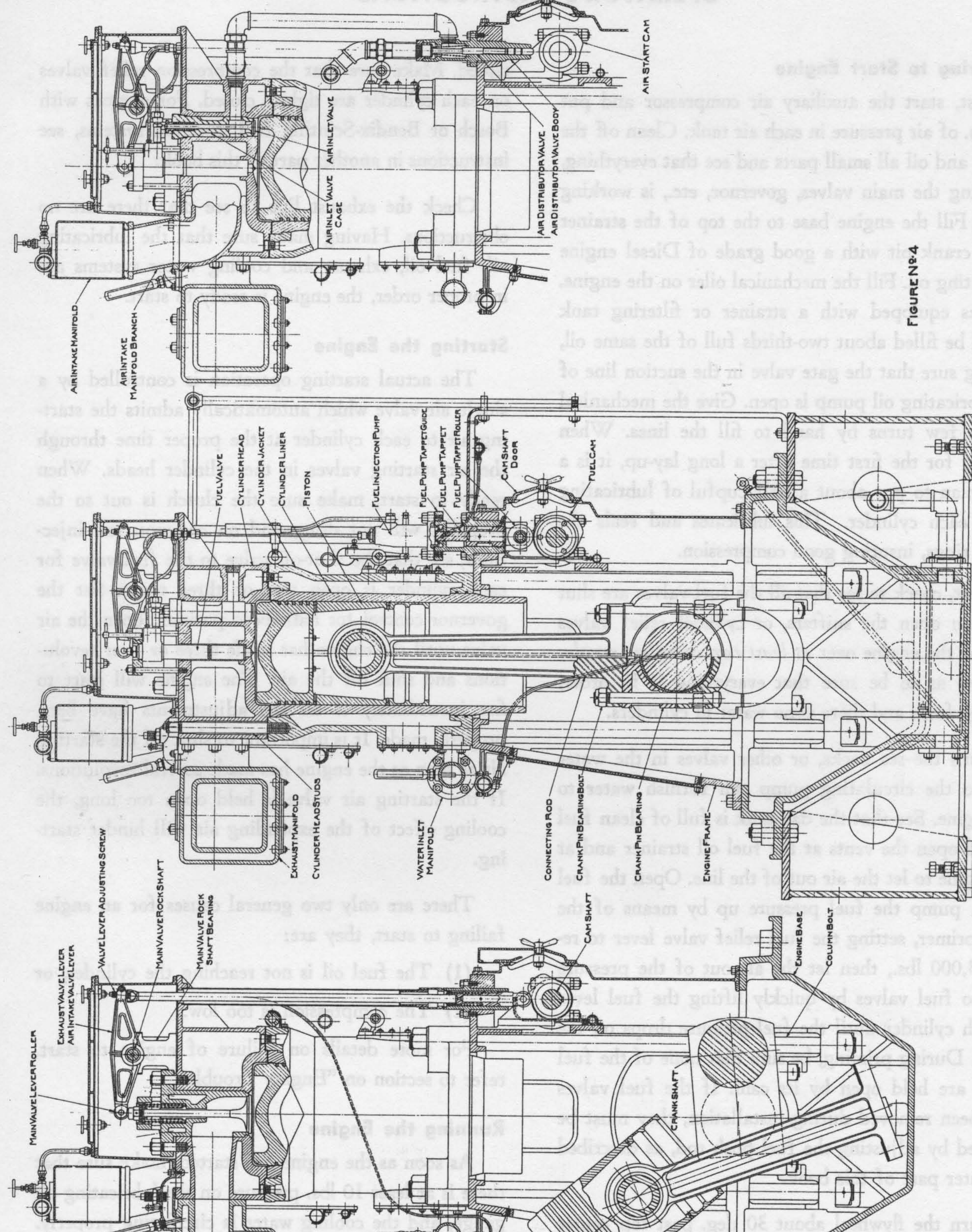


FIGURE No 4
AIR START CAM
AIR DISTRIBUTOR VALVE
AIR DISTRIBUTOR VALVE BODY
AIR INLET VALVE
AIR INLET VALVE CAGE
AIR INTAKE MANIFOLD
AIR INTAKE MANIFOLD BRANCH
FUEL VALVE
CYLINDER HEAD
CYLINDER JACKET
CYLINDER LINER
PISTON
FUEL INJECTION PUMP
FUEL PUMP TAPPET GUIDE
FUEL PUMP TAPPET
FUEL PUMP TAPPET ROLLER
CAM SHAFT DOOR
FUEL CAM
CYLINDER HEAD STUDS
WATER INLET MANIFOLD
CONNECTING ROD
CRANK PIN BEARING BOLT
CRANK PIN BEARING
ENGINE FRAME
CAM SHAFT
ENGINE BASE
COLUMN BOLT
CRANK SHAFT
MAIN VALVE ROCK SHAFT
VALVE LEVER ADJUSTING SCREW
EXHAUST VALVE LEVER
AIR INTAKE VALVE LEVER
MAIN VALVE LEVER ROLLER

oiler are left well open when the engine leaves the factory, but the amount of this oil should be cut down after approximately two hundred (200) hours of operation. Pump up the air tanks again with the engine driven air compressor, making it a habit to always have enough air in the tanks to start at any time. If the air tanks and fittings are properly put in, you can hold air indefinitely, making it unnecessary to use the auxiliary air compressor.

The engine should be run light for a few minutes, then the load should be applied gradually in order to warm the engine uniformly. After the engine has been running a while, feel the cylinders and other parts of engine to see that no area is heating up due to lack of cooling water or lubricating oil, and make certain that all parts are operating freely.

Regulate the fuel pressure until the engine runs smoothly. About 1200 to 1500 lbs. pressure gives the best results for idling, and about 3,500 to 4,500 lbs. under full load. While engine is operating under normal full load, be sure to balance the load on all cylinders.

Before stopping the engine, make sure that there is enough air in the tanks to start again.

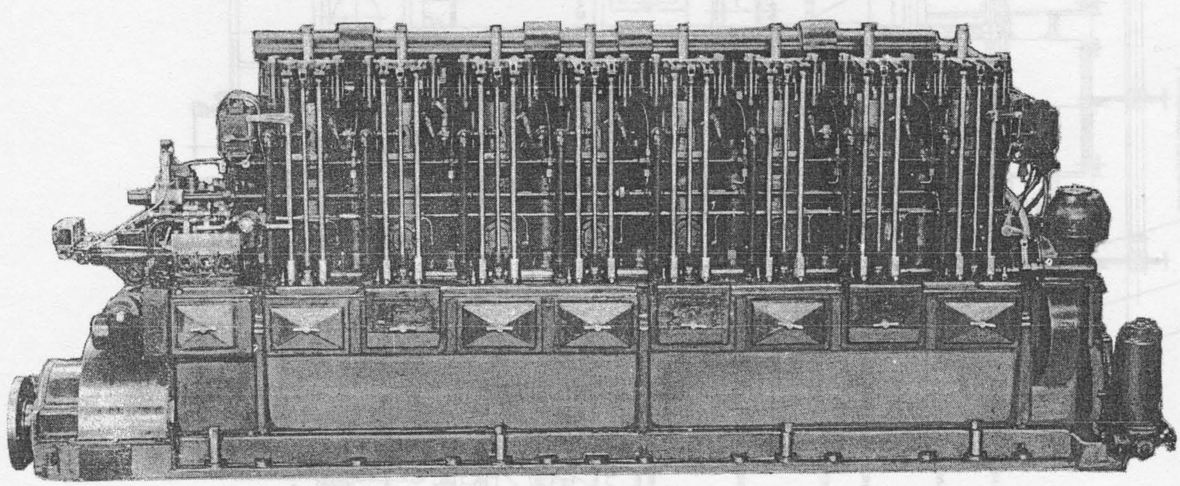
On the clutch-type engine, the governor control is set so the engine will not stop when it is in the extreme slow position, making it impossible to kill the engine accidentally. To stop the engine, hold the governor rod back with the hand lever provided for that purpose until the engine stops, or shut off the fuel to each cylinder.

Engine Controls, Reversing

The larger sizes of Washington Diesel Engines are made direct reversing, the maneuvering from ahead to astern being accomplished in a few seconds by a single hand wheel, or an air cylinder, which slides the cam shaft longitudinally to bring each cam under its respective roller. When reversing, turn the hand wheel, or control lever, to the proper position and start the engine by a slight pull on the air throttle. Reversing is done with moderate air pressure (from 125 lbs. to 300 lbs.), and a very small volume of air, especially if the engine is allowed to slow down itself.

With the exception of the sliding cam shaft, the starting and operation of direct reversing engines is the same as for those equipped with the reversing clutch.

If it is necessary to reverse the engine quickly, after the camshaft has been shifted always apply the starting air to get the engine turning in the right direction before opening the governor to give the engine fuel.



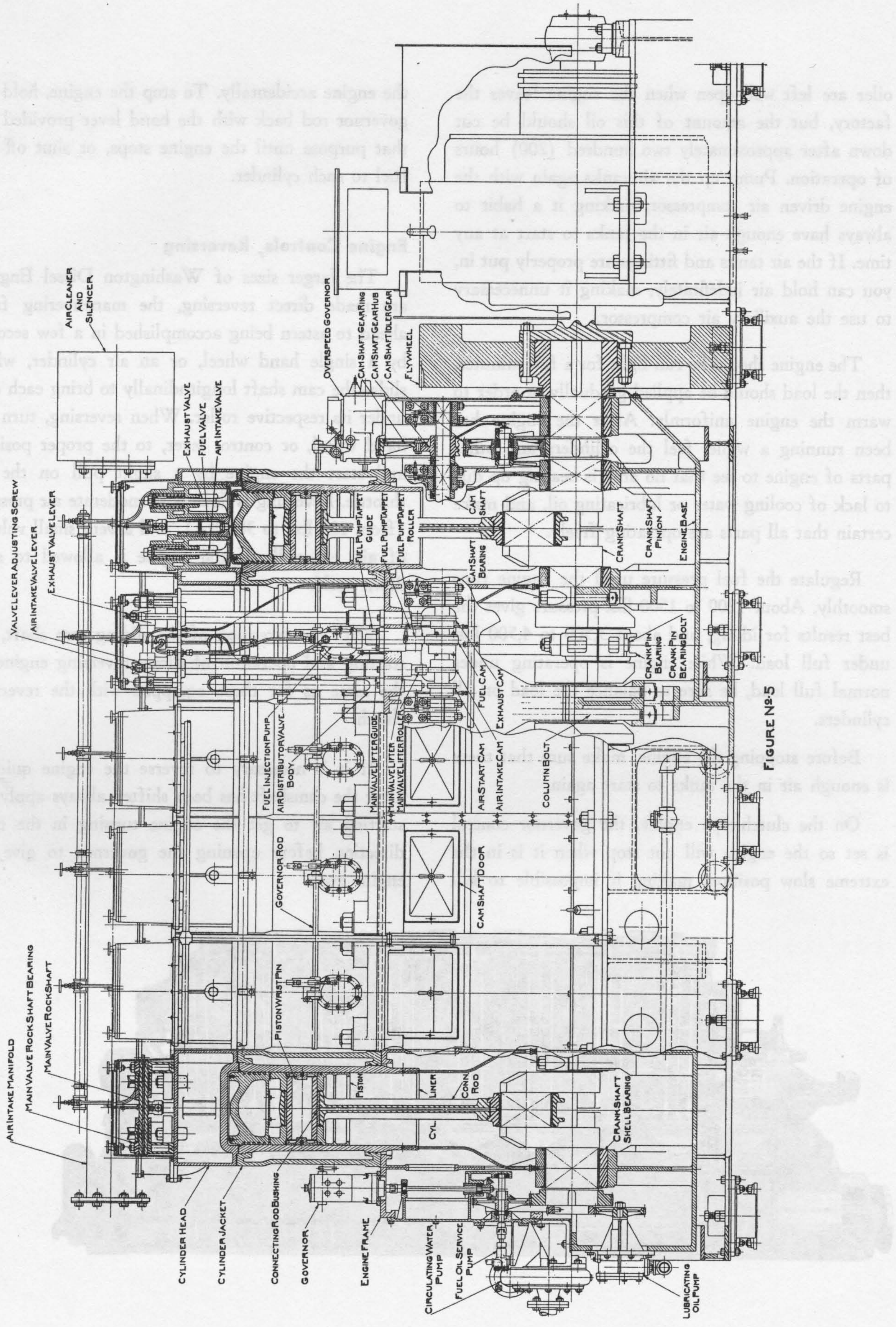

AIR INTAKE MANIFOLD
MAIN VALVE ROCK SHAFT BEARING
MAIN VALVE ROCK SHAFT
VALVE LEVER ADJUSTING SCREW
AIR INTAKE VALVE LEVER
EXHAUST VALVE LEVER
AIR CLEANER AND SILENCER
EXHAUST VALVE
FUEL VALVE
AIR INTAKE VALVE
OVERSPEED GOVERNOR
CAM SHAFT GEAR RING
CAM SHAFT GEAR HUB
CAM SHAFT IDLER GEAR
FLYWHEEL
FUEL PUMP TAPPET GUIDE
FUEL PUMP TAPPET
FUEL PUMP TAPPET ROLLER
CAM SHAFT BEARING
CRANK SHAFT
CRANK SHAFT PINION
ENGINE BASE
FUEL INJECTION PUMP
AIR DISTRIBUTOR VALVE BODY
MAIN VALVE LIFTER GUIDE
MAIN VALVE LIFTER
MAIN VALVE LIFTER ROLLER
FUEL CAM
EXHAUST CAM
CRANK PIN BEARING
CRANK PIN BEARING BOLT
AIR START CAM
AIR INTAKE CAM
COLUMN BOLT
CAM SHAFT DOOR
GOVERNOR ROD
PISTON WRIST PIN
PISTON
LINER
CONN ROD
CRANK SHAFT SHELL BEARING
CYLINDER HEAD
CYLINDER JACKET
CONNECTING ROD BUSHING
GOVERNOR
ENGINE FRAME
CIRCULATING WATER PUMP
FUEL OIL SERVICE PUMP
LUBRICATING OIL PUMP

FIGURE No 5

CARE AND MAINTENANCE OF ENGINE

Engine Should Never Smoke

If properly adjusted, even when pulling well over its rated load, the engine should never smoke. A smoky exhaust is usually caused by leaky or dirty fuel valves, or leaky exhaust or inlet valves. If the engine is allowed to smoke for any length of time, an excessive amount of carbon will be formed which tends to gum up the piston rings and valves, and also causes slow burning and overheating.

Lubricating System (Pumps)

All main parts of the engine are well lubricated from a force feed oiling system. The lubricating oil pumps are of either simple plunger type with hardened and ground plungers, or gear type. The plunger type should be packed with a good grade of packing, using a leather washer between each packing ring. The check valves on these pumps are of the standard type and should require no attention other than cleaning occasionally to prevent dirt being lodged under the seat.

On direct reversing engines equipped with gear pumps, double check valves are provided. These are so arranged as to enable the pumps to continue to operate when the engine is running in either direction.

Some types of small engines have one lubricating oil pump, and the oil is carried in the base of the engine.

The base of the engine and the entire lubrication system should be kept clean by washing out with a solvent about every 350 to 500 hours running.

Lubrication System, Cylinders

The cylinder walls are oiled with fresh oil from a Manzel oiler on the engine. The amount of oil delivered to each of these feed pipes can be seen in the sight glass on the oiler. These oil feeds are left well open when the engine leaves the factory. As soon as the engine has been in operation for about a week, this oil should be cut down to about six to eight drops a minute on each pipe. When cutting down the oil feed on a marine engine with a Navy type Babbitted thrust, trace out the oil pipe to the thrust bearing and see that this pipe gets about twice as much oil as the ones leading to the cylinder walls.

Lubrication System, Bearings

All main bearings, crank bearings, and wrist pins are lubricated by means of a force-feed oiling system. The oil is drawn from the engine base through a screen and delivered to the top of a combined strainer and settling tank. Another pump takes the oil from the bottom of this tank and puts it through an oil cooler on the engine and then to the bearings. When the engine is first started up, the oil is cold and the pressure on the gauge will run high. As the oil warms up, this pressure may drop down to 10 lbs. The bearings will receive plenty of oil as long as there is 10 lbs. pressure on the lubricating oil gauge. The lubricating oil pressure can be regulated to some extent by adjusting the relief valve located in the line near the pumps.

Be sure at all times that the strainers and filters on the lubricating oil system are clean. This applies to the strainer in the base and the basket strainer in the service tank, as well as any other strainers or filters on the engine. There is no excuse for a dirty engine, either inside or outside.

Fuel System (Common Rail)

Fuel Valve, Balanced and Spring Type

The fuel valve is one of the most important parts of the engine, but will be found to give very little trouble. With clean fuel oil it should operate for a very long period without requiring attention, simply setting up easily on the packing nuts from time to time when there is no pressure on the fuel line. Black smoke in the exhaust usually indicates that one or more of the fuel valves may not be working right. With a new engine, some dirt may have worked into the small fuel nozzle holes and cut off the fuel supply to one of the cylinders. This would overload the remaining cylinders, causing more or less smoke in the exhaust. When this occurs, the fuel nozzle should be removed from the cylinder and cleaned out. The nozzle nut holding the tip is removed by a spanner wrench supplied with the engine.

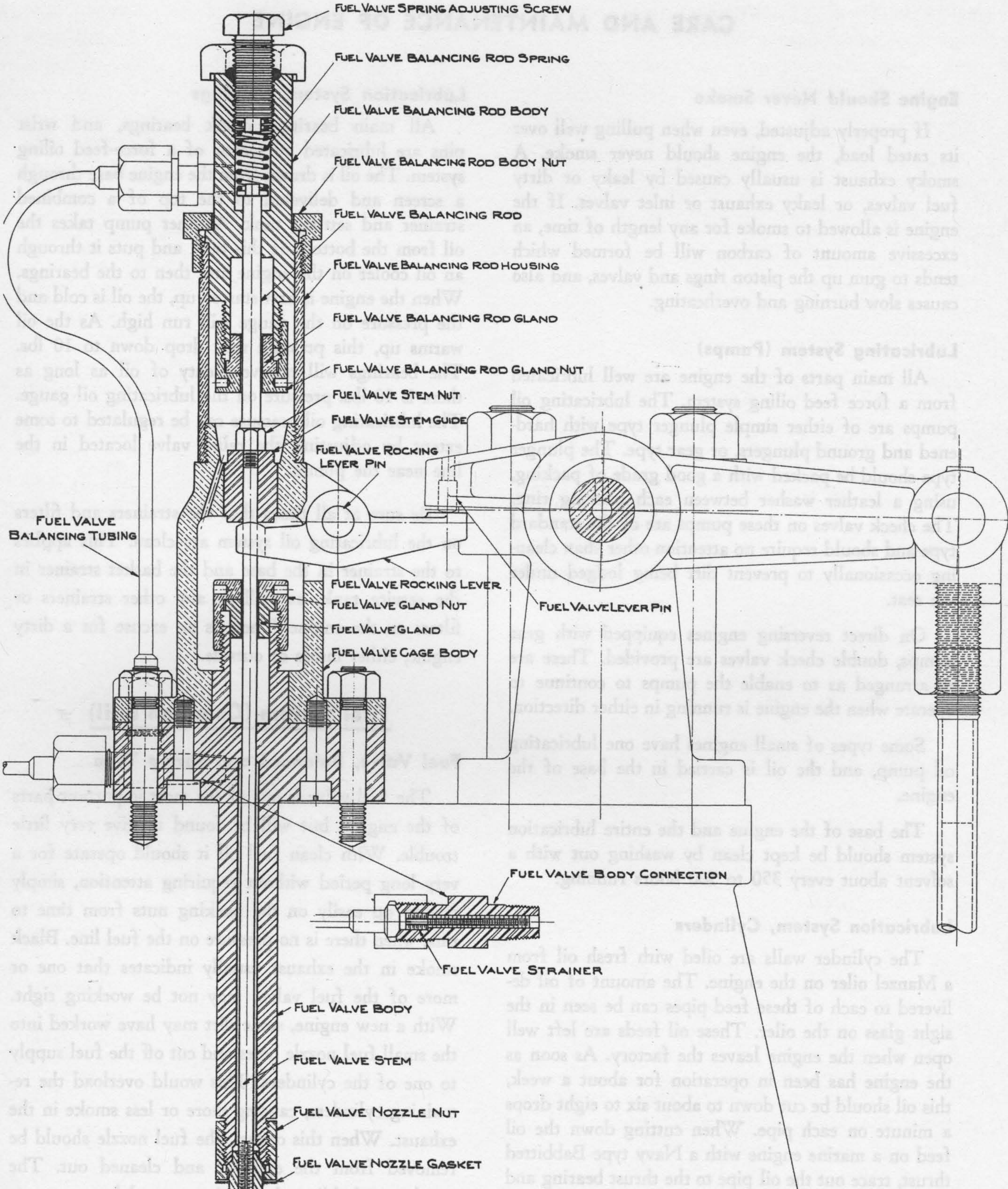

FUEL VALVE SPRING ADJUSTING SCREW
FUEL VALVE BALANCING ROD SPRING
FUEL VALVE BALANCING ROD BODY
FUEL VALVE BALANCING ROD BODY NUT
FUEL VALVE BALANCING ROD
FUEL VALVE BALANCING ROD HOUSING
FUEL VALVE BALANCING ROD GLAND
FUEL VALVE BALANCING ROD GLAND NUT
FUEL VALVE STEM NUT
FUEL VALVE STEM GUIDE
FUEL VALVE ROCKING LEVER PIN
FUEL VALVE BALANCING TUBING
FUEL VALVE ROCKING LEVER
FUEL VALVE GLAND NUT
FUEL VALVE GLAND
FUEL VALVE CAGE BODY
FUEL VALVE LEVER PIN
FUEL VALVE BODY CONNECTION
FUEL VALVE STRAINER
FUEL VALVE BODY
FUEL VALVE STEM
FUEL VALVE NOZZLE NUT
FUEL VALVE NOZZLE GASKET
FUEL VALVE NOZZLE

FIGURE Nº 6

Before removing a nozzle, always insert a screw driver between the rocker lever and the gland nut to take the spring force off of the nozzle. If the nozzle is put on with the spring force on it, there is danger of cutting the seat in the nozzle, or spoiling the seat between the nozzle and the fuel valve body.

