OPERATORS MANUAL

TC 856

ATLAS IMPERIAL MARINE DIESEL ENGINE

MODEL 6HM1558—320 HORSEPOWER

6 CYLINDER 11½ x 15 DIRECT REVERSIBLE

Price $2.00

ATLAS IMPERIAL DIESEL ENGINE CO.

OAKLAND, CALIFORNIA

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FOREWORD

During the war every branch of the armed forces powered many of their ships and vehicles with Diesel engines. To meet the ever increasing requirements, manufacturers doubled their output again and again. As the demand for operators grew, the industry responded well. Service and assembly line men from the factories, operators from the fishing fleets, mines, contracting companies and truck lines joined up in great numbers to care for the country's Diesels of war.

But the industry's output of Diesel engines soon exceeded the supply of experienced operators. The Transportation Corps found it necessary to recruit men from the farms and offices. Most of them were familiar with the family car, truck or tractor but that was about the extent of their knowledge of internal combustion engines.

The Atlas Imperial Diesel Engine Co. was asked, by the War Department, if a manual could be prepared which would explain the principles and operation of a Diesel engine in simple every-day language without blueprints, technical terms, or lengthy explanations.

In offering this manual to our friends, we trust that many of them will find it interesting and instructive. The operator, who has charge of an Atlas Diesel for the first time, can learn why it runs, how it runs and also a few simple rules which will enable him to get the best out of the careful design and fine workmanship that goes into all Atlas products.

The operator, who has had experience with Atlas Diesels, will find it useful as an aid to instructing those under him. This manual should only supplement the regular Atlas Imperial Instruction Book which details at great length the steps to be taken during major overhauls or replacements.

ATLAS IMPERIAL DIESEL ENGINE CO.

OAKLAND, CALIFORNIA

SECTION 1
PRINCIPLES OF ENGINE OPERATION

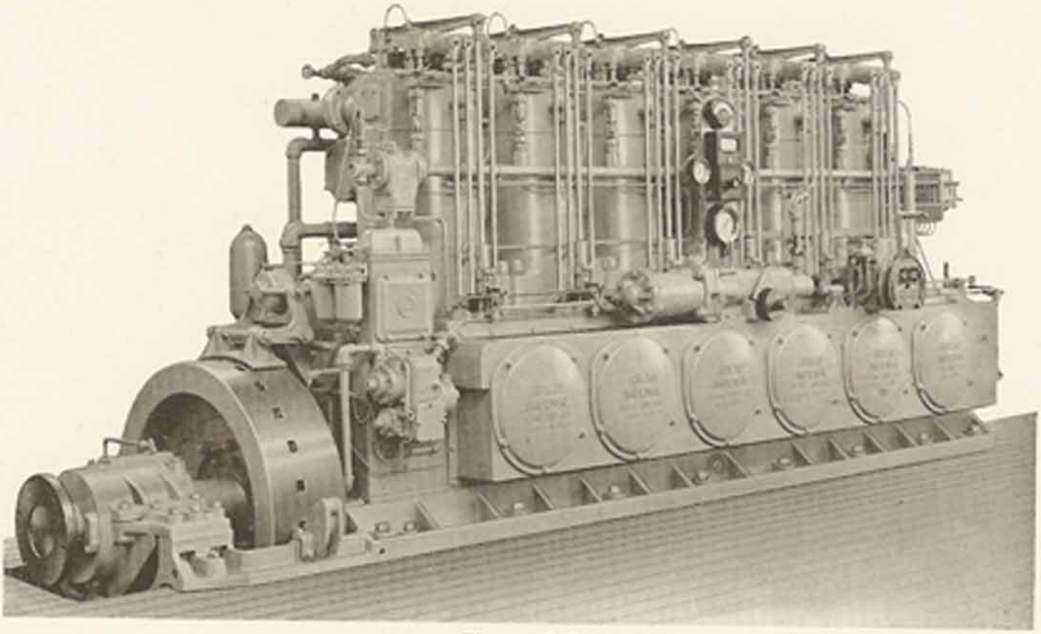


Figure 1-1
ATLAS IMPERIAL DIESEL ENGINE
This illustration is typical of the slow speed, heavy duty engine, the operation, repair, and maintenance of which are illustrated and described in this manual.

1. DIESEL NOT COMPLICATED: A Diesel engine is really a very simple engine. You have probably had some experience with the ordinary automobile engine, and will be reassured to know that the Diesel is similar in design and operation but does not have the complicated electric ignition system required by gasoline engines.

2. NATURE OF BURNING: It is common knowledge that certain substances, such as wood, coal, kerosene, will burn if there is air present and an open flame or a spark starts the fire. In engineering we call burning, combustion, and the starting off of the combustion is called ignition. In a Diesel engine we burn Diesel fuel oil, which is a product made from crude petroleum and is similar to kerosene, but heavier, and usually darker in color.

What really happens when something burns is that one of the gases composing ordinary air, namely oxygen (air is about one-fifth oxygen and four-fifths nitrogen), unites with the substance being burned and forms new gases. When Diesel fuel burns the gases formed are carbon-dioxide gas and water vapor.

3. COMPOSITION OF COMBUSTION GASES: After burning is finished, where once there was Diesel fuel and air there will be carbon-dioxide gas, water vapor, nitrogen left after the oxygen has been used up, and any air not needed to burn the amount of fuel that was available. This unused air is called excess air.

4. GENERATION OF HEAT: These gases will fill about the same space that the air and fuel filled originally—after they have cooled down. But at the time of burning they will be extremely hot, as combustion generates heat. Heating any gas makes it expand. If combustion takes place in a closed chamber, the heated gases will push, or exert pressure, against the chamber walls. If the walls will not expand, the gases will build up in pressure; if the chamber can stretch or expand in any way, the gases will make it larger.

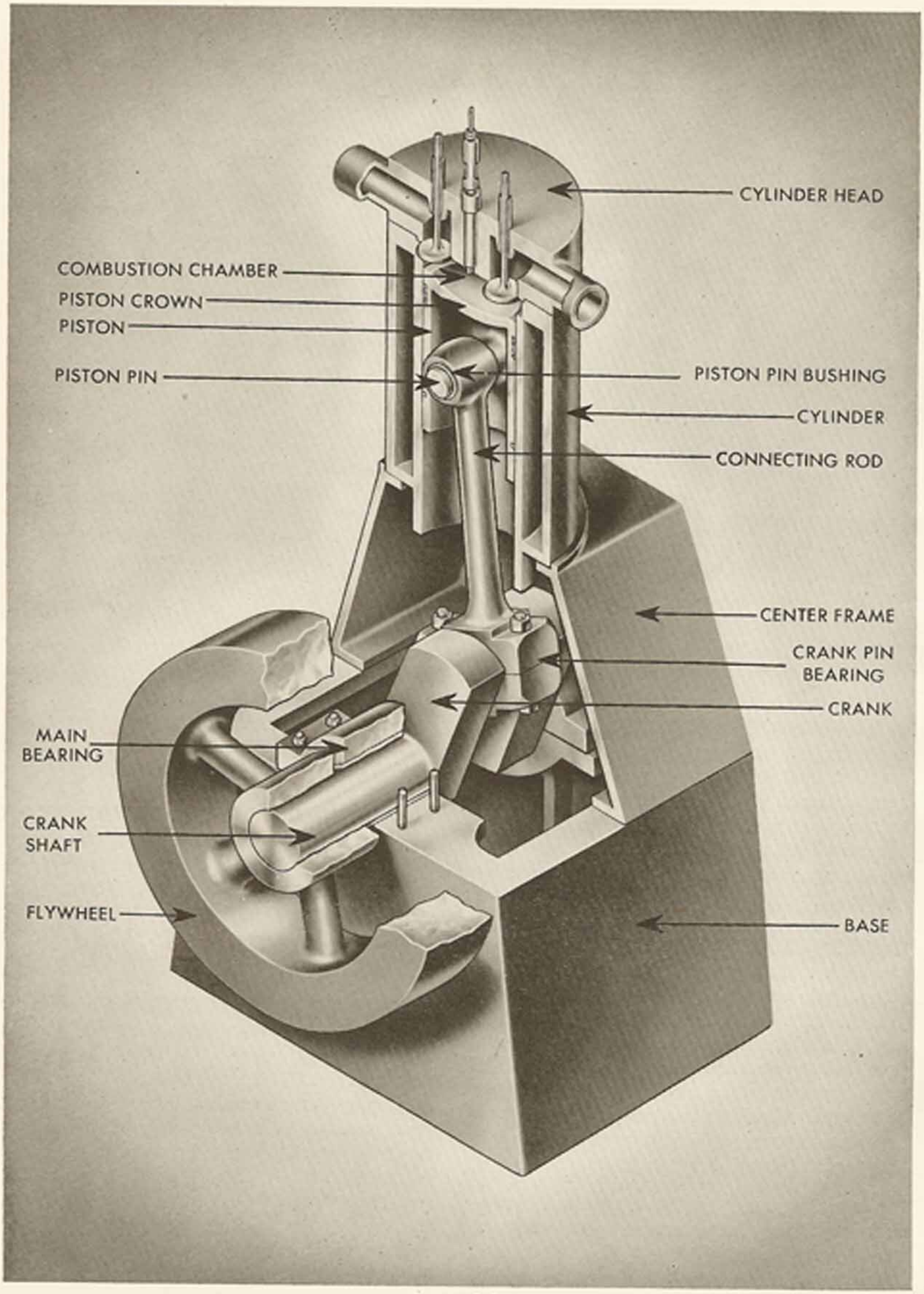

CYLINDER HEAD
COMBUSTION CHAMBER
PISTON CROWN
PISTON
PISTON PIN
PISTON PIN BUSHING
CYLINDER
CONNECTING ROD
CENTER FRAME
CRANK PIN
BEARING
CRANK
MAIN
BEARING
CRANK
SHAFT
FLYWHEEL
BASE

Figure 1-2

5. A SIMPLE ENGINE: Before we see how the burning of fuel can be made to produce motion that will do work, let us consider a simple form of Diesel engine, such as the one shown in Figure 1-2. **(In references to illustrations throughout this manual, the first number indicates the section, and the second number indicates the drawing or photograph in that section.)** This is a view in which some parts of the engine are cut away as if sawed off, so that the inside working parts can be seen. There is a cylinder and a cylinder head. A piston is inside the cylinder and is free to slide up and down. Sometimes this piston is called the power piston, and the cylinder the power cylinder, to distinguish them from pistons and cylinders used in auxiliaries of the engine. The piston is hollow, but is closed off at the top by the piston crown. The clearance between the piston and the cylinder wall is sealed by piston rings.

The cylinder head, cylinder and piston crown enclose a space that is called the combustion chamber. This chamber will be larger or smaller depending upon whether the piston is up or down in the cylinder. When the piston is at the very top of its travel (called top center) the combustion chamber is at its smallest size, and is then called the clearance volume.

The up and down movement of the piston is controlled by its being connected to a crank which is on a crankshaft. You will see that there is a round piece of steel through the center of the piston. This is the piston pin (sometimes called wrist pin). The top end of a connecting rod fits around this piston pin, and as it must rock from side to side, or oscillate, on the piston pin, the hole through the connecting rod is lined with a bronze sleeve, called the piston pin bushing. Steel turning inside steel has a tendency to stick fast; but a steel pin inside a bronze bushing turns easier, in other words, there is less friction.

The lower end of the connecting rod is fastened to a bearing which fits around the crank pin. As the crank pin must be free to revolve inside this bearing, a lining of babbitt is fitted to the inside of the bearing. Babbitt is also used to line the main bearings and parts of the thrust bearing. Babbitt is a smooth soft metal that presents minimum friction.

6. HOW COMBUSTION DOES WORK: In Figure 1-2 the piston has been to the top of its stroke and is just starting a downstroke (a movement of a piston from top position to bottom, or from bottom position to top, is called a stroke). The combustion chamber was filled with air at high pressure — about 400 pounds per square inch. This air was very hot, about 1,000 degrees Fahrenheit.

Into this air, which we might call "red hot," a small amount of Diesel fuel has been sprayed. As 1,000 degrees Fahrenheit is well above the temperature needed to ignite Diesel fuel, it starts to burn, and at the point shown in Figure 1-2, this burning is well under way.

The first result of combustion is an increase in pressure in the combustion chamber. The pressure rises from 400 pounds to about 600 pounds. Your engine has a piston that measures 11½ inches across (or has a piston 11½ inches in diameter, or has a bore of 11½ inches) which gives it a top area of about 104 square inches. The total push downward on the piston crown is 600 pounds per square inch times 104 square inches, or 62,400 pounds. With this pressure being exerted downward, the piston moves, but in doing so it must turn the crank and the crankshaft.

That, briefly, is how combustion of fuel is put to work. Of course, the explanation leaves many questions unanswered: How did the air in the combustion chamber become compressed, and why was it at 1,000 degrees Fahrenheit? What happens to the combustion gases when the piston reaches the lower limit of its travel (bottom center)? How does the fresh air get into the cylinder to be compressed? How was the fuel injected at the proper time and in the proper amount? We shall now explain such matters.

7. THE POWER STROKE: The downstroke of the piston, just described, is called the power stroke (sometimes is called the working stroke, firing stroke, or the expansion stroke). The combustion gases expand as the piston goes down, and their pressure drops as they expand, until at the bottom of the stroke the pressure has dropped to about 50 pounds.

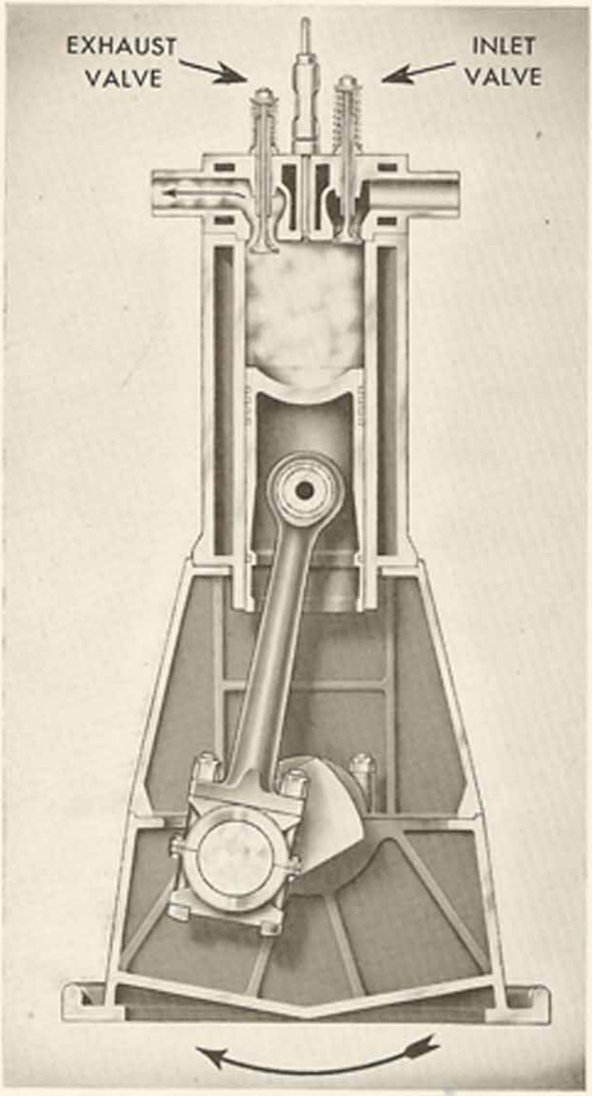


Figure 1-3

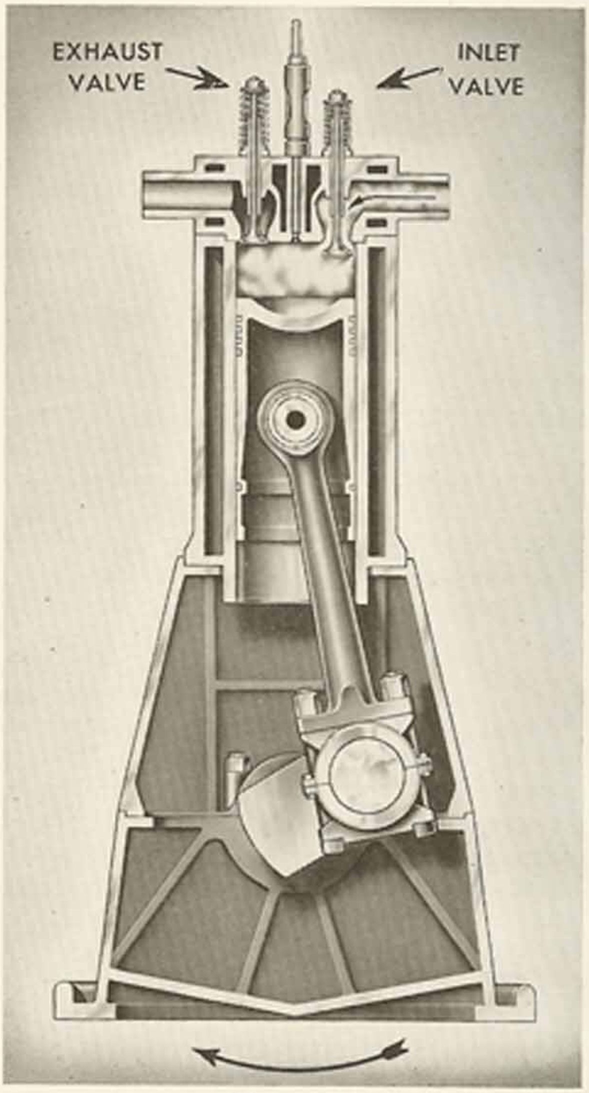


Figure 1-4

8. THE EXHAUST STROKE: Somewhere near bottom center at the end of the power stroke a valve opens in the cylinder head. A valve is merely something to open or close a passage. An ordinary water spigot is a valve. So this valve opens and most of the combustion gases rush out and the pressure inside the cylinder drops to nearly atmospheric pressure. But the crank keeps on turning (we shall explain why in due time) and moves the piston into an upstroke. As the piston rises it pushes the remainder of the combustion gases (they are usually called exhaust gases from this point on) ahead of it and out through the valve, which is called the exhaust valve. The stroke is also called the exhaust stroke, and sometimes the scavenging stroke, Figure 1-3.

9. THE INLET STROKE: At the end of the exhaust stroke the piston is at top center. The exhaust valve closes, and another valve, called the inlet valve, opens (this is sometimes called the intake valve, suction valve, or admission valve). Although the exhaust valve leads to a passage (not shown in Figure 1-3) that ends with a muffler to lessen the noise of the exhaust, the inlet valve may simply open the cylinder to the atmosphere. As the piston starts the next downstroke after the end of the exhaust stroke, it draws air from the atmosphere into the cylinder by suction. This stroke is called the inlet stroke (also the intake stroke, suction stroke, or admission stroke). It is illustrated in Figure 1-4.

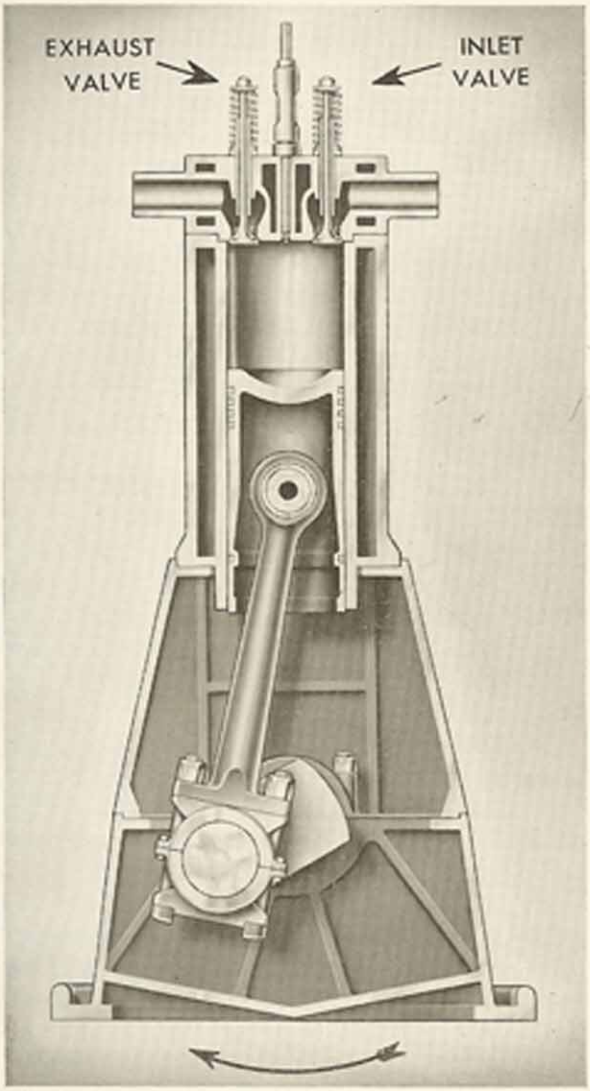


Figure 1-5

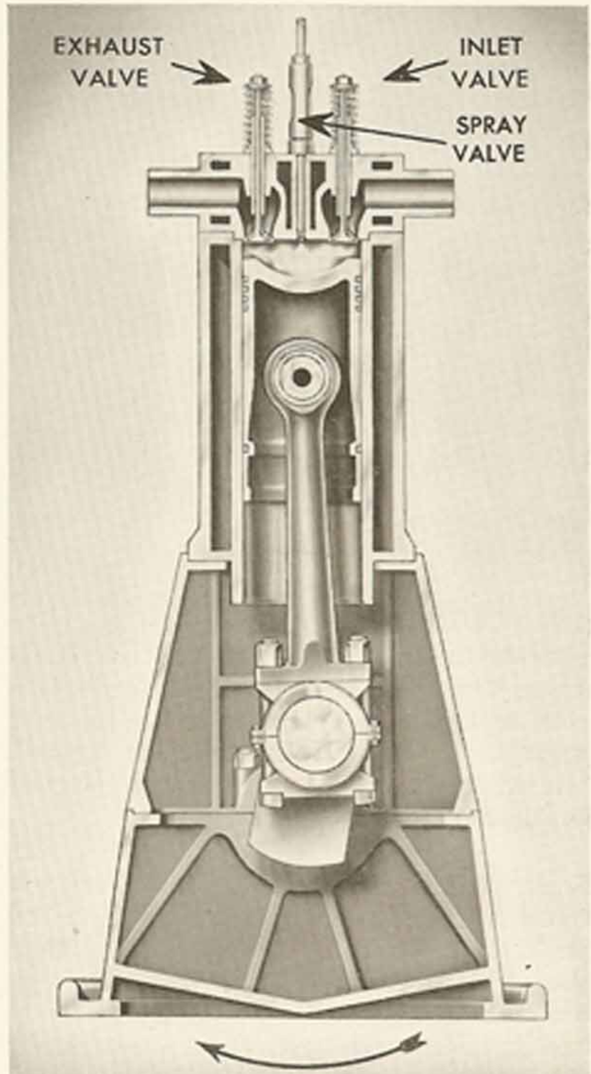


Figure 1-6

10. THE COMPRESSION STROKE: At the end of the inlet stroke the piston is at bottom center and the cylinder is full of fresh air. The inlet valve closes, and the exhaust valve, closed at the end of the exhaust stroke, remains closed. The air is trapped in the cylinder with no chance to escape. The piston starts on an upstroke and crowds, or compresses, the air into smaller and smaller volume. Finally as the piston approaches top center the air that originally filled the cylinder is compressed into the small clearance volume. This stroke is called the compression stroke and is illustrated in Figure 1-5.

11. RESULTS OF COMPRESSION: Compression has two results. The most obvious one is an increase in air pressure. The compression stroke increases the air pressure in the Atlas engine to about 400 pounds per square inch. The other result is an increase in air temperature. If you have ever had to pump up an automobile tire by hand you probably remember that the pump barrel became quite hot. When air is compressed in an engine cylinder in one stroke to 400 pounds, it increases in temperature to about 1,000 degrees Fahrenheit.

12. FUEL INJECTION: So now we have the combustion chamber full of compressed air at a red-hot temperature. All that remains is to spray or inject Diesel fuel into the combustion chamber, as indicated in Figure 1-6.

This injection commences slightly before the end of the compression stroke and continues past top center. Burning begins at once and the engine starts on a power stroke.

13. THE MEANING OF "CYCLE": When the power stroke begins we are back to the situation shown in Figure 1-2. As a movie-goer would say, "this is where I came in." From now on, the engine goes through the motions all over again. What happens in an engine cylinder from any one occurrence (usually called an event) to a repetition of that occurrence is called a cycle. You could call a movie program from the beginning of the main feature, to another such beginning of the same main feature, one cycle. After that, there is just repetition.

14. FOUR CYCLE: To review the engine cycle, we had (1) a power stroke, (2) an exhaust stroke, (3) an inlet stroke, and (4) a compression stroke. That is a total of four strokes, or a four-stroke cycle. The English still call it that, but Americans have shortened the name to FOUR CYCLE.

Some engines are designed so that firing, exhaust, inlet, and compression are accomplished within one downstroke and one upstroke; they are called two-cycle engines. While other cycles are theoretically possible, all practical Diesel and gasoline engines today operate on either the four-stroke cycle or the two-stroke cycle.

15. INTERNAL COMBUSTION: As the actual combustion of the fuel takes place within the power cylinders of a Diesel engine, it is called an INTERNAL-COMBUSTION ENGINE. Gasoline engines are also internal-combustion engines.

16. FUNCTION OF THE FLYWHEEL: Of all four strokes in the cycle, only one produces power. The remaining three require power instead—especially the compression stroke. Why doesn't the engine stop some time during the three power-consuming strokes? The power stroke produces far more power than the three other strokes combined require, so the problem can be solved if some way can be found to store up some of the energy of the power stroke, and to feed it back to the engine over the other three.

Some of the energy of the power stroke can be stored in a flywheel, such as is shown in Figure 1-2. On the power stroke, the rotational speed of the flywheel is slightly increased, thus building up the momentum of the flywheel. Momentum is the term applied to the tendency of any heavy body in motion, to keep moving. As the engine goes through the power-consuming strokes, flywheel momentum supplies the energy needed. As energy is fed back to the engine, the flywheel speed decreases slightly.

17. ENGINES OF MORE THAN ONE CYLINDER: The problem of keeping the engine in motion over power-consuming strokes is greatly simplified if the engine has more than one cylinder. The engine you operate has six cylinders. In such an engine the power strokes need not occur at the same time, but can be evenly spaced. During any two revolutions of the engine there will be six power strokes, spaced at equal intervals, or one beginning each one-third of a turn. In this way one cylinder produces power while others consume some of it.

Figure 1-7 is a drawing of a six-cylinder engine, showing the events that are taking place in the various cylinders at the precise moment that No. 1 cylinder is firing. We see that at this instant:

- No. 1 cylinder is just starting the power stroke with both valves closed
- No. 2 cylinder is on the exhaust stroke with the exhaust valve fully open
- No. 3 cylinder is on the inlet stroke with the inlet valve fully open
- No. 4 cylinder is on the latter part of the power stroke with both valves closed
- No. 5 cylinder is on the compression stroke with both valves closed
- No. 6 cylinder is on the first part of the inlet stroke with the inlet valve just opening.

You will note that even with a six-cylinder engine a flywheel is used, although it may be lighter in weight than would be required for a single-cylinder engine. The flywheel smooths out the pulsations of the power strokes and causes the engine to turn at a more even speed.