Use the small cleaning wire which is furnished to clean out the fuel nozzle holes. After cleaning, fill tip with a solvent and force it out the spray holes with a small rod used as a plunger to make sure they are all open. If the valve has been leaking, or a new nozzle is put on, grind in the seats with a little fine grinding compound and wash out thoroughly with a solvent. If the seat cannot be made tight by grinding, it is cut and must be reamed with the special reamer which is furnished with the engine. The grooves near the end of the fuel stem form a mechanical strainer which has a capacity of many times the volume of the spray valve holes, and also, a mechanical strainer is built into the tubing fitting of each fuel valve. This strainer should be removed occasionally and washed in a solvent. These strainers catch practically all the dirt before it reaches the fuel valves, which is the main reason they seldom become plugged.

Balanced Pressure Type Fuel Valve *(See Figure 6)*

The adjusting screw on top of the fuel valve (balanced pressure type) regulates the pressure on the spring inside, which holds the stem on the seat, assisted by the fuel pressure on the balance rod. The tension, or draw, on this spring should be the same on all cylinders, from 1/8″ to 3/16″. To set this, slip the nozzle loosely on the stem and measure the distance between the two faces where the nozzle bears on the fuel valve body when nozzle nut has been tightened, and turn the adjusting screw to get the proper setting. BE SURE that the metallic packing under the locknut for the adjusting nut is in good shape.

Balanced Spring Type Fuel Valve *(See Figure 7)*

On the later type fuel valves, the balancing pressure chamber has been removed and a stronger spring substituted. To properly adjust this spring, mount the fuel valve in the test bracket on the side of the engine and connect it to the high pressure fuel system by means of the pipe provided for that purpose. Pump up the fuel pressure with the hand priming pump to 4000 lbs. and set the spring nut on the fuel valve so the stem is just held tight on the seat without leaking at that pressure. Then turn the spring nut down *two turns more* to get the additional spring tension necessary for proper operation of the fuel valve. If the engine smokes with the fuel valve set this way, it may be necessary to set up another half or three-quarter turn on the fuel valve spring nut while the engine is running.

Fuel valves are packed with a special grade of soft twisted packing which can be secured from the factory. First, place a leather washer in the bottom of the stuffing box, then put in the packing and put another leather washer under the gland. Set the packing up fairly tight and work the fuel valve stem back and forth by hand until it is absolutely free in the packing.

If it is necessary to set up again on the gland nut while the fuel valve is in the engine, be sure to shut off the fuel line to that cylinder and release the pressure in the line, as it is difficult to turn the gland nut when the fuel pressure is against it.

After packing or cleaning the fuel valve, hook it up to the line, pump up the pressure, and make sure that it does not leak before replacing it in the engine. See that the spray holes are all open by tapping the lever lightly with a hammer. CAUTION! Keep your hands away from the nozzle spray as a direct spray may puncture the skin of the hand and possibly be injurious. When setting the valve into the cylinder, tighten down first on the lever side and then bring down the other nut. This holds the valve over in the working position, keeping it rigid in the cylinder.

Adjusting Fuel Valve

When the fuel valve is put back in the cylinder head it must be reset so that it opens at the proper time. To do this, close all the (fuel valve) shut-off valves on the fuel manifold and open the compression relief valve on each cylinder. Bar the engine over by hand in the same direction it turns while running until the pointer is exactly at the correct opening point as marked on the flywheel. Shorten the fuel valve push rod and leave it loose.

Open the fuel stop valve for the cylinder which is being timed, set the governor lever in full speed position and pump up the fuel pressure by hand to

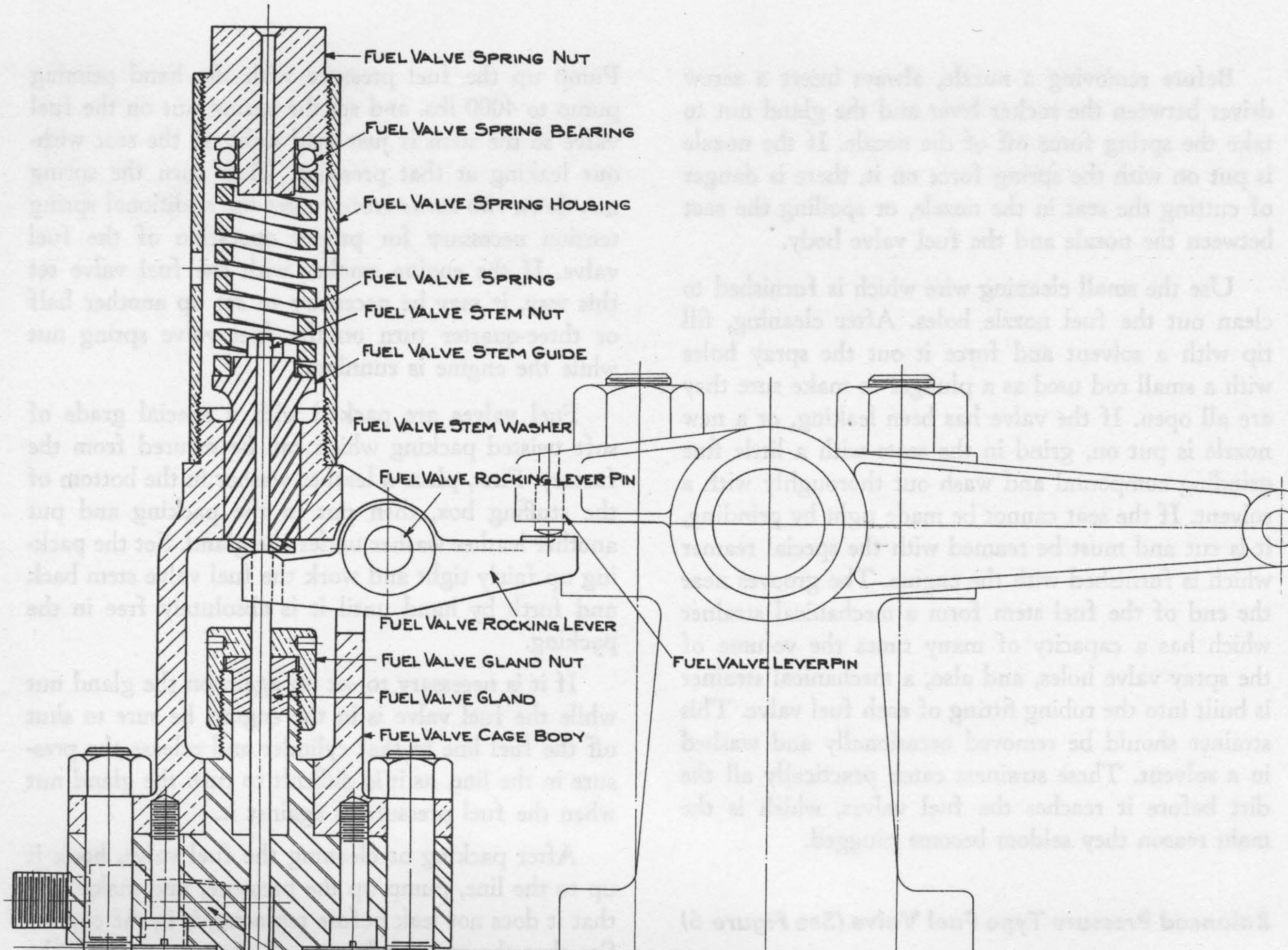

FUEL VALVE SPRING NUT
FUEL VALVE SPRING BEARING
FUEL VALVE SPRING HOUSING
FUEL VALVE SPRING
FUEL VALVE STEM NUT
FUEL VALVE STEM GUIDE
FUEL VALVE STEM WASHER
FUEL VALVE ROCKING LEVER PIN
FUEL VALVE ROCKING LEVER
FUEL VALVE LEVER PIN
FUEL VALVE GLAND NUT
FUEL VALVE GLAND
FUEL VALVE CAGE BODY
FUEL VALVE BODY CONNECTION
FUEL VALVE STRAINER
FUEL VALVE BODY
FUEL VALVE STEM
FUEL VALVE NOZZLE NUT
FUEL VALVE NOZZLE GASKET
FUEL VALVE NOZZLE

FIGURE No. 7

4000 lbs. Then lengthen the fuel valve push rod, watching the fuel pressure gauge, until the pressure drops to 2000 lbs. Then tighten up on the jam nut on the push rod. To check the setting, back the engine a few degrees, pump up the fuel pressure again, and in turning the engine in the ahead direction the fuel pressure should drop to almost zero at the correct time of opening of the fuel valve. The engine will not idle properly unless this is carefully done. After the fuel valves are properly adjusted, *it is very important* to remove the excess fuel oil from the cylinders by shutting off the fuel stop valves, opening the compression relief valves and turning the engine over on air a few times. The engine should idle well with a fuel pressure of about 1200 to 1500 lbs.

If the fuel cams have been changed and it is desired to re-set the timing, proceed as follows: Loosen the fuel cam body bolts just enough so that the cam body can be moved. Take off the fuel valve push rod. Barring the engine in the direction it should turn, set the engine, for the cylinder you are working on, just eight degrees after top center. Fix a dial indicator on the fuel valve tappet. Then move the fuel cam body until it raises the fuel valve tappet to the highest position. In other words, the fuel cam is at its top center when the engine is eight degrees after top dead center of the cylinder.

If the engine races at any time when not under load, it may be caused by the governor rod sticking, clearance less than the correct clearance on the fuel valve lifter, or fuel valve stem sticking in the packing.

Fuel Relief Valves *(See Figures 8 and 9)*

The fuel relief valve regulates the fuel injection pressure from about 1200 to 4500 lbs., and by-passes the excess fuel from the fuel pumps back into the suction line. The adjusting cam, or helix, on the fuel relief valve is connected to the governor lever to provide about 1200 lbs. fuel pressure when idling and 4000 lbs. pressure at full speed. If the valve does not hold the fuel pressure, there is probably a small particle of dirt on the seat. To clean this out, pump up the full fuel pressure, place a small bar under the spring seat and lift the stem quickly from the seat, washing the dirt out.

While the engine is running, or if the pressure is up on the fuel relief valve, the valve stem can be worked back and forth by turning the stem with a small wrench. This can be done on the old type relief valves by means of the set screw on the spring adjusting screw. On the new type fuel relief valves there is a flat on the stem just below the spring seat. On the old type fuel relief valve do not release the set screw on the spring adjusting screw. If the set screw is loosened, the spring adjusting screw will come down and it will be necessary to dismantle the whole top end of the relief valve in order to get it in place again.

If this does not stop the leakage it may be necessary to grind in the seat.

Insert a bar or large screw driver between the fuel relief gland nut and the spring adjusting screw or spring seat. Put it in hard enough to take most of the pressure off of the stem. Remove the body nut on the end of the valve, which leaves the seat free for grinding with some fine compound. Before replacing, wash out with a solvent and make sure the small copper gasket on each end of the seat is in place.

The packing of this valve is done in exactly the same way as described for the fuel valve.

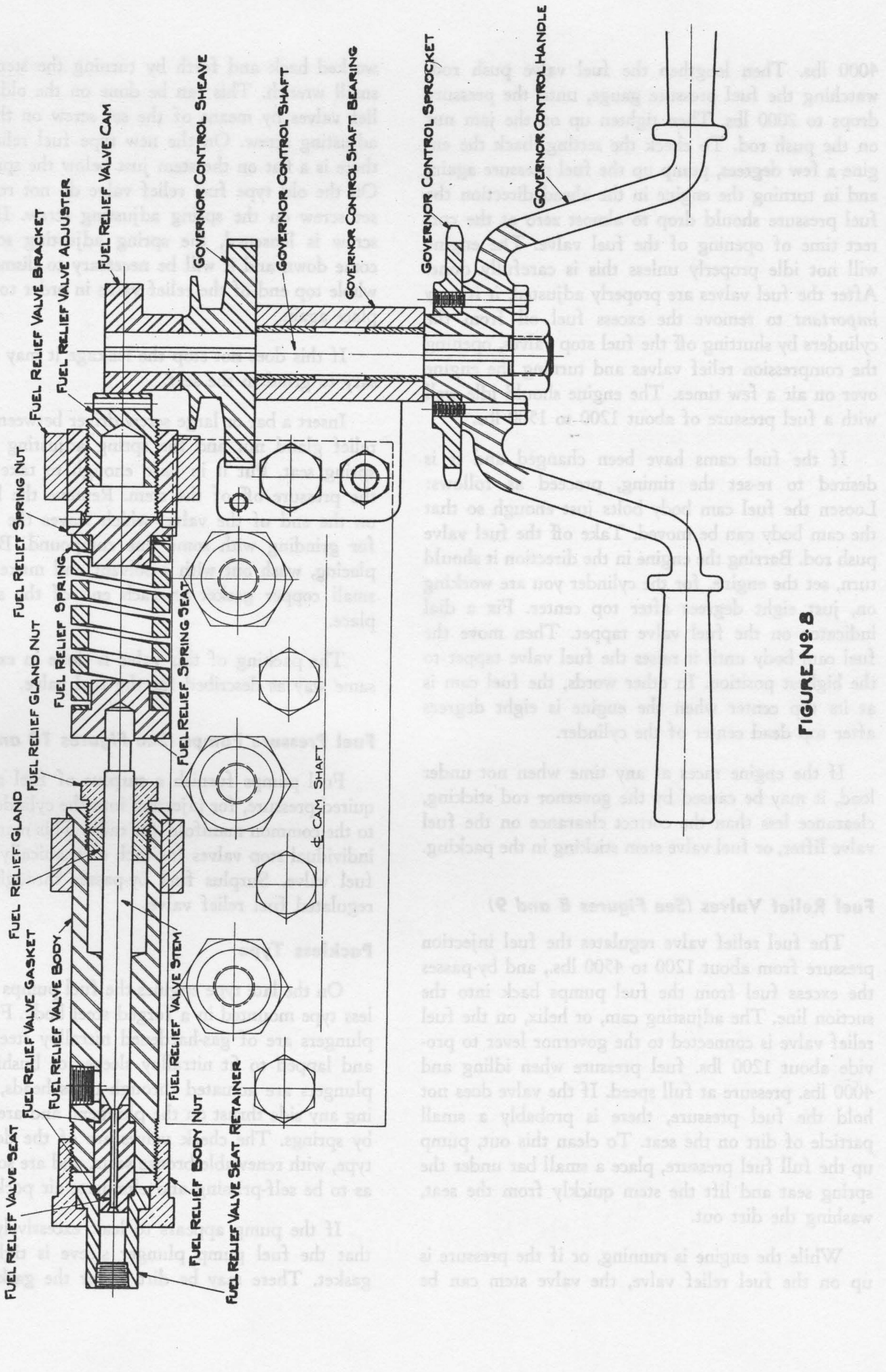
Fuel Pressure Pumps *(See Figures 10 and 11)*

Fuel pumps furnish a surplus of fuel at the required pressure, for injection into the cylinders, direct to the common manifold (or rail). This manifold has individual stop valves for each mechanically operated fuel valve. Surplus fuel by-passes through a hand regulated fuel relief valve.

Packless Type

On the late type engines the fuel pumps are packless type mounted in a forged steel body. Fuel pump plungers are of gas-hardened nitralloy steel, ground and lapped to fit nitralloy sleeves or bushings. The plungers are actuated through cross heads, eliminating any side thrust on the plungers, and are returned by springs. The check valves are of the double ball type, with renewable bronze seats, and are so designed as to be self-priming and eliminate air pockets.

If the pump appears to leak excessively, be sure that the fuel pump plunger sleeve is tight on the gasket. There may be dirt under the gasket or the



FUEL RELIEF VALVE SEAT
FUEL RELIEF VALVE GASKET
FUEL RELIEF GLAND
FUEL RELIEF GLAND NUT
FUEL RELIEF SPRING NUT
FUEL RELIEF VALVE BRACKET
FUEL RELIEF VALVE ADJUSTER
FUEL RELIEF VALVE CAM
FUEL RELIEF VALVE BODY
FUEL RELIEF SPRING
FUEL RELIEF SPRING SEAT
FUEL RELIEF VALVE STEM
FUEL RELIEF BODY NUT
FUEL RELIEF VALVE SEAT RETAINER
CAM SHAFT
GOVERNOR CONTROL SHEAVE
GOVERNOR CONTROL SHAFT
GOVERNOR CONTROL SHAFT BEARING
GOVERNOR CONTROL SPROCKET
GOVERNOR CONTROL HANDLE

FIGURE No. 8

gasket may not be forced down hard enough. In tightening the fuel pump plunger sleeve, be sure that it is not too tight so as to bind the plunger.

Packed Type

The packed type pump is fitted with hardened steel plungers running in removable bronze or bronze-bushed bodies. They are packed with die formed rings of packing (with leather washers between), which may be secured ready to use from the factory. This packing must be set up a little tighter than is allowable on the fuel valves, but the packing should always be loose enough to allow a trace of oil to leak by as this lubricates the plungers and keeps them from cutting.

Pump Valves

The pump valves are double ball checks working on copper seats for both the suction and discharge sides. These balls set one above the other and should have 1/16" clearance between them in order to work properly. After a year or two of operation, the lower ball may have to be re-seated in order to regain this clearance. To do this, ream the lower seat the required amount with a proper sized drill and set the ball home by a few light taps with a copper drift.

Fuel System (Bosch or Scintilla Type)

Fuel Injection Pump

The fuel injection pump used is of the variable cut-off, constant stroke plunger type. The amount of fuel injected is regulated by a horizontal control rod connected to the governor and hand control. The pumps are accurately calibrated by the manufacturer and are re-checked and adjusted by the Washington Iron Works while the engine is being tested. No re-calibration should be necessary for many thousands of hours of operation where good fuel is used. No maintenance is required on this pump, other than occasionally putting a little engine oil on the plunger follower which shows through a small inspection opening on the side of the pump housing.

Should one of these pumps become inoperative while the engine is running, it is very probable that dirt has lodged under the pump delivery valve. This can best be checked by unscrewing the delivery valve holder on top of the pump, making the delivery valve available for inspection and cleaning.

Prior to any long period of shut-down, the pump should be drained and flushed with a good, clean, thin lubricating oil of the rust-preventative type.

General Construction and Operation

The construction of the pumps is shown on Figure 12.

The plunger follower (22) is held against the engine tappet by return spring (23) which also holds the plunger (3) against the inner face of the plunger follower (22) by means of the lower spring plate (1). These parts are reciprocated by the fuel cam of the engine. During the up stroke, the plunger first closes the inlet port of the fuel pump barrel and begins to deliver fuel through the delivery valve (7). As the plunger continues to rise, a helical groove in the plunger surface (metering helix) uncovers the bypass port, ending delivery of fuel through the delivery valve, thus terminating injection into the engine cylinder. As the plunger continues to rise, fuel is expelled out of the pump barrel through a central and cross-hole in the plunger, the helical groove and the bypass port into the suction chamber of the pump housing (2).

When the plunger reaches the end of its up stroke it is returned to its lower position by the return spring (23) at a rate determined by the engine fuel cam. On the downstroke it uncovers the inlet port and the fuel flows into the pump barrel under the action of the vacuum formed when the plunger descends, and the pressure in the supply line.

The quantity of fuel delivered to the engine cylinder is controlled by rotating the plunger so that the helical metering groove uncovers the bypass port earlier or later during the upstroke. This is accomplished by the control rack (26) engaging with teeth on the control sleeve (4) which is slotted at the lower end. The slots engage with a cross bar of the plunger. The control rack is connected to the engine controls and governor.

Installation and Timing

A high grade fuel filter should be installed in the suction line leading to the pump. Care must be taken during installation that no dirt or other foreign matter enters the pump or the suction line connecting it to the filter. The vent screw (13) permits bleeding of the air out of the pump and suction line.

Timing windows are provided on each side of the pump housing and a circular timing mark on the plunger follower (22). When pumps are mounted on the engine, the timing mark on the plunger fol-

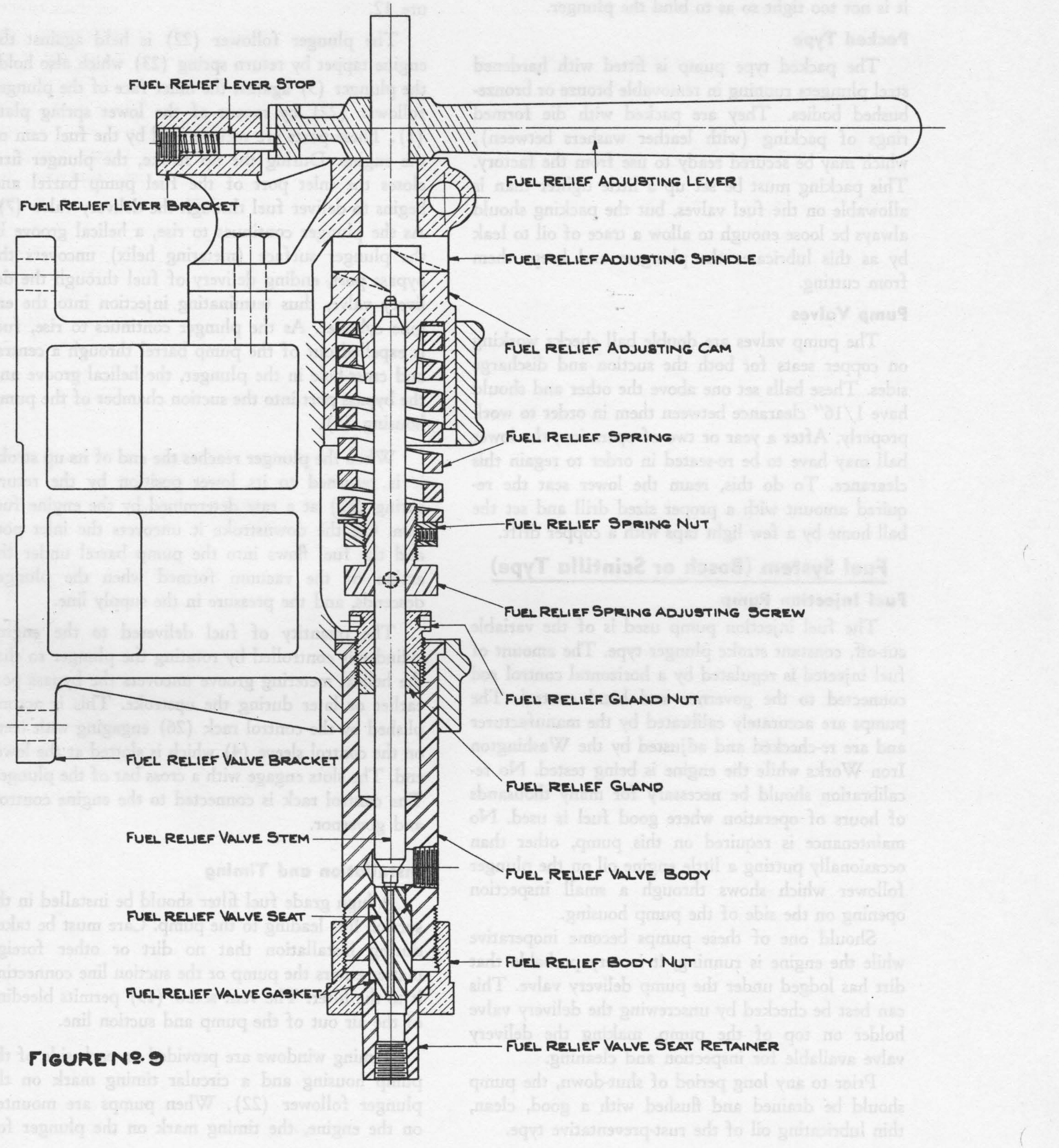

FUEL RELIEF LEVER STOP
FUEL RELIEF ADJUSTING LEVER
FUEL RELIEF LEVER BRACKET
FUEL RELIEF ADJUSTING SPINDLE
FUEL RELIEF ADJUSTING CAM
FUEL RELIEF SPRING
FUEL RELIEF SPRING NUT
FUEL RELIEF SPRING ADJUSTING SCREW
FUEL RELIEF GLAND NUT
FUEL RELIEF VALVE BRACKET
FUEL RELIEF GLAND
FUEL RELIEF VALVE STEM
FUEL RELIEF VALVE BODY
FUEL RELIEF VALVE SEAT
FUEL RELIEF BODY NUT
FUEL RELIEF VALVE GASKET
FUEL RELIEF VALVE SEAT RETAINER

FIGURE No. 9

lower should appear at the lower end of the housing window when the fuel cam tappet rides on the base circle of the cam. When the tappet is in its highest position, the mark on the plunger follower *must never go beyond the upper edge of the housing windows.* Otherwise, damage will occur to the pump. The tappet must not be adjusted higher than .187″ nor lower than .250″ measured from the mounting face of the pump flange to the top of the tappet. A tappet adjustment of less than .187″ will result in reduced volumetric efficiency of the pump at higher speeds.

Timing marks are provided on the side faces of the housing windows. When the circular mark on the plunger follower registers with these timing marks, the inlet port is closed and actual pumping has begun. Since the pump lag, that is, the time elapsing between the beginning of the actual pumping at the pump and the actual delivery of fuel from the nozzle orifices, varies with different engines, it is necessary to determine by actual test the flywheel position at which the timing marks on the pump should register in order to obtain the desired engine performance. Thereafter this flywheel position can be used for timing the pumps in original installation and in field service.

Timing of Pumps on Engines Using Adjustable Fuel Cams

Rotate fuel cam until cam tappet rides on base circle of cam. Adjust tappet to .218″ and install pump. Place flywheel in position recommended by engine manufacturer for pump timing. Rotate cam, raising tappet and plunger follower (22) until timing marks on housing window and plunger follower are in line. Lock cam.

Timing of Pumps on Engines Using Fixed Cams

On engines of this type, fuel cams are keyed to or forged integral with the cam shaft. The cam shaft is properly geared to the crankshaft and the drive gears are marked for proper meshing. The engine manufacturer recommends the proper tappet adjustment which is between .187″ and .250″. The adjusting screw is usually accessible, so that the pump may be installed and adjustment made without removing it.

When tappets of fixed length are used shims are employed under the mounting flange of the pump for timing purposes.

Accurate Balancing of Maximum Firing Pressures on Multicylinder Engines

The preceding methods of timing do not necessarily result in uniform maximum firing pressures on multicylinder engines. These pressures vary with the compression pressures. They can be balanced by adjusting the beginning of injection. This is accomplished by readjustment of the fuel cam or the tappet or both. Caution must be exerted not to adjust the tappet higher than .187″ or lower than .250″ as explained in the preceding paragraphs. The maximum firing pressure is raised by advancing the timing and lowered by retarding it.

Balancing of Cylinder Loads by Regulating Exhaust Temperatures

Most engines are provided with exhaust pyrometers and an adjustable connection between the governor or throttle mechanism and the control rack of the pumps. The control racks are graduated. In stop position the zero mark on the control racks (26) should be within two marks (2 millimeters) of the pointer (29).

Maintenance and Repair

Defective pumps are best replaced by spares and the defective unit sent to the Washington Iron Works or the Scintilla Magneto Division, Sidney, New York, or an authorized service station. For repair in an emergency proceed as follows:

To dismantle the pump hold it in inverted position with the delivery valve holder (9) in a vise. (Use soft jaws.) Compress spring (23) approximately 1/8″ and insert pin (1/8″ dia.) through small hole in pilot of pump flange. Remove snap ring (24) and plunger follower (22). Now the plunger (3) can be removed together with return spring (23) and lower spring plate (1). Control sleeve (4) is removed together with the retaining ring (21) and the upper spring plate (20) by engaging a hook on the inner shoulder of the control sleeve. If no tool is available, the control sleeve may be extracted by a sharp pull with the finger, inserted into the bore of the sleeve.

When tappets of fixed length are used shims are employed under the mounting flange of the pump for timing purposes.

Accurate Balancing of Maximum Firing Pressures on Multicylinder Engines

The preceding methods of timing do not necessarily result in uniform maximum firing pressures on multicylinder engines. These pressures vary with the compression pressures. They can be balanced by adjusting the beginning of injection. This is accomplished by readjustment of the fuel cam or the tappet or both. Caution must be exerted not to adjust the tappet higher than .187" or lower than .250" as explained in the preceding paragraphs. The maximum firing pressure is raised by advancing the timing and lowered by retarding it.

Balancing of Cylinder Loads by Regulating Exhaust Temperatures

When engines are provided with exhaust pyrometers and an adjustable connection between the governor or throttle mechanism and the control rack of the pumps. The control racks are graduated. In any position the zero mark on the control racks (26) should be within two marks (2 millimeters) of the pointer (29).

Maintenance and Repair

Defective pumps are then replaced by spares and the defective unit sent to the Washington Iron Works or the Scintilla Magneto Division, Sidney, New York, for standard service [illegible]. For repair in the field proceed as follows:

To dismantle the pump, hold it in inverted position [illegible] (29) in a vise. (Use soft jaws.) Compress spring (24) approximately 7/8" [illegible] through small hole in pilot of [illegible] and plunger [illegible] spring (23) and lower spring plate (17). Control sleeve (4) is removed together with the retaining ring (21) and the upper spring plate (20) by engaging a hook on the inner shoulder of the control sleeve. If no tool is available, the control sleeve may be extracted by a sharp pull with the finger, inserted into the bore of the sleeve.

lower should appear at the lower end of the housing window when the fuel cam tappet rides on the base circle of the cam. When the tappet is in its highest position, the mark on the plunger follower must never go beyond the upper edge of the housing windows. Otherwise, damage will occur to the pump. The tappet must not be adjusted higher than .187" nor lower than .250" measured from the mounting face of the pump flange to the top of the tappet. A tappet adjustment of less than .187" will result in reduced volumetric efficiency of the pump at higher speeds.

Timing marks are provided on the side faces of the housing windows. When the circular mark on the plunger follower registers with these timing marks, the inlet port is closed and actual pumping has begun. Since the pump lag, that is, the time elapsing between the beginning of the actual pumping at the pump and the actual delivery of fuel from the nozzle orifices, varies with different engines, it is necessary to determine by actual test the flywheel position at which the timing marks on the pump should register in order to obtain the desired engine performance. Thereafter this flywheel position can be used for timing the pumps in original installation and in field service.

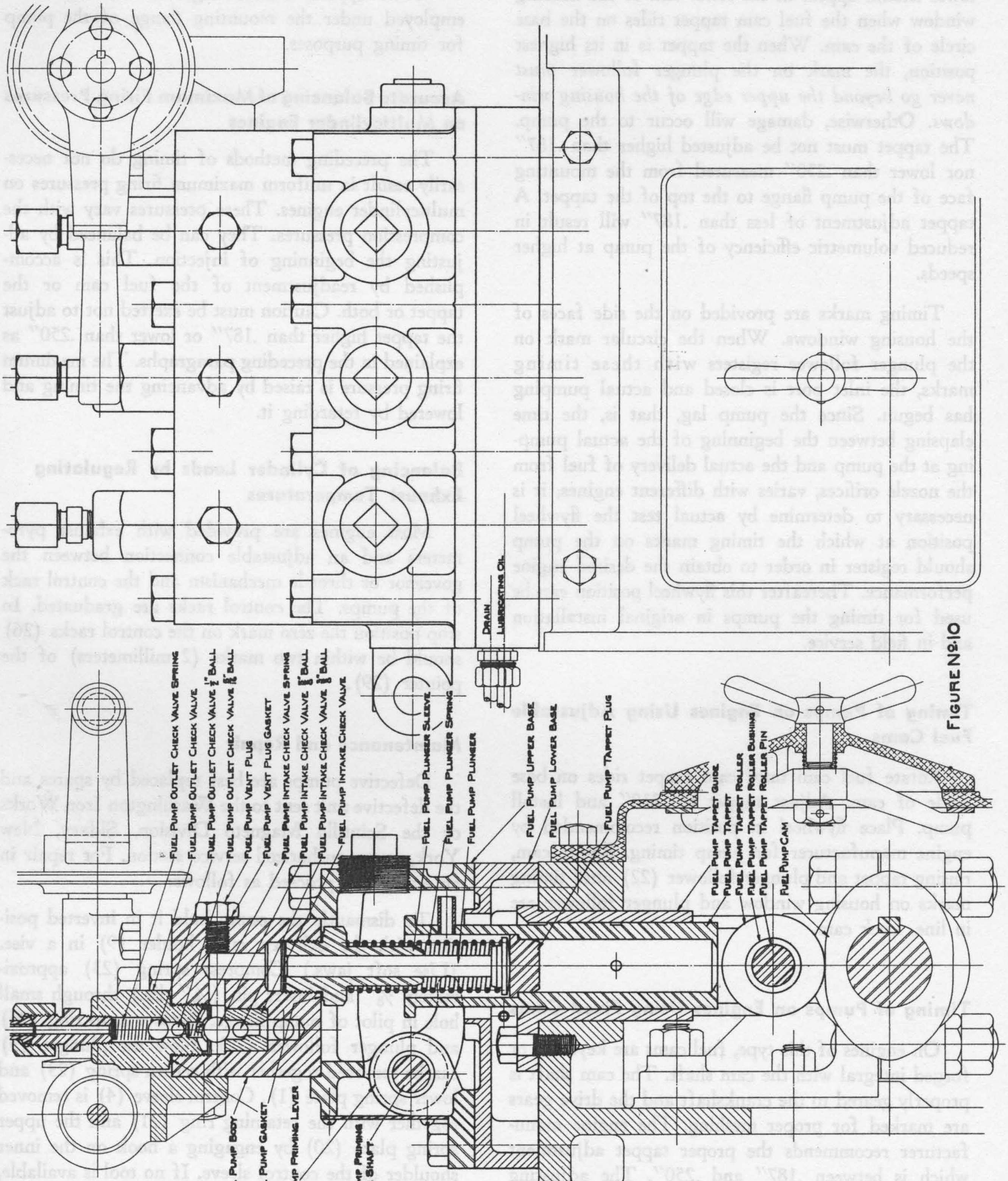


FIGURE No. 10

Timing of Pumps on Engines Using Adjustable Fuel Cams

Rotate fuel cam until cam tappet rides on base circle of cam. Adjust tappet [illegible] and install pump. Place flywheel in position recommended by engine manufacturer for pump timing. Loosen cam, rotating cam [illegible] plunger follower (22) [illegible] marks on housing window and plunger follower are in line. Lock cam.

Timing of Pumps on Engines [illegible] Cams

On engines of this type, fuel cams are keyed or forged integral with the cam shaft. The cam shaft is properly geared to the crankshaft and the drive gears are marked for proper meshing. The engine manufacturer recommends the proper tappet adjustment which is between .187" and .250". The adjusting screw is usually accessible, so that the pump may be installed and adjustment made without removing it.

Now hold the pump in upright position with the mounting flange. Loosen delivery valve holder (9) with HEX box wrench, 1-7/16 HEX. Extract delivery valve body after the valve proper and spring (8) have been removed. Use delivery valve puller tool 4-17742 for type FC and FCR. Puller must engage thread in valve body at least 3 full turns to avoid damage to threads. After removal of screw (5) the barrel may be pushed out of the pump housing and loosening screw (18) approximately 3/16″ will permit removal of the control rack (26).

To reassemble pump, ascertain that the shoulder of the pump barrel and the seat in the barrel housing are clean. Line up keyway in barrel with the hole for the barrel locating screw (5). Tighten screw (5), use lockwasher (6). Barrel must not be clamped by screw and should be free to move axially. Apply lubricating oil to upper end face of barrel and install delivery valve assembly (7), spring (8), and delivery valve holder (with delivery valve stop (11) inserted). Use HEX box wrench with 18″ to 24″ handle and pull down hard. Insert control rack (26) and tighten control rack screw (18). Use lockwasher (19). The control rack should move freely.

Hold pump in inverted position in vise. Place control rack (26) in middle position so that the index mark on the center tooth space is visible. Install control sleeve (4) by engaging index tooth in index tooth space of the control rack. Both control sleeve and rack must move freely. Install upper spring plate (20) and lock it with retainer ring (21). Use plunger follower (22) to push the ring (21) into place. Now insert the plunger *engaging the marked end of the cross bar with marked slot of the control sleeve.* See Figure 13. Install plunger return spring (23) and pull plunger back far enough to engage lower spring plate (1). Ascertain that marked cross bar of plunger will enter the marked slot of the control sleeve when the plunger follower (22) is installed. Hold the follower in place by inserting a ⅛″ pin in housing pilot and insert snap ring (24).

Fuel Injection or Spray Valve

The fuel injection or spray valve will normally require practically no attention other than occasional cleaning and inspection of the spray tips. This valve is equipped with a feeler pin at the top and by placing the finger on this pin, the rise of the nozzle valve can be felt by a slight shock. Failure to register indicates a plugged nozzle or a vapor lock. Vapor lock, or failure of fuel delivery can be checked by loosening the bleeder valve slightly at the nozzle to allow the fuel to drain, then operating the pump with handle provided until a solid flow of fuel appears. Should the nozzle be plugged, remove the valve assembly and clean as follows: Unscrew the nozzle cap nut and remove the nozzle valve and examine carefully. *The nozzle valve and stem are not interchangeable and should always be kept together.* Clean the nozzle in a good grease solvent, drying it on a soft rag free of lint and strings. *On no account should a hard, sharp tool, emery cloth or grinding compound be used.* For the final grinding and touching up of nozzle tips, we recommend jewelers' rouge, which can be obtained usually at drug stores or jewelry stores.

When refitting the nozzle and body special care should be taken to see that both ground joints are absolutely clean before reassembling.

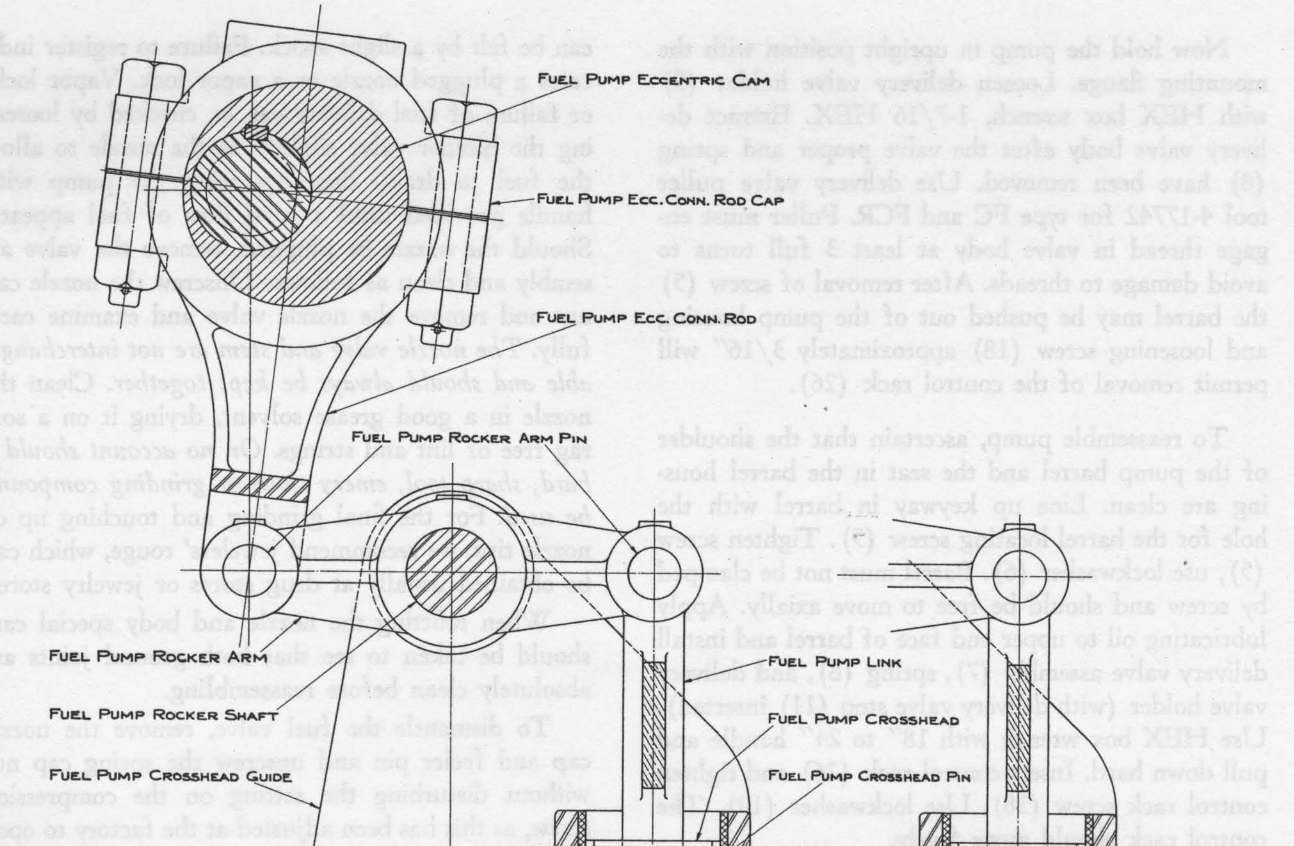
To dismantle the fuel valve, remove the nozzle cap and feeler pin and unscrew the spring cap nut without disturbing the setting on the compression screw, as this has been adjusted at the factory to open at 3000 lbs. pressure and cannot be reset without the proper instruments.