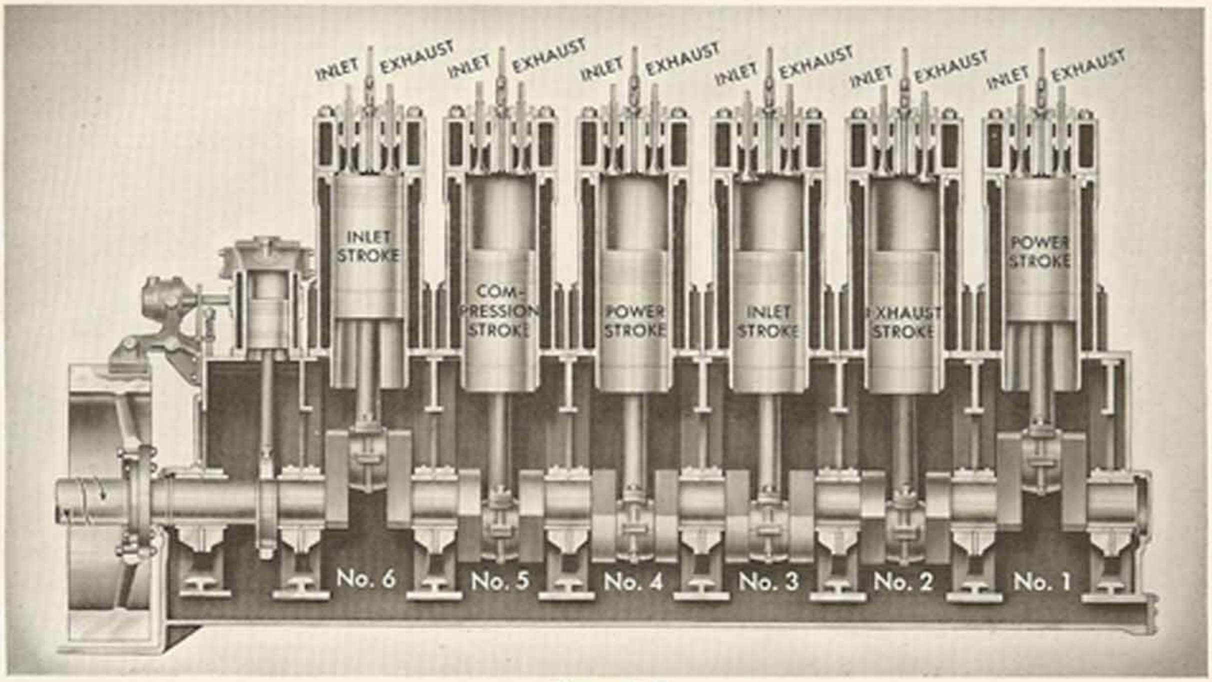


Figure 1-7

18. FOUNDATION AND SEATINGS: Figure 1-8 shows a Diesel engine installed in a ship. Each side of the engine base has a flange, and these flanges support the engine on seatings, which are the top surfaces of the foundation. The latter is a built-up part of the ship's structure, and furnishes a strong support for the engine, while it distributes the engine weight over a large area.

19. MAIN BEARINGS AND JOURNALS: The illustrations of this section show several other things about engine construction. For example, Figure 1-2 shows that the crankshaft is supported by, and rotates in, main bearings. Each bearing is made up of two halves, sometimes called top-half main bearing and bottom-half main bearing, and sometimes top main-bearing shell and bottom main-bearing shell.

That part of the crankshaft that revolves inside a main bearing is called a main journal (the part of any shaft that rotates inside a bearing is called a journal) and sometimes the main bearings are called main-journal bearings.

20. PROPELLER THRUST AND THRUST BEARING: The engine rotates the propeller, and the propeller sends the ship forward by pushing water astern, just as an electric fan pushes air.

This thrust or pushing effort must be taken and stopped somewhere before it reaches the engine crankshaft or the crankshaft would be crowded hard against the forward end of its clearance and would bind in its bearings. So a thrust bearing is located at the after end of the engine. This bearing has a thrust shaft, which is coupled to the engine flywheel at the engine end, and to the intermediate shaft at the after end. Forged as one piece with the thrust shaft is a thrust collar, or round steel disc. This collar rotates between two sets of shoes mounted in the thrust-bearing housing, which is firmly bolted to the engine base. The babbitt lined shoes prevent the thrust collar from moving fore or aft.

21. PORT AND STARBOARD ENGINES: A ship may have one engine turning one propeller, as in Figure 1-8, in which case it is said to be of single screw type with single-engine propulsion. Some ships, however, have two engines, each connected to a propeller, and are said to be of twin-screw type. The engines will be built to the same design except that one of them will be turned around with the flywheel and thrust bearing mounted at what would

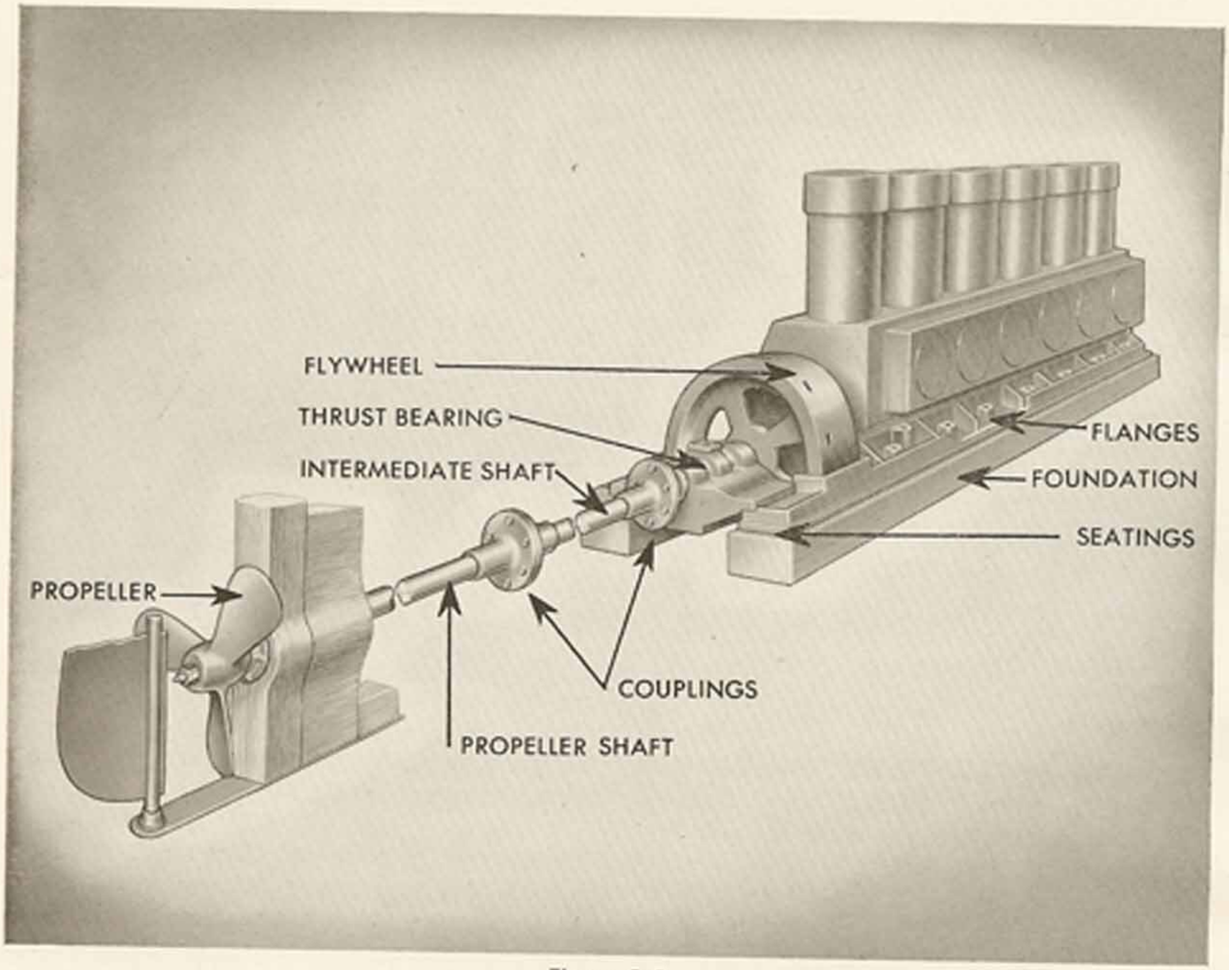


Figure 1-8

ordinarily be the forward end. This is done so that the controls can be located inboard, or facing the center of the ship, for both engines.

The engine to the right of the ship when looking forward is called the starboard engine, and the engine to the left is called the port engine. The flywheels of the two engines will travel in opposite directions, and the Atlas standard is to have them turn towards each other at the top when the ship is going forward.

22. LUBRICATION: When an engine is running there are a number of places where metal slides over metal, or rotates inside metal. We have seen how the power piston slides in the cylinder and how various pins and journals rotate or oscillate in bearings. None of these sliding, rotating or oscillating motions could continue for more than a very few seconds without the parts sticking fast, if it were not for lubrication. How lubricating oil is supplied to such moving parts will be described in Section 2.

23. ENGINE COOLING: We have already said that combustion produces heat. Some of this heat will be absorbed by the cylinder head, cylinder and piston, and if these parts were not cooled in some way, their temperature would increase until the lubricating oil would be burned off, and the piston would stick fast in the cylinder, and the valves would do likewise in the cylinder head. The cylinder and cylinder head are consequently made hollow and water is circulated through the hollow spaces, or water jackets. The piston is not cooled directly on the Atlas engine, but is kept at a safe temperature because it travels in a cooled cylinder. The details of the water-cooling system are discussed in Section 3.

24. PHASES OF FUEL INJECTION: Just to say, as we did, that Diesel fuel is sprayed into the combustion chamber at the beginning of the power stroke, is to raise many questions. The supply of fuel is kept in one or more large storage tanks on board ship. First it must be pumped to a smaller tank near the engine, called a day tank. Then it must be pumped up to a very high pressure and stored in the fuel rail, a manifold which distributes oil to the various cylinders. Lastly it must be injected into the cylinders at the proper time, and in the proper amounts. Each such fuel amount, or charge, will not be over one-thirtieth ($1/30$) of an ounce, and will be smaller for light engine loads. This charge of fuel when released by the spray valve passes through several small holes, called orifices, in the spray valve tip. Each orifice is very small—from 0.007 inch to 0.014 inch in diameter, depending upon the engine size.The fuel charge must pass through these orifices in a fine spray against air in the combustion chamber under 400-pound compression pressure. The fuel pressure must be higher than the air pressure, to make sure that the fuel penetrates all parts of the combustion chamber. How all of this is done is told in Section 4.

25. AIR INLET AND EXHAUST: We have already spoken about the inlet and exhaust valves. We have not explained, however, how these valves are opened and closed at the proper times. This subject together with other details about supplying the engine with air and leading exhaust gases out, will be discussed in Section 5.

26. STARTING AND MANEUVERING: Diesel engines cannot be started merely by turning on fuel, as a steam engine is started by turning on steam. They must first be put in motion before fuel is fed to the cylinders. How this is done by compressed air, and how the engine can be reversed so as to propel the ship astern, will also be told in Section 5.

27. APPARENT COMPLEXITY NOT REAL: When you look at your engine you may get the impression that there is a lot of complicated mechanism attached to it. You will find, however, that all this mechanism is used to do only the things we have just outlined. When any particular system—lubricating, water cooling, etc.—is traced around or through the engine, its parts and operation become relatively simple. It is only the grouping of a number of individually simple things that gives the appearance of complexity. When studied one by one they become simple.

SECTION 2
LUBRICATION

1. PURPOSE OF LUBRICATING SYSTEM: The only reason for the engine lubricating system is to furnish oil in sufficient quantity to the various places in the engine, and its attached auxiliaries, where there is rubbing contact between metal parts—where metal slides on metal, or turns inside metal. Without oil, these parts would have metal-to-metal contact, and would soon "freeze" fast. Supplied with oil, the contact is metal-to-oil-to-metal, friction is greatly reduced, and wear of the parts is reduced to a minimum. Correct lubrication is absolutely essential for reliable engine operation.

2. SUBDIVISIONS OF THE LUBRICATING SYSTEM: The entire lubricating system has several subdivisions, as the methods for supplying oil are not all the same. These are:

(a) pressure lubrication, by which oil is delivered under pressure from a pump, to the bearings in which the crankshaft revolves, to the crank-pin bearings, piston-pin bearings, and various other bearings,

(b) sight feed lubrication, in which a mechanical lubricator, composed of a number of pumps grouped together, sends oil to the cylinders to lubricate the pistons, piston rings, and the cylinder liners,

(c) bath lubrication of the thrust bearing, in which the housing of the thrust bearing is partly filled with oil, and

(d) hand-oiling, which involves the various oil cups, oil reservoirs, and oil holes that must be hand filled or hand serviced.

3. PRESSURE LUBRICATION: The components of the pressure lubrication subdivision are: a lubricating service tank, a high-pressure oil pump, a pressure-regulating valve, an oil filter, an oil cooler and an oil sump pump, and piping, pipe fittings and drilled passageways. The paragraphs immediately following discuss these various components.

4. LUBRICATING SERVICE TANK: This tank, shown in Figure 2-1, is usually called the lube service tank for short, and furnishes storage capacity for the oil of the pressure system.

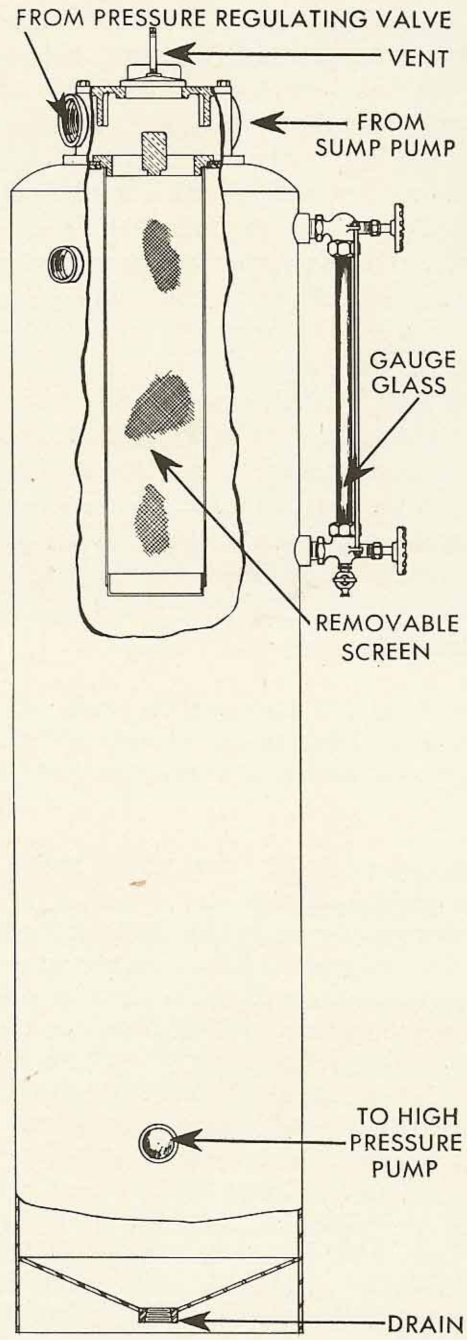


FIGURE 2-1

The two inlet openings at the top are for the entry of oil from sources that will be mentioned later. Any oil entering the tank through these openings must pass through the screen, so that large dirt particles will be caught and prevented from going through the system. The opening through which oil is drawn from the tank is near to, but not quite as low as the bottom. This allows fine dirt to settle to the bottom. A drain valve at the very bottom, is for the purpose of drawing off such settlings. This drain should be opened once each day and the oil should be allowed to drain until it runs clear of dirt particles.

The lube service tank has a gauge glass to show the level of the oil inside. When the engine is running the oil level in the gauge glass should be from three to four inches below the top of the glass (if there are two glasses, as there sometimes are, the operating level should be from three to four inches below the top of the upper glass). The lube service tank does not have to be located in any set place, but it should be fairly close to the engine, and the draw-off opening near the bottom should be higher than the high-pressure pump, so that oil will flow to the pump and flood it.

5. HIGH-PRESSURE PUMP: The high-pressure pump is mounted on the engine as shown in Figure 2-2. The construction of the pump is shown in Figure 2-3. As the pump is slightly below the level of the lube service tank draw-off or discharge opening, oil flows to the pump under a slight pressure. The job of the high-pressure pump is to boost this slight pressure to a pressure of 35 to 40 pounds and send the oil on through the pressure system.

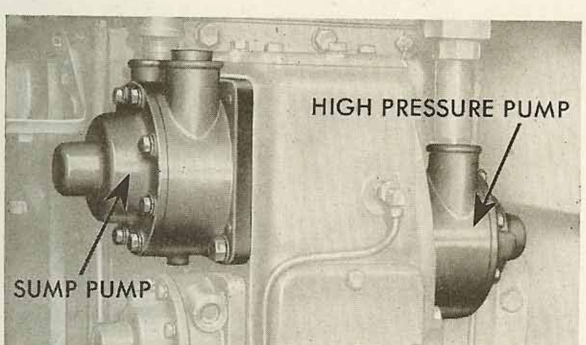


FIGURE 2-2

This pump has a hollow cylinder called a rotor, because it is rotated by gears driven from the engine crankshaft. The circular rim of the rotor has slots cut in it. The fit of the pump housing to the sides of the rotor is close, or, in other words, the clearance is small. At the top and bottom of the rotor the housing has shoes, which also have very little clearance from the rotor. The close fit at the rotor sides, and at these shoes, has the effect of dividing the pump housing into two chambers. Oil can pass from one to the other only by going through the rotor, with the exception of the small amount leaking through the clearances.

Inside the rotor there is an idler gear and a crescent. The idler gear is not driven by its shaft but is free to idle on it. Both idler gear and crescent are supported on a circular plate that is free to revolve one-half turn.

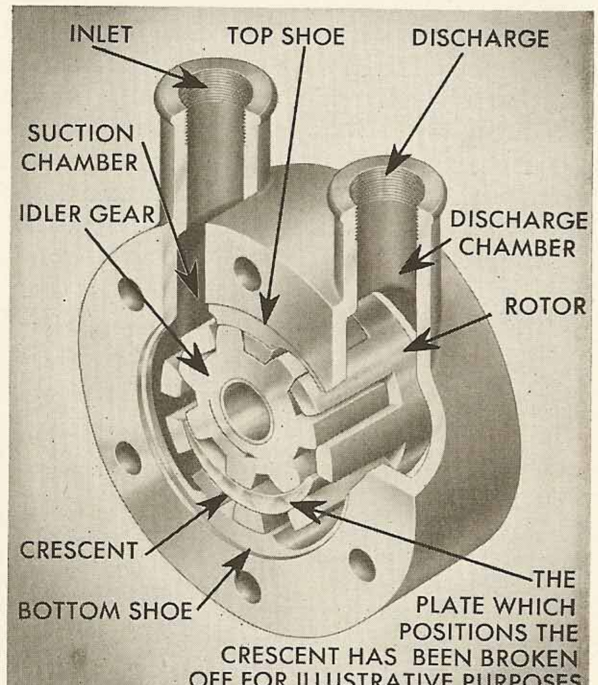


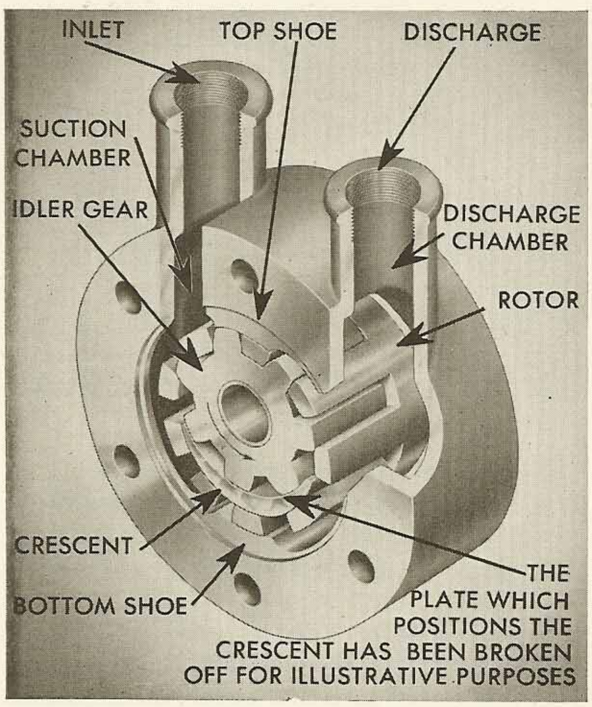
FIGURE 2-3

The idler gear has teeth which fit into the slots in the rotor. Because the idler gear is mounted off center from the rotor and is smaller than it, some of the idler gear teeth are engaged in the rotor slots and some are out. As the rotor turns it causes the idler gear to turn because of the teeth that are engaged. But the idler-gear teeth are constantly entering, filling and then leaving these slots. Study of Figure 2-3 will show that the idler-gear teeth are leaving the rotor slots in the half of the pump shown as the suction chamber. As the teeth leave these slots, oil is drawn into the slot spaces by suction. As the slots rotate on around, and as the idler gear turns, this oil is carried along in the slots and between idler-gear teeth, and is eventually moved past the shoe that divides the suction chamber from the discharge chamber. In the discharge chamber the idler-gear teeth are entering the rotor slots and closing them up, thus forcing the oil out into the chamber itself. In this way oil is continuously drawn into the rotor and idler gear from the suction chamber, carried around to the discharge chamber and forced out into that chamber.

As the main engine reverses its direction or rotation to propel the ship astern, and the pump is driven from the crankshaft, it follows that the pump must also reverse, but it must still pump oil from the suction chamber to the discharge chamber. When the pump reverses its direction of rotation, the plate on which the idler gear and crescent are mounted tends to turn with the rotor. It is free to make a half turn and does so, thus reversing the position of the idler gear and crescent. The plate comes up against a stop, and cannot go beyond the half turn of travel. Now, although the rotor and idler are turning in the opposite direction, the idler-gear teeth are still withdrawing from the rotor slots on the suction-chamber side and entering them on the discharge side. When the engine reverses again, the rotor carries the gear and crescent back one-half turn to the original position. The two positions of the idler gear and crescent are shown in Figure 2-4.

6. PRESSURE-REGULATING VALVE: It is essential that the engine constantly receives sufficient oil at the right pressure. That result is attained by selecting a high-pressure pump, large enough so that it delivers more oil than needed and at a pressure higher than necessary. The supply and pressure are reduced to the desired amounts by the action of a pressure-regulating valve. This valve is shown in Figure 2-5 on the opposite page.

It is a valve constructed so that oil pressure tends to open it, while a spring exerts a pressure to hold it closed. It will open whenever the oil pressure overcomes the spring tension. When it opens it bleeds off some of the oil from the discharge side of the pump and sends it back through a by-pass line to the lube service



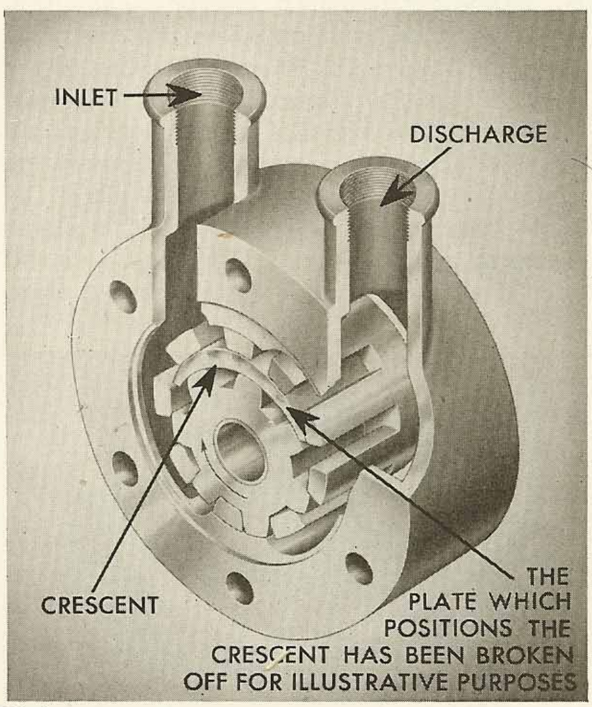


FIGURE 2-4

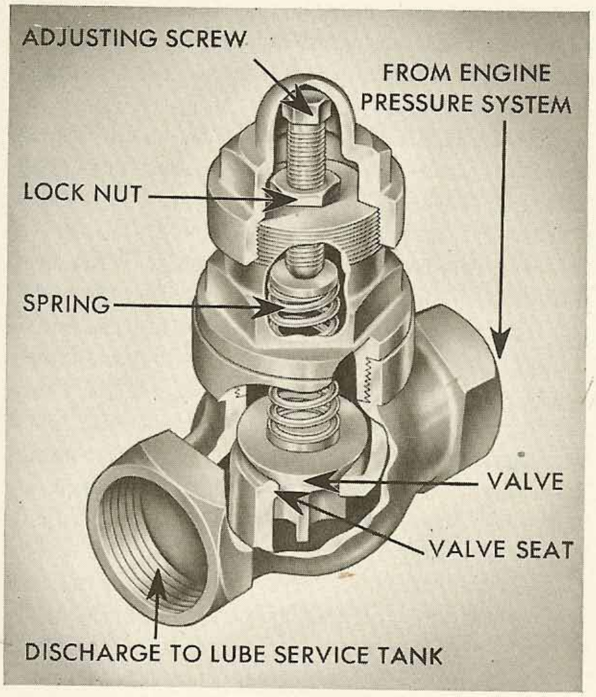


FIGURE 2-5

tank, where it enters the tank through one of the top openings. The spring tension in the pressure-regulating valve is adjustable—a higher tension means a higher oil pressure to open the valve, a lower tension means a lower oil pressure. This adjustment should be such that when the engine is hot the oil pressure reads from 35 to 40 pounds on the pressure gauge.

7. VARIATIONS IN OIL PRESSURE: When the engine has been standing idle and the oil is cold, the pressure reading on first starting up will be higher—sometimes as high as 65 pounds. As the engine warms up and the oil thins, the reading will drop, but should hold to 35 or 40 pounds. If the oil pressure falls much below these limits while the engine is operating, it is a sure sign of trouble of some kind. The trouble may be a burned-out bearing, a broken oil line, a stuck pressure-regulating valve, a broken pressure-regulating valve spring, no oil in the lube service tank, or failure of the high-pressure pump. In any event look for the cause if the oil pressure should drop below 30 pounds; and if it should fall below 20 pounds, shut the engine down immediately. Thoroughly inspect all external oil equipment and piping to make sure the oil is not leaking out of the system.

After an engine is some years old, the bearing clearance will be increased by wear, the oil of the pressure system will escape from the bearings more easily, and the pressure, if not stepped up by adjusting the pressure-regulating valve, will gradually drop. That is not a condition likely to come about in a new engine, but when the engine becomes older the pressure-regulating valve should be adjusted as needed to hold oil pressure within the 35 to 40 pound limit.

8. OIL FILTER: The discharge from the high-pressure pump and pressure-regulating valve is not piped directly to the engine bearings but is first put through two auxiliaries. The one to which the oil goes first is the oil filter, shown in Figure 2-6.

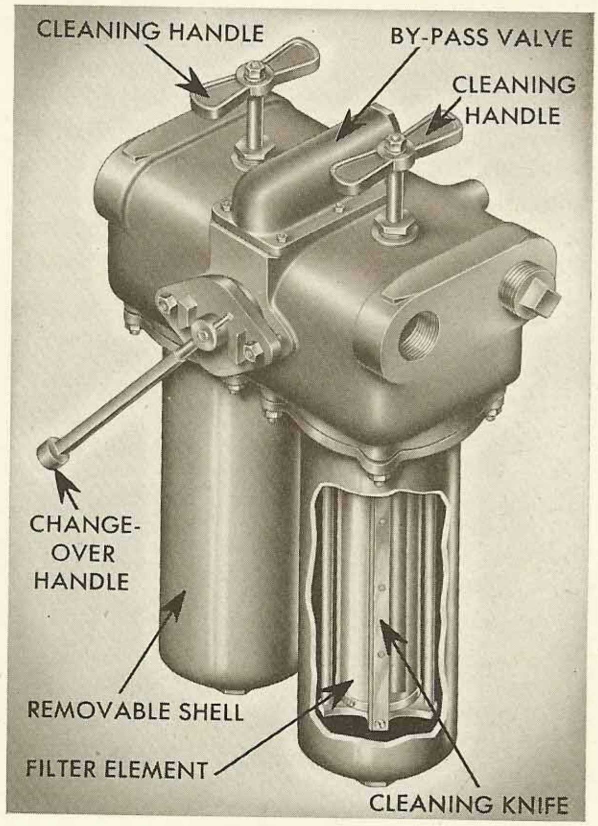


FIGURE 2-6

This filter is of a duplex type. In other words, it is really two filters, with piping and valves hooked up so that one side or the other operates, but never both at once. This permits the cleaning of one side while the other is in use. The filter has a plug valve, or round plug that can be rotated by a lever or handle from one position to the other. In the one position of the handle, one half of the filter is connected through to the high-pressure oil pump and the oil cooler; with the handle in the other position, the other half of the filter is connected.

Each half of the filter has a body or shell. The oil from the high-pressure pump enters this body. In the center of the body is a stack of thin discs known as the filter element. Oil can pass from the outer body of the filter into the outlet from the filter only by passing through the close clearances between the discs. This clearance is about one-thousandth of one inch (0.001 inch). Any dirt particles with a dimension greater than 0.001 inch will be stopped at the outside of the disc stack.

Most of the dirt particles filtered out by the discs will fall to the bottom of the body, but some will adhere to the outer edges of the discs. In order that such particles may be cleaned off periodically, there is a knife that bears against the outside of the stack of discs. A handle at the top of the filter turns the stack and causes the knife to scrape any dirt from the outside edges. This handle should be given one full turn once each day. **Once each week the filter that was used in the week preceding should be cut out and taken apart for cleaning.**

9. FILTER BY-PASS VALVE: In the top of the filter there is a by-pass valve. Anything called a "by-pass" could be likened to a road detour—it permits flow around something. As it is possible for the filter half in use to become plugged to the point where oil passes through it with great difficulty, so that the engine bearings might be starved for oil, the by-pass valve is provided so oil can go around, rather than through the filter. This is a valve kept closed by a spring (spring-loaded valve), on the same principle as the pressure-regulating valve. If the filter becomes plugged, resistance to oil flow will cause the oil pressure to build up. The increased pressure will overcome the spring tension and the by-pass will open, permitting oil to flow around the filter.

10. OIL COOLER: The other auxiliary through which the oil passes before being piped to the engine bearings is the oil cooler. As the oil makes a complete circuit of the system in less than two minutes it absorbs considerable heat from the engine. This tem-

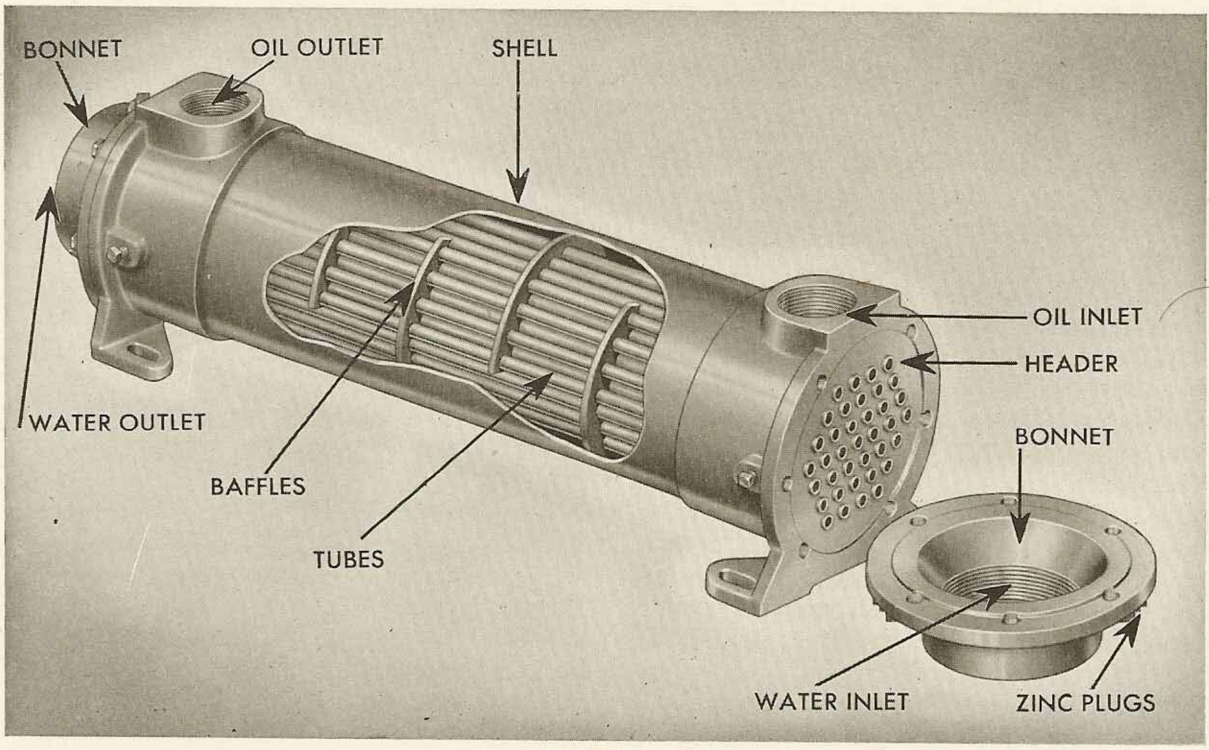


FIGURE 2-7

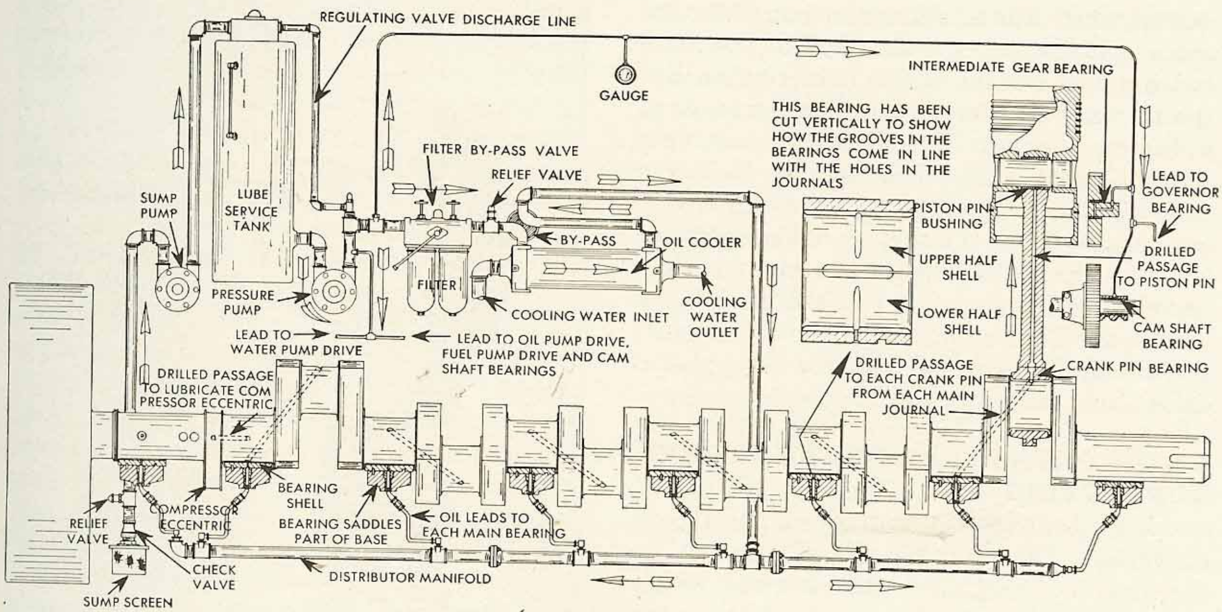


FIGURE 2-8

perature will vary with the condition of the engine, the load it is carrying and the climate the engine is operating in. As it is desired to hold the operating temperature of the oil below 160 degrees Fahrenheit, the cooler is used to dissipate the excess heat. This very simple auxiliary is shown in Figure 2-7.

The cooler consists of a tank, usually called the shell, with circular heads at each end. Each head (the heads are called headers or tube sheets) has a number of holes drilled in it, and tubes run from the holes in one header to corresponding holes in the other. Chambers, called bonnets, bolt on the ends of the shell. Each bonnet has a water connection. Water is piped to the water inlet on one bonnet, enters the tubes of the header on that end, passes through the tubes and out the opposite header, and is piped away through the water outlet of the bonnet on that end. The shell has two oil connections, one for inlet and one for outlet. Oil cannot flow directly from inlet to outlet inside the shell because there are plates, called baffles, so placed that the oil must pass back and forth through the tube bundle. The circulating water flowing through the tube bundle keeps it cool and much of the heat in the oil is removed as it passes around the tubes.

The cooler is provided with a by-pass that can be operated by hand. If there is work to be done on the cooler, the by-pass can be cut in so oil flows around the cooler, and the latter can be taken apart without shutting the engine down. Water passing through the tubes may leave scale deposits or mud in them, so, periodically the bonnets should be removed and the tubes cleaned with a round wire brush. The tubes should be inspected about once in six months to see if they need cleaning.

11. DISTRIBUTOR MANIFOLD: The oil is now filtered and cooled, and is ready to be delivered to the engine bearings. It is desirable that it be divided up more or less equally between the main bearings, and to do that there is a large pipe running the length of the engine base and at the bottom of it. The oil is delivered to this pipe, which is called the distributor manifold. Any "manifold" is a pipe or long narrow chamber with a number of smaller pipes or outlets leading from it, in this case, to the main bearings. This piping arrangement is shown in Figure 2-8.

12. OIL PATH THROUGH MAIN BEARINGS: The oil pipe to any one main bearing delivers oil to the bottom of the bottom-half bearing shell. The shell has a hole in it, so that the oil passes through the shell to the main bearing and journal, which it lubricates. But the bottom-half bearing area has a groove cut in it over almost a half circle, and the main journal has a drilled hole leading from the center of the journal through the crank web, and coming out at the surface of the center of the crank pin. The hole in the main journal travels over the groove in the bottom shell for almost one-half revolution of the crankshaft, and during that time oil is forced through the drilled hole to the crank pin.

13. OIL PATH IN THE CRANK PIN AND CONNECTING ROD: The top half of the crank pin bearing is also grooved, and the oil delivered to the crank pin fills this groove. At the center of this groove there is a hole which is drilled the length of the connecting rod up to the piston-pin bushing. Oil travels up this hole to lubricate the piston pin. This construction is shown in Figure 2-9.

At the lower end of the connecting rod drilled hole there is a check valve. This is a valve constructed so oil can flow up, but not down, the drilled hole. This valve is installed to keep the hole full of oil while the engine is shut down, as otherwise it would drain back through the drilled hole in the crankshaft into the engine base. Then, in starting up, the piston pin would receive no lubrication until the whole system filled up, whereas with the check valve, part of the system is kept full and the flow of oil to the pin begins much sooner.

14. OIL PATH IN THE PISTON-PIN BUSHING: The outside of the piston-pin bushing has a groove cut around the entire circumference, and the oil coming up the rod fills this groove. The groove communicates with the inside of the bushing by two holes. Oil passes through these holes, and is distributed over the surface of the piston pin by suitable grooving on the inside of the bushing.

15. OTHER BRANCHES OF THE PRESSURE SYSTEM: Several other locations on the engine are lubricated from the pressure system. A lead goes from the distributor manifold to the rear camshaft bearing. Other leads lubricate the cam idler gear and the eccentric that drives the air compressor. These

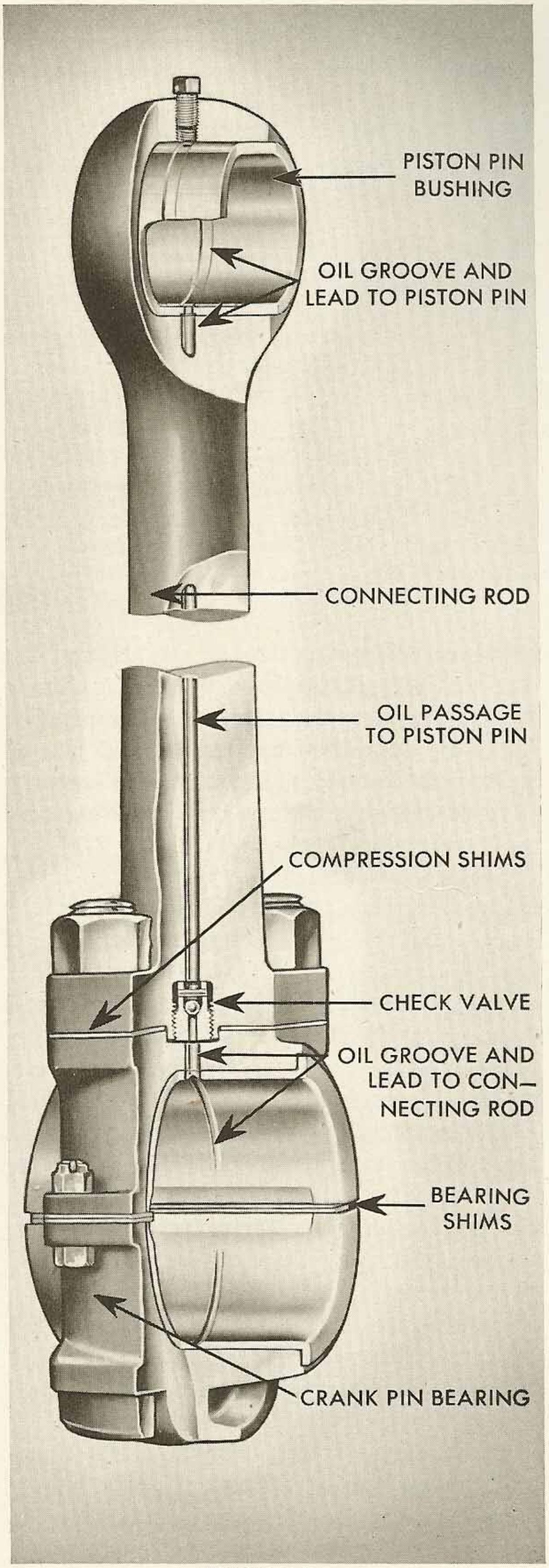


FIGURE 2-9

leads can be seen in Figure 2-8. (An eccentric is a circular disc mounted off center on a shaft. As the shaft revolves, the eccentric gives a reciprocating, or back and forth, motion to some driven machine by means of an eccentric strap, which goes around the circumference of the eccentric, and the eccentric rod.)

16. ESCAPE OF OIL FROM BEARINGS: No bearing is without clearance and oil will not stay in any bearing indefinitely. The oil that is pumped to a bearing lubricates it and eventually escapes from the bearing ends. This end leakage of oil occurs at the main bearings, crank pin bearings and piston-pin bearings, as well as at the other bearings supplied from the pressure system. Some of this oil leakage is splashed up on the lower part of the cylinder walls and helps to lubricate them. Some is splashed to the intermediate camshaft bearings and other working parts inside the engine. All of the oil, however, sooner or later, drains down to the engine base.

17. OIL SUMP: The bottom of the base has a slight slope from the forward end down to the after end, where the oil sump is located, as shown in Figure 2-8. The oil runs back to the sump, collects, and is picked up by a pump constructed exactly like the high-pressure oil pump, but is called the sump pump, and sometimes the scavenging pump. This pump delivers the oil back to the top of the lube service tank, where it is screened before entering the body of the tank.

The sump pump suction line is equipped with a foot valve, a screen and a relief valve. The screen prevents solid matter from entering the pump. The foot valve is merely a check valve at the bottom end of the suction pipe leading from the sump to the pump. It keeps the suction pipe full of oil while the engine is stopped. The screen should be removed and cleaned whenever the engine base is cleaned.

As the sump pump reverses whenever the engine reverses, pressure might be built up in the suction line against the foot valve during the short time required for the idler gear and crescent to turn into the reversed position. The relief valve, set to open and return oil to the sump, if suction-line pressure builds up, is a safeguard.

18. OIL LEVEL IN LUBE SERVICE TANK: There is usually no shut-off valve between the lube service tank and the high-pressure oil pump, for the very good reason that the operator might forget to open such a valve on starting the engine. If the engine stands for a long time without running, and the high-pressure pump is somewhat worn with the clearances opened up, it is possible for the oil in the lube service tank to drain through the pump, filter, cooler and main bearings into the engine base. If that happens, the operator, in getting ready to start, will notice that there is no oil in the lube service tank. But if he fills it without first finding out if the engine base is full or empty of oil, he may overfill the system. The sump pump will proceed to pump oil to the lube service tank and the tank will overflow. So if the oil level has disappeared in the lube service tank gauge it is wise to take off the rear cover plate from the base to check the oil level inside. If the level is high enough to indicate that the lube service tank contents are in the base, start the engine and let it run for a time before attempting to add oil. Of course, if there is only a little oil in the sump, you should add oil to bring the lube service tank level about half way up, start the engine and wait until the tank gauge level becomes stable. Then oil can be added, if required, to bring the level to within three to four inches of the top of the gauge.

In a new engine the oil level in the lube service tank often rises. This is because the engine burns up very little of the oil of the pressure system, but the oil fed to the cylinders (by means which will be described) is constantly draining to the base and augmenting the pressure system supply. If there is a constant rise in the oil level during operation, you should remove enough oil at the time of the daily lube service tank draining, as discussed in paragraph 4, to lower the level to the recommended point.

19. MECHANICAL LUBRICATOR: (Sight-feed system) The power cylinders of the engine are lubricated by a mechanical lubricator. It is made up of a group of pumps, one set of two pumps for each cylinder, and all assembled in a housing, and driven from a

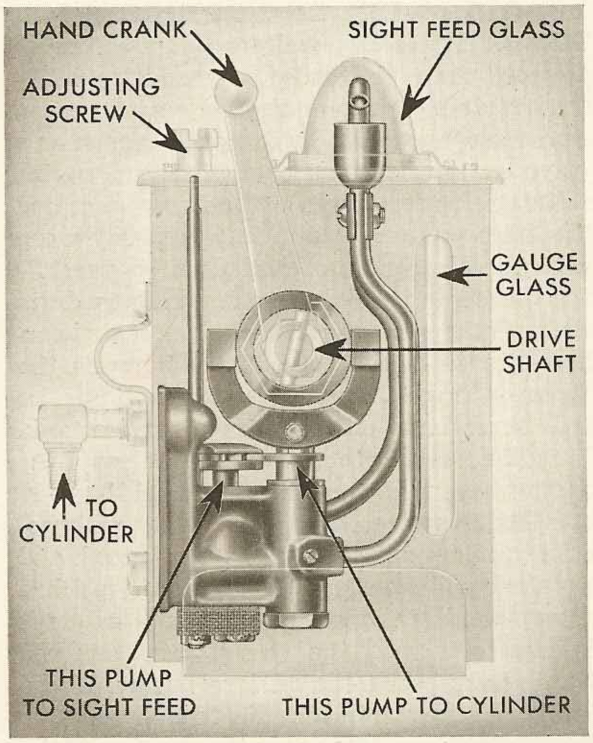


FIGURE 2-10

shaft with an eccentric for each set. The shaft is driven by an eccentric on the end of the engine camshaft.

The first pump of each set draws oil from the lubricator reservoir, and forces it up to the top of the case where it escapes in drops from a small pipe. These drops can be seen through the glass front of the lubricator. The drops drain into a second chamber, which acts as the suction chamber for the second pump, which picks up the oil and forces it through piping to the cylinder it serves. The mechanical lubricator has adjusting screws, one for each set of two pumps, and the rate of drop feed can be regulated by these screws. For a new engine the rate should be from 25 to 30 drops per minute per cylinder. After the engine is well worn in, say after 500 hours of operation, the rate should be reduced to from 15 to 20 drops per minute per cylinder.

The mechanical-lubricator oil supply should be replenished with NEW OIL ONLY. The amount of oil in the lubricator is indicated by a gauge glass at one corner, and you should check the level every four hours, adding new oil if required.The level should be carried high, as the eccentrics which operate the pumps are lubricated directly by the oil in the reservoir. When the level is low the eccentrics receive no lubrication.

20. OIL PIPING TO CYLINDERS: The oil is piped to each cylinder by copper tubing. At the cylinder the piping is branched, with one line running to one side of the cylinder and the other going to the opposite side. The oil passes through the water-jacket space in a metal tube that screws into a hole in the cylinder liner. This tube is packed with rubber rings, called grommets, where it passes through the cylinder. This construction is shown in Figure 2-11. Whenever a liner is removed from a cylinder this tube should first be unscrewed and removed.

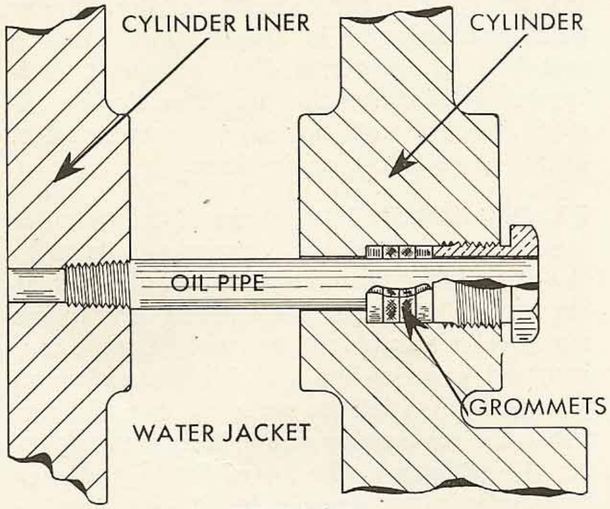


FIGURE 2-11

21. THRUST-BEARING LUBRICATION: Figure 2-12 shows the Kingsbury Thrust Bearing which operates within a housing and is lubricated from an oil supply in the base of the housing. The oil level should be carried high enough to cover the lower part of the thrust collar, but not high enough to touch the thrust shaft. A gauge glass at the side of the housing indicates the oil level; if oil shows in the gauge glass there is enough oil in the housing. The collar rotates in the oil bath, picks up the oil and carries it up to a scraper that wipes the oil from the collar and directs it to the faces of the collar and fore and aft sets of thrust shoes.

The oil in the thrust-bearing housing should be drained every 500 hours of engine operation. The time to drain is just after the engine

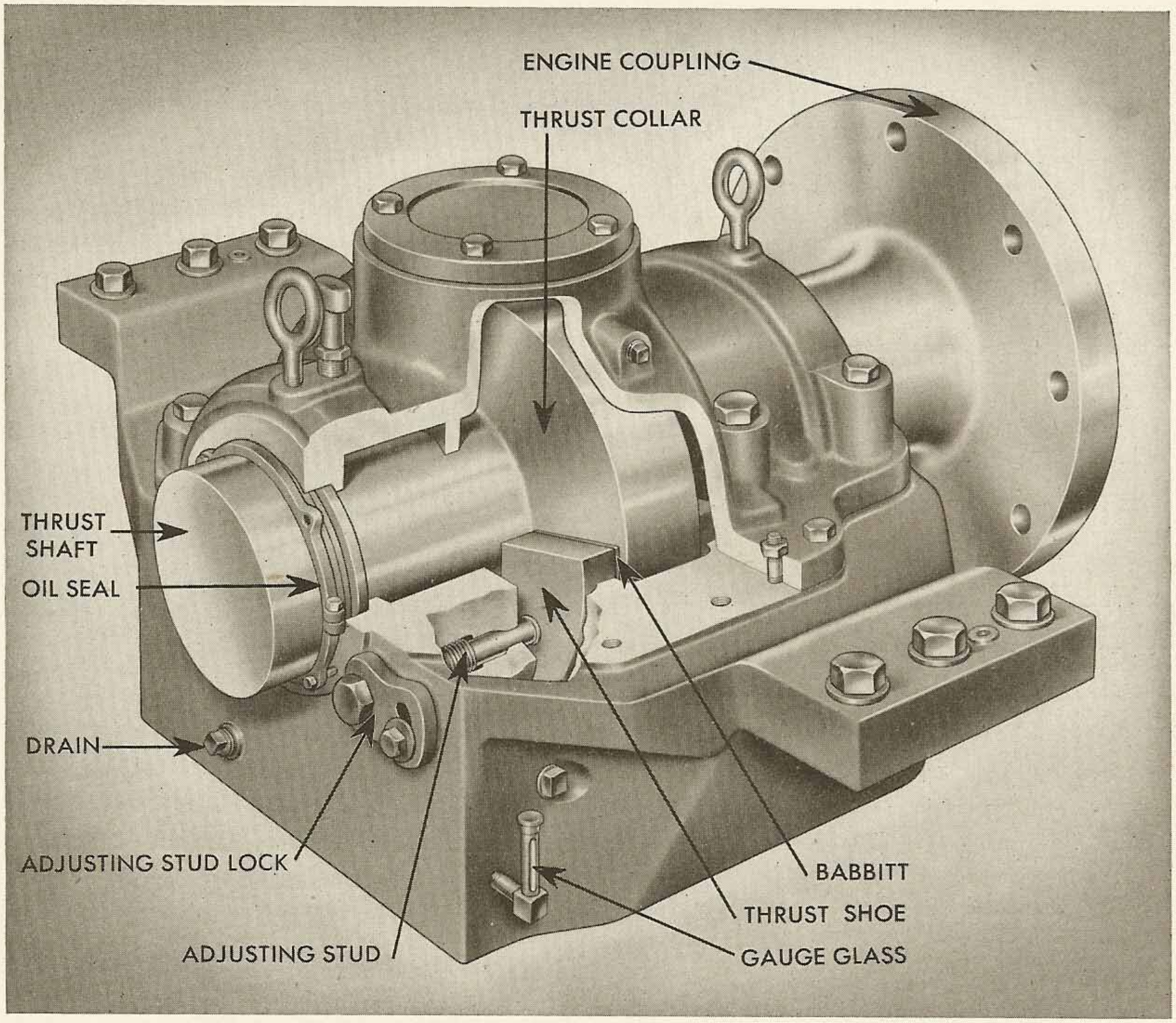


FIGURE 2-12

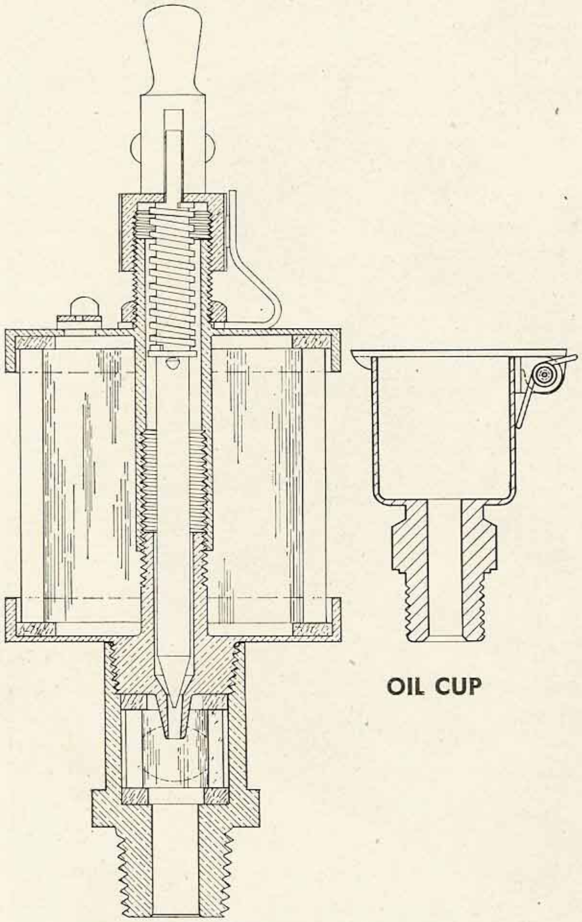
has been running so that the oil is warm. The housing should then be refilled with new oil until the oil level shows in the gauge glass.

22. HAND OILING: Some parts of the engine have recesses which are packed with waste to take oil. The bilge-pump drive shown in Figure 2-13 is an illustration. Such recesses should be oiled once every four hours of operation. The waste should be removed once a month, the recess should be cleaned, and fresh, clean waste used to repack.

FIGURE 2-13

There are a number of places on the engine and its auxiliaries that cannot be conveniently connected to the pressure system and must be oiled by hand. Such places may be fitted with oil cups. Some oil cups are to be filled with waste, oiled once in four hours of operation, and, of course, the cover should be kept closed when not actually adding oil. Figure 2-14 shows an oil cup and a sight-feed oiler.