Testing Nozzles

As explained above, the nozzle operating pressure is set at 3000 lbs. before shipment from our factory; however, there are many factors in field service which may affect this adjustment, such as lost spring tension due to fatigue or heat; wear of nozzle valve and seat; or incorrect adjustment by an inexperienced operator, etc. We therefore recommend that nozzles be cleaned and inspected every 1500 hours, and should they then not operate properly, we suggest that they be returned to our factory for adjustment. This is sometimes inconvenient to the user, and a "Maximum Pressure Indicator" a simple inexpensive instrument, can be obtained to enable the nozzle assemblies to be quickly adjusted in the field. Instructions for operating this instrument are available with it.

Fuel Oil Filter in Valve

A special efficient filter and strainer has been provided in the suction side of the fuel pressure pumps, and it is very essential that it be cleaned at regular intervals.



PACKED PLUNGER TYPE | PACKLESS PLUNGER TYPE

FIGURE No. 11

VALVES

Exhaust and Inlet Valves

The inlet valves require little attention as they are kept cool by the inlet air coming into the cylinder. The exhaust valves, being exposed to the action of the exhaust gases, will have to be ground from time to time. With a new engine it is a good idea to tighten down on the valve cages after the first and second weeks to take up the give in the copper gaskets. If the cages are kept tight on the gaskets they can always be easily removed from the cylinder head; if they are allowed to work loose, carbon from the cylinder will work in around the outside of the cages, making them hard to remove. If this occurs, remove the upper valve nut and put on the valve puller stud which is furnished with the engine by means of which the cage can easily be removed.

When replacing the valve cages in the cylinder head, put a small amount of graphite and oil on the outside and be sure the small dowel pin on the cages is in line with its slot in the cylinder head. On valve cages of the flanged type there is no dowel pin. The cage is marked on the top on one side with a "P." This shows the side which has the opening to match with the cylinder head. Be sure the valve is put in properly. A mixture of 1/3 lubricating oil and 2/3 kerosene should be used to lubricate the valve stems.

In some of the small engines, the valves seat directly in the head. With this type the head is removed and the grinding is then done in the usual manner. When replacing the cylinder head, care should be exercised to see that all gaskets are in good condition, also that all surfaces are well cleaned.

Do not grind valves or cages excessively. With forged steel valves especially, an appearance of pitting is not cause for grinding unless the dent or pit in the valve seat extends across the valve seat. It is not necessary to grind out all the marks, but just enough so there is a continuous seat around the valve.

Air Starting Valves *(See Figure 15)*

The earlier engines have the starting air admitted through the main inlet valve, and on the later designs the air is admitted through a light spring loaded valve in the head. The valves for distributing air to the various cylinders are located in a housing on the frame just above the camshaft. There are no adjustments to be made on these valves and they should never require grinding as they are never exposed to the action of anything but cold starting air. If it is desired to remove them for inspection, merely take off the air piping above the valve housings and the air starting valve can then be lifted out.

The clearance between the starting air distributor valve and the starting air cam should be 1/16" when the cam is not in a position as shown on Figure 15.

Cylinder Relief Valves *(See Figure 16)*

Each cylinder is equipped with a relief or safety valve to take care of any excess pressures in the cylinder. THESE VALVES SHOULD BE KEPT CLEAN AND IN WORKING ORDER AT ALL TIMES. In order to make sure they do not plug with carbon, they should be blown out every five or six days. This is done while the engine is running by screwing back two or three turns on the bronze adjusting nut in the top of the relief valve. Allow this to blow three or four times and then turn the adjusting nut back to its former position. If the valve still leaks a little, twist the stem a few times with a wrench and tap lightly with a hammer to put the valve back in its seat. If the relief valve has not been properly blown out from time to time, it will have to be taken apart and the carbon cleaned out to put it in working order. On later type engines, this valve has a hand lever to open it. The hand lever may be used to relieve compression for barring the engine over and for blowing out the valve while running.

Governor

The governor used on most all engines is a simple flyball type as shown in Figure 22. On the older type engines the governor is horizontal and is the same as Figure 22 from the Governor Separator Plate up with the governor pinion mounted in the place of the Governor Body Miter Gear as shown. All parts should work freely. For other types of governors as used on engines driving generators, etc., special instructions apply.

BENDIX-SCINTILLA
Fuel Injection Equipment

PUMP TYPE FCR (Shown)
Control Rod at Right Angles to Mounting Flange

PUMP TYPE FC (Not Shown)
Control Rod Parallel to Mounting Flange

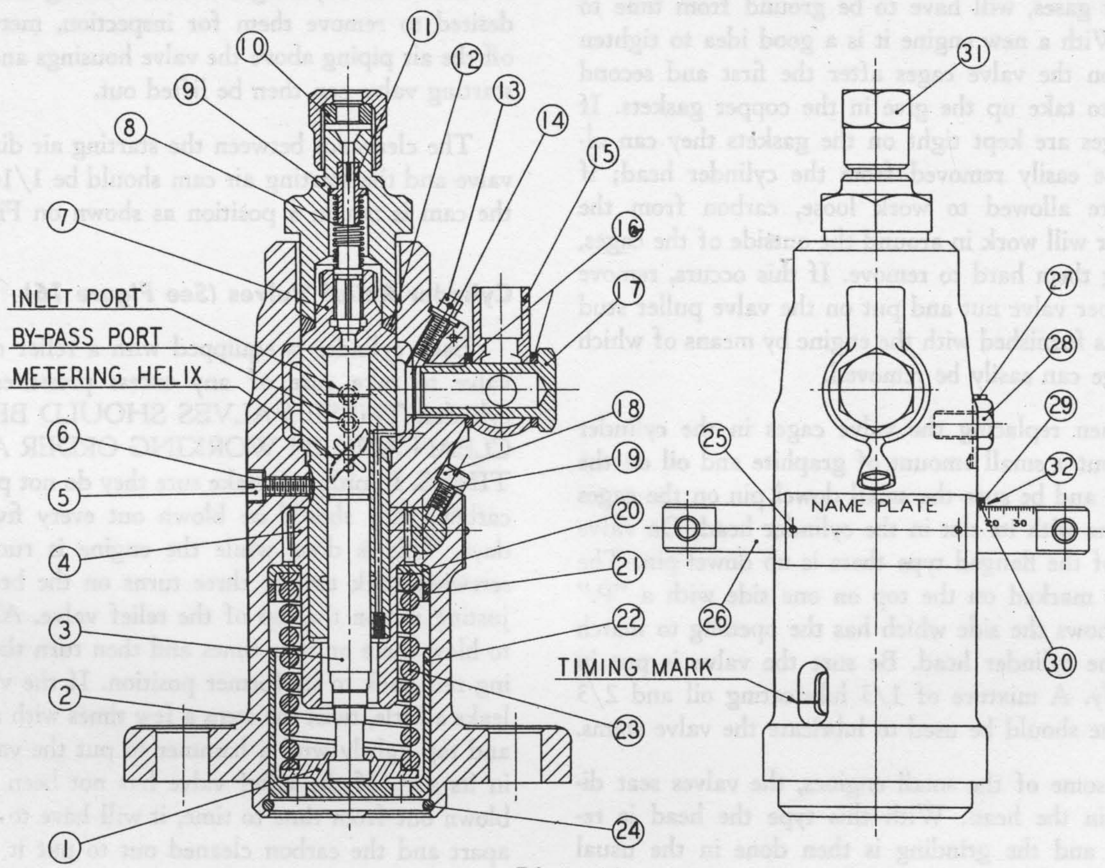


Fig. 12

Item *Part Name*

1. Lower Spring Plate
2. Housing
3. Plunger and Barrel Assembly
4. Control Sleeve
5. Barrel Locating Screw
6. Lock Washer
7. Delivery Valve Assembly
8. Delivery Valve Spring
9. Delivery Valve Holder
10. High Pressure Line Washer
11. Stop
12. Delivery Valve Assembly Gasket
13. Air Bleed Screw
14. Copper Gasket
15. Inlet Pipe Connection
16. Copper Gaskets
17. Inlet Housing Connection
18. Control Rack Screw
19. Lock Washer
20. Upper Spring Plate
21. Retainer Ring
22. Plunger Follower
23. Plunger Return Spring
24. Snap Ring
25. Drive Screw
26. Control Rack
27. Lock and Seal Washer
28. Vent Screw
29. Pointer
30. Shims
31. Hign Pressure Tubing Nut
32. Pointer Screw (not shown)

RUNNING AND INSPECTION

Pressures

While operating the engine under normal load, the pressure should be as follows:

(1) Lubricating Oil:	When engine is warmed up, pressure should be above 10 lbs., per square inch.
(2) Discharge Water:	Check overboard discharge for full stream of water flowing. If gauge is provided, pressure should be 5 to 15 lbs. per square inch.
(3) Fuel Oil:	See that the day tank is at proper level.
(4) Starting Air:	Pressure should be 150 to 300 lbs. per square inch.

Temperatures

While running under full load, the temperatures should be as follows:

(1) Lubricating Oil from engine:	90°-130° F.
(2) Circulating Water from engine:	90°-120° F. for salt water cooling
	90°-140° F. for fresh water cooling
(3) Exhaust Temperatures:	500°-700° F.

General

The engine should operate with no exhaust visible at any load except overload.

All parts of the engine should be examined frequently, especially during the first few hundred hours of operation, to detect any extreme difference in temperature on head, cylinders and side covers. Undue high temperatures in any connecting rod or main bearing can usually be detected by the higher temperature of the respective side cover.

Lubricating and fuel oil filters should be cleaned and water and sludge drained at frequent intervals. every 8 hrs

Oil level in lubricating service tank should be checked daily. every 8 hrs

Force feed oiler should be kept full at all times. After engine has been well broken in, adjust all feeds for four to eight drops per minute, depending upon the size of cylinder.

The valve mechanism, including the valve stems, should be lubricated often. every 4 hrs

Use ~~light~~ valve oil for the valves. OE SAE 10

Keep the water pump bearings well packed.

Check the cylinder relief (sniffer) valves ~~frequently~~. weekly

Keep spare nozzle and exhaust valve properly ground in ready for use.

TROUBLES

The following is a list of troubles with their possible causes:

Engine Will Not Start or Is Hard Starting

(1) No fuel in day tank or main tanks.
(2) No fuel in fuel pumps.
(3) Fuel too heavy to flow thru pipes.
(4) Fuel valves not properly adjusted.
(5) Water in fuel.
(6) Engine not properly prepared for starting. (See: "*Starting*.")
(7) Starting-Air low.
(8) Air starting cams worn, or air starting valves stuck open.
(9) Low compression—poor rings and/or valves.
(10) Water in cylinder.
(11) Valves put in head backwards.

Sudden Stopping of Engine

(1) No fuel. (See that there is fuel in the day tank. If not, check main tanks, also shut-off valves in fuel supply lines.
(2) Control lever set for too slow an idling speed, causing engine to stop when slowed down rapidly.
(3) Dirty fuel. (Clean fuel filter.)
(4) Fuel pumps air-bound. (As the fuel system is practically a closed type, it is hardly probable that air could get into it; however, if the day tank should go empty or the tank supply valves be shut off while the engine is operating, air could reach the pumps. A drain or vent plug is provided in the base of the high pressure fuel pumps to bleed same of air or water.)
(5) Slug of water in fuel injection valves—from excessive water in fuel.
(6) Plugged fuel line. (Investigate fuel supply line for obstructions.)
(7) Piston seizure due to lack of lubrication or failure of water system causing engine to overheat excessively.

Loss of Power

(1) Cylinders missing intermittently due to poor fuel, water in fuel, sticking of fuel pressure pump plungers.
(2) Compression poor due to worn piston rings, liners or both.

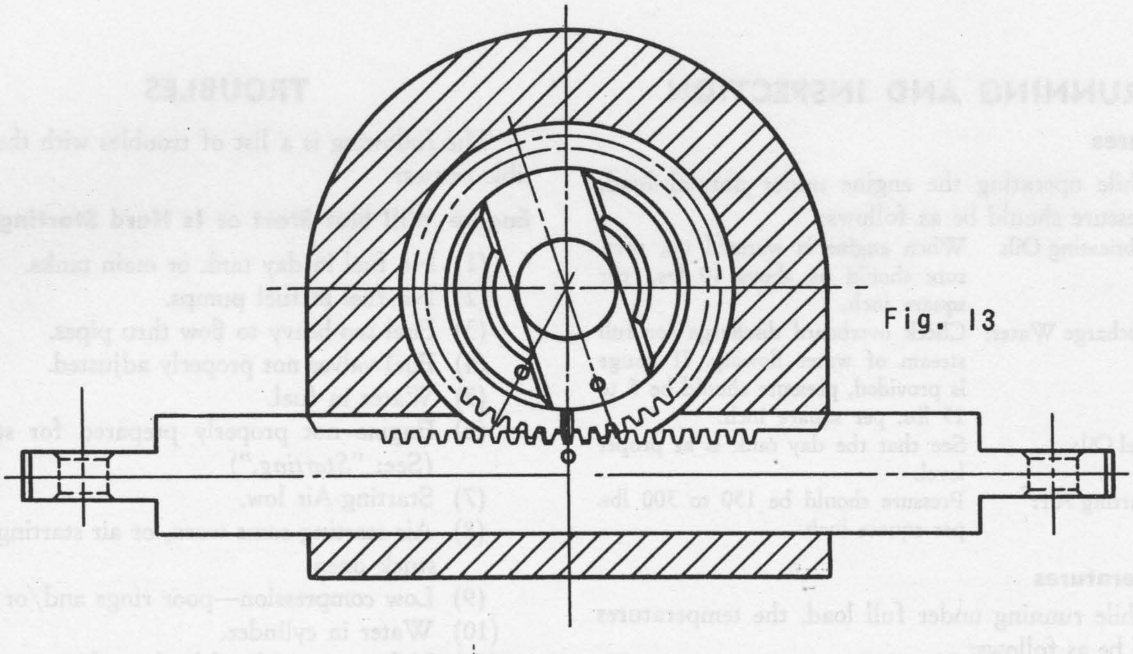


Fig. 13

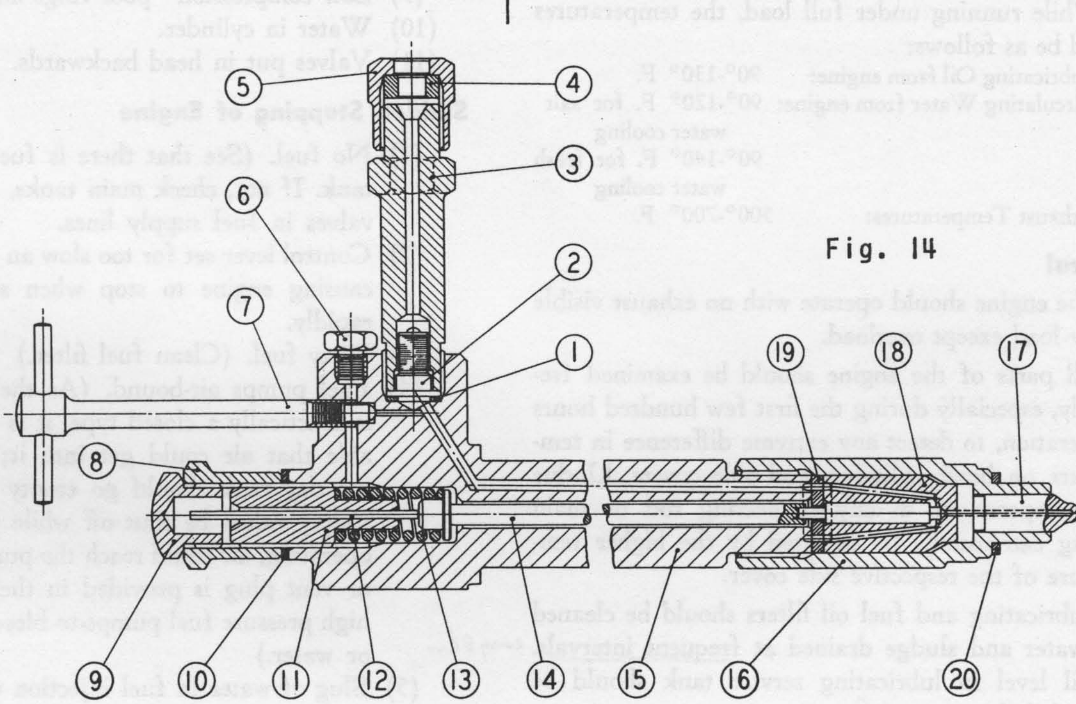


Fig. 14

Item	*Part Name*	*Item*	*Part Name*
1.	Copper Gasket	11.	Adjusting Screw
2.	Filter	12.	Feeler Pin
3.	Inlet Nipple	13.	Spring
4.	High Pressure Line Washer	14.	Pressure Pin
5.	High Pressure Line Nut	15.	Holder Body
6.	Leakage Return Fitting	16.	Assembly Nut
7.	Bleeder Valve	17.	Spray Tip
8.	Lock Nut	18.	Nozzle Valve Assembly (Includes Item 19)
9.	Cap	19.	Stop Plate
10.	Copper Gasket	20.	Copper Gasket

SCINTILLA FUEL VALVE

(3) Leaky intake or exhaust valves.
(4) Air intake becoming partially plugged due to rags or dirt.
(5) Timing of fuel injection valves changed by fuel cam changing position, or by wear.
(6) Fuel valve nozzles partially plugged by dirt in fuel.
(7) Fuel pressure relief valve leaking or sticking open causing fuel pump pressure to drop.
(8) Excessive carbon in cylinder and/or exhaust port.
(9) Back pressure in exhaust line.

Engine Missing on One or Two Cylinders

(1) Fuel valve stuck in body or dirt in nozzle.
(2) Dirt under delivery valve of fuel pump (Bosch type injection).
(3) Air or gas forming a vapor lock in fuel pump or lines, this may be caused by heating fuel oil to excessive temperatures.
(4) Exhaust or intake valve stuck open or in poor condition.
(5) Compression poor.
(6) Water leaking into cylinder.

Knocking

Knocking may be classified as two kinds: those directly assigned to fuel or combustion, and those of a mechanical nature.

Fuel knocks are caused by too early an injection of fuel, which is probably due to either improper timing or sticky fuel valve stems causing excessive quantities of fuel to be injected into the cylinder.

Mechanical knocks such as loose bearings, pistons, etc., can usually be found by the nature and location of same or by sounding out under different load conditions and by cutting out one cylinder at a time.

Mechanical clutch knocks are frequently caused by misalignment of the thrust shaft coupling and intermediate shaft coupling. This may be checked by removing the coupling bolts and inserting feelers between the couplings. Should the clearances vary or the outside edges not line up with each other the couplings are out of line, causing misalignment in clutch and probable trouble at a later date.

Overheating

(1) Lack of cooling water.
(2) Sediment, rust or salt in water jackets.
(3) Obstruction to circulation of water.
(4) Water pump worn or damaged.
(5) Fuel injection too late.
(6) Excessive carbon in cylinders.

Excessive Smoking (black)

(1) Sticking or worn and leaky fuel valves.
(2) Exhaust and intake valve in poor condition and lacking proper clearances.
(3) Engine overloaded.
(4) Poor compression.
(5) Poor fuel oil.

Engine Racing

(1). Sticky governor mechanism.
(2) Losing of propeller wheel.
(3) Fuel valve stuck open.

CLEARANCES

Piston

With liner ground to size, piston is ground under size approximately 0.001″ per inch of diameter.