If your engine has a reciprocating water pump, there will be a sight-feed oiler on the pump crosshead. This should be checked for oil supply once each four hours and filled if necessary. This type of oiler has a needle valve that can



SIGHT FEED OILER
FIGURE 2-14

be raised by a stem lifter that extends through the top. When the stem is lifted the needle valve is open and oil drops from the oiler to the bearing or part being lubricated. A sight glass shows the oil drops and there is an adjustment for increasing or decreasing the rate. For the pump crosshead the feed should be about ten drops per minute.

There are bearings that are oiled through an oil hole, as shown in Figure 2-15. These bearings should be oiled once every four hours of operation, using a hand oil can.

There are other places where a cup or waste-packed reservoir would not be convenient, and oil must be dropped on the working parts from a hand oil can.

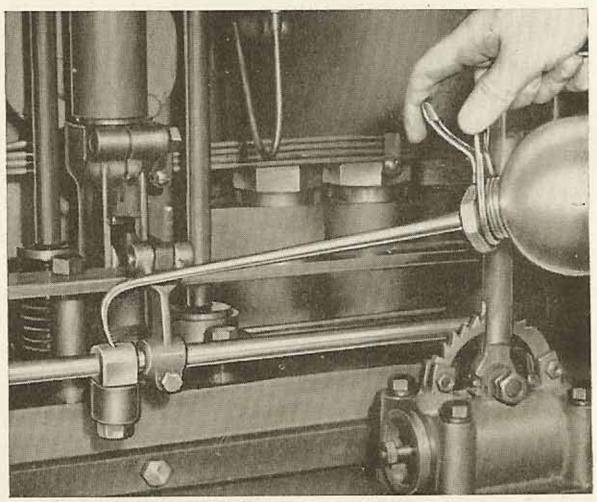


FIGURE 2-15

23. OILING ROUTINE: In this section we have been concerned primarily with the reason for the engine lubricating system and how it works. We have given some rules about pressures and frequency of oiling, but have not been particularly concerned about specifying all of the oiling routine. That subject comes more appropriately under the subject of operation, and in Section 6 we shall include all directions for routine lubrication.

SECTION 3
ENGINE COOLING SYSTEM

1. FUNCTION: The function of the engine-cooling system is to cool the engine parts that absorb heat from the combustion gases. These are the cylinders, cylinder heads, and exhaust valves. If they were to be left uncooled, these parts would rapidly burn dry of lubricating oil and the moving surfaces would stick fast. There are also auxiliary functions of the cooling system; such as, cooling the oil of the pressure system (see Section 2), cooling the air compressor, which supplies compressed air for starting and maneuvering, and cooling the exhaust manifold. While the exhaust manifold has no moving parts, it contains exhaust gases up to 725 degrees Fahrenheit which require cooling. As was pointed out in Section 1, compressing air generates heat, so it is necessary to cool the air compressor. Certain engines are equipped with a type of thrust bearing which requires cooling. Other engines use water cooling for the entire length of the exhaust pipe.

2. TYPES OF COOLING SYSTEMS: Several different types of cooling systems are used with Atlas engines. In writing this book, we cannot know which type you will have in your installation, so we shall describe them all and leave it to you to select the description that fits the cooling system on your engine. These types are:

- Raw-water cooling
- Raw-water recirculating cooling
- Fresh-water cooling

"Raw-water" in this connection means the water in which the ship floats, whether that be salt, brackish, or fresh water. "Fresh-water" means a supply of water which is carefully protected against dirt and loss on shipboard, and may often be a soft water, such as collected rain water.

The principal parts and general layout of a raw-water system are illustrated in Figure 3-1.

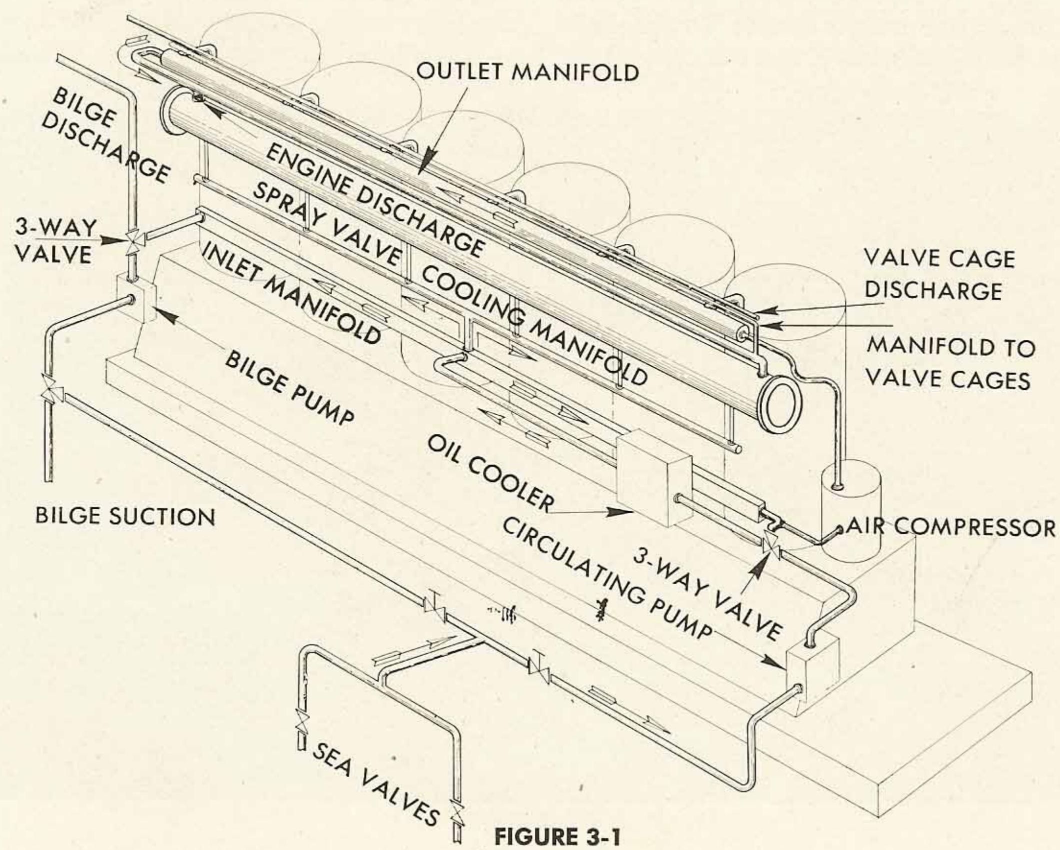


FIGURE 3-1

3. RAW-WATER SYSTEM: A raw-water cooling system is the easiest to install, but it is more likely than the others to result in scale or mud deposits in the engine jackets. The essential parts of a raw-water system are: a sea valve in the ship's hull below the water line to admit water; a raw-water circulating pump; manifolds and piping on the engine; a hull fitting or opening through the hull above the water line for the discharging overboard of water; and pipe, valves and fittings for connecting the various parts of the system. Figure 3-1 shows the principal items in a raw-water system.

4. SEA VALVE: The sea valve controls an opening in the hull below the water line. There is usually a strainer fastened to the outside of the hull and covering the hole leading to the sea valve. This is a plate pierced with holes or slots, and its purpose is to strain out rubbish and prevent its entry into the system. On a steel hull, there is usually a sea chest or box riveted or welded to the inside of the ship and located below the water line. The outside wall of this chest, which is a portion of the ship's side, is constructed of bars spaced equally so as to form a strainer. Wooden hulls are seldom so equipped. If there is a sea chest, it will have an opening inboard and the sea valve will be flanged to the chest (or a flange on the valve bolts to a flange on the sea-chest opening). If there is no sea chest, the hull opening itself is flanged to the sea valve. The two types of suction openings are illustrated in Figure 3-2.

THE SEA VALVE MUST BE OPEN WHENEVER THE ENGINE OPERATES, for when closed, it prevents water from entering and would, therefore, stop the flow or circulation of water through the cooling system. The sea valve should be closed only when the engine is to be overhauled; work is to be done on the cooling system; or the ship is to be laid up for a long period.

The sea valve is usually operated by a hand wheel. To open it, you turn the wheel in a direction opposite to the movement of the hands of a clock (counter-clockwise); to close it, you turn it clockwise.

5. RECIPROCATING RAW-WATER CIRCULATING PUMP: The pump shown in Figure 3-3 is used on an Atlas engine intended for a raw-water system and is called a reciprocating pump because the piston moves back

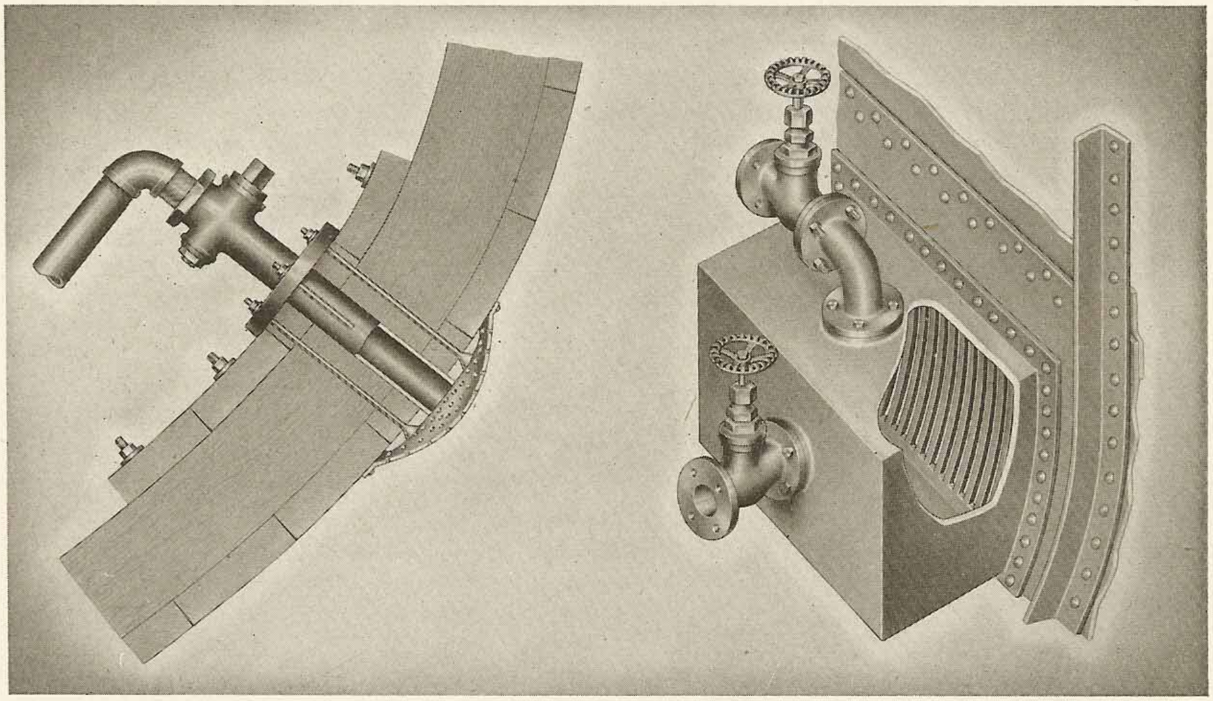


FIGURE 3-2

and forth. It is also called double acting because it is really two pumps with each end of the piston functioning for one cylinder.

A small gear on the engine crankshaft drives a larger gear, which drives a short shaft extending through the aft face of the frame of the engine and ending in a pump-drive crank pin. This crank pin actuates a pump-drive connecting rod. The other end of the connecting rod is attached to the pump crosshead, which moves back and forth in a crosshead guide. This crosshead moves the pump piston by means of a piston rod.

As both ends of the pump operate on the same principle, let us consider the end next to the crosshead. As the piston goes away from the crosshead, it increases the volume of that end and creates suction. Suction tends to hold the discharge valve on its seat but it lifts the suction valve, which is held down by light spring pressure, easily overcome by suction. Water enters through the suction valve and fills the space created as the piston moves along the cylinder. At the end of the stroke, the piston reverses and moves toward the crosshead. This creates pressure and forces the suction valve down on its seat. Pressure in the pump forces the discharge valve open against its spring and water is forced out of this valve and into the line. The operation just described is duplicated at the other end of the piston on each stroke. So while one end is discharging the other end is drawing in a cylinder full of water.

6. PISTON LEATHERS: As it is desirable to have the fit of the piston in the pump cylinder as water-tight as possible, the piston has two piston leathers, one near each end. The leathers are faced towards the respective ends of the piston so that the discharge-stroke pressure expands the cupped part against the cylinder wall.

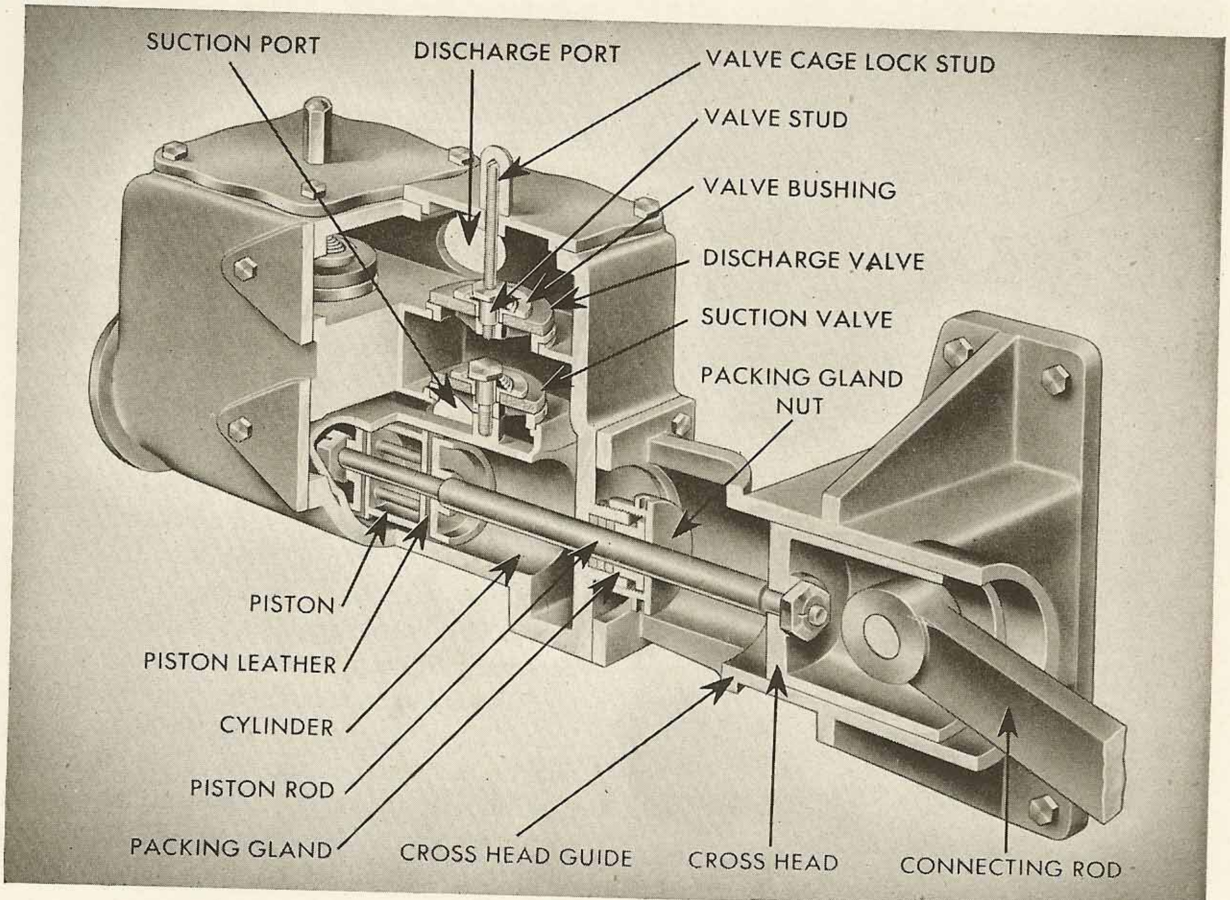


FIGURE 3-3

7. PISTON-ROD PACKING: The piston rod must be packed to prevent excessive leakage where it enters the pump. This is done by surrounding the rod with packing, which is made of fabric rings, impregnated with graphite. Packing of this kind usually comes in long coils. This packing should be cut into lengths just long enough to go around the piston rod once and the ends of each ring should be cut on an angle so that a lap joint is made. These rings should be cut so that the ends are just short of touching. This allows for expansion when the packing is compressed by the packing gland. Metallic or dry flax packing should not be used as scoring of the piston rod may result.

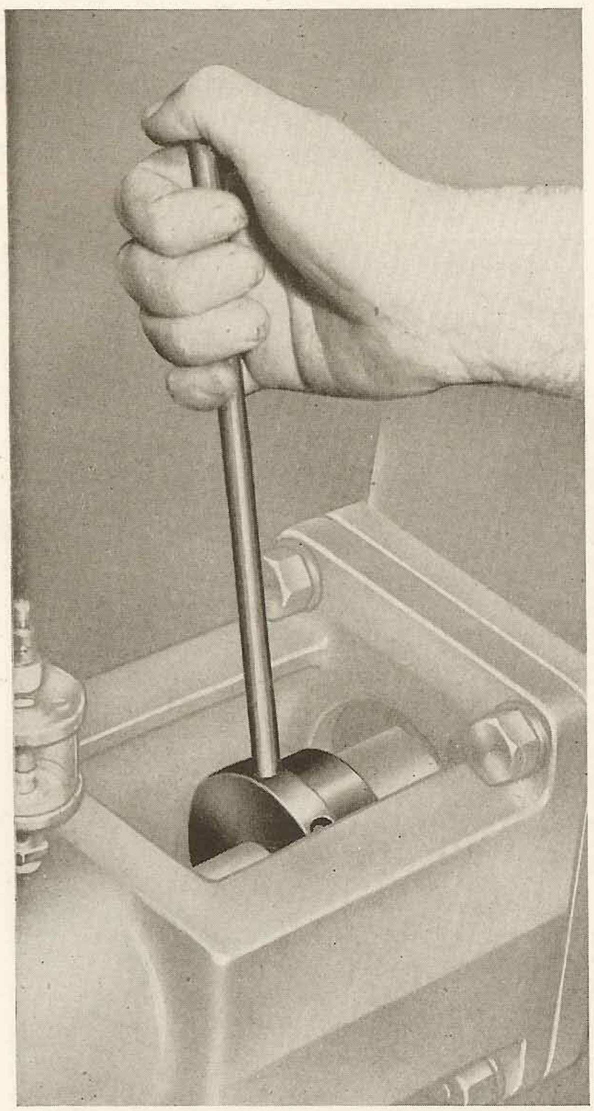


FIGURE 3-4

In removing old packing with a hook, be very careful not to score the rod. When inserting new packing, stagger the joints. If the bottom ring has a joint at 12 o'clock, put the next in at three, and the next at six, etc.

The packing is compressed in the packing box by a gland which is forced into the box against the packing by a packing gland nut, or thimble, threaded on the inside and engaged by threads on the outside of the box. The gland nut has holes in its rim so that it can be turned in the manner shown in Figure 3-4.

It should be turned clockwise to tighten, in other words, it has a right-hand thread. This gland nut should not be tightened sufficiently to stop water leakage entirely; there should be several drops of water per minute escaping. If the escape of water from the gland is excessive, no matter how tightly the gland nut is screwed down, the packing has lost its "life" and should be renewed. If new packing does not stop excessive leaking, it is likely that the piston rod is scored. If so, it should be replaced.

8. AIR CHAMBERS: The pump discharge fluctuates, or varies. When the piston is at either end of the stroke, the discharge, momentarily at least, is nil, but the discharge increases in rate as the piston moves down the cylinder, reaching a maximum as the piston passes the half-way point. To cushion these fluctuations, and prevent water hammer, air chambers are provided, one in the suction and one in the discharge side of the pump. The chamber on the suction side is fitted with a ball check, or snifter valve, and a pet cock. When the pet cock is opened, air is admitted to the chambers with each suction stroke of the pump. This valve should be opened as often as necessary to keep the chamber charged with air. Water hammer in the system indicates a lack of air in the chamber and the snifter valve should be opened. If the pet cock is left open continuously it should be opened just enough to prevent water hammer. If left wide open the pump capacity is lowered and the engine may not receive enough cooling water.

9. RELIEF VALVE: When a reciprocating pump discharges water, the water must go somewhere. If the line should be closed, either by an obstruction or an overlooked closed valve, the result would be a burst pipe, or a broken pump or pump drive. To guard against any such possibility, a relief valve is put in the discharge line. This is a spring-loaded valve set to open if the water pressure materially exceeds the normal working pressure, which is between five and fifteen pounds per square inch.

10. OIL COOLER: The discharge from the pump is piped to the oil cooler, which was described in Section 2. If the oil cooler is to be cut out for any reason a by-pass valve is installed which will direct the water around the cooler and to the engine inlet water manifold.

11. INLET-WATER MANIFOLD: The water leaving the oil cooler is piped to a manifold running the length of the engine, called the inlet water manifold. This has openings along its length for supplying water to the various cylinders and other parts. By turning a three-way valve, the discharge of the bilge pump can be directed into this manifold. Providing the bilge pump is connected to the sea, this water can be used to assist in engine cooling if part of the capacity of the circulating pump has been lost through accident. Bilge water, however, should never be pumped through the engine.

12. CYLINDER INLET PIPING: Where the inlet-water manifold passes each cylinder, a flanged opening leads from the manifold to the bottom of the cylinder-water jacket. The water flows up the jacket space as indicated in Figure 3-5. These cylinder-water jackets have inspection plates which can be used for the removal of scale or silt deposits.

13. CYLINDER LINER: From Figure 3-5 you can also see that the water-jacket space is formed by the liner itself on the inside and the cylinder on the outside. At the top, the liner has a flange or shoulder that rests on the shelf of a recess in the cylinder. A thin ring, or gasket, separates the bottom of the liner flange from the shelf of the recess. This gasket is made of thin paper. Gaskets are usually put between two faces if they are to be gas or water-tight, to fill up irregularities in the machined surfaces and to make a tight joint. Around the lower end of the liner are two rubber rings, called cylinder-liner grommets, which seal that end of the fit of the liner in the cylinder.

14. WATER BY-PASS PIPES: As the water flow reaches the top of the cylinder-water jacket space, it is led into the cylinder head through water by-pass pipes. These pipes are screwed into the top of the cylinder just outside of the cylinder-head gasket and between each cylinder-head stud. They project upward about one inch and fit loosely into corresponding holes in the cylinder head. To prevent any leakage from these pipes, rubber grommets are placed around each pipe before the cylinder head is put on. These are small rubber rings which just fit around the pipes. They are thick enough to be compressed, when the cylinder head is drawn down, and form a water-tight joint. Incidentally, rubber grommets should NOT be coated with any preparation, such as white lead.

15. OUTLET-WATER MANIFOLD: The water leaves the cylinder heads and is collected in an outlet-water manifold, which also extends the length of the engine. It is located just above and to the side of the cylinder heads.

16. SPRAY-VALVE COOLING: The fuel-spray valve, located in the center of the cylinder head, requires more cooling than is provided by the jacket water circulation, and special provisions are made to insure effective cooling. The valve fits in a recess in the cylinder head that is surrounded by the cylinder-head cooling water, but the temperature of this water has been increased by its trip up the cylinder jacket. So in order to obtain additional cooling, pipes lead directly from the inlet-water manifold and terminate in a jet in each cylinder head. This jet is directed at the wall of the spray-valve recess.

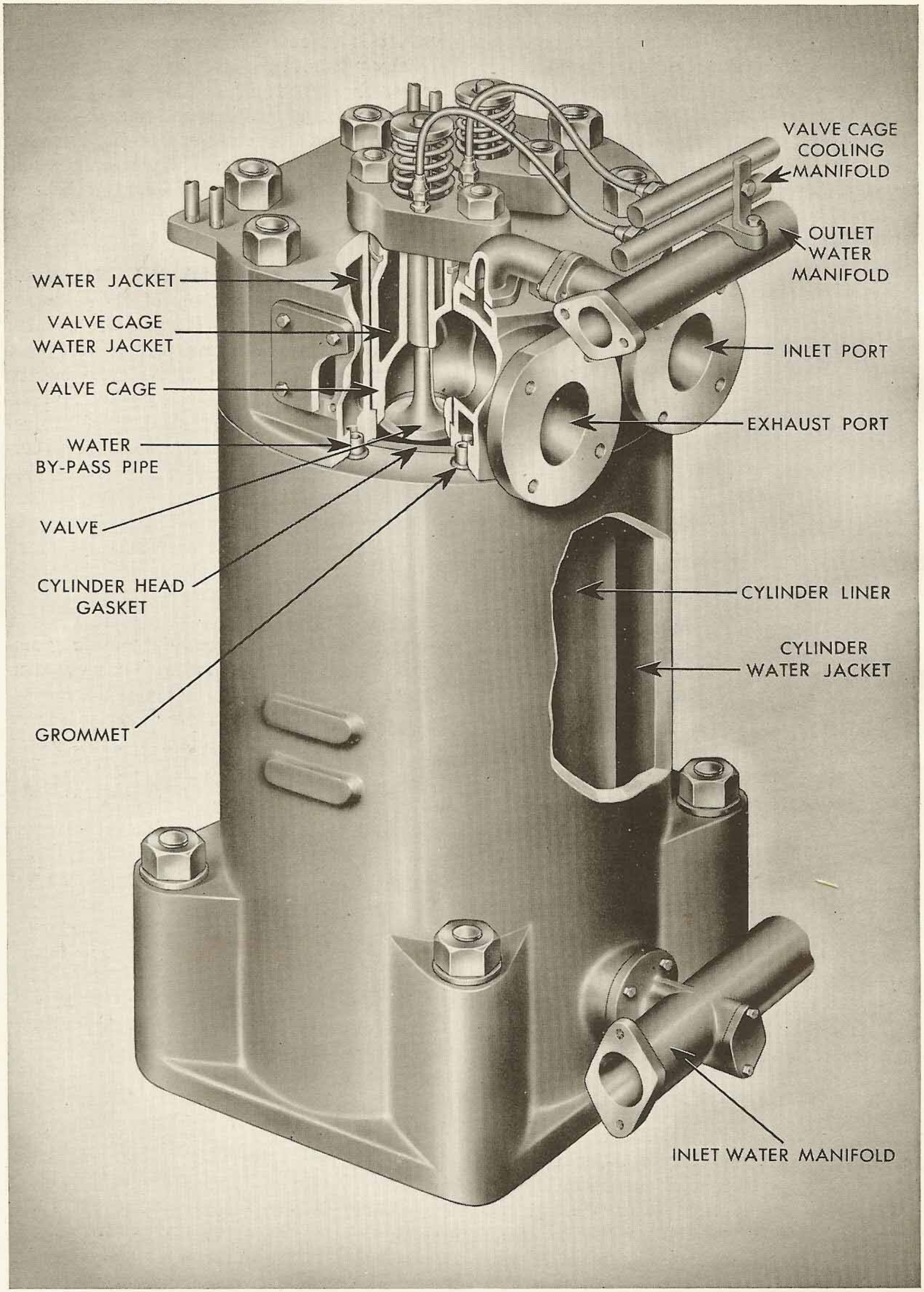

VALVE CAGE
COOLING
MANIFOLD
OUTLET
WATER
MANIFOLD
WATER JACKET
VALVE CAGE
WATER JACKET
INLET PORT
VALVE CAGE
EXHAUST PORT
WATER
BY-PASS PIPE
VALVE
CYLINDER HEAD
GASKET
CYLINDER LINER
CYLINDER
WATER JACKET
GROMMET
INLET WATER MANIFOLD

FIGURE 3-5

17. EXHAUST-VALVE CAGES: So that the inlet and exhaust valves may be ground and serviced without removing the cylinder heads, they are installed in removable cages which bolt into the heads. As the exhaust valves get very hot through their contact with the exhaust gases it has been necessary to provide the exhaust valve cage with water jackets. Each exhaust cage is connected by tubing to a small manifold which is supplied with water from the outlet water manifold. The discharge from the cages is collected in a pipe and led overboard. The inlet valves do not require cooling as the inrush of air, each time the valve opens, carries off excess heat. So that the valves and cages may be interchangeable, Atlas uses the same assembly for both exhaust and inlet. The inlet cages are dry as they are not connected to the cooling system.