Piston Rings

Diameter	*Minimum Side Clearance 2 Top Rings*	*Minimum Side Clearance Others*	*Minimum End Clearance*
7½″ to 12½″	.006″	.004″	.006″ x diameter
12¾″ and over	.008″	.006″	.006″ x diameter

Wrist Pin

Fit to .001″ per inch of diameter.

Main Bearings

Fit to 0.00075″ per inch of diameter.

Thrust Bearing

On direct reversing and clutch type engines with Navy type Babbitted thrust bearings, a fore and aft running clearance of (0.010), ten one-thousandths of an inch is required.

On direct reversing and clutch type engines with large roller bearing thrust bearings, a fore and aft running clearance of (0.002″ to 0.004″) two to four one-thousands of an inch is required.

Crank Pin Bearing

Fit to 0.00075″ per inch of diameter.

Intake and Exhaust Valve

Valve Clearance—0.025″ to 0.030″.

Clearance Between Top of Piston and Cylinder Head

7½″, 8″ & 8½″x10″	= 1/8″	12½″x16″	=15/32″
8″x11″	= 5/32″	12¾″x16″	= 5/16″
9″x11½″	= 5/16″	13″ x16″	= 1/2″
9″x12½″	=15/32″	13½″x18″	= 5/8″
8½″, 8¾″, 9½″ & 10″x12½″	= 5/16″	14½″x18″	= 5/8″
10¼″x13½″	= 3/8″	17″ x24″	= 1″
10¾″ & 11½″x16″	= 3/8″	18″ x24″	= 1″

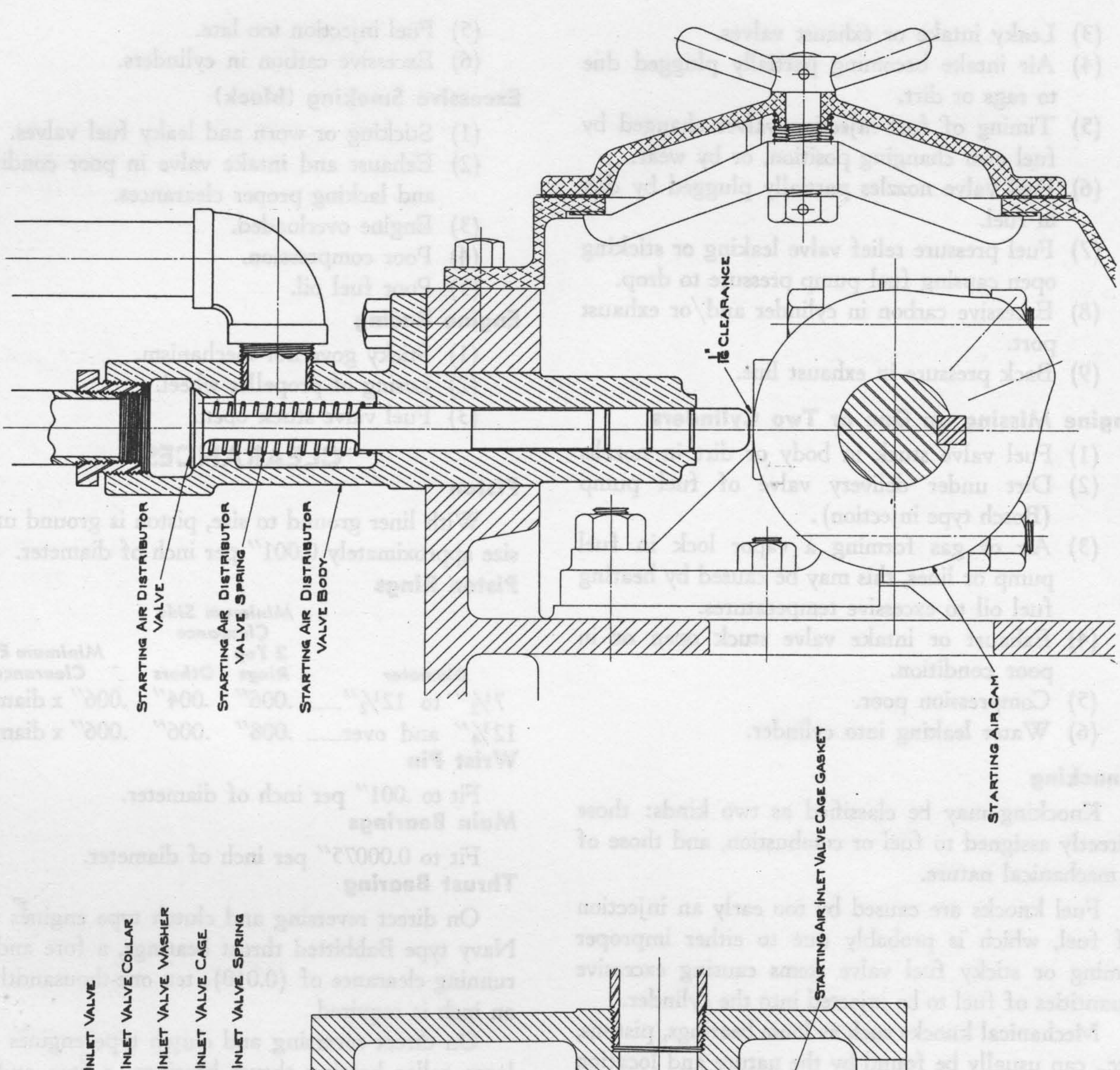

Starting Air Distributor Valve
Starting Air Distributor Valve Spring
Starting Air Distributor Valve Body
1/16" Clearance
Starting Air Inlet Valve
Starting Air Inlet Valve Collar
Starting Air Inlet Valve Washer
Starting Air Inlet Valve Cage
Starting Air Inlet Valve Spring
Starting Air Inlet Valve Cage Gasket
Starting Air Ram
Starting Air Inlet Valve in Cylinder Head
Starting Air Distributor Valve

FIGURE No. 15

PISTON RINGS AND CYLINDER LINERS

The pistons and cylinder liners are made of Meehanite iron, heat-treated before finish machining. The upper piston ring is located some distance below the top of the piston; for this reason it generally remains free even after long periods of service. Plain one-piece compression and oil rings are used. When overhauling the engine, the pistons can be easily removed through the large doors on the port or exhaust manifold side of the engine. In doing this, take off the crank bearing, turn the crankshaft till the web is flat (with the pin on the starboard or operating side), lower the foot of the connecting rod into the base and tip the piston out the door, as shown in cross section, Figure 1.

A hole is tapped in the center of the piston head so the piston may be lifted by a long eyebolt through the fuel valve hole in the center of the cylinder head. In some of the later model engines, the tapped holes in the center of the piston is not used, but in its place two holes are placed on the piston rim under the main valves. A large bevel is provided at the bottom end of the liner so the rings can be easily guided into the bore when replacing the piston. If there is not head room enough to use the eyebolt, the piston can be raised from below with bars. Be sure the piston is well oiled and the ring joints are set opposite each other.

The correct installation of piston rings is essential for the efficient functioning of an engine. In all cases, when installing rings it is important that each ring should be carefully checked for diameter and clearance at the smallest part of the cylinder bore. The piston grooves should also be carefully inspected to see that they are free from fillets and shoulders and are not flared or tapered. Before being installed on the piston, each ring should be rolled around in the piston groove in which it is to be used to make sure that it does not bind at any point. All burrs and sharp edges should be carefully removed before the rings are used.

For assistance in fitting the rings to the piston, we have inserted a page on recommended clearances in this book.

In checking the clearance between the piston and the head, always take leads on both sides of the piston at one time. If a lead is only taken on one side, the piston might cock enough to give a false reading.

The cylinder walls are oiled through nipples which are screwed into the liner. These nipples are covered with a heavy cast iron sleeve where they pass through the water jacket, with packing at each end completely protecting them from the action of salt water. It is very important that these nipples do not leak water into the cylinder. If there is doubt about the nipples being tight, they should be replaced.

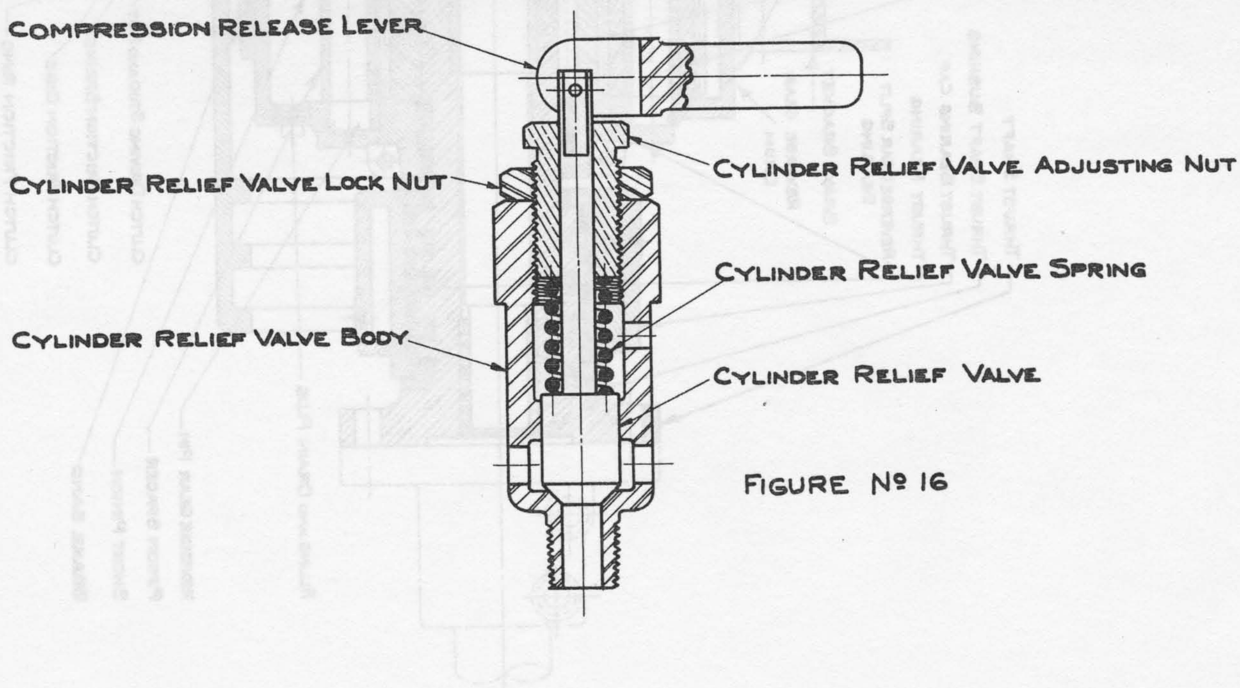
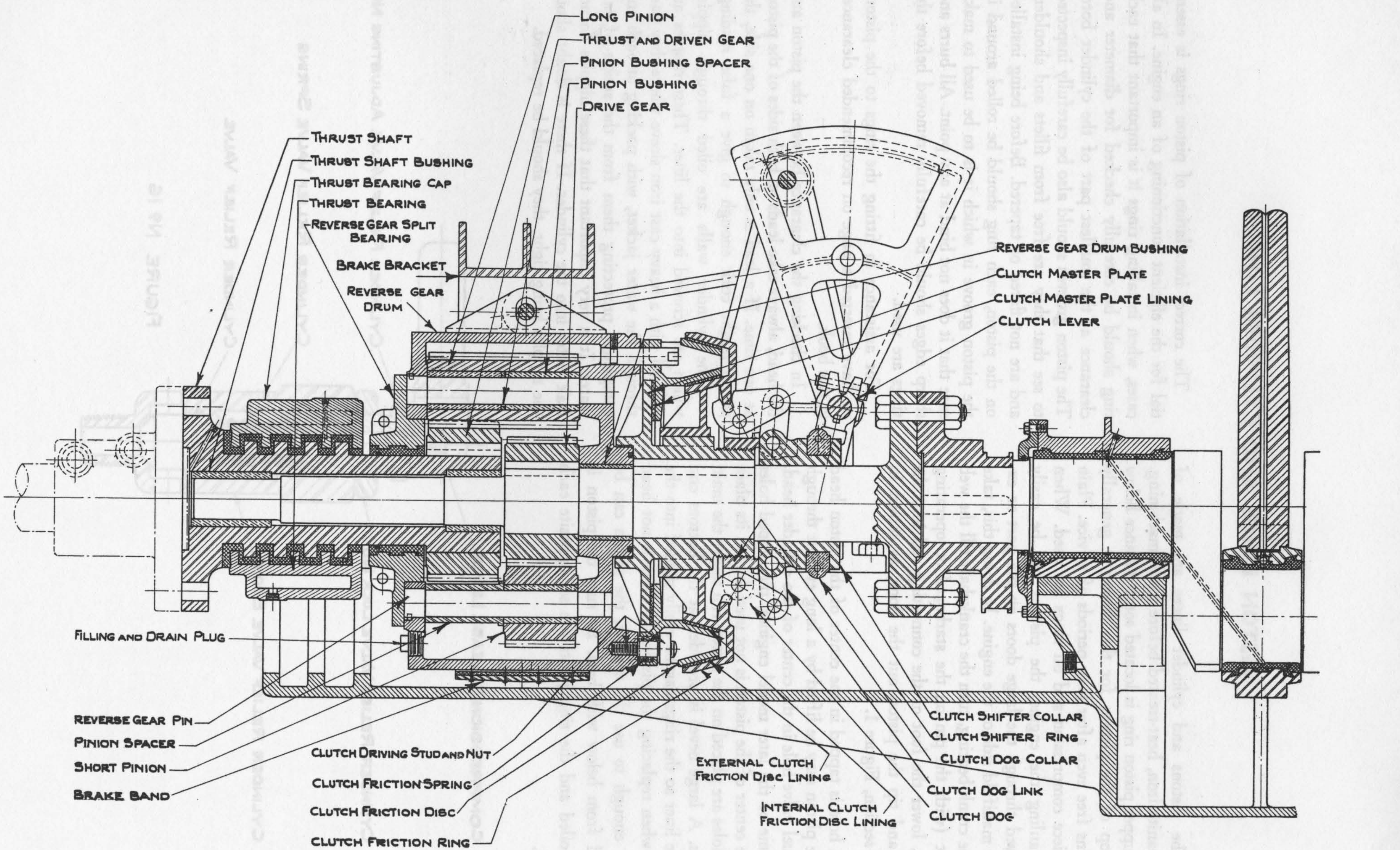


FIGURE № 16



Long Pinion
Thrust and Driven Gear
Pinion Bushing Spacer
Pinion Bushing
Drive Gear
Thrust Shaft
Thrust Shaft Bushing
Thrust Bearing Cap
Thrust Bearing
Reverse Gear Split Bearing
Brake Bracket
Reverse Gear Drum
Reverse Gear Drum Bushing
Clutch Master Plate
Clutch Master Plate Lining
Clutch Lever
Filling and Drain Plug
Reverse Gear Pin
Pinion Spacer
Short Pinion
Brake Band
Clutch Driving Stud and Nut
Clutch Friction Spring
Clutch Friction Disc
Clutch Friction Ring
External Clutch Friction Disc Lining
Internal Clutch Friction Disc Lining
Clutch Shifter Collar
Clutch Shifter Ring
Clutch Dog Collar
Clutch Dog Link
Clutch Dog

Figure No 18

BEARINGS

Main Bearings

All bearings are extra large, adjustable and pressure oiled. In re-fitting bearings see section on *Clearances.*

The main bearings on the earlier engines were square set into the base and after years of service could be shimmed up to the line and the bearings scraped in without re-babbitting. On the later model engines, a replaceable shell type bearing is being used which can be rolled into place without disturbing the crankshaft. Never allow the crank bearing to run too slack, as this allows the lubricating oil to escape at that point, and as a result the wrist pin bearing does not receive proper lubrication.

To check the alignment of the main bearings, a strain gauge can be used to a very good advantage. This can be done without disturbing anything on the engine, except to remove the cover plates to get at the shaft of the engine. A strain gauge is simply a dial indicator with an extra heavy spring. The dial rod is pointed instead of flat and there is an adjustable pointed rod on the opposite side of the dial.

Bar the engine over so the crank bearing is at the bottom of the stroke. Insert the strain gauge between the crank webs as shown in Figure 17. Then bar the engine over, taking readings at each quarter turn. This can be done with the connecting rod in place.

If a strain gauge is not available, the same thing can be done with inside micrometers. In using inside micrometers, care must be taken that the readings at each quarter are taken at exactly the same spots on the webs.

The maximum difference in any readings should not exceed

0.0025″ for 10″ stroke engines
0.003″ for 11½″ to 13½″ stroke engines
0.004″ for 15″ to 18″ stroke engines
0.006″ for 24″ stroke engines

For more detailed information on the above, consult the factory.

Thrust Bearing

The thrust bearing on the Washington Marine Diesel engine, with the exception of some later types, is of the ring babbitted Navy type, water-cooled both top and bottom. It is extra large and will never give any trouble if properly oiled. When starting an engine which has been shut down for several hours, or when running in extremely rough weather, always fill the oil cup on the top of the thrust bearing. This will take care of the bearing until the oil reaches it through the long tube from the Manzel oiler.

The later model engines with enclosed reversing clutch are equipped with a large roller bearing thrust enclosed within clutch housing and are lubricated from the engine pressure system. On the reversing clutch engines there is about ⅜″ clearance fore and aft in the clutch. On the direct reversing type engines, the thrust bearing is in two halves, one for ahead and one for astern, with wedge adjusting blocks between them. These wedges must be set up from time to time as the thrust bearing wears in order to prevent any thrust from being transmitted to the crank webs.

When adjusting the fore and aft clearance of the thrust bearing, be sure that the crankshaft is properly centered fore and aft in the main bearings and is not riding on the fillets of the pins or journals.

For proper fore and aft clearance of these bearings, see section on *Clearances.*

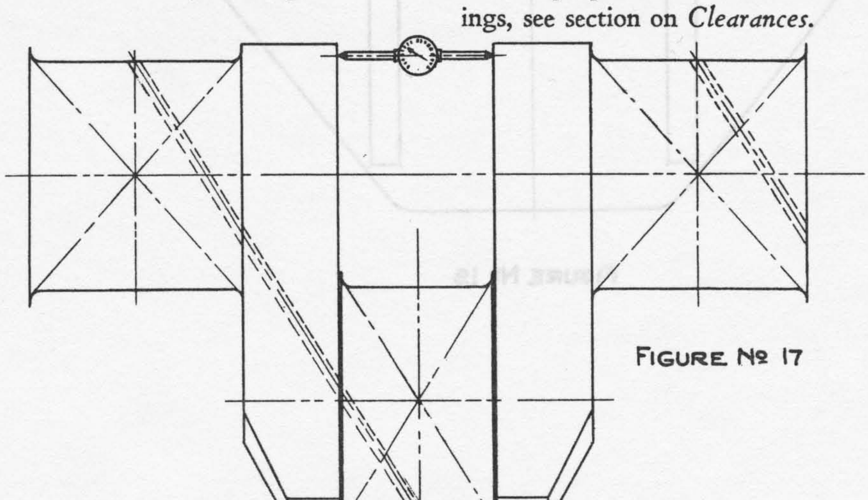


FIGURE № 17

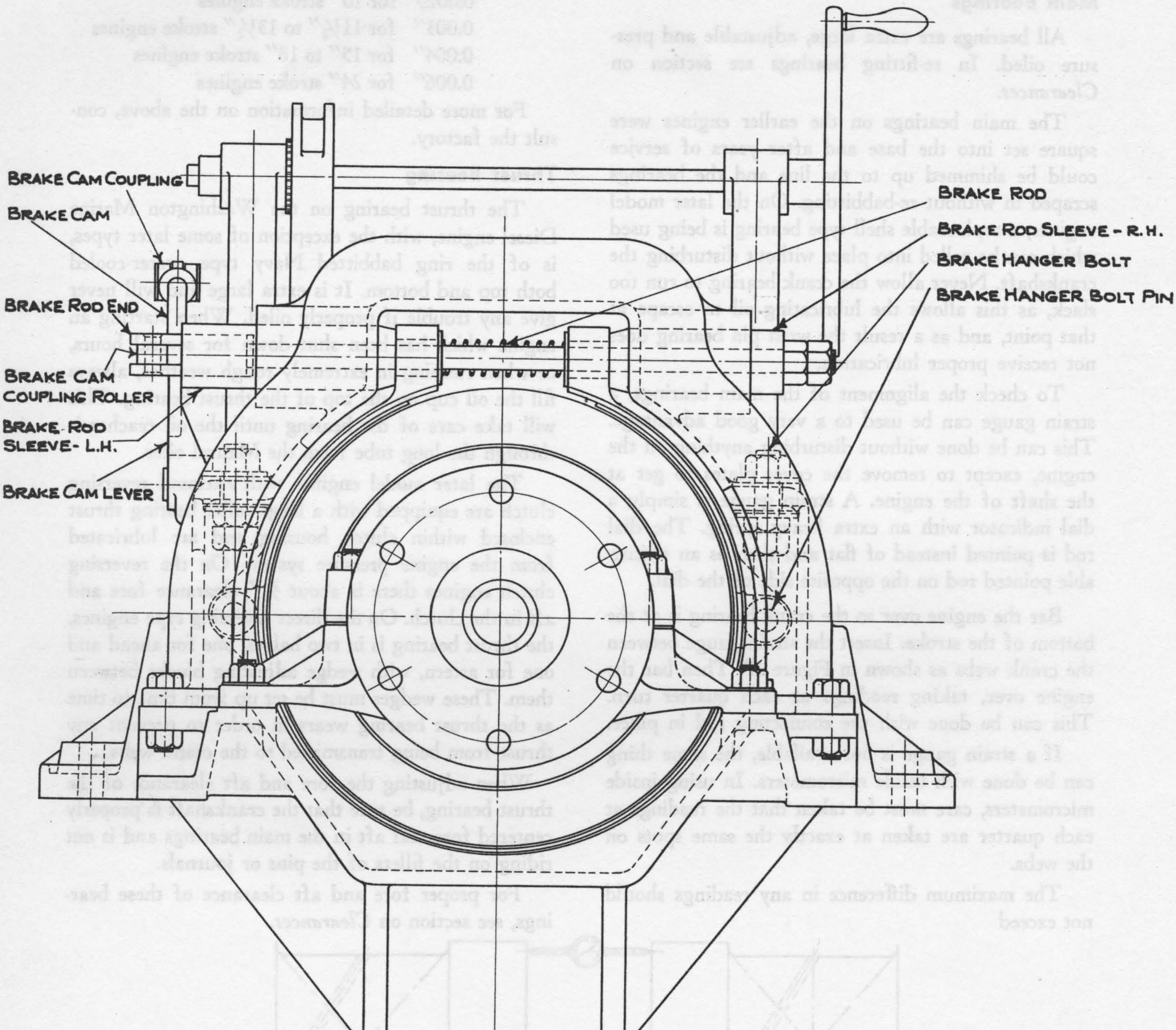

BRAKE CAM COUPLING
BRAKE CAM
BRAKE ROD END
BRAKE CAM COUPLING ROLLER
BRAKE-ROD SLEEVE-L.H.
BRAKE CAM LEVER
BRAKE ROD
BRAKE ROD SLEEVE - R.H.
BRAKE HANGER BOLT
BRAKE HANGER BOLT PIN

FIGURE Nº 19

MARINE REVERSE GEAR

Combination Cone and Disc

The larger sizes of clutch type "Washington" Diesel engines are equipped with our own type heavy duty reverse gear which is mounted on a continuous clutch shaft forming a backbone to hold the drum assembly in line, and keeping wear down to a minimum. A shaft coupling is provided at each end so the assembly may be easily removed from the engine.