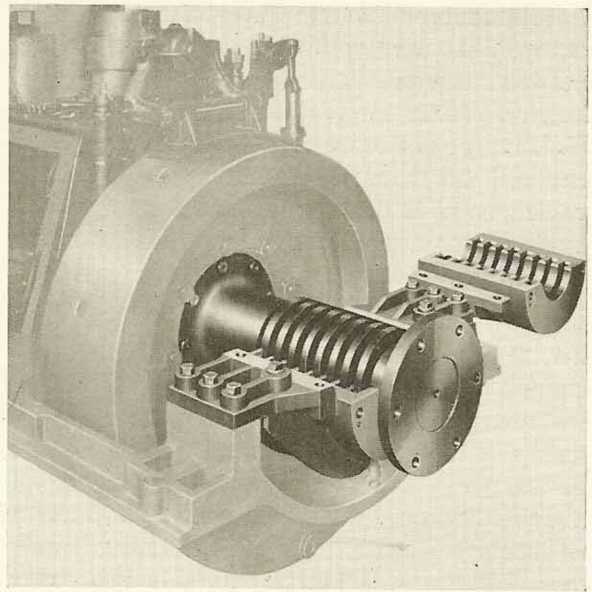


FIGURE 3-6

18. EXHAUST-MANIFOLD COOLING: The exhaust manifold, which collects the exhaust gases from the cylinders, is water jacketed, and water discharged from the outlet manifold is piped to this jacket. After the water traverses the exhaust-manifold jacket, the cooling in a raw-water system is completed. So the water discharge from the exhaust manifold is piped overboard through an opening called a hull fitting, which is usually above the water line. Often there is a glass fitting in the discharge piping, so that the flow of water is visible.

19. AIR-COMPRESSOR COOLING: The cylinder and cylinder head of the air compressor are also jacketed and water is piped from the inlet-water manifold to the bottom of the compressor-cylinder jacket. It passes up this jacket, goes through the cylinder head, and leaves through piping leading to the outlet-water manifold on the engine.

20. MARINE TYPE THRUST BEARINGS: Most Atlas engines have a thrust bearing of the Kingsbury type, which does not require cooling. A few, however, have marine-type thrusts, which have a number of thrust collars rotating in grooves. These bearings require cooling and if an engine is so equipped a pipe leads water from the engine inlet-water manifold to the thrust-bearing jacket, and the discharge water is led overboard. This type of bearing is shown in Figure 3-6.

21. TEMPERATURE RISE: Atlas engines equipped with reciprocating water-cooling pumps are designed for a temperature rise of about 35 degrees Fahrenheit. In other words, if the water going to the pump is at 70 degrees Fahrenheit, the water discharge from the exhaust-manifold jacket will be at about 105 degrees Fahrenheit.

22. SIMILARITY OF WATER-COOLING SYSTEMS: We have gone into some detail in describing a raw-water system for the reason that many of its parts are also found in the other two systems. As a matter of fact, to make a raw-water system into a recirculating system involves only a slight change.

23. RECIRCULATING SYSTEM: An engine equipped with raw-water cooling operates at best efficiency if the cooling water enters it at about 85 degrees Fahrenheit. The water in which the ship floats, however, may be at any temperature down to freezing, and it is advantageous to have a way of increasing its temperature. This can be done by installing a by-pass water line from the discharge line of the exhaust manifold to the suction pipe of the pump. With a valve in the pump-suction line, between the sea valve and the by-pass line, and a valve in the by-pass line itself, the proportions of water being drawn from outside the hull and from the engine discharge can be varied, so as to build up the temperature. The by-pass line and valves convert a raw-water system into a raw-water recirculating system.

24. DESIRABLE TEMPERATURES: Although engine efficiency is better with cooling water entering it at about 120 degrees Fahrenheit, salt water has a tendency to deposit salt in the jackets if it leaves the engine much above 120 degrees Fahrenheit. If you have a recirculating system and are operating in salt or brackish water, you should hold your inlet water below 85 degrees so your discharge will not exceed 120 degrees. If you are operating on a fresh-water lake, however, you can go to 120 degrees inlet and 155 degrees outlet. Recirculating water through the engine raises the temperature without reducing the amount of water circulated. It is possible to increase the outlet-water temperature by reducing the flow of water to the pump. However, it is not good practice to "throttle" or partly close any valve in the pump-suction line. In a recirculating system the suction may be throttled, but the pump gets a full supply of water by drawing on the discharge line. This keeps a full flow of water circulating through the engine, which is desirable.

25. FRESH-WATER COOLING: A way of preventing salt or mud deposits in the engine jackets is to circulate only fresh, clean water through the engine in a closed system, namely, a system in which all of the discharge water is returned to the pump suction, making a closed circuit. This supply of fresh water is cooled after it leaves the engine by a heat exchanger. An engine equipped for fresh-water cooling is shown in Figure 3-7.

26. ENGINE-COOLING SYSTEM FOR FRESH-WATER COOLING: On Atlas engines intended for fresh-water cooling systems, centrifugal pumps, which will be described, are used instead of the reciprocating pump used for raw-water systems.The engine-water manifolds and piping are arranged exactly the same, except that the oil cooler is taken out of the fresh-water circuit.

27. RAW-WATER CIRCUIT: The fresh water is cooled by raw water in a heat exchanger constructed much like the oil cooler described in Section 2. Usually the heat ex-

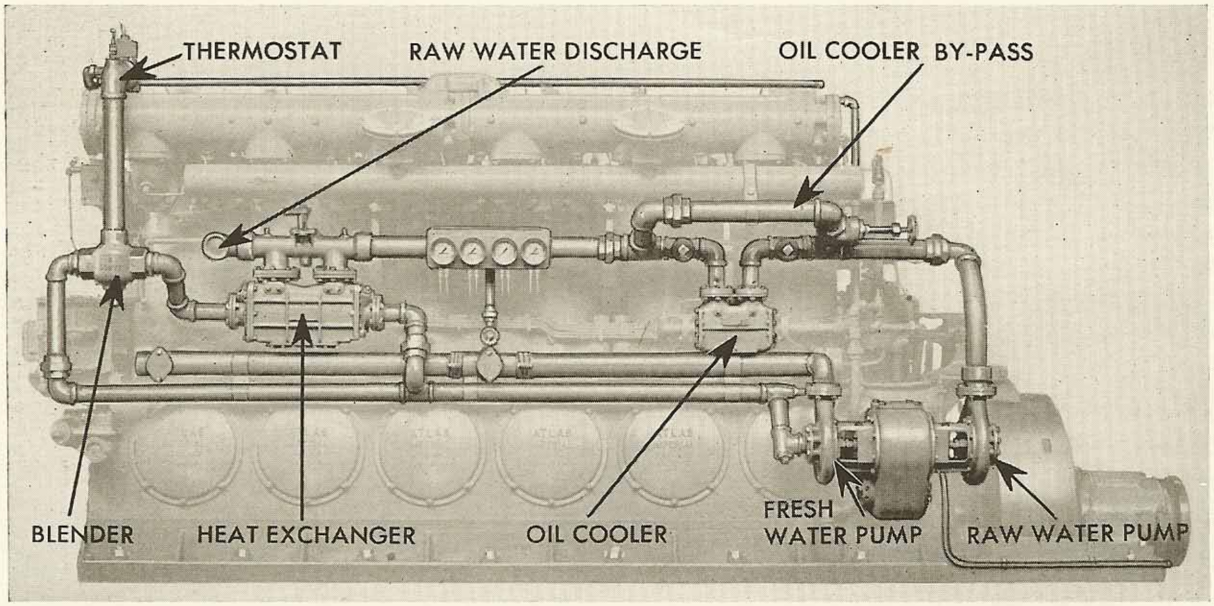


FIGURE 3-7

changer is piped so that the fresh water passes through the tubes and the raw water passes around them in the shell. Twice a year the heat exchanger should be inspected to see if the tubes have any scale deposits, which, if found, should be cleaned out with a wire brush.

28. TEMPERATURE REGULATION: The pumps used on Atlas engines intended for fresh-water cooling systems have a capacity greater than those for raw-water systems, so that the temperature rise through the engine is reduced to about 20 degrees. A desirable condition is to have the fresh water enter the engine at 120 to 130 degrees, which means it will leave at 140 to 150 degrees. The temperature of the fresh water can be regulated by varying the amount of raw water being circulated. A valve in the discharge line of the raw-water pump permits throttling of the flow (throttling the discharge of a centrifugal pump reduces its output). More raw-water flow causes the fresh-water temperature to drop; less raw-water flow causes the fresh-water temperature to rise.

29. RAW-WATER CIRCULATION: The raw water enters the ship through a sea valve and is piped to the raw-water circulating pump. The pump discharge is controlled by a valve, as we have already said, and goes through the oil cooler and the heat exchanger, usually in that order. It then discharges to the sea through a hull fitting.

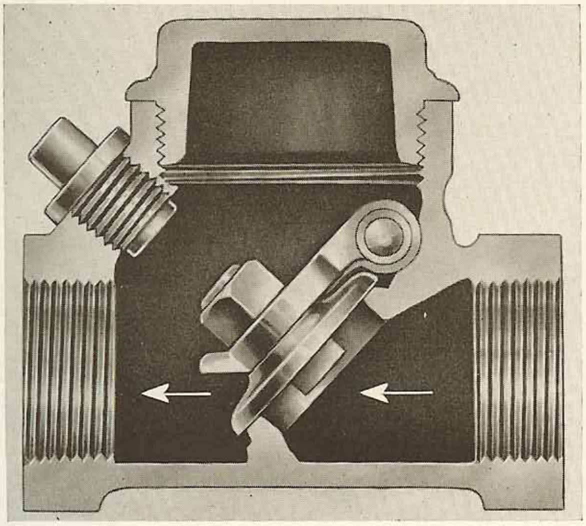


FIGURE 3-8

30. PRIMING RAW-WATER PUMP: If the raw-water pump is above the level of the water line, it will have to be primed or filled with water to start. Usually the pump is below the water line so that water will automatically fill it if the sea valve is opened. In any event, a swing-check valve shown in Figure 3-8, in the suction line allows water to flow in but not back out of the suction line, so the pump should stay full of water during all but long lay-ups.

31. FRESH-WATER EXPANSION TANK: A pipe leading from the suction line of the fresh-water pump goes to the bottom of an expansion tank which is located well above the engine. There is a vent leading from the top of this tank to the outside of the ship for the purpose of allowing air or steam to escape. The expansion tank will usually have a gauge glass, and you should check up on each watch to see that water shows in the glass. If it does not, enough should be added to bring the level into the gauge glass. Usually the tank has a filling opening, and if so, fresh water is added to the system at that point.

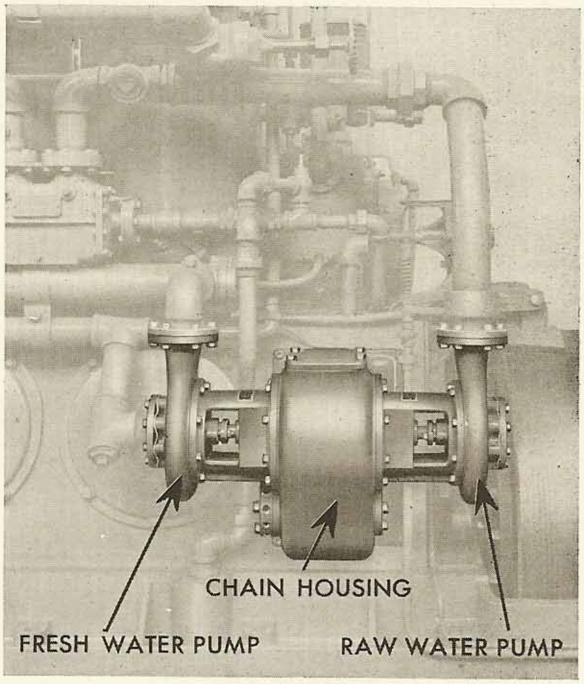


FIGURE 3-9

32. CENTRIFUGAL PUMPS: Figure 3-9 shows how the two centrifugal pumps are mounted on the engine and are driven from a sprocket (shown in Figure 3-10) on the engine crankshaft by a roller chain. If this chain becomes slack, it is possible to tighten it by a tightener idler, which can be shifted over a range of positions.

The driven pump sprocket is mounted on a shaft as shown in Figure 3-11. This shaft; the bearings in which it revolves; and the tightener idler; are all in a housing to which the two pumps are bolted, one at each side.

The bearings for the idler and the driven shaft are ball bearings. On the rotating shaft is an inner race, or a track for the balls. There is also an outer race, which is stationary in the bearing housing. Balls in the race support the shaft and roll with it.

The adjustment of the chain tension is important as a slack chain will wear both itself and the sprockets, rapidly. This adjustment is described in Section 22.

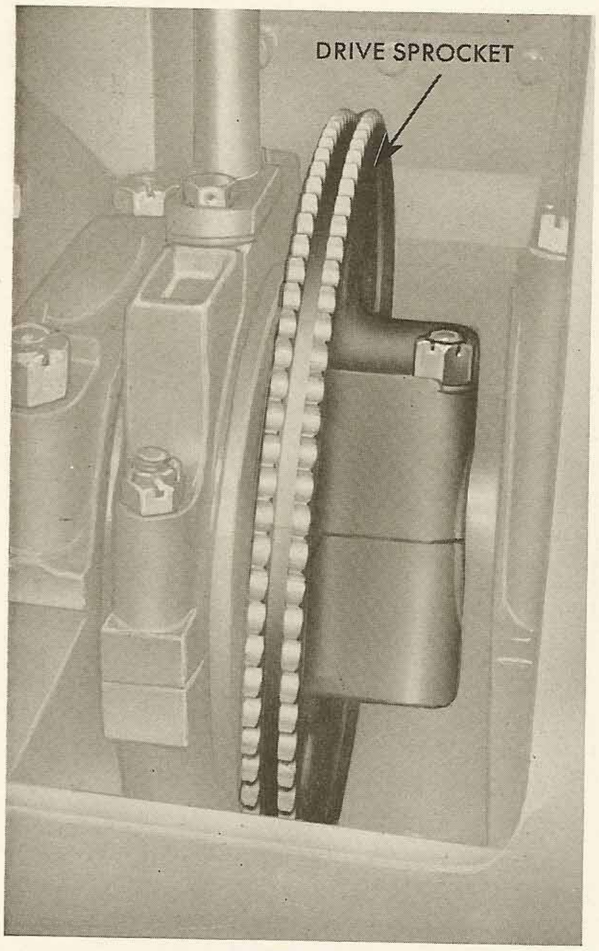


FIGURE 3-10

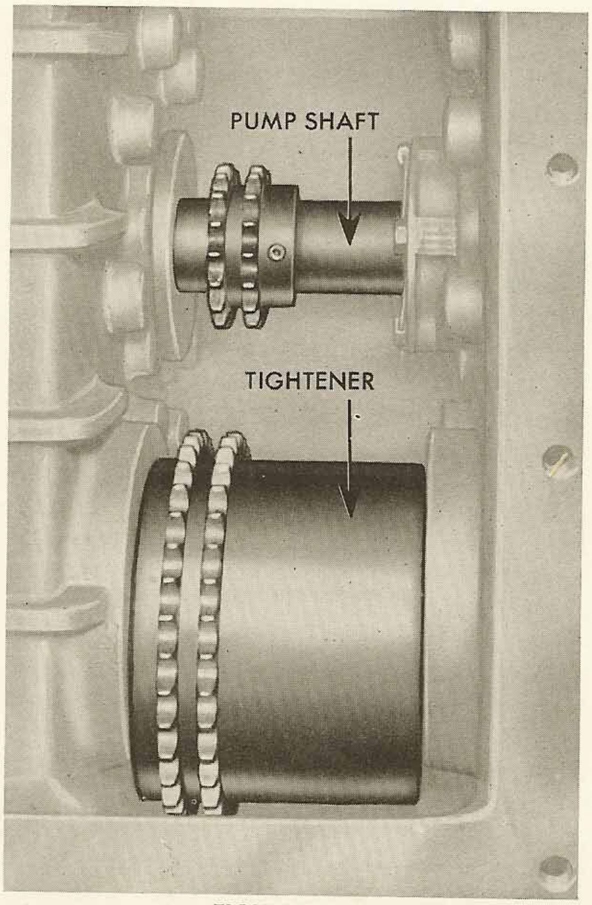


FIGURE 3-11

33. PUMP-DRIVE LUBRICATION: A pipe from the pressure system delivers oil to the inside of the tightener idler and lubricates the ball bearings of the idler. Holes allow oil to escape and lubricate the roller chain. The splash of the chain lubricates the bearings of the driven shaft.

The driven shaft attaches to the pump shafts by couplings, which in this case are called solid couplings, to distinguish them from flexible couplings used in some drives.

34. PUMP PRINCIPLE: The water from the suction line enters the center of the pump through the suction opening, is caught between the vanes of the impeller, and is given a rapid rotating motion. Anything that is rotated rapidly tries to move away from the center of rotation, namely, it is affected by centrifugal force. This force throws the water out of the impeller into the volute, where it is led into the discharge pipe.

Each pump has a stuffing box which should be packed in the manner prescribed for reciprocating pump. These stuffing-box glands are held in by two nuts on stud bolts, and care should be taken to alternate between the nuts when turning them down in order to avoid cocking the gland. These nuts may be prevented from backing off by locknuts. A locknut is screwed on each stud bolt after the gland nut. When the gland nut has been turned down sufficiently, it should be held by a wrench from turning and the locknut should be turned down until it jams against the gland nut. Each time the gland nut is to be tightened or loosened, the locknut must first be backed away from it.

35. BILGE PUMP: The pump shown in Figure 3-12 is a single acting reciprocating pump driven by an extension of the forward end of the camshaft. It operates on the same principle as the circulating pump on a raw-water cooled engine. The packing gland is on the end of the pump cylinder and the piston moves in and out of the packing. As the pump operates all the time the engine is running, it is usually connected to the bilge lines so that the bilge is kept dry. For emergency bilge service there usually is a large auxiliary pump driven by the auxiliary engine. How the bilge pump can be used as an auxiliary to the cooling system was described in paragraph 11.

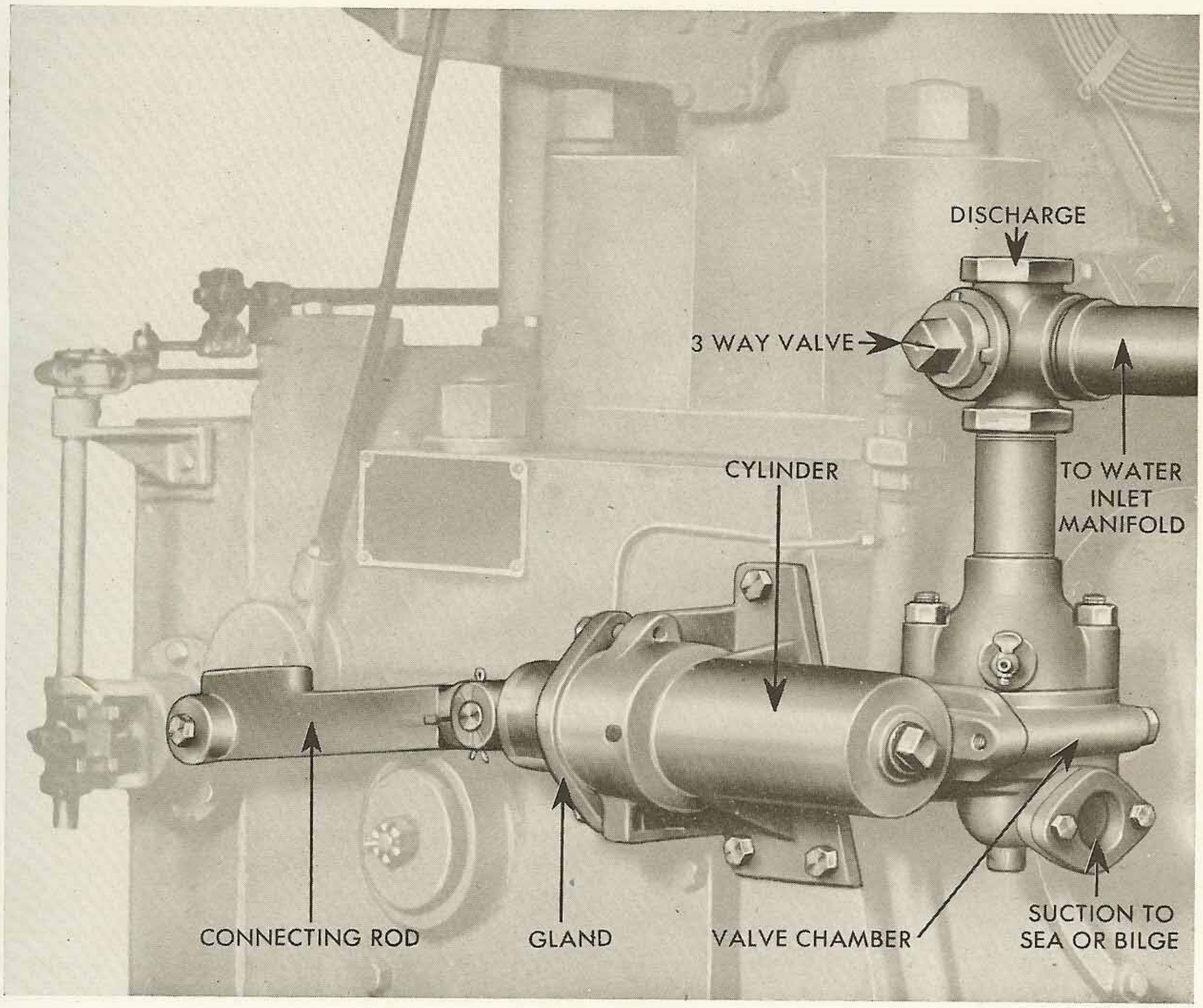


FIGURE 3-12

SECTION 4
ENGINE FUEL SYSTEM

1. FUNCTION: The engine fuel system shown in Figure 4-1 must do several things:—

(a) it must carry the fuel from the ship's storage tank or tanks to the engine combustion chambers.

(b) it must measure out, or meter, the fuel into charges, each of which is just enough for one power stroke, and

(c) it must force each charge into a combustion chamber under high pressure.

2. FUEL-TRANSFER PUMP: The pump that transfers oil from the ship's storage tank or tanks to a smaller tank at the engine is called the fuel-transfer pump, or usually just the transfer pump. It is mounted on the engine as shown in Figure 4-1 and is driven by gears from the engine crankshaft. The construction and operation of the transfer pump is the same as the reversible lubricating oil pumps described in Section 2 and illustrated in Figure 2-4. This pump is partly lubricated by Diesel fuel oil but a drain is provided to carry off any leakage past the gland so that the fuel oil will not reach the engine oil in the base.

3. DAY TANK: The small fuel tank located near the engine is called a day tank. It is a tank constructed similarly to the lube service tank described in Section 2 and illustrated in Figure 2-1, the exceptions being that the day tank has an overflow connection at the side of the shell near the top, and the screen has much smaller openings (has a finer mesh). The

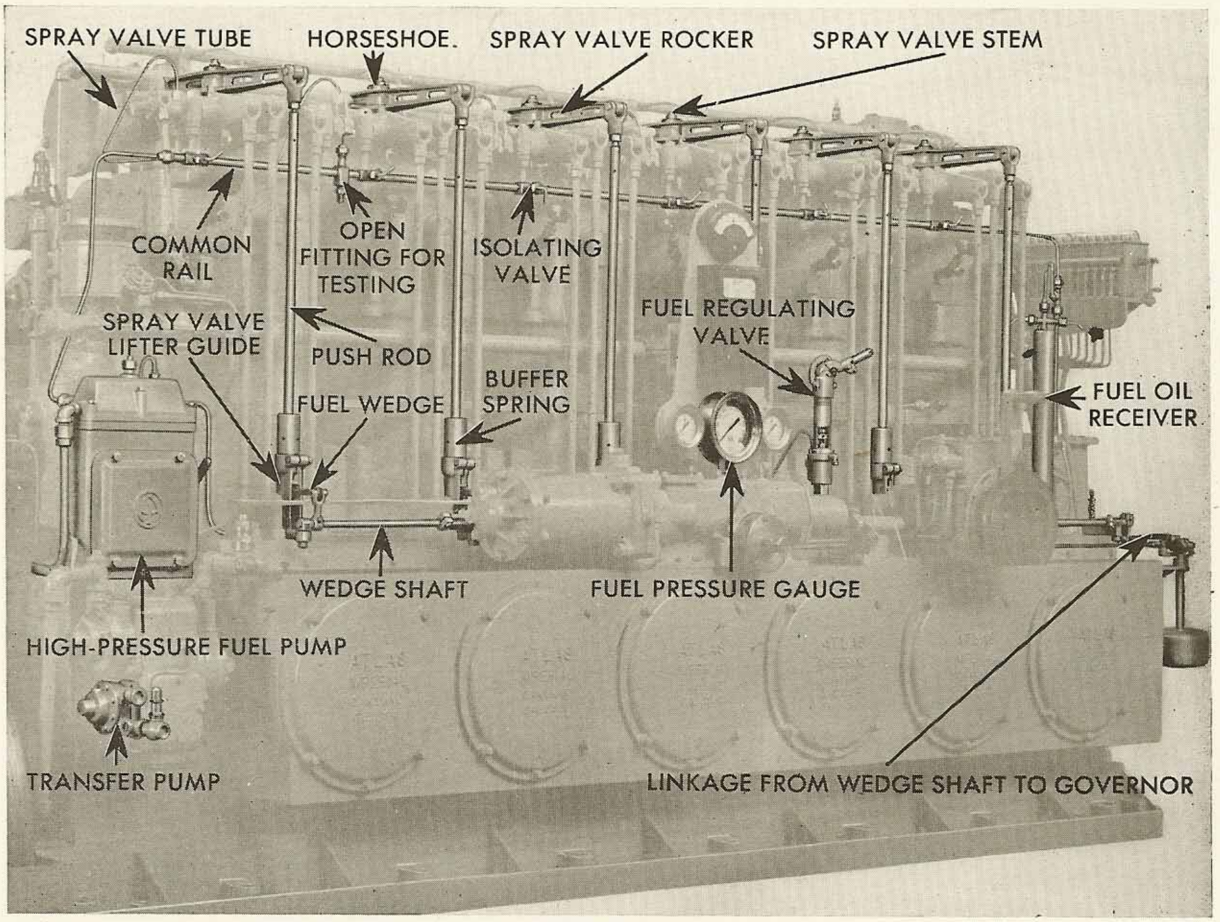


FIGURE 4-1

transfer pump delivers more fuel than the engine uses, and the excess fuel drains back to the pump suction. As long as there is fuel in the ship's storage tank and the transfer pump is working, the day tank will be full to the level of the overflow, and the level in the gauge glass should so indicate. In starting a new engine in a new ship, you should fill the day tank by means of a bucket or hand pump.

4. FUEL FILTER: The fuel oil filter is a metal edge type filter, similar to the lubricating oil filter described in Section 2 and the detailed description will not be repeated here. There are two elements in series, with 0.002 inch and 0.003 inch spacing. The dirt may be scraped off the elements by turning the cleaning handles on the top, and this preferably should be done when the engine is not running so that the dirt can settle freely to the bottom of the sump tanks although there is no real objection to cleaning with the engine running. The sumps should be drained before the dirt builds up to the level of the elements.

After draining refill the filter through the priming plug in the top, and leave the vent cocks slightly open when starting the engine to allow the trapped air to bleed out. The filter elements may be replaced by removing the handles and sump tanks and unscrewing the elements from the head. CAUTION: The element is attached to the head with a left-hand thread. Assemble with the 0.003 inch element on the inlet side of the filter.