Large sized alloy steel spur gears are used throughout with heavy bronze floating bushings running on hardened and ground pins. IT IS EXTREMELY IMPORTANT TO CHECK the oil level in this gear drum about once a week and see that it is always about one-third full of a good grade of gear lubricant, which is put in through the large plugged hole at the after end of the drum. The reverse gear compartment should be washed out clean about three times a year by filling the pot with kerosene and idling the engine, then draining out all the old grease

The clutch is of the combination cone and disc type, as shown in Figures 18 and 19. In this clutch, the friction ring is free to slide on the bolts which are screwed into the gear drum. As the clutch is thrown in, the cone surfaces come together first and the friction ring slides back about 1/32" until it is clamped against the clutch shaft plate. When the clutch is thrown out, the friction ring is forced out against the three stop nuts by means of springs. THE TOTAL TRAVEL OF THIS RING SHOULD NOT BE MORE THAN ABOUT 1/32", as it will drag on the cone in neutral if too much clearance is allowed. To cut down on this clearance, screw in the required amount on the three stop nuts.

If the clutch runs hot in the go-ahead position, it is too slack and must be adjusted by loosening one of the bolts in the clamp collar and screwing it in about one-quarter or one-half turn.

Enclosed Disc Type

The late model engines with reversing clutch are equipped with a fully enclosed disc type clutch. See Figures 20 and 21. This unit, including the large roller bearing thrust, is lubricated from the engine pressure system, excess oil draining back into the engine base. The adjustments of this clutch are similar to the above described cone type clutch. Adjustments for the roller thrust bearing are accomplished by rotating the lock spring nut or clutch shaft collar ahead of the roller thrust bearing. Shims are provided between this lock nut and a shoulder on the shaft. The thrust bearing is set up with a fore and aft clearance of .002" to .004". This should not require adjustment during the life of the bearing.

Joe's Husky Reverse Gear

Some of the smaller sizes of "Washington" Diesel engines are equipped with the well-known Joe's Husky Reverse Gear. This gear has a coupling at each end so it may be easily removed for inspection.

To lubricate, first throw the lever to the forward position. Then remove the small plug in the edge of the forward flange and force in one or two guns of soft gear grease. This should be done about once a week.

To tighten the clutch, throw the lever in the go-ahead position; then set up moderately tight on each of the three slotted nuts at the after end of the drum. If not tight enough to hold the engine, give each nut another fraction of a turn until the cluch will hold the motor without slipping. Be careful to tighten the same amount on each of the three adjusting nuts.

To adjust the brake band for the reverse, remove the cast iron cover plate on top of the brake bracket. Loosen the set screw in the ear of the brake band, insert a pin in the sliding collar and turn until the brake band holds the drum in reverse.

Clutch Alignment

We have found that most clutch trouble is caused by the engine being out of line. If any trouble develops in the clutch, the first thing to do is remove the bolts from the flange coupling back of the engine and check the alignment. If this alignment is out, all the clutch and reverse gear parts are forced out of place and trouble is bound to result.

The alignment of the engine should be checked from time to time as a matter of precaution in order to forestall any such troubles before they develop. This may be done by loosening the bolts in the coupling and with feelers, or a thickness gauge, check the amount of opening between the flanges at about four equal distant locations around the circumference of the flanges.

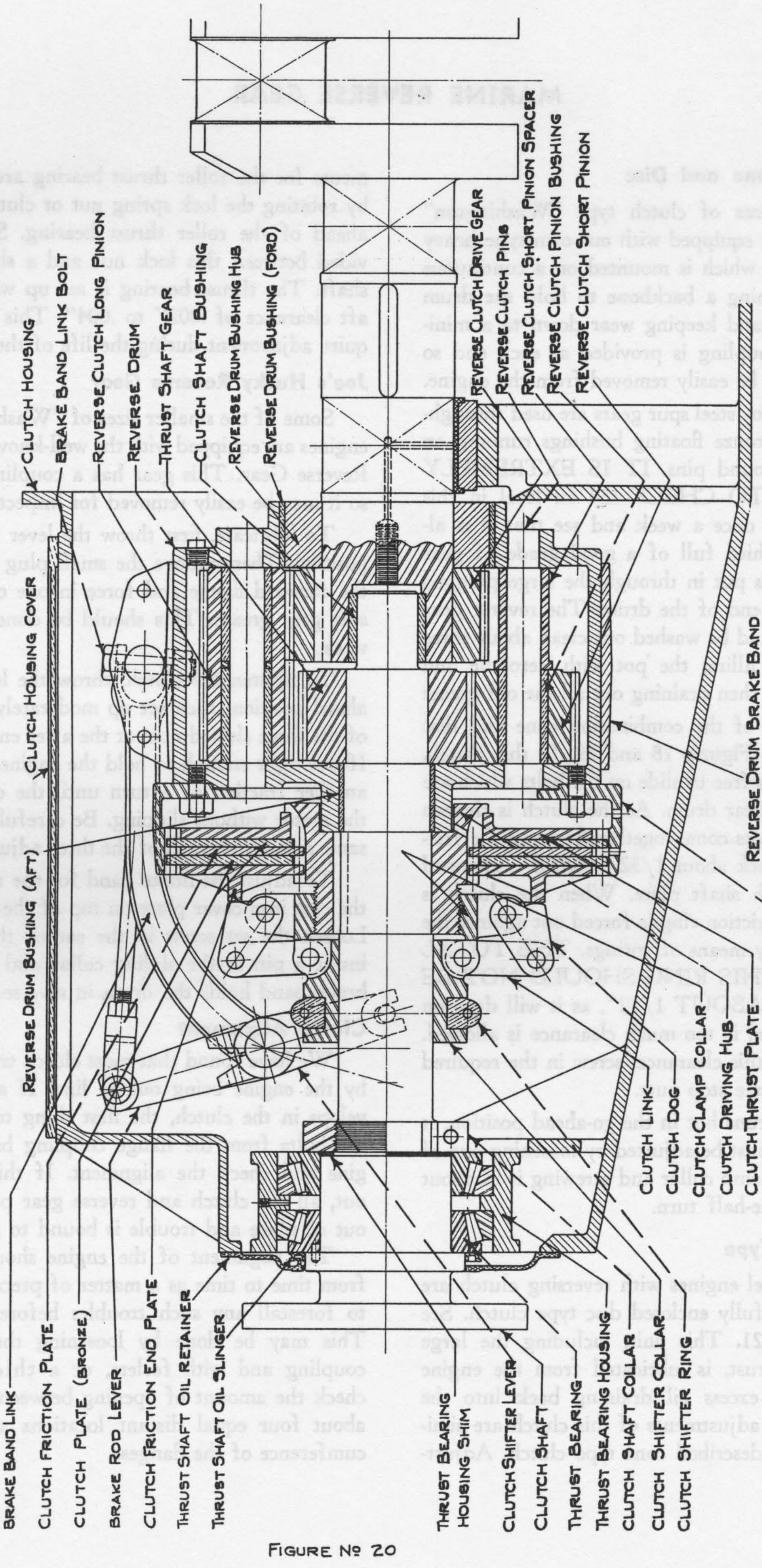

REVERSE DRUM BUSHING (AFT)
CLUTCH HOUSING COVER
CLUTCH HOUSING
BRAKE BAND LINK BOLT
REVERSE CLUTCH LONG PINION
REVERSE DRUM
THRUST SHAFT GEAR
CLUTCH SHAFT BUSHING
REVERSE DRUM BUSHING HUB
REVERSE DRUM BUSHING (FORD)
REVERSE CLUTCH DRIVE GEAR
REVERSE CLUTCH PINS
REVERSE CLUTCH SHORT PINION SPACER
REVERSE CLUTCH SHORT PINION BUSHING
REVERSE CLUTCH SHORT PINION
REVERSE DRUM BRAKE BAND
CLUTCH LINK
CLUTCH DOG
CLUTCH CLAMP COLLAR
CLUTCH DRIVING HUB
CLUTCH THRUST PLATE
CLUCH CAGE
BRAKE BAND LINK
CLUTCH FRICTION PLATE
CLUTCH PLATE (BRONZE)
BRAKE ROD LEVER
CLUTCH FRICTION END PLATE
THRUST SHAT OIL RETAINER
THRUST SHAT OIL SLINGER
THRUST BEARING HOUSING SHIM
CLUTCH SHIFTER LEVER
CLUTCH SHAFT
THRUST BEARING
THRUST BEARING HOUSING
CLUTCH SHAFT COLLAR
CLUTCH SHIFER COLLAR
CLUTCH SHIFTER RING

FIGURE No 20

MAIN VALVE AND FUEL VALVE TIMING

				Common Rail Fuel Injection Sys.				
Fly-wheel Dia.	1 Deg. on Fly-wheel Rim	Air Inlet opens 6 deg. before top center	Air Inlet closes 14 deg. after bottom center	With full Gov. Fuel Valve open 8 deg. before top center	With full Gov. Fuel Valve closes 24 deg. after top center	Bosch or Jerk Pump Inj. Sys. With full Gov. Fuel Valve opens 10 deg. before top center	ExhaustValve opens34 deg. before bottom center	Exhaust Valve Closes 12 deg. after top center
22	.192	1 5/32	2 11/16	1 17/32	4 5/8	1 15/16	6 9/16	2 5/16
30	.262	1 9/16	3 11/16	2 3/32	6 9/32	2 5/8	8 15/16	3 1/8
32	.279	1 11/16	3 15/16	2 7/32	6 23/32	2 25/32	9 1/2	3 3/8
34	.296	1 13/16	4 5/32	2 3/8	7 3/32	2 31/32	10 3/32	3 9/16
36	.314	1 29/32	4 13/32	2 1/2	7 17/32	3 1/8	10 11/16	3 25/32
38	.332	2	4 5/8	2 21/32	7 31/32	3 5/16	11 5/16	4
40	.349	2 3/32	4 7/8	2 25/32	8 3/8	3 1/2	11 7/8	4 3/16
42	.367	2 7/32	5 1/8	2 15/16	8 13/16	3 31/32	12 15/32	4 7/16
42 1/2	.371	2 1/4	5 3/16	2 31/32	8 29/32	3 23/32	12 5/8	4 1/2
46	.401	2 13/32	5 5/8	3 7/32	9 5/8	4	13 5/8	4 13/16
48	.419	2 1/2	5 7/8	3 11/32	10 1/16	4 3/16	14 1/4	5
52 1/2	.458	2 3/4	6 3/8	3 21/32	11	4 19/32	15 5/8	5 1/2
54	.472	2 13/16	6 5/8	3 25/32	11 5/16	4 23/32	16 1/16	5 21/32
56	.488	2 15/16	6 27/32	3 29/32	11 23/32	4 7/8	16 5/8	5 27/32
58	.506	3 1/32	7 1/8	4 1/16	12 5/32	5 1/16	17 1/4	6 1/16
60	.524	3 1/8	7 3/8	4 3/16	12 19/32	5 1/4	17 7/8	6 1/4
72	.628	3 25/32	8 13/16	5 1/32	15 3/32	6 9/32	21 3/8	7 17/32
78	.680	4 1/16	9 9/16	5 7/16	16 11/32	6 13/16	23 1/8	8 1/8
96	.838	5 1/32	11 23/32	6 11/16	20 1/8	8 3/8	28 1/2	10 1/16

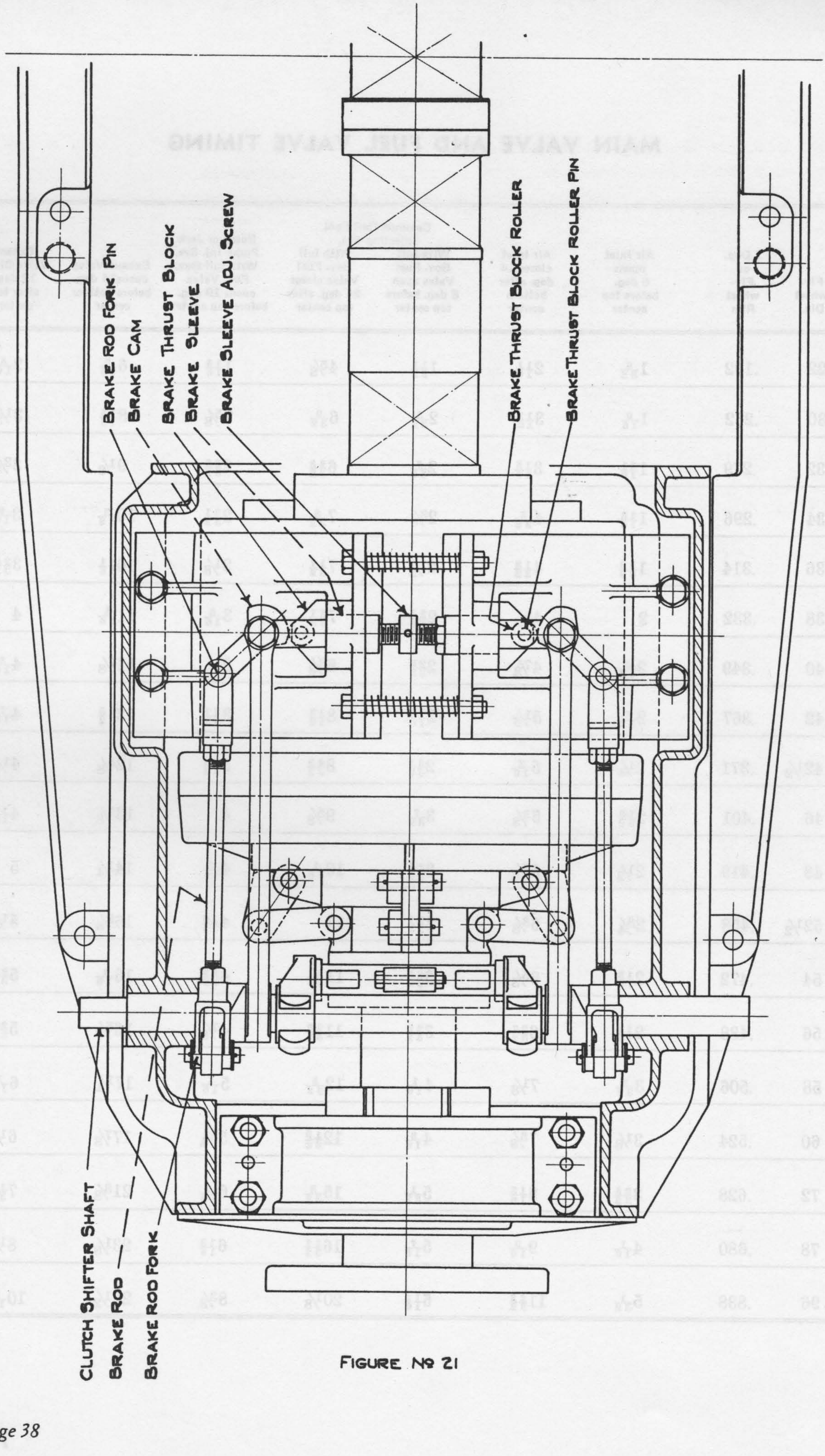

BRAKE ROD FORK PIN
BRAKE CAM
BRAKE THRUST BLOCK
BRAKE SLEEVE
BRAKE SLEEVE ADJ. SCREW
BRAKE THRUST BLOCK ROLLER
BRAKE THRUST BLOCK ROLLER PIN
CLUTCH SHIFTER SHAFT
BRAKE ROD
BRAKE ROD FORK

FIGURE No 21

SUGGESTIONS FOR MARINE INSTALLATIONS

In installing a Diesel engine a good substantial bed should be provided, using timbers as large as possible. This is especially important where the engine is to be installed in an old boat, replacing steam or gasoline power.

Engine Installation

The engine timbers should be as long as possible, running well forward and aft of the actual length of the engine itself in order to distribute the load over a greater part of the boat. They should be well supported underneath by heavy cross timbers and well blocked at the sides to prevent them from rocking. Frequently, concrete ballast is placed in around these timbers after they have been firmly secured in position. The entire foundation should be fastened to the boat with drift bolts and through bolts to the frames. If it is not practical to through bolt the engine foundation it will probably be necessary to run a few of the engine hold-down bolts thru the hull, using bronze bolts with large washers, about 5″ or 6″ dia., on the outer end. It is also sometimes advisable to brace the top of the cylinder heads to the deck timbers. When this is done, it is best to cut a piece of ½″ or ⅝″ plate and fit it over two of the cylinder head studs, then fasten the brace to this plate instead of bolting the brace direct to one of the cylinder head studs. It is customary to leave the main engine bed about 1½″ low, and fit full length first grade firm shims under the engine for final lining up.

When lining up an engine equipped with a reversing clutch, it has been a practice to leave an opening of fifteen to twenty thousandths of an inch on the bottom of the couplings, thus taking care of the weight of the flywheel which is on the front end of all reversing clutch Diesels.

The direct reversing engines are just the opposite as all flywheels are on the after end. The opening in thousandths of an inch, which would be on the top of the couplings, would depend on the length of the engine and the weight of the flywheel.

After the couplings have been thoroughly lined up, make the engine shims approximately one-eighth of an inch thicker than indicated, thus taking care of the settlement of the engine due to weight and the tightening of the holding down bolts. Make sure the tailshaft and intermediate shaft are in line and free in their bearings, and carefully check the faces of all couplings before bolting them together. If the engine is installed before the boat is put into the water, as is sometimes done, the FINAL ALIGNING MUST BE DONE AFTER THE BOAT IS LAUNCHED, also check alignment after fuel and water tanks have been filled.

Lubricating Oil Piping *(See Figure 23)*

All lubricating oil pipes and fittings should be of black iron. It is not advisable to use galvanized pipe on account of the danger of scale.