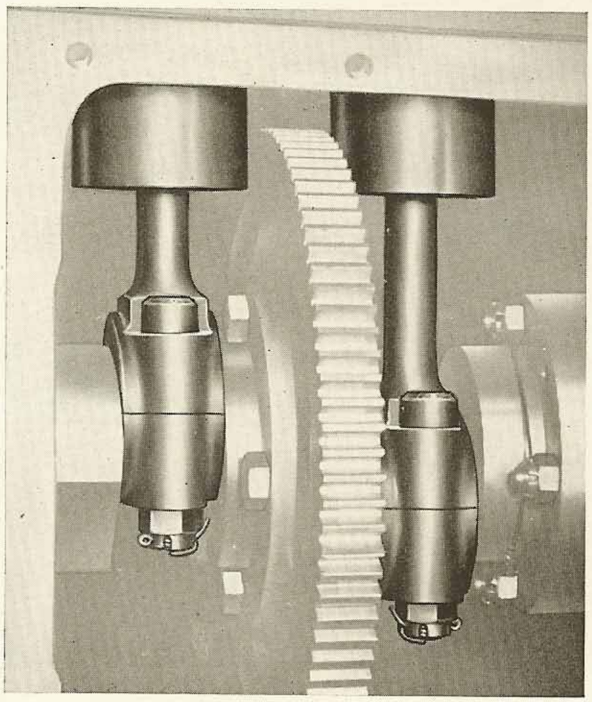


FIGURE 4-2

NOTE: the fuel oil filter as described is furnished as standard. When specially ordered, a duplex filter with switchover valve is furnished. The construction of this filter is similar to the filter described but allows either of the filter elements to be cut out for cleaning while the engine is running.

5. HIGH-PRESSURE FUEL PUMP: The after end of the engine camshaft has two cranks shown in Figure 4-2, which drive the two plungers of the high-pressure fuel pump. These two drives are lubricated by a passage drilled from the after camshaft bearing. This pump is really two pumps, each taking fuel from a suction chamber common to both, and pumping it into one discharge line. The construction of one half of the double pump is shown in Figure 4-3.

The day tank is located so that fuel flows from it by gravity to the suction chamber on the high-pressure fuel pump. A downstroke of either plunger creates suction that draws fuel into the half of the pump in which the stroke is made. The suction valve is held shut by a spring, but the spring tension is not sufficient to hold the valve closed against the suction of a downstroke. An upstroke puts the fuel under pressure, closes the suction valve, and forces the discharge of fuel into the high-pressure line. The discharge valve needs no spring because it is held to its seat by the fuel pressure in the high-pressure line, and can open only when the discharge stroke pressure overcomes line pressure.

6. PLUNGER AND BARREL: The pump plunger moves in a barrel or pump body. There is a lapped clearance so fitted that no packing is needed. Each plunger is individually fitted to its barrel, so they should always be dealt with as a matched set. In ordering new parts, therefore, always order a plunger and a barrel together.

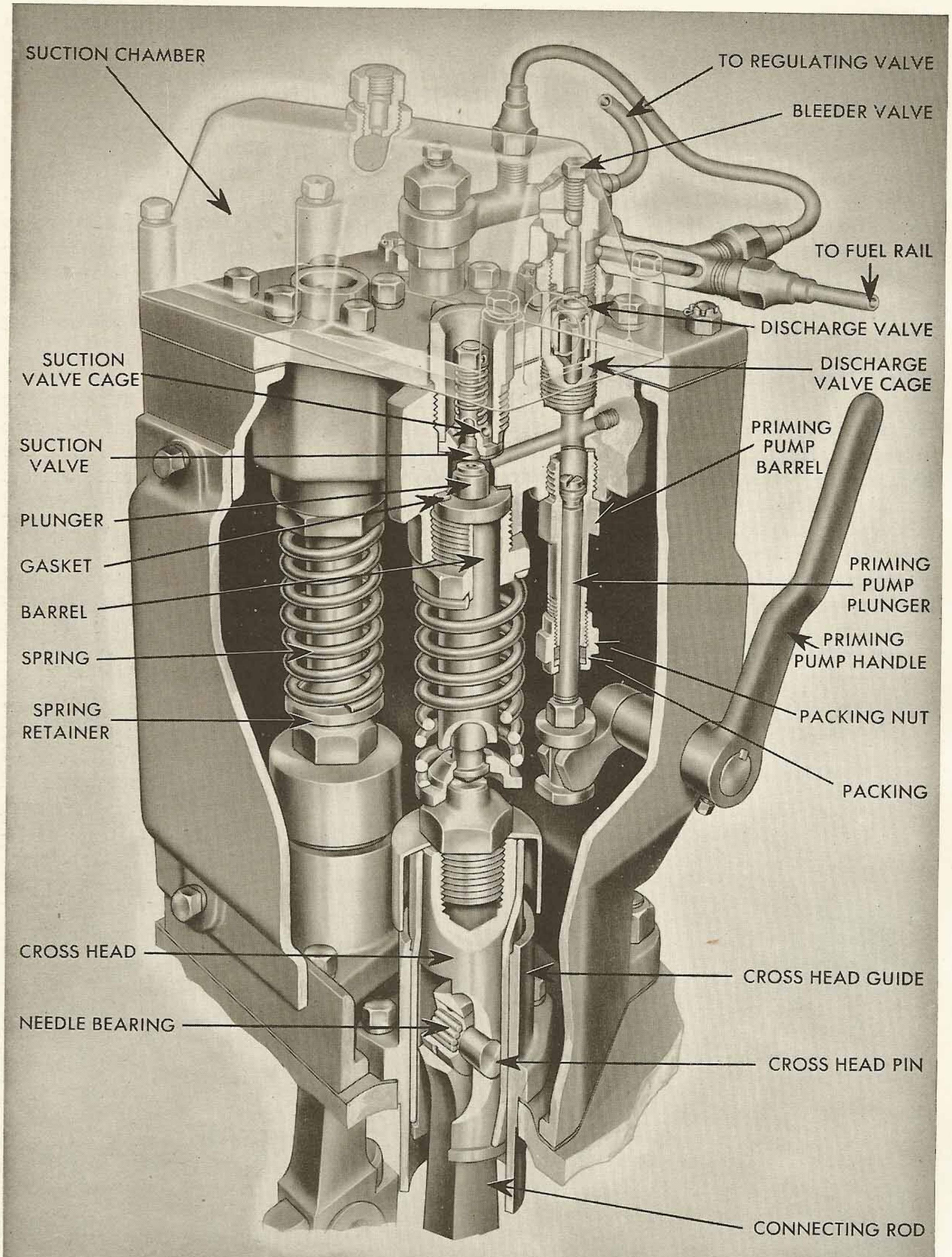

SUCTION CHAMBER
TO REGULATING VALVE
BLEEDER VALVE
TO FUEL RAIL
DISCHARGE VALVE
DISCHARGE VALVE CAGE
SUCTION VALVE CAGE
PRIMING PUMP BARREL
SUCTION VALVE
PLUNGER
GASKET
BARREL
PRIMING PUMP PLUNGER
SPRING
PRIMING PUMP HANDLE
PACKING NUT
SPRING RETAINER
PACKING
CROSS HEAD
CROSS HEAD GUIDE
NEEDLE BEARING
CROSS HEAD PIN
CONNECTING ROD

FIGURE 4-3

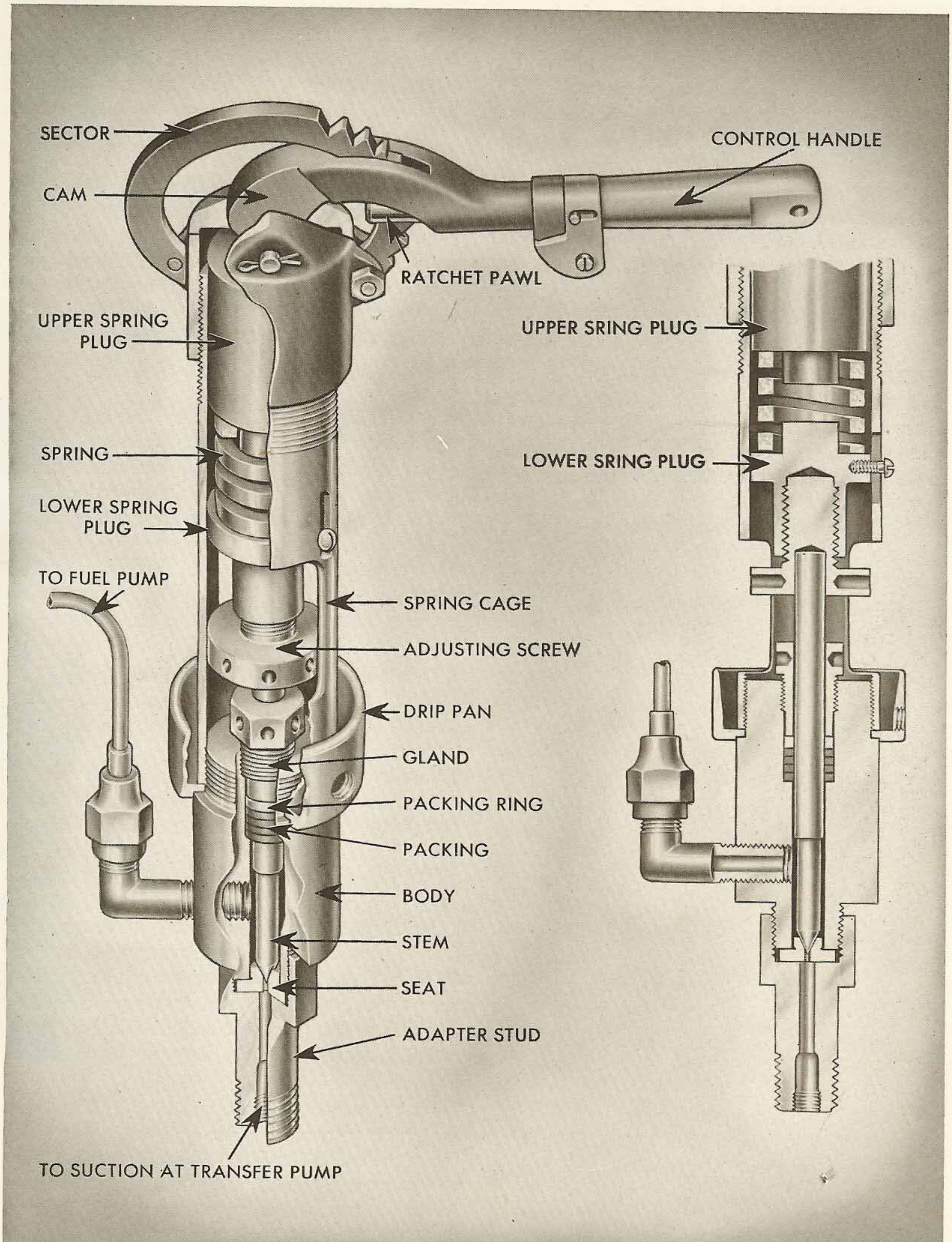

SECTOR
CONTROL HANDLE
CAM
RATCHET PAWL
UPPER SPRING
PLUG
UPPER SRING PLUG
SPRING
LOWER SRING PLUG
LOWER SPRING
PLUG
TO FUEL PUMP
SPRING CAGE
ADJUSTING SCREW
DRIP PAN
GLAND
PACKING RING
PACKING
BODY
STEM
SEAT
ADAPTER STUD
TO SUCTION AT TRANSFER PUMP

FIGURE 4-4

7. HAND-PRIMING PUMP: There are times when fuel pressure must be built up by hand: (1) in starting the engine after a long stop, (2) timing the spray valves, and (3) testing spray valves. One unit of the pump (the half shown in Figure 4-3) has a hand-priming plunger that can be operated by a handle. Working this plunger up and down has the same effect as up and down strokes of the main plunger. When the hand-priming plunger is not in use, it rests on a seat, and the plunger head is ground to a tight fit in that seat to prevent leakage.

8. FUEL-REGULATING VALVE: For reasons that will be explained, it is desirable to control the fuel pressure, not only to hold it constant for any running condition, but also to change the pressure for a changed running condition. This control is accomplished by means of a fuel-regulating valve. Construction of this valve is shown in Figure 4-4 on the preceding page, while the completely assembled valve is shown in Figure 4-5 below.

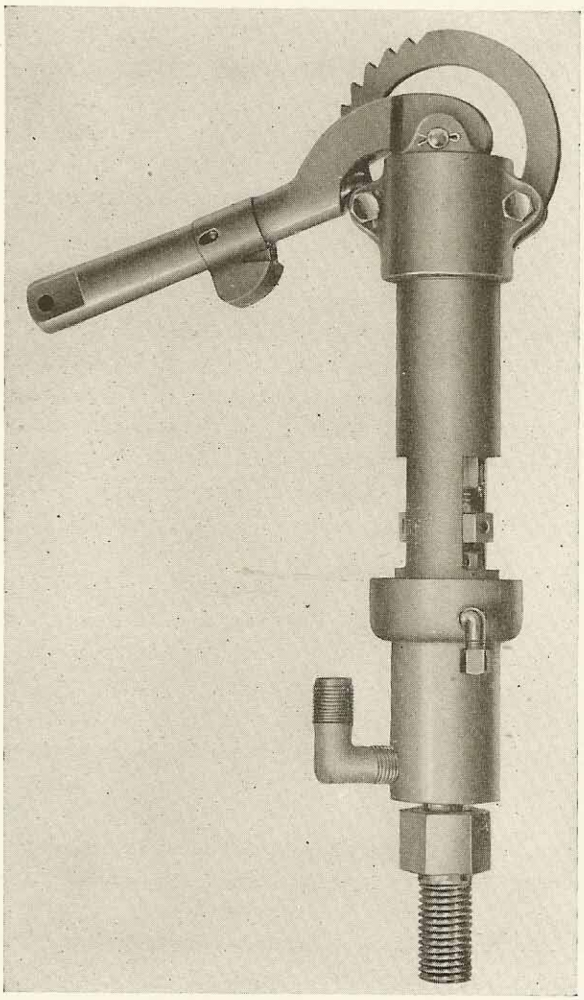


FIGURE 4-5

The valve stem is ground to fit on a removable seat and is held on this seat by an adjustable spring. The fuel pressure acting against the shoulder on the stem, shown just above the tip, will lift the valve off its seat if the pressure is greater than the spring tension. In this way the fuel pressure is regulated and the excess fuel is by-passed to the suction of the transfer pump.

9. HAND CONTROL: The tension of the regulator spring is altered by a control handle operating in a sector, or a curved and toothed track that holds the handle in any position in which it is set. The shape of the handle is such that raising it forces the upper spring plug down the spring cage and increases the spring tension. Increasing the spring tension increases the fuel pressure, and vice versa.

10. HAND CONTROL ADJUSTMENT: It is possible to vary the fuel pressure from about 1,000 pounds when the engine is idling, or just turning over at a very light load, up to about 4,200 pounds at full speed and full engine load. The 1,000 pound pressure should be obtained with the handle in its lowest position. If the fuel pressure should be materially above or below 1,000 pounds with the handle in this position, it is possible to adjust the valve so that the pressure will be brought to 1,000 pounds without moving the control handle. This is done by screwing the adjusting screw in or out of the lower spring plug. Screwing it into the plug will reduce the fuel pressure; backing it out will increase the pressure.

Do not tighten the packing gland of the regulating valve more than is required to prevent leakage, and if excessive tightening appears to be necessary, renew the packing. Dirt can lodge between the valve-stem tip and the seat, which will result in the loss of fuel pressure. In that event the stem and seat should be removed, cleaned and ground to a proper fit. Directions for this work are given in Section 16.

11. COMMON RAIL: The high-pressure fuel line from the high-pressure pump ends on the engine itself in a tube or pipe that runs the length of the engine at the level of the tops of the cylinder heads. This pipe has branches leading from it, one branch going to the spray valve in each cylinder. This pipe serves all cylinders or is common to all cylinders and is called a common rail.

12. ISOLATING VALVES: The pipe leading from the common rail to each spray valve has an isolating valve, or shut-off valve with a needle-like stem, which can be hand operated to close the line, so as to prevent the flow of fuel. At times it is necessary to crank the engine over without any fuel being injected, and these isolating valves are installed for that purpose.

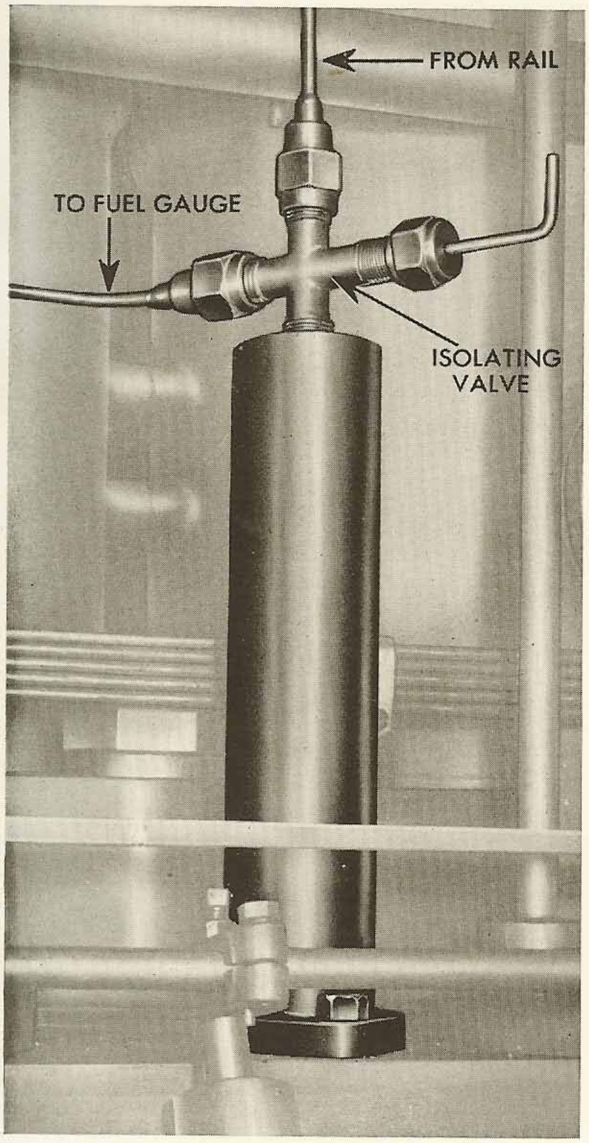


FIGURE 4-6

13. FUEL OIL RECEIVER: The forward end of the common rail connects to a fuel-oil receiver shown in Figure 4-6. This is a tank of small diameter, the purpose of which is to increase the volume of the fuel in the rail which is at high pressure, and thereby reduce pressure fluctuations. The fuel-pressure gauge is usually connected by tubing to this tank, and has an isolating valve which can be partly closed to reduce the vibration of the pointer of the gauge.

14. FUEL-SPRAY VALVE: We now have fuel at a pressure which can be regulated and held at any point between 1,000 pounds and 4,200 pounds, and it remains but to meter the fuel into charges and spray each charge into a combustion chamber at the right time. This is the job of the spray valve and the mechanism which operates it. This valve is located in the exact center of the cylinder head and protrudes slightly into the combustion space between the exhaust and inlet valves.

The construction of the spray valve and the fuel filter attached to it is shown in Figure 4-7 and the assembled valve in Figure 4-8, both on the following page. The filter is of metal edge type having openings of 0.0015 inch. The spray valve itself consists essentially of a body, a valve stem, a spring, a packing gland, and a valve tip on the lower end of the body.

The clearance between the stem and the body is large enough to permit fuel to pass freely from the fuel inlet (from the filter) down to the tip. The fuel cannot escape through the holes in the tip when the valve stem is on its seat, where it is normally held by the valve spring in the spring casing.

If the stem is raised, by mechanism we shall describe, the fuel flows down the stem clearance, out past the seat in the tip, and through the radial orifices (or holes radiating from the center). These holes are spaced equally around the circumference of the tip, as will be seen in

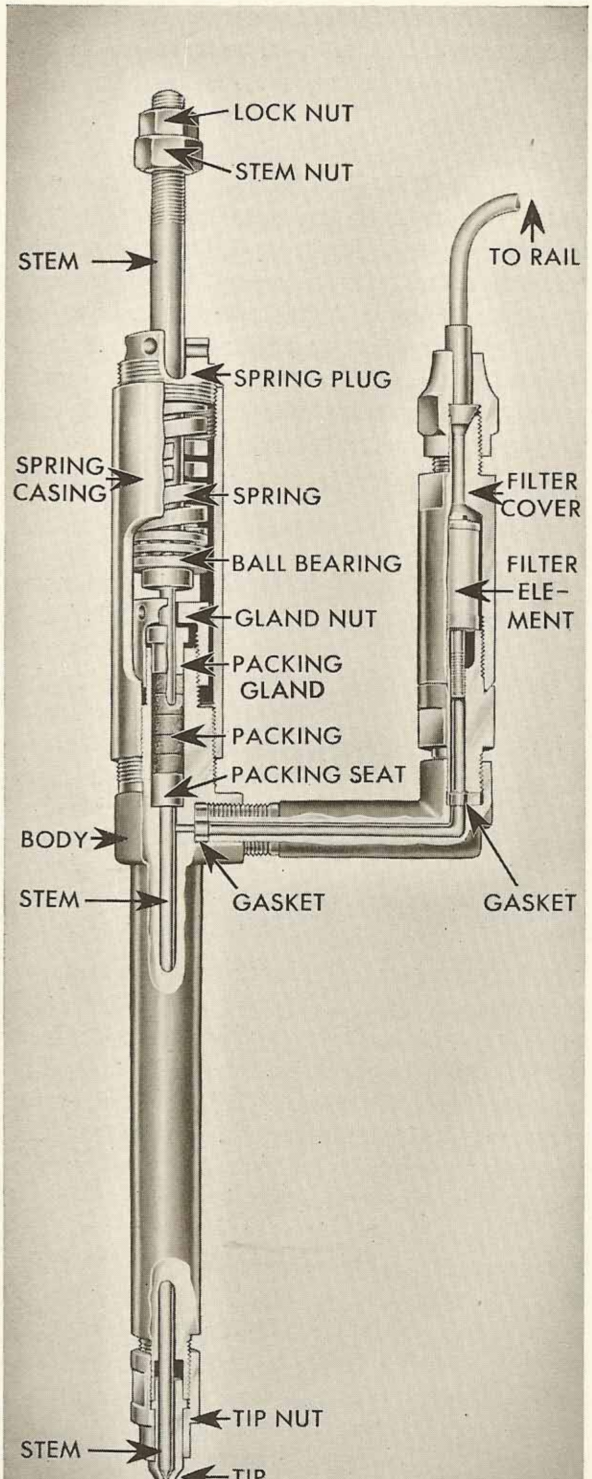


FIGURE 4-7

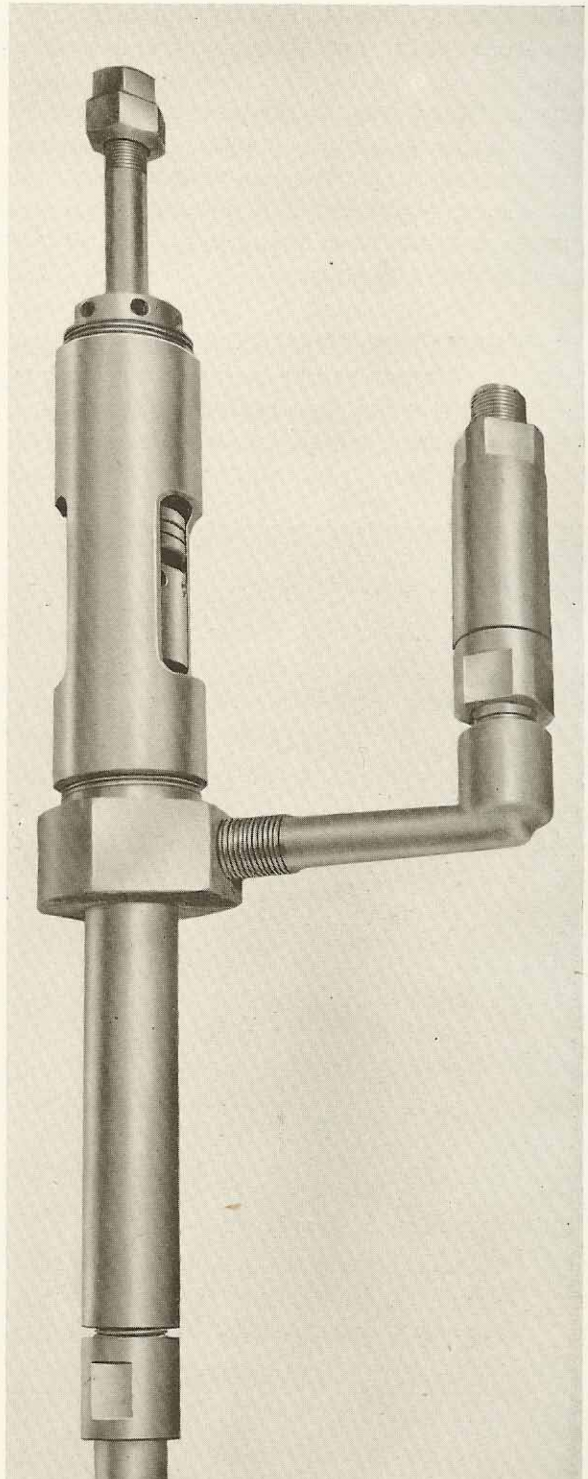


FIGURE 4-8

Figure 4-9. The number and sizes of these orifices varies with engine size:

Each tip on the $7\frac{1}{2}$ x $10\frac{1}{2}$ engine has five orifices, each 0.008 inch in diameter.

Each tip on the $11\frac{1}{2}$ x 15 engine has seven orifices, each 0.012 inch in diameter. (early)
0.013 (later)

Each tip on the 13 x 15 engine has seven orifices, each 0.013 inch in diameter.

Each tip on the 15 x 19 engine has seven orifices, each 0.016 inch in diameter.

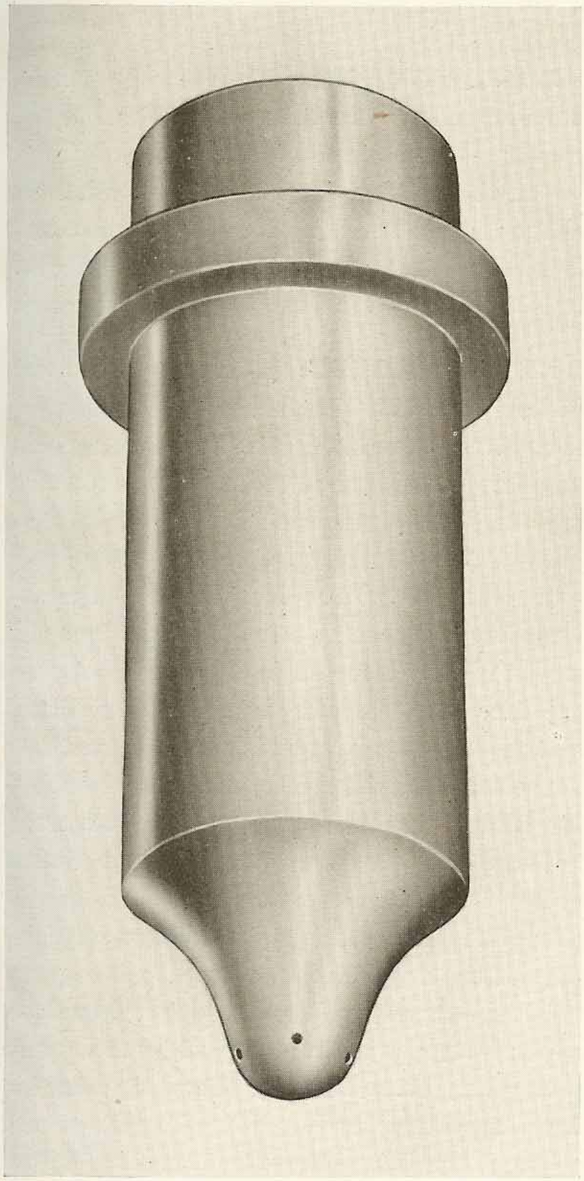


FIGURE 4-9

15. FUEL-CHARGE VARIATION: The amount of fuel going through a tip when the valve stem is lifted will depend on:

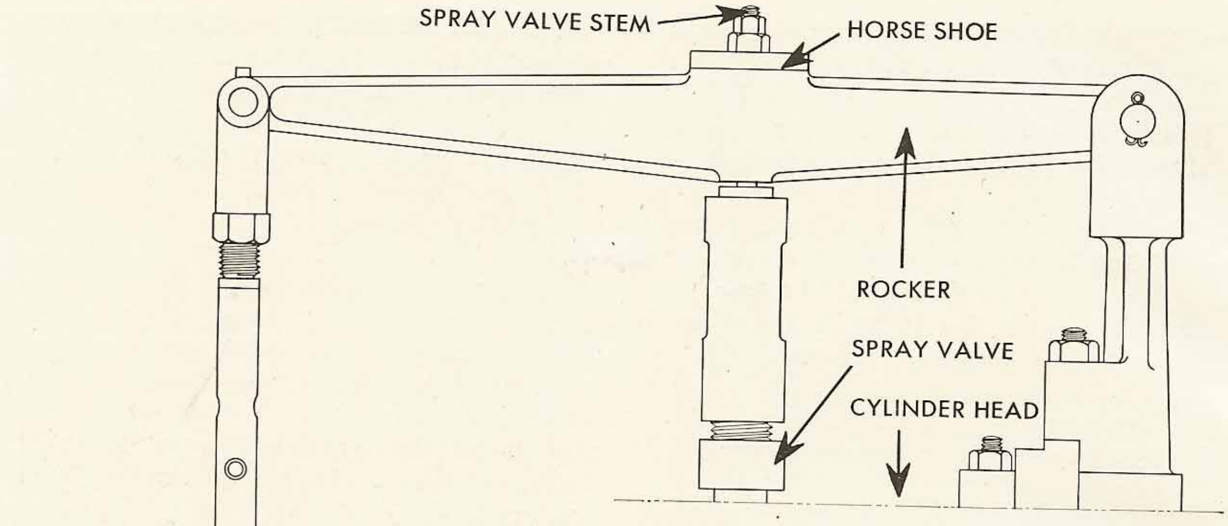
(a) the length of time the stem is off the seat in the tip, and
(b) the fuel pressure.