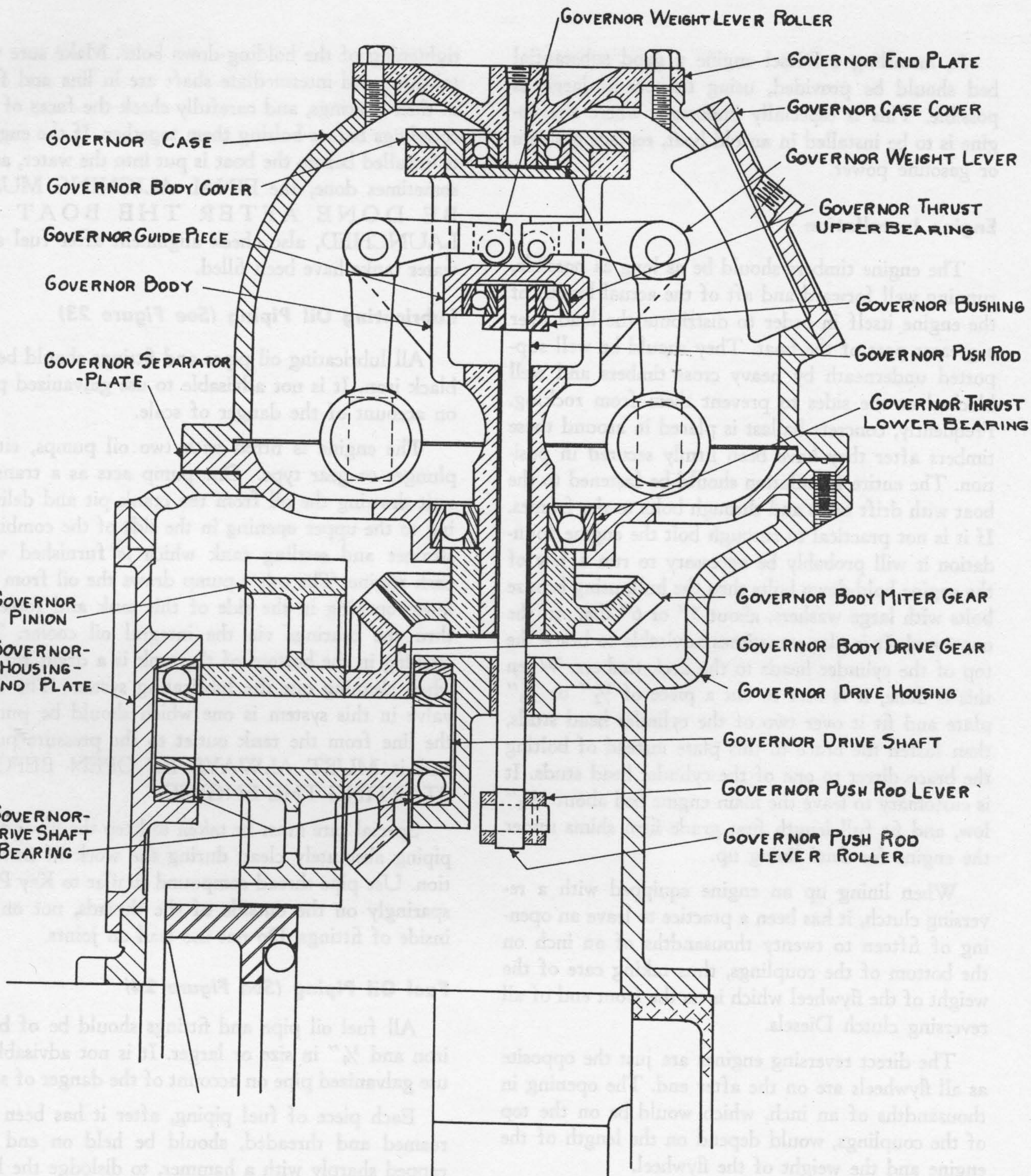
The engine is fitted with two oil pumps, either plunger or gear type. One pump acts as a transfer unit drawing the oil from the crank pit and delivering to the upper opening in the side of the combined strainer and settling tank which is furnished with each engine. The other pump draws the oil from the lower opening in the side of this tank and forces it thru the bearings via the integral oil cooler. The opening in the bottom of the tank is a drain for use when cleaning out the lubricating system. The only valve in this system is one which should be put on the line from the tank outlet to the pressure pump and it MUST ALWAYS BE OPEN BEFORE STARTING THE ENGINE.

Special care must be taken to keep the lubricating piping absolutely clean during the work of installation. Use pipe thread compound similar to Key Paste sparingly on the outside of the threads, not on the inside of fittings. Do not use lead on joints.

Fuel Oil Piping *(See Figure 24)*

All fuel oil pipe and fittings should be of black iron and ¾″ in size or larger. It is not advisable to use galvanized pipe on account of the danger of scale.

Each piece of fuel piping, after it has been cut, reamed and threaded, should be held on end and rapped sharply with a hammer, to dislodge the loose scale from the inside. If possible, then wash out with a solvent. Use thread compound on all the joints, putting it on the pipe threads, NOT IN THE FITTINGS.



GOVERNOR ASSEMBLY

FIGURE No. 22

The main tanks are connected through a valve to a common suction line which is run to the suction side of the fuel service pump which is either gear or plunger type. The fuel from this pump is delivered to the top of the day tank. The side outlet near the bottom of this tank is piped to the suction side of the engine fuel pressure pumps via the fuel oil strainer furnished with the engine. Overflow is from the outlet provided on the side about four inches from the top. Run a ¾″ or 1″ line back into the main tank line, which is the suction line of the fuel service pump. With the piping as described, the day tank is always full but never overflows, the extra oil being pumped around in a circle. A drain is provided in the bottom of the day tank where any water that may collect there be occasionally drained off.

The day tank must be enough higher than the fuel pumps on the engine that the fuel will flow freely through the filter to the pumps. If the day tank is not high enough to give sufficient head on the fuel, an automatic air vent valve (similar to Crane No. 984) can be put in the day tank vent line and a relief valve set for about 10 lbs. put in the overflow line close to the tank. This will allow the fuel transfer pump to keep the day tank under pressure and the air valve will allow the fuel to run out when the engine is not running.

The relief valve next to the fuel transfer pump as shown in Figure 24 is only used on direct reversing engines that have fuel transfer pumps pumping in the ahead position only. This relief valve is installed so that when the engine is reversed and the fuel transfer pump tries to pump fuel backwards, the check valve stops the fuel and the relief valve unloads the pressure.

Air Piping *(See Figure 25)*

All air pipe and fittings should be of black iron. Valves, pipe and fittings should be of the type classified for not less than 300 lbs. pressure.

Use a thread compound similar to Key Paste on all joints in the air lines. Be sure all pipe threads are good, clean cut threads. The line from the air tanks to the engine should be as large or larger than the connection provided on the engine. Run the pipe as directly as possible, leaving outlets for the whistle and auxiliary air compressor, but avoid all unnecessary fittings. A gauge and safety valve are provided on the engine. Put a small valve on the drain of each tank and a shut-off valve at each tank so that it can be kept absolutely tight.

It is a practice on direct reversing engines to run air lines separately from each tank to a manifold on the engine. This enables the operator to open one tank and close another without leaving his post while maneuvering.

Water Piping *(See Figures 26 and 27)*

All water pipes and fittings, including circulating and bilge water pipings, should be of brass of standard pipe sizes. The size of pipe to use may be determined by the suction and discharge openings on the pumps. Pipe sizes may be increased but not decreased. The bronze seacocks and sea strainers should be put in the hull well below the water line, with filler blocks inside the hull for them to pass through.

Do not use the same compound on the threads of the water piping as used on lube oil, fuel oil or air piping. Use a pipe compound made for water pipe or use white lead. On the suction and discharge lines to the engine use a section about 18 inches long of reinforced rubber suction hose. This will provide a flexible connection to allow for some movement of the engine in relation to the boat and sometimes also helps in preventing electrolysis.

It is customary to provide two pumps—a plunger type used as a bilge pump, and a centrifugal or gear type used ordinarily for circulating water. The latter pump is connected through a check valve to one seacock. The plunger pump suction is run to a manifold where, by means of cross and angle valves, it can be turned on to any of the bilge suctions or the sea connections as desired. NEVER PUMP THE BILGE WATER THROUGH THE ENGINE, but provide a direct overboard discharge. AVOID THE USE OF ANY VALVES WHICH WOULD SHUT OFF THE DISCHARGE LINES, causing excessive hydraulic pressure, resulting in a broken pump or water jacket.

Any place where a water pipe is tapped into an iron casting, a black iron nipple should be used in the casting. If this is not done, the casting will probably corrode excessively and in time spoil the threads in the casting. Using a black iron nipple, the nipple will corrode instead of the casting and the nipple can be easily replaced.

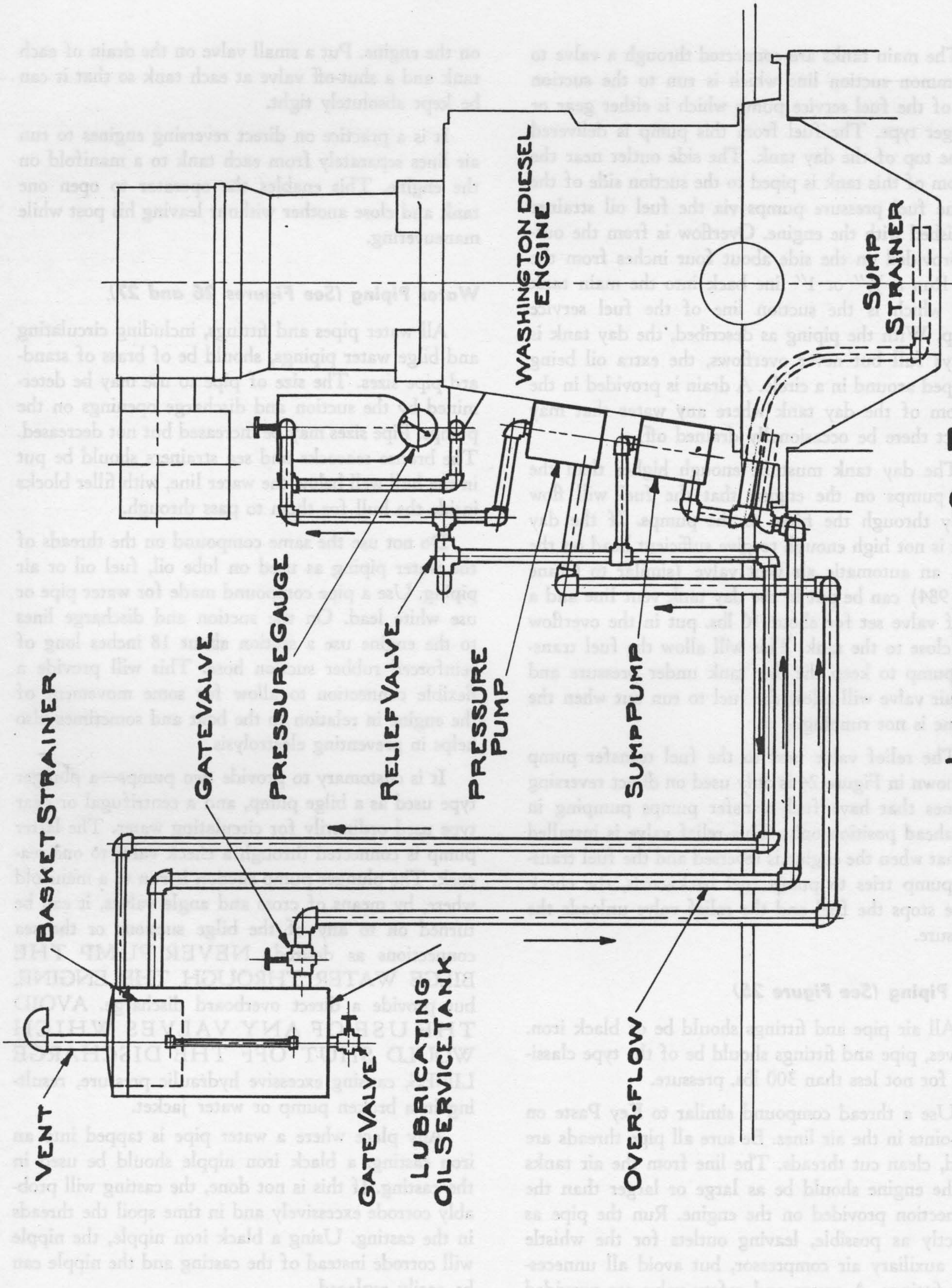


FIGURE No. 23 LUBRICATING OIL PIPING

Exhaust Pipe

The overhead exhaust is used with all our engines since the muffler effect of the wet exhaust is not needed with an engine of this type, and the dry exhaust leaves no possibility of sea water getting back into the engine cylinder where it might do a great deal of damage. Use black pipe of the same size or larger than the exhaust fitting provided with the engine, with 45 deg. or long sweep elbows at all turns. Keep the pipe well clear of the wood at all places to safeguard against fire, using asbestos covering where necessary. It is a good idea to provide a sheet iron jacket around the pipe, open at top and bottom, with three to four inches of space between the two. This is very effective in carrying the exhaust heat away from the engine room.

An expansion joint of some type should be used in the exhaust line. We recommend the use of flexible tubing. The length of the flexible tubing should not be less than eight times its inside diameter. It should be installed in a straight line, or as nearly straight as possible. Some types of tubing can be made bent to the curvature required.

Be sure that the weight of the exhaust piping is not carried on the engine. It is satisfactory to have the engine carry one end of the flexible tubing, and possibly a short piece of pipe or long sweep elbow. The weight of the exhaust pipe should be carried at one point (assuming a vertical pipe). Other braces on the pipe should be arranged so the pipe can expand in length.

The Company can furnish an efficient muffler if desired. If using another muffler, be sure that it does not contain a lot of small passages which may become clogged and put a back pressure on the engine.

Pilot House Control

There are so many different types of pilot house controls used and so many different types of ships that it is not within this book to describe them. On clutch controls, always be sure that there is no possibility of the clutch shifter collar being held tight while running. On electro-pneumatic controls be sure that all electrical connections are tight and contacts are clean. On gauges used in the pilot house or some distance from the engine, use large enough tubing so that the gauge will register properly. This is especially true on lubricating oil. 5/16″ copper tubing is generally satisfactory.

Auxiliaries and Accessories

There are generally special instructions for auxiliaries and accessories on the engine. There is a pocket provided in the back of this book to hold such instructions if they cannot be put in the binder itself. In ordering parts for material not made by the Washington Iron Works, always give all the information possible; such as manufacturer's name, model number, serial number, pipe size, etc. Often, parts are changed on an engine or were not sold with the engine and the factory has no record of them. The Washington Iron Works carries a good stock of spares for accessories, etc., and the more information given in ordering parts, the better service the factory can give you on parts.

Loss of Pressure in Pipe

The resistance to flow or the loss of pressure of oil in piping is not often realized by men installing engines. The figures on page 45 are approximate and will give an idea of what restrictions are imposed by different fittings and pipe sizes. Comparisons are for the same oil at the same temperature.

The flow of oil will vary as the fourth power of the inside diameter of the pipe and inversely as the length of the pipe.

Assuming that a given length of ½″ standard pipe will carry ½ G.P.M. of oil, the same length of larger pipe with the same pressure on the oil will carry the following G.P.M. of the same oil:

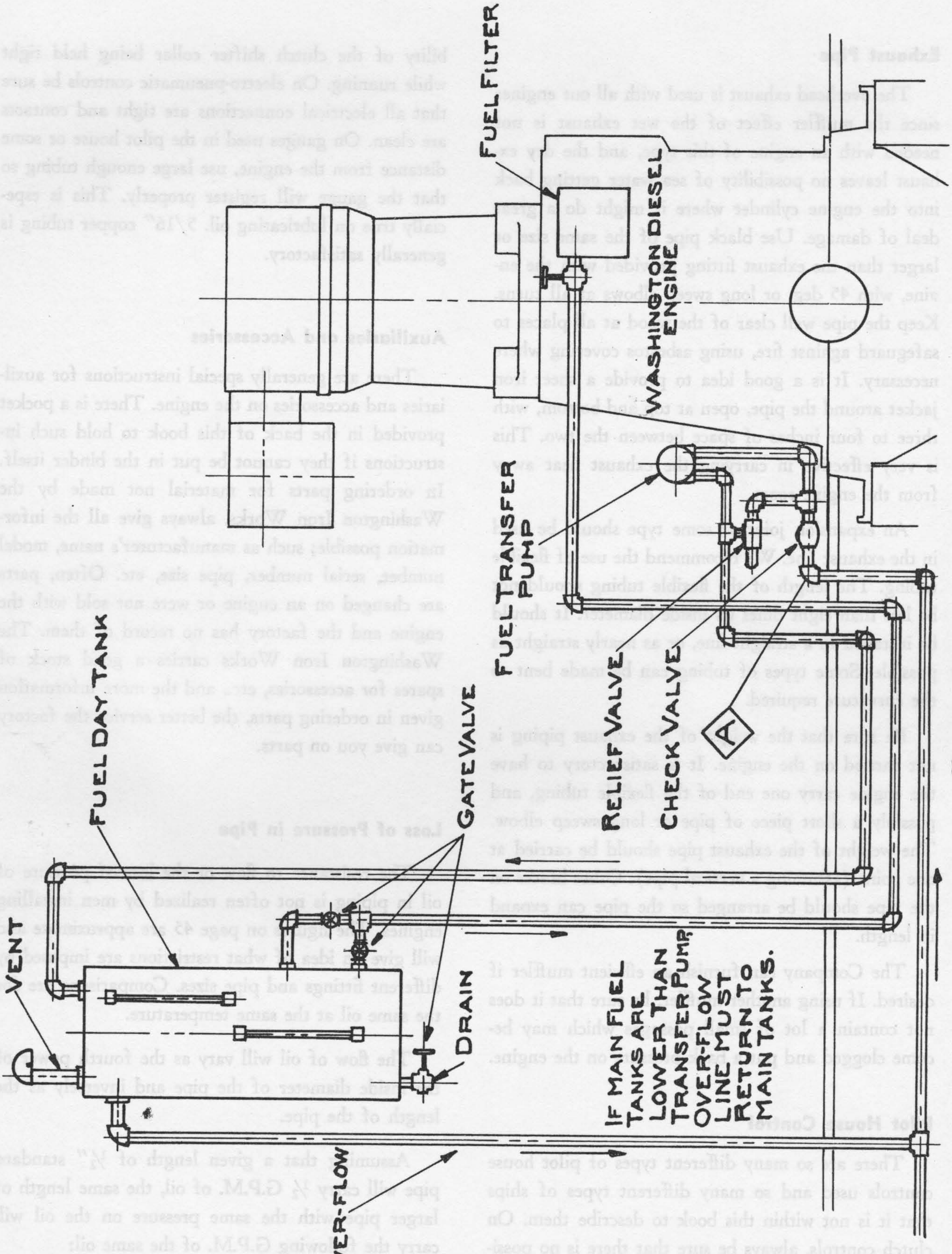


FIGURE No. 24 FUEL OIL PIPING

Pipe Size	½″	¾″	1″	1¼″	1½″	2″	2½″	3″	4″
G.P.M.	½	1½	4	12	23	62	126	300	900

The following table gives the length of pipe in feet that offers the same resistance to flow as the pipe fittings shown.

Standard Pipe Size	½″	¾″	1″	1¼″	1½″	2″	2½″	3″	4″
Inside Diameter of Pipe	.62″	.82″	1.05″	1.38″	1.61″	2.07″	2.47″	3.07″	4.03″
Globe Valve	16	22	27	36	43	55	58	80	110
Angle Valve	8.5	11	15	18	22	28	33	41	55
Tee (through side outlet)	3.5	4.5	6	7.5	9	11	14	17	22
90 degree Ell	1.5	2	2.75	3.25	4.25	5.5	6.5	8	11
Long Sweep Ell	.75	1	1.25	1.6	2	2.5	3	3.75	5.5
45 degree Ell	.6	.8	1	1.3	1.5	2	2.25	2.75	3.75
Gate Valve (Open)	.35	.45	.6	.8	1	1.2	1.3	1.75	2.25

USEFUL INFORMATION

1 Gallon = 231 Cubic Inches

1 Gallon = 0.1337 Cubic Feet

1 Cubic Foot = 7.481 Gallons

1 Barrel = 42 Gallons

A 52-55 gallon barrel is often used for lubricating oil.

1 U.S. Gallon = 1.2 Imperial Gallons

Diesel Fuel Oil (27+ fuel as commonly used, about 31 Baume Gravity) weighs 7.25 pounds per gallon or 54.25 pounds per cubic foot.

Fresh water weighs 62.4 pounds per cubic foot or 8.35 lbs. per gallon.

Salt water weighs 64.3 pounds per cubic foot or 8.6 pounds per gallon.

Lubricating oil weighs (approximately) 56 pounds per cubic foot or 7.5 pounds per gallon.

Concrete weighs 120-155 pounds per cubic foot.

For general estimating purposes, the fuel consumption of heavy duty diesel engines using so-called 27+ diesel fuel oil will be approximately 6 gallons per 100 horsepower hours. Or in other words a 100 horsepower engine will burn 6 gallons per hour.