We have already explained how the fuel-regulating valve may be used to vary the pressure. Higher pressure increases the amount of fuel spraying through a tip in any period of time. That is the reason pressure should be stepped up as engine load increases. Now we must describe how the period of time the valve is open can be varied.

16. CAMSHAFT AND FUEL CAM: Lifting of the spray-valve stem starts with a cam on the camshaft. A cam is a round disc with a nose or lobe. The cams are mounted on the camshaft and rotate with it. The camshaft rotates only half as fast as the crankshaft so that the lobe of any fuel cam comes around only once in two revolutions of the crankshaft. As it takes two revolutions to develop a power stroke we need only to inject fuel into each cylinder once every two revolutions. This is one of the reasons the camshaft turns only half as fast as the crankshaft.

17. SPRAY-VALVE LIFTER: To carry the lifting action of the fuel-cam lobe on up to the spray valve, there is a lifter that has a roller riding on the cam. Each time it comes around, the lobe raises the roller and lifter (as a matter of fact, the fuel cam acts on the spray-valve lifter roller through some intermediate parts, as will be explained in the next section, but for our purpose here we can assume the cam and lifter roller are in direct contact) as shown in Figure 4-10 on the following page.

18. SPRAY-VALVE PUSHROD AND ROCKER: The lifter acts on the spray-valve pushrod, so that the pushrod lifts when the fuel-cam lobe comes around. The pushrod raises one end of the spray-valve rocker, which is pivoted on the other end. (Although an arm pivoted at one end is, strictly speaking, a lever, this part is referred to herein as the spray-valve rocker.)



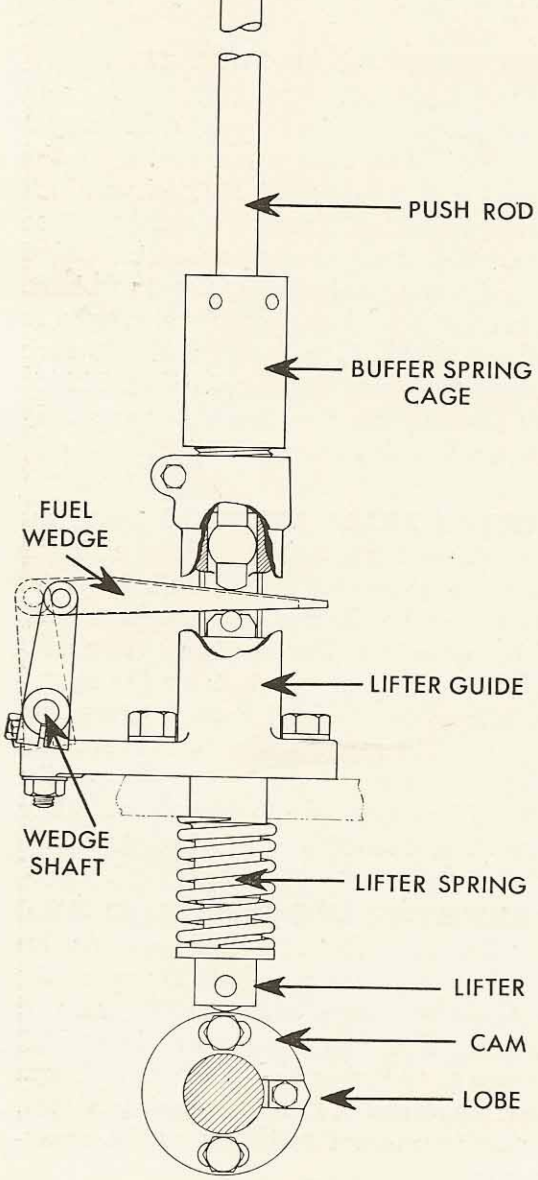


FIGURE 4-10

19. SPRAY-VALVE STEM: The spray-valve stem extends up through a hole in the rocker and ends in a nut with a locknut. Between the nut and the rocker is a horseshoe-shaped collar. The action of the nut and collar is to raise the spray-valve stem when the rocker is lifted by the fuel cam, lifter and pushrod.

20. FUEL WEDGES: The spray-valve lifter is held down on the fuel cam by the lifter spring. The pushrod and rocker are held against the horseshoe collar and spray-valve stem nut by the pushrod spring shown in Figure 4-11. This leaves a gap between the lifter and the pushrod, and this gap is filled to greater or lesser degree by a fuel wedge. When the wedge is fully inserted the clearance between the lifter, wedge, and pushrod is very little, and the spray-valve stem is lifted by practically the full action of the fuel cam. As the wedge is withdrawn, however, the slack or clearance between lifter, wedge and pushrod becomes greater, so that part of the fuel-cam action is needed to take up this clearance, leaving only part of the cam action for opening the spray valve. The spray valve then opens later and closes earlier, injecting less fuel into the combustion chamber. Finally, the wedge can be withdrawn to a position in which the slack is so great that the cam cannot open the spray valve at all, and the fuel is completely cut off.

The position of the wedges is controlled by partial rotation of the wedge shaft and the resultant motion given to the levers keyed on it. The wedge shaft is connected to the governor, as we shall see.

21. TIMING OF FUEL VALVE: The position of the cam lobe determines the timing of fuel injection, and if the fuel cam is turned on the camshaft so the cam comes around sooner or later, the timing of injection will be advanced or delayed, as we shall see in Section 10. We shall also see in Section 5 that the fuel cam really works against either one of two rollers, which support a plate called a latch shown in Figure 4-11, in order that the fuel-injection timing may remain the same no matter which way the engine rotates.

22. GOVERNOR: Selection of various engine speeds by manual control is desirable and some means of maintaining a selected speed during varying engine loads is necessary. This is accomplished through the control of the wedge shaft by the governor shown in Figure 4-12. In this drawing many parts have been left out and others simplified so that the action of the governor could be illustrated more clearly. The lay-out shown is of a hand wheel controlled engine but with a single lever controlled engine the governor action is the same, except that the spring tension is increased by a cam on the single lever instead of the ratchet and lever shown.

The governor is of the flyball type as it has two revolving ball-shaped weights (the drive is from the camshaft gear). The faster these weights revolve the farther they move apart, as a result of centrifugal force. But as they move apart, they push down on the thrust block and quill rod. The latter is connected to the wedge shaft and the effect of outward movement of the governor weights is to withdraw the fuel wedges and reduce the amount of fuel injected.

Let us say that the engine speed has been set, by the hand control, to 300 revolutions per minute. A decrease in the engine load, a longer period of fuel injection or an increase in fuel pressure will cause the engine to speed up. The governor balls will spread further, imparting a lengthwise movement to the thrust block and quill rod. This action is transmitted through linkage to the wedge shaft. As the wedges are withdrawn, the period of injection is shortened, causing the engine to slow to the desired speed. Any undesired reduction in engine revolutions per minute allows the weights to come together, and the thrust block follows them because of the governor spring, making the wedges enter farther between lifters and

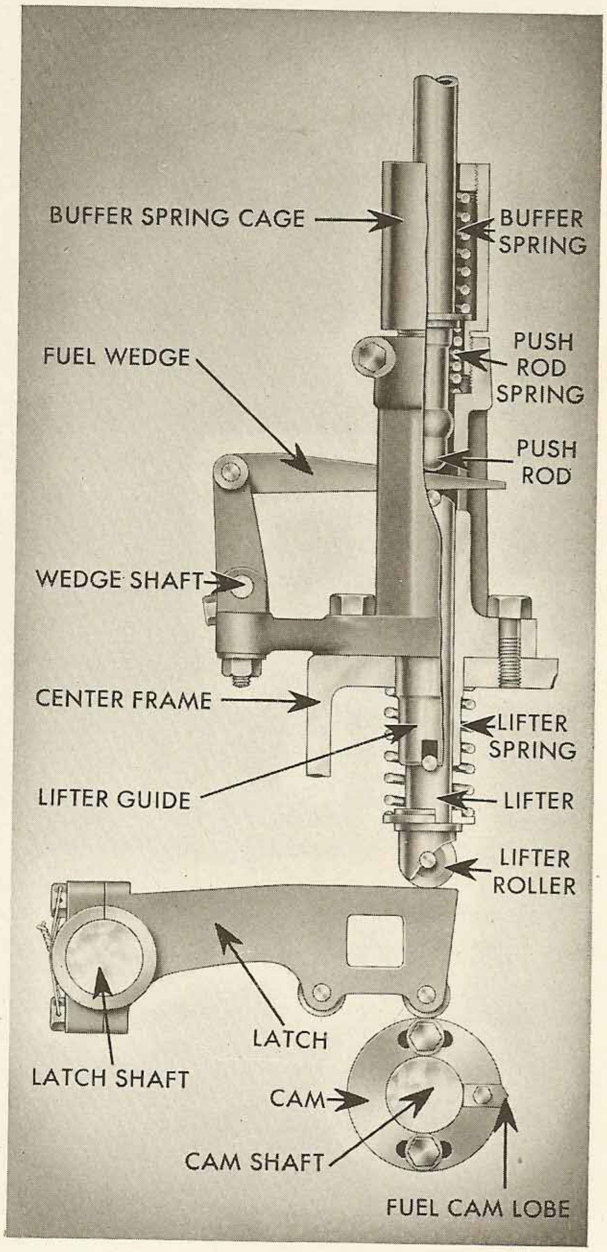


FIGURE 4-11

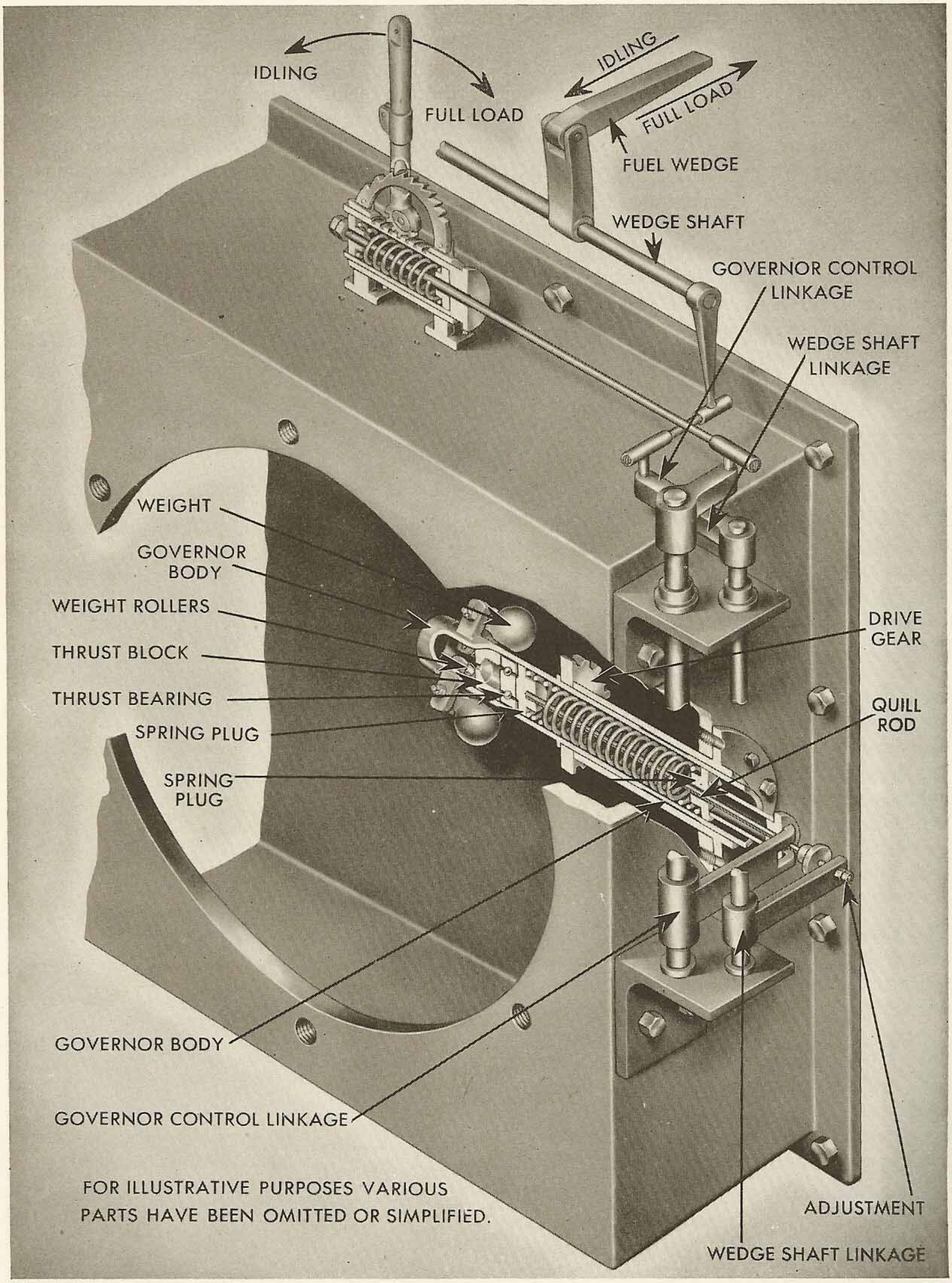

IDLING
FULL LOAD
IDLING
FULL LOAD
FUEL WEDGE
WEDGE SHAFT
GOVERNOR CONTROL LINKAGE
WEDGE SHAFT LINKAGE
WEIGHT
GOVERNOR BODY
WEIGHT ROLLERS
THRUST BLOCK
THRUST BEARING
SPRING PLUG
SPRING PLUG
DRIVE GEAR
QUILL ROD
GOVERNOR BODY
GOVERNOR CONTROL LINKAGE
FOR ILLUSTRATIVE PURPOSES VARIOUS PARTS HAVE BEEN OMITTED OR SIMPLIFIED.
ADJUSTMENT
WEDGE SHAFT LINKAGE

FIGURE 4-12

pushrods, thus increasing the amount of fuel injected until the revolutions per minute increase to the original setting.

23. HAND SPEED VARIATION: The position of the weights for any speed depends upon the pressure of the governor spring. If the spring tension is increased, it holds the weights in with greater force, so that it requires a higher speed to force them apart. The spring tension can be varied by changing the distance between the two spring plugs, which is done by the control lever. After any speed is set by the hand control, the function of the governor is to hold that speed steadily.

24. GOVERNOR ADJUSTMENT: The governor is adjusted by varying the position of the cranks on the wedge-shaft control, and by changing the spring tension as will be explained in a later section.

25. FUEL-REGULATING VALVE AND GOVERNOR: The time during which the fuel-spray valve is open at full load and full speed is about one-seventieth of one second. At light load, it is much less. To avoid cutting down too much on the valve-opening time for reduced speed and load, we reduce the fuel pressure with the fuel-regulating valve, as has been described. As the pressure is dropped, the opening time is lengthened over what it would be with a higher fuel pressure. This makes the job of the governor and wedges easier.

26. HIGH-PRESSURE FUEL FITTINGS: It is not an easy matter to hold 4,000 pound fuel pressure without leakage occurring, and ordinary pipe fittings would be entirely inadequate. Special fittings, called compression fittings, shown in Figure 4-13, are used and are made up without gaskets or any sealing compound. These fittings do not need to be drawn as tightly as you might imagine, in fact, drawing them up too tight may injure the fitting.

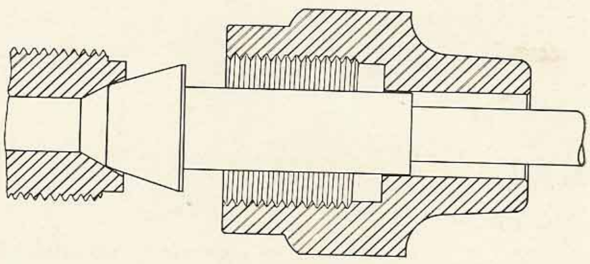


FIGURE 4-13

SECTION 5

AIR INLET AND EXHAUST STARTING AND MANEUVERING

1. RELATION OF SUBJECTS: The title of this section may indicate that many subjects will be grouped in it, and so they will be, but they are inter-related to such an extent that they should be explained under one heading. Air, inlet, and exhaust valves must be arranged so that they open and close at the correct time whether the engine runs in one direction or the other, that ties in with the maneuvering. Maneuvering, in turn, ties in closely with starting.

2. CAMSHAFT: We have had occasion several times in past sections to refer to functions of the camshaft. It is located to one side of the crankshaft and above it and is supported by

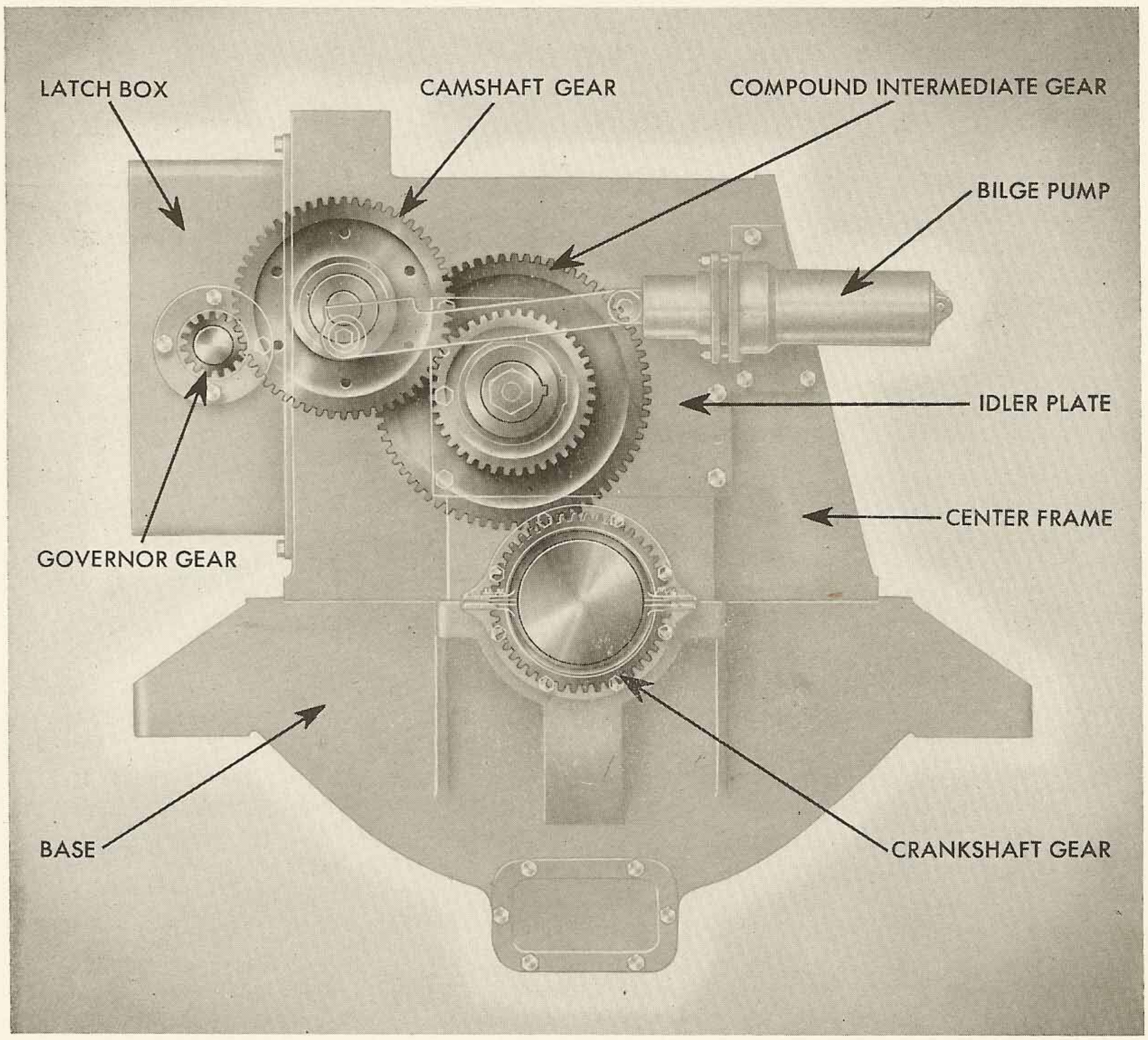


FIGURE 5-1

bronze bushed bearings which are secured in the center frame. A gear mounted on the crankshaft drives a gear on the camshaft through a compound intermediate gear. The crankshaft gear has half as many teeth as the camshaft gear, so the camshaft rotates only half as fast as the crankshaft. This gear train, shown in Figure 5-1, is positioned, during manufacture, in such a way that it will operate smoothly and quietly. Renewal of major parts of the engine, in the field, can change the fit or mesh of these gears. For this reason adjustment is provided by moving the plate which supports the compound intermediate gear.

3. CAMS: On the camshaft are various cams, or round discs, each with a nose or lobe. These cams operate valves through mechanisms that will be described. The rotation of a cam brings the lobe against the roller on the end of the valve-operating mechanism, and moves the roller upward by the height of the lobe. When the lobe rotates on past the roller, the latter returns to its free position, which usually is riding on the base circle of the cam.

When the cam lobe raises the roller and lifter, the valve operated by the cam is opened; when the lobe leaves the roller, the valve closes.

4. REASON FOR HALF-SPEED CAMS: The valves to be controlled by cam action are the inlet, exhaust, fuel and air-start valves and they open only once in a cycle, or two revolutions. It is for this reason that the camshaft makes but one revolution while the crankshaft is making two.

5. VALVE LIFTER: Actually the valve-lifter roller is not in direct contact with the cam, but for the moment we can assume that it is. The lifter moves up and down in a lifter guide that is bolted to the center frame as shown in Figure 5-2.

6. PUSHRODS: The upper end of each lifter is bored to receive a pushrod. The other end of each pushrod is attached by a fork and pin to one end of a rocker arm.

7. ROCKER ARMS: Each valve has a rocker or lever pivoted at its center on a rocker shaft supported in bearings on studs screwed into the cylinder heads. As the pushrod raises one end of the rocker, the other end lowers,

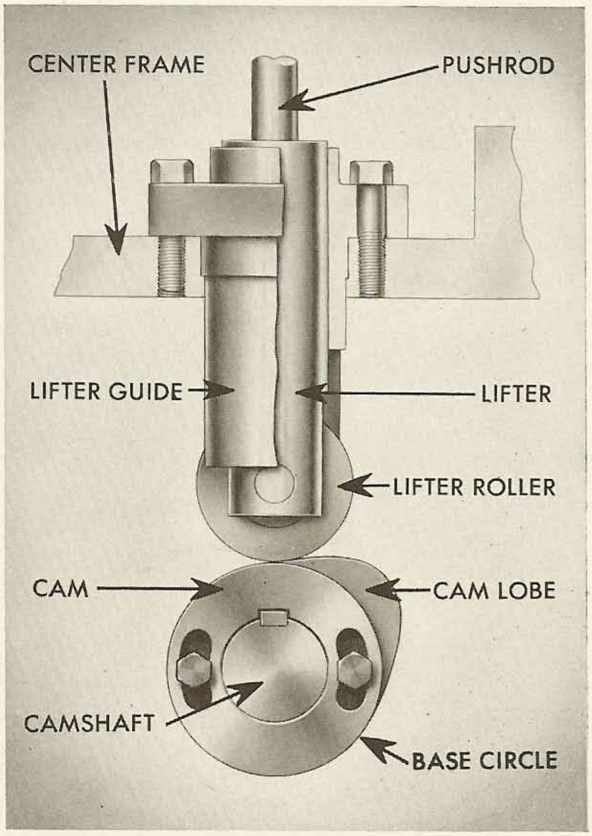


FIGURE 5-2

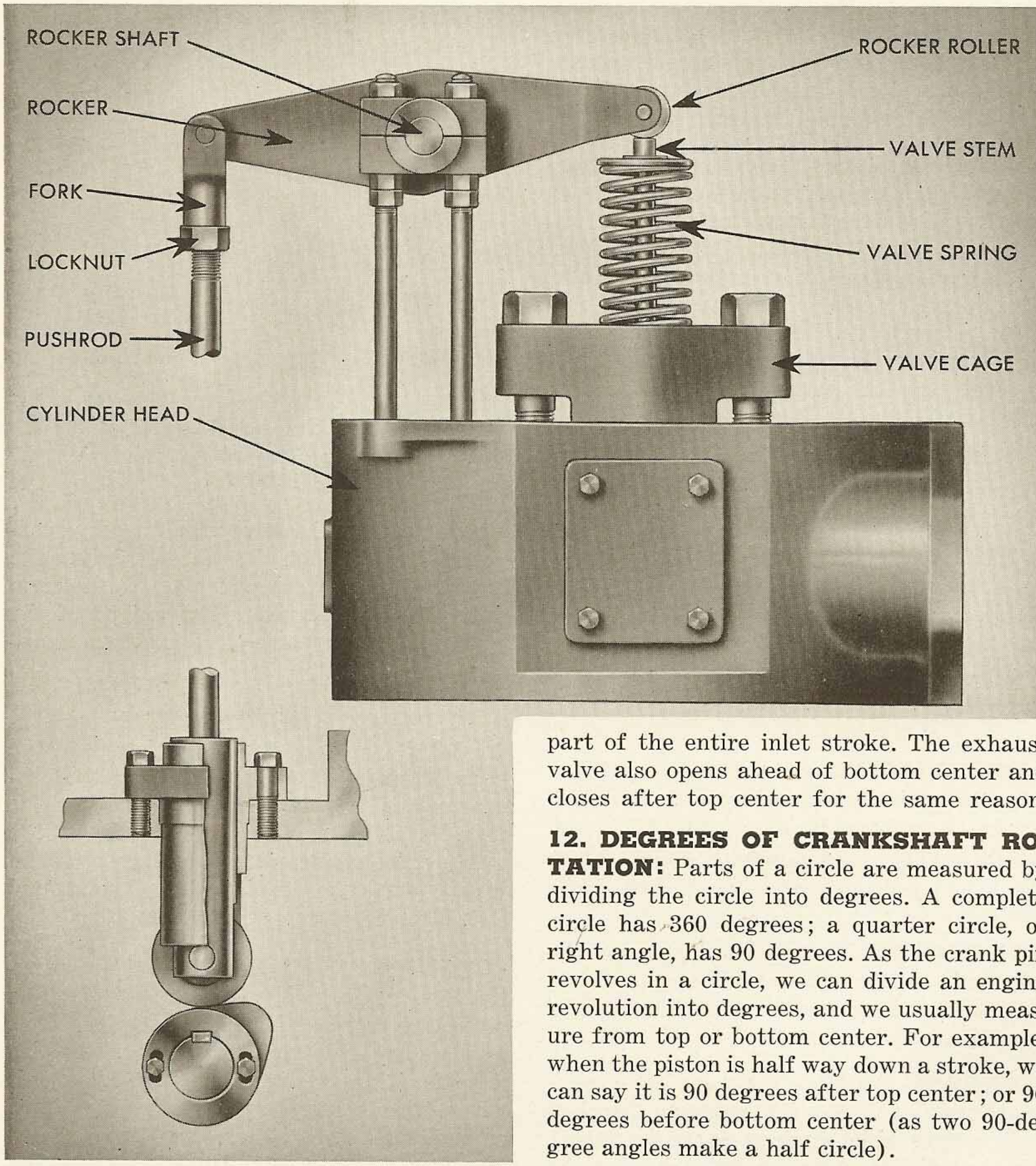
pushing against the valve stem, thereby opening the valve. When the cam lobe leaves the lifter roller, the valve spring raises the stem and returns the rocker. The weight of the pushrod and lifter helps in this return movement.