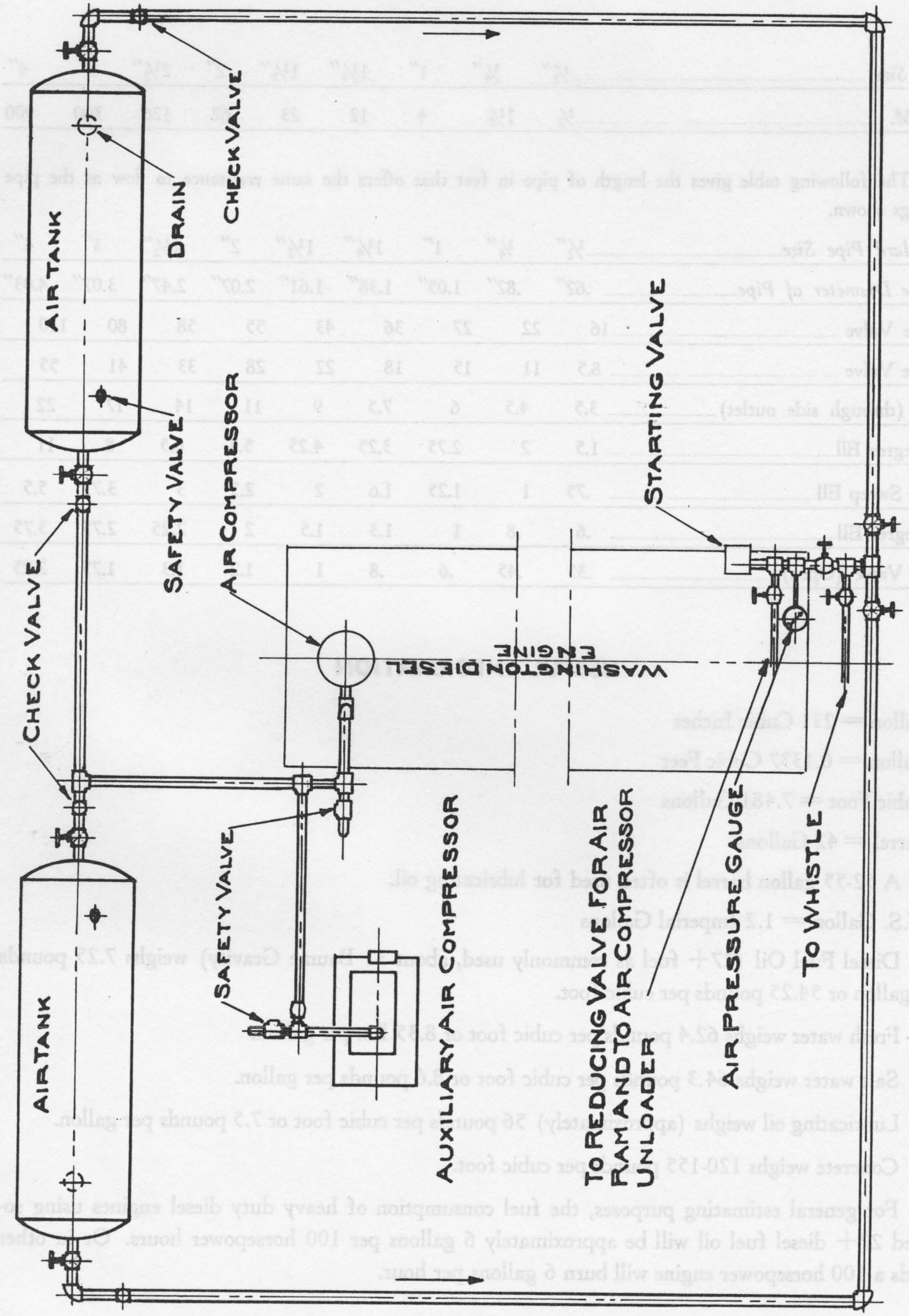
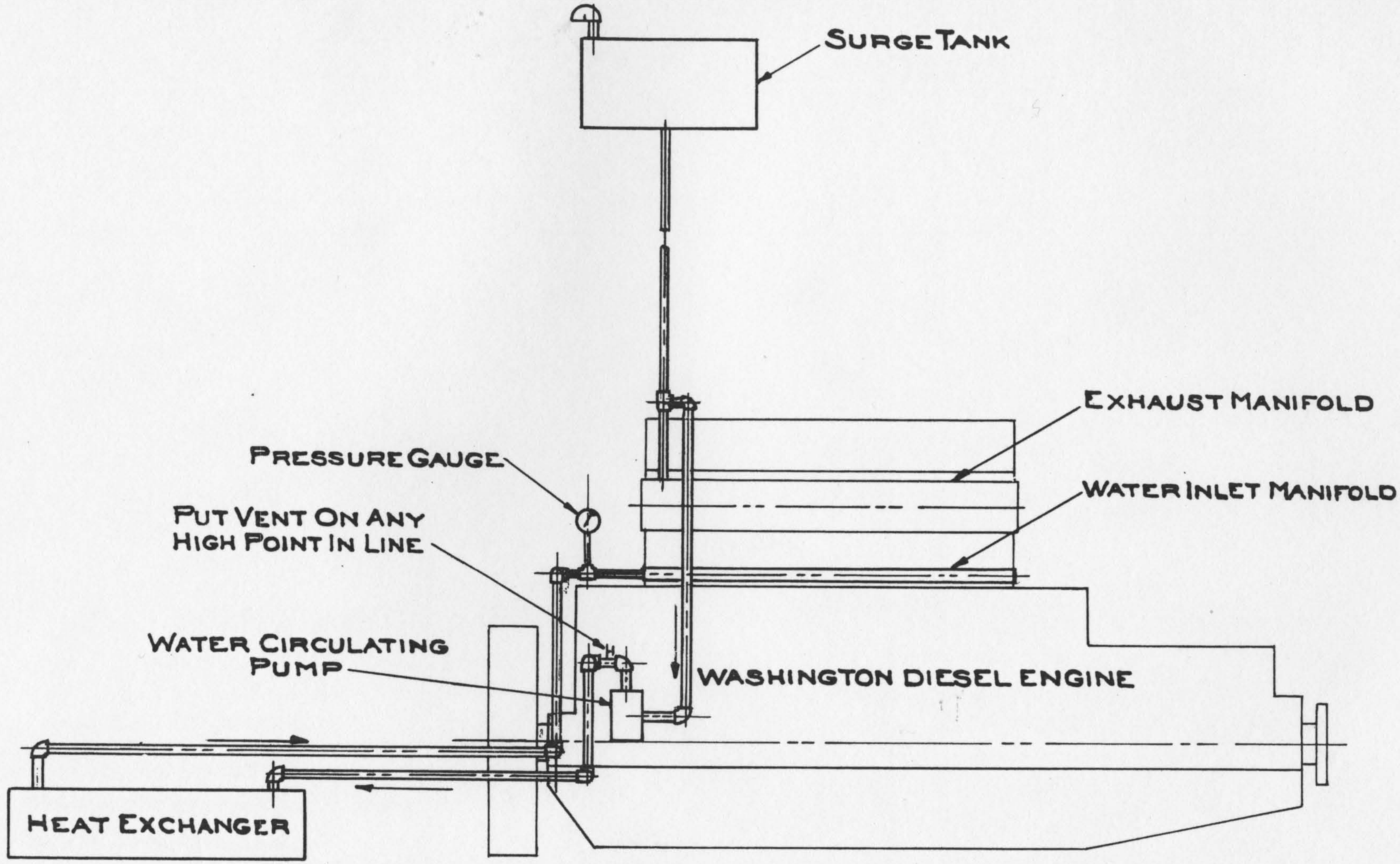
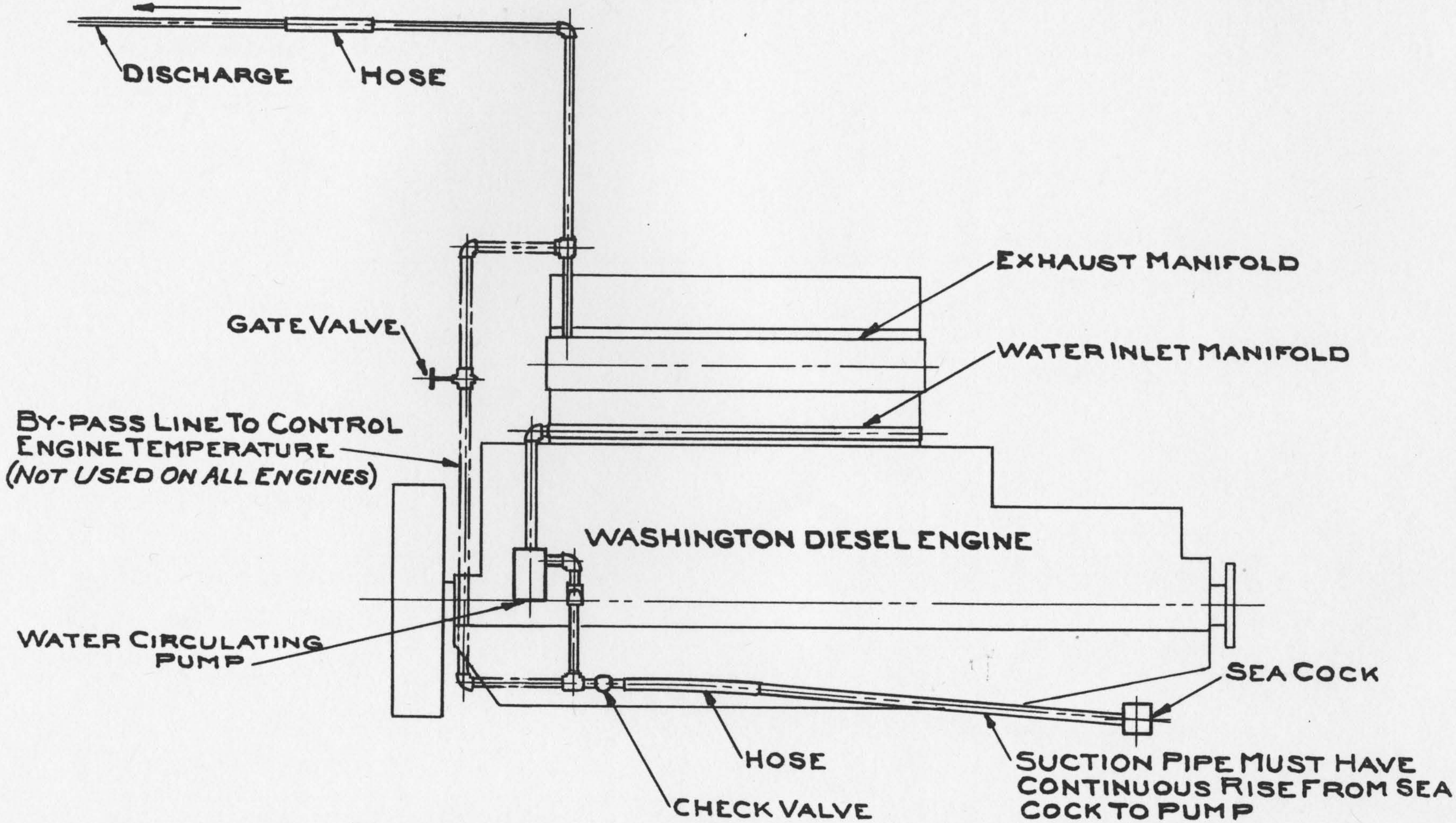


FIGURE Nº 25
AIR PIPING



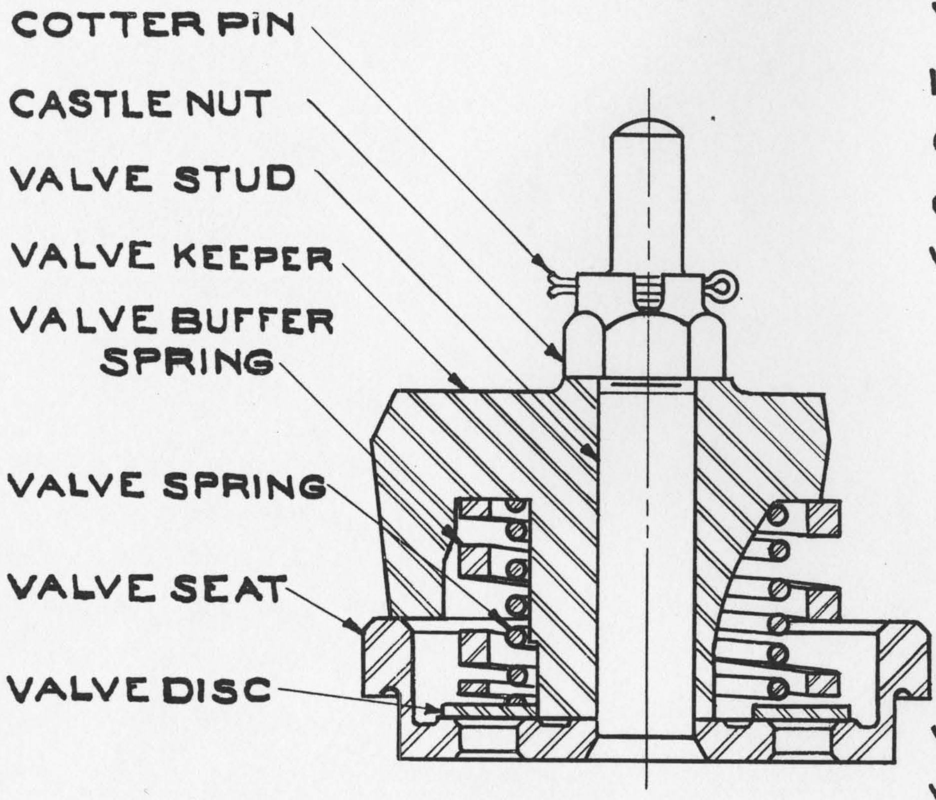
FRESH WATER COOLING SYSTEM

FIGURE No. 26



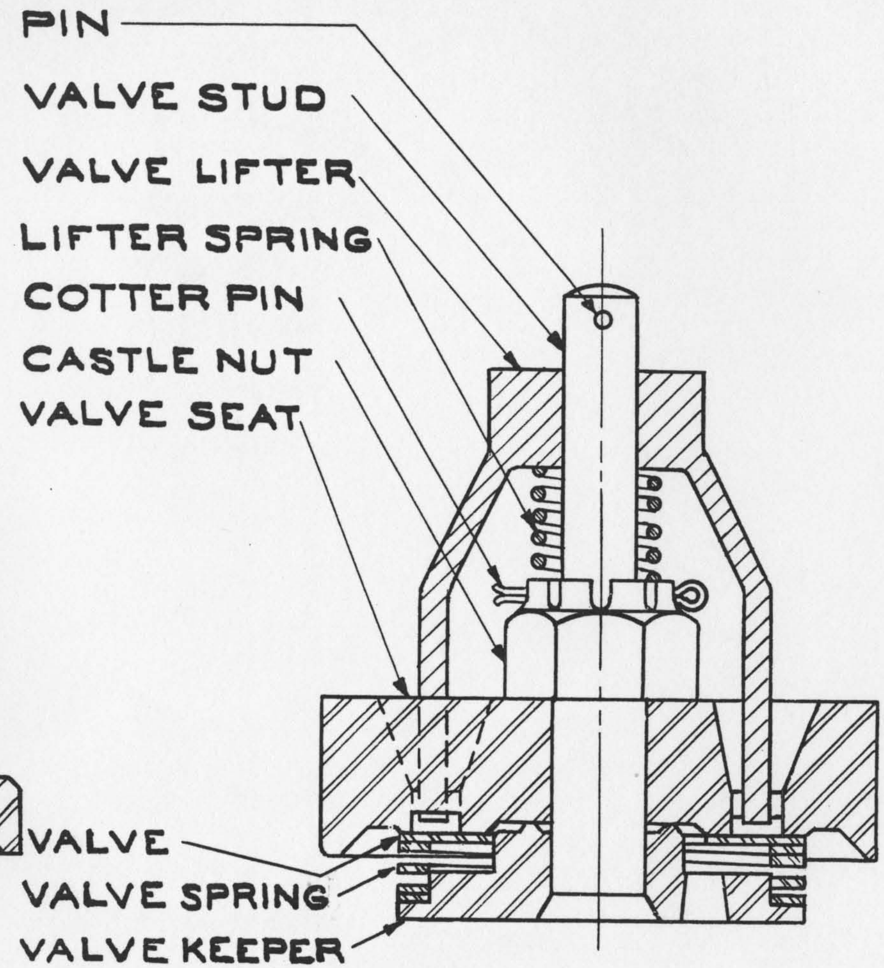
SALT WATER COOLING SYSTEM

FIGURE No. 27



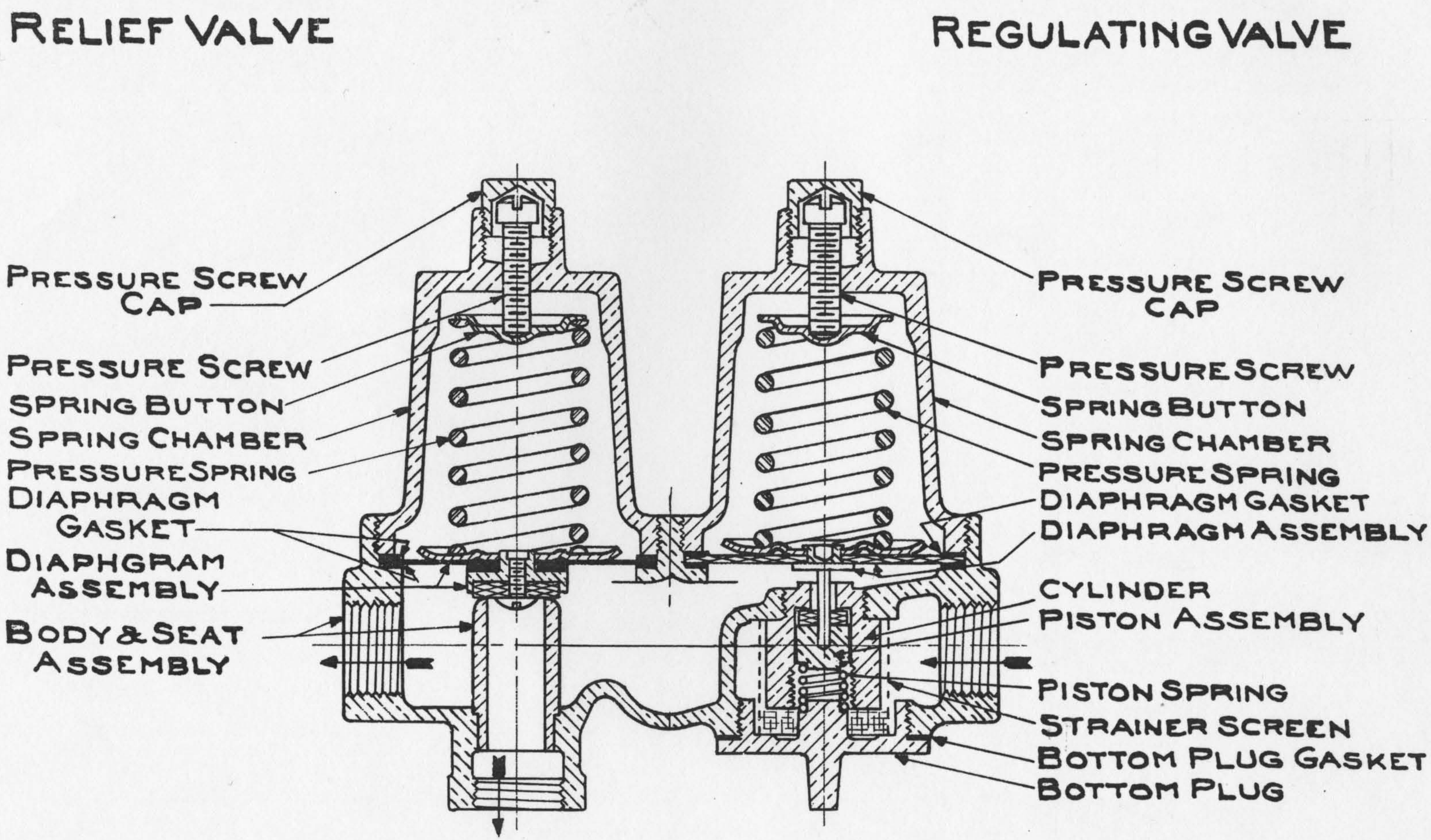
AIR COMPRESSOR
DISCHARGE VALVE

FIGURE No. 28



AIR COMPRESSOR
SUCTION VALVE

FIGURE No. 29



AIR REDUCING VALVE
"CASH" MODEL 21

FIGURE No. 30