8. PUSHROD ADJUSTMENT: From Figure 5-3, it can be seen that the length of the pushrod can be adjusted by loosening the locking nut and screwing the rod in or out of the fork. The adjustment should be such that the rocker roller has clearance from the valve stem when the valve is closed (all adjustments and clearances are covered in Section 10).

9. SPRAY-VALVE ROCKER: The spray-valve rocker is really a lever because it is pivoted at one end instead of at the center. This is done so it can lift the spray valve, as it is the lifting of the stem that opens this valve. The other valves open by pushing down on their stems, and therefore have rockers. However, the fuel-valve lever is often called a rocker and we shall refer to it as such.

10. VALVE OPENING AND CLOSING: Any valve operated by a cam will not open to its full lift instantaneously. The lobe of the cam must be sloped, so that it lifts gradually. When the extreme height of the lobe is under the roller, the valve is fully open, but as the cam continues revolving the closing of the valve is also gradual.

11. VALVE-OPENING OVERLAP: In Section 1, we explained valve action by inferring that inlet and exhaust valves open and close instantaneously on dead centers. As a matter of fact, the inlet valve opens ahead of top center, so that it will be well open as the piston starts down. It closes after bottom center so as not to restrict the valve opening over any part of the entire inlet stroke. The exhaust valve also opens ahead of bottom center and closes after top center for the same reason.



12. DEGREES OF CRANKSHAFT ROTATION: Parts of a circle are measured by dividing the circle into degrees. A complete circle has 360 degrees; a quarter circle, or right angle, has 90 degrees. As the crank pin revolves in a circle, we can divide an engine revolution into degrees, and we usually measure from top or bottom center. For example, when the piston is half way down a stroke, we can say it is 90 degrees after top center; or 90 degrees before bottom center (as two 90-degree angles make a half circle).

FIGURE 5-3

13. INLET- AND EXHAUST-VALVE TIMING: On Atlas engines, the inlet valve opens ten degrees before top center and closes 35 degrees after bottom center. The exhaust valve opens 35 degrees before bottom center and closes five degrees after top center. How valve timing is set and checked is explained in Section 10.

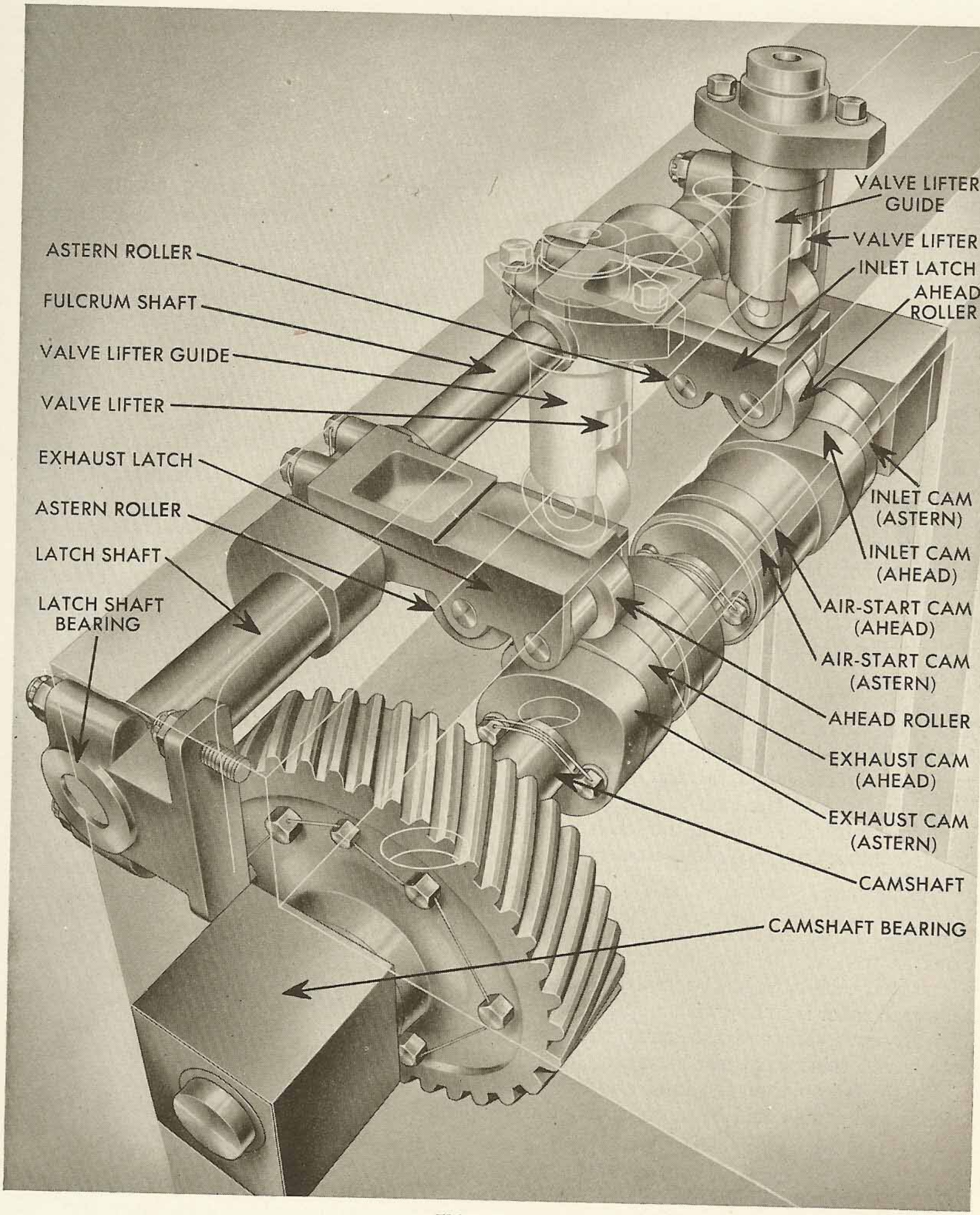


FIGURE 5-4

14. REVERSING: When your engine is operating in the ahead rotation, the cylinders produce power strokes in the following order: 1-5-3-6-2-4. When operating in the astern rotation it is necessary to change this firing order to: 1-4-2-6-3-5. Such a change in the sequence of events in the engine requires a completely different cam arrangement for each rotation.

15. AHEAD AND ASTERN CAMS: Proper valve timing for both ahead and astern rotation is obtained by having two sets of cams on the camshaft. One set is keyed on the camshaft in the proper sequence and positions to provide correct timing for ahead operation. The other set provides correct timing for going astern. Provisions are also made to shift the valve-lifter rollers from one set of cams to the other when the direction of rotation is changed.

16. LATCHES: In order to shift from one set of cams to the other, a device is located between the cam and the valve lifter. For want of a better name this is called a latch and it is merely a short lever fulcrumed at one end on a movable latch shaft. The other end is free to follow the motion of the cam as it is equipped with a roller which tracks on the cam lobe and base circle.

The valve lifter is located directly above the free end of the latch and the lifter roller rides on a planed surface on the top of the latch. When the lobe of the cam passes under the latch roller the free end of the latch swings upward imparting the same motion to the valve lifter.

Figure 5-4 shows the ahead and astern exhaust cams as well as the two inlet cams. It also shows that each latch has two rollers so placed that each roller is in line with a different cam. The air-start cam and the spray-valve cam both have latches but these have been left out of Figure 5-4 so that the inlet and exhaust latches and cams could be more clearly illustrated.

Reference to the fulcrum shaft in this drawing will show that this shaft is offset to the latch shaft. When the latch shaft is revolved a half turn the fulcrum shaft will be closer or farther away from the camshaft by twice the distance of the offset. This is the same distance the rollers in the latch are staggered or placed one ahead of the other. When the fulcrum shaft is in the "out" position, as illustrated, the roller nearest the end of the latch is directly over the "ahead" cam. When the fulcrum shaft is swung to the "in" position the other latch roller is directly over the "astern" cam.

17. FUEL SPRAY-VALVE LATCH: The fuel spray valve starts to open at eight degrees before top center and closes at 18 degrees after top center. If the latch rollers were to be placed in line at the same center-to-center distance as other latch rollers, and were operated by one cam, both ahead and astern, the astern timing would be the reverse of ahead, or for opening at 18 degrees before top center and closing eight degrees after top center. This is not far away from the correct timing and the situation can be corrected by moving the latch rollers closer together. When the latch is "out" or in the ahead position, the ahead latch roller is slightly "out" from being vertically above the one cam, and in the astern position, the astern latch roller is moved slightly "in" beyond the same vertical line. In this way, the inequality of opening and closing time (from top center) is averaged out so the same cam can serve for both ahead and astern rotation.

18. LATCH-SHAFT ACTION: The latch shaft moves the latches in or out by being turned half a revolution. The shaft is made up of six sections. Figure 5-5 shows the complete shaft assembled to the engine frame. Each section of the latch shaft consists of two journals, each journal between a coupling at the outer end and a disc at the inner end. The latch-fulcrum journal is between the discs, but off center, so that a turn of the latch shaft in its journal moves the latch-fulcrum shaft around in a circular path.

The latch shaft has stops bolted to one of its couplings, so that it can make only one half turn. At one end of this half turn the latch-fulcrum journals are "out" and pull the latches out; at the other end of the half turn, the latch-

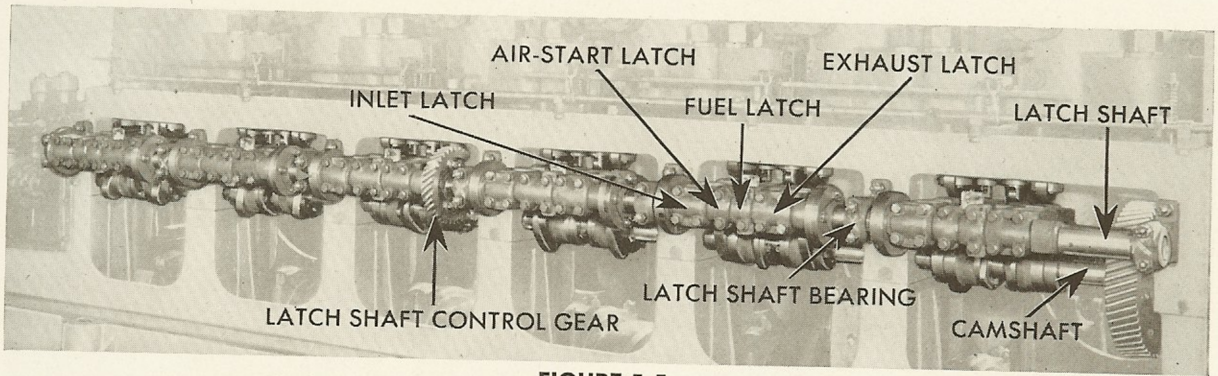


FIGURE 5-5

fulcrum journals are "in," with the latches in. The latch shaft is rotated by means of gearing. On some engines this gearing is connected to a hand wheel while on other engines the latch shaft is rotated by the pneumatic single lever control. The gear on the latch shaft is shown in Figure 5-5. The rest of the gearing will be described later.

19. LATCH SHAFT END PLAY: The latch shaft is prevented from moving endwise along its bearing by the center set of bearings, one on each side of the gear. The adjacent sides of the discs are machined and the bearings are set close to them so that end movement, or play, is held to a running clearance. The other bearings of the latch shaft have greater clearance from their discs, as it is undesirable to restrict play at more than one place on a shaft.

20. COMPRESSED AIR STARTING: All of our explanations so far have assumed a running engine. Now let us consider an engine stopped and standing still. To stop the engine, we withdraw the fuel wedges until no fuel is fed through the spray valves. This is done by a bell crank on the wedge shaft, operated from the single lever control box, which will be described later.

To start the engine again it is necessary that it be put in motion. An automobile engine is started by an electric starting motor, but a large Diesel would require too large a motor or battery. Compressed air is used instead in a manner similar to steam in a steam engine.

21. AIR-START VALVE OPERATING MECHANISM: Figure 5-6 shows the valve operating mechanism by which the air-start valve in any cylinder is opened five degrees before top center beginning the power stroke, and closed 45 degrees before bottom center on the same stroke. Compressed air is admitted to each cylinder on what, if running, would be the power stroke. During this power stroke, as described before, both valves are closed so that compressed air, passing through the opened air-start valve, forces the piston down. As the exhaust valve opens 35 degrees before bottom center, on a power stroke, the air-start valve is closed ten degrees earlier to avoid wastage of the starting air through the open exhaust valve. As the piston is forced down during this starting stroke, momentum is stored in the flywheel which carries the engine over until the next cylinder is ready to receive air. This is the way in which starting speed is built up by compressed air. The inlet and exhaust valves operate as usual. The air-start valve for each cylinder has its ahead and astern cams, and the latch shaft shifts the air-start latch from one cam to the other at the same time it shifts the latches for all other valves.

22. AIR-START VALVES: The air-start valves are constructed much like inlet or exhaust valves, but are smaller in diameter. They are fitted in cages, which are inserted into the cylinder heads in the same manner as the exhaust and inlet valve cages. These cages do not need cooling, as the air-start valves are closed all the time the engine is running. Therefore, they are not exposed to high temperatures so no water jackets are provided.

23. ROTATION OF ROCKER SHAFTS: Figure 5-6 shows the air-start valve mechanism in the "at rest" position. During the time the engine is in operation the assembly is as

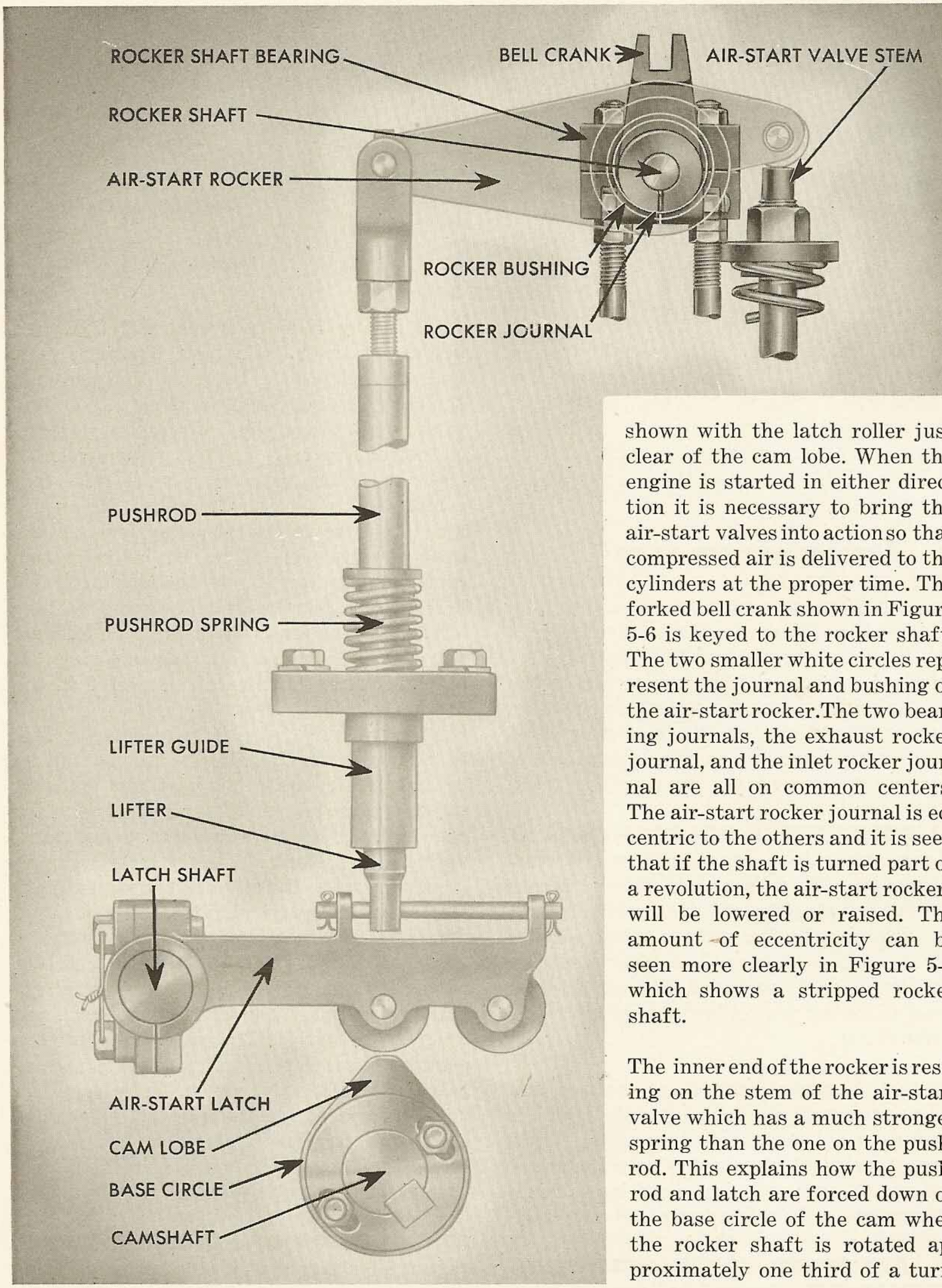


FIGURE 5-6

shown with the latch roller just clear of the cam lobe. When the engine is started in either direction it is necessary to bring the air-start valves into action so that compressed air is delivered to the cylinders at the proper time. The forked bell crank shown in Figure 5-6 is keyed to the rocker shaft. The two smaller white circles represent the journal and bushing of the air-start rocker. The two bearing journals, the exhaust rocker journal, and the inlet rocker journal are all on common centers. The air-start rocker journal is eccentric to the others and it is seen that if the shaft is turned part of a revolution, the air-start rockers will be lowered or raised. The amount of eccentricity can be seen more clearly in Figure 5-7 which shows a stripped rocker shaft.

The inner end of the rocker is resting on the stem of the air-start valve which has a much stronger spring than the one on the pushrod. This explains how the pushrod and latch are forced down on the base circle of the cam when the rocker shaft is rotated approximately one third of a turn.

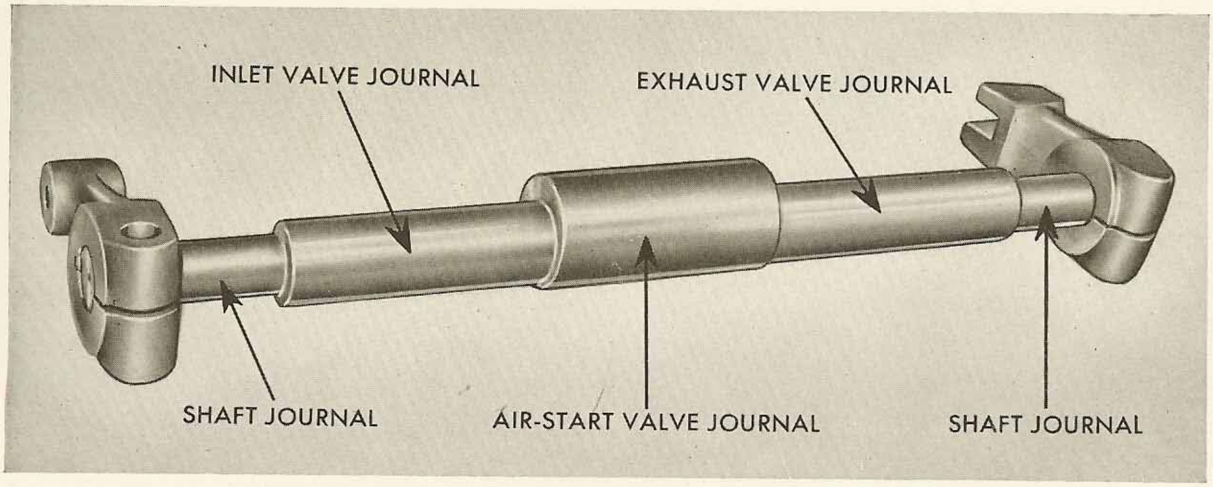


FIGURE 5-7

It is now clear that the air-start valve stem must be forced down and open when the lobe of the cam comes under the latch roller. As the lobe passes under the roller an upward motion is given to the lifter and pushrod. When this motion is transferred through the rocker to the valve stem the valve is opened.

These rocker shafts are connected together by bell cranks so that all shafts are turned the same distance at the same time. As the air-start valves are used so little, in comparison to the exhaust and inlet valves, it is not necessary to have a roller in the end of the lifter. Instead the air-start latch is attached to the lifter. When the lifter, the pushrod and rocker are raised by the eccentric rocker shaft, the latch and its roller are also raised above the cam lobe causing the entire assembly to remain stationary until the engine is again started.

24. AIR RAM: The rocker shaft of number one cylinder has a forward extension on which there is a lever, and this lever is moved through an arc of 110 degrees to rotate the shafts and lower the air-start rockers. This is done by an air ram, which is shown in Figure 5-8, and is merely a cylinder with a piston and rod. This piston is moved up or down by air pressure, turned on and off by the single-lever control, as we shall see later.

Reference to Figure 5-8 shows that the piston diameter is almost as large as the cylinder bore. At the lower end of the piston there are two piston leathers faced in opposite directions. The upper end of the cylinder is sealed off by a packing gland and this packing and the upper piston leather form a space to which air is constantly admitted under pressure. This forces the piston down at all times. The air can only exert pressure on an area equal to the difference of the diameter of the piston and the cylinder.

When it is necessary to move the piston up, air is admitted to the chamber formed by the lower piston leather and the lower end of the cylinder. This air exerts pressure on an area equal to the total area of the end of the piston which is much greater than that of the upper piston leather. The piston is forced upward and held there until the air supply to the lower end of the cylinder is shut off. As the piston moves down, the air displaced in the lower chamber is bled off by the same valve that originally admitted the air.

25. ROCKER SHAFT BELL CRANK: The various rocker shafts are inter-connected by bell cranks. When the ram piston is down as far as it will go, the bell cranks should point straight up. The length of the plunger can be increased or decreased by backing off the locknut and turning the piston rod out or in the fork, which connects to the rocker shaft lever.

26. AIR-START MANIFOLD AND MASTER VALVE: The air-start valves are supplied with compressed air from the ship's air tanks piped to a manifold on the engine. The air may be at any pressure from 125 to 250 pounds. It would be undesirable to have

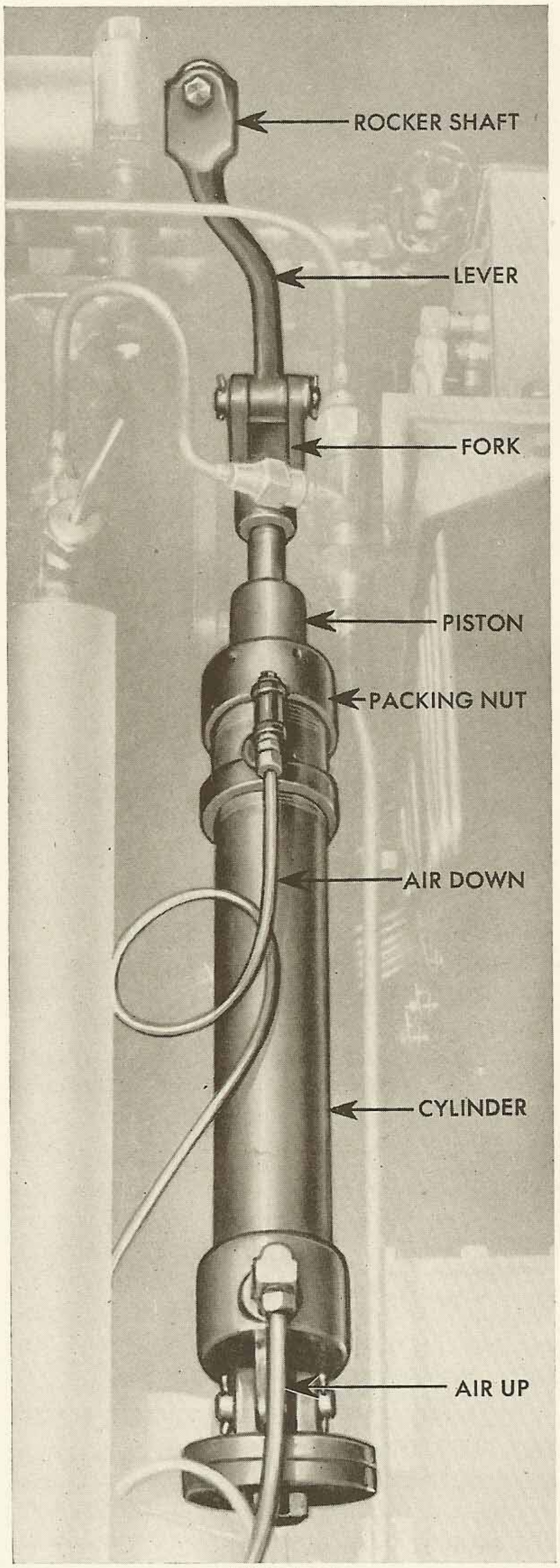


FIGURE 5-8

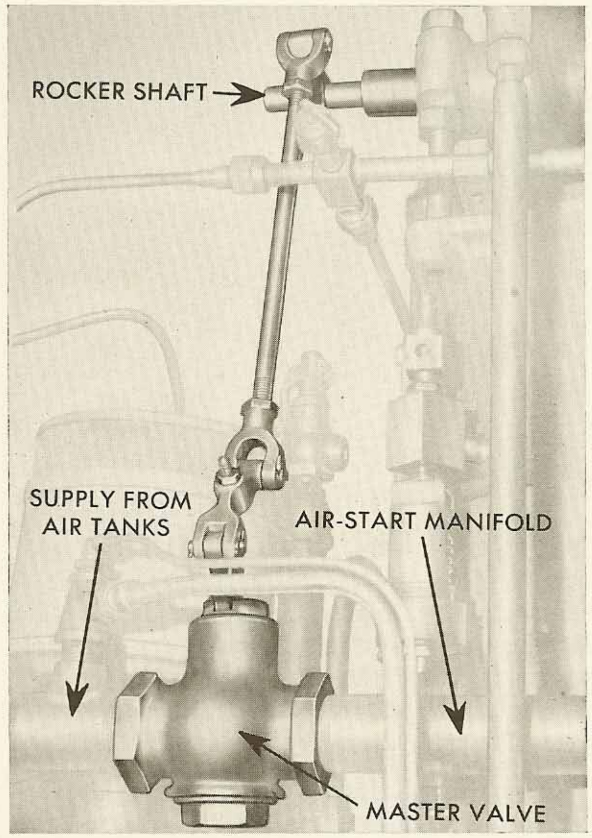


FIGURE 5-9

pressure in the air-start manifold during normal engine operation, so the manifold is shut off from the air supply when air is not needed. This is done by a master valve as shown in Figure 5-9.

The rocker shaft of number six cylinder also has an extension at the after end to which is attached a bell crank. As the rocker shaft turns to lower the air-start valve rockers into the starting position, the bell crank moves linkage which pushes down on the master-valve pin. The first action of the pin is to lower the pilot valve from its seat. This is a valve with a head area of about one-tenth that of the main valve, so that it requires only one-tenth the opening force the main valve would require if it were opened against full air pressure. When the pilot valve opens, it admits air through to the upper side of the main valve, thus balancing the pressure on both sides of the main valve, making it easy to open. Further travel of the pin brings a stop down on the top of the main valve and pushes it open.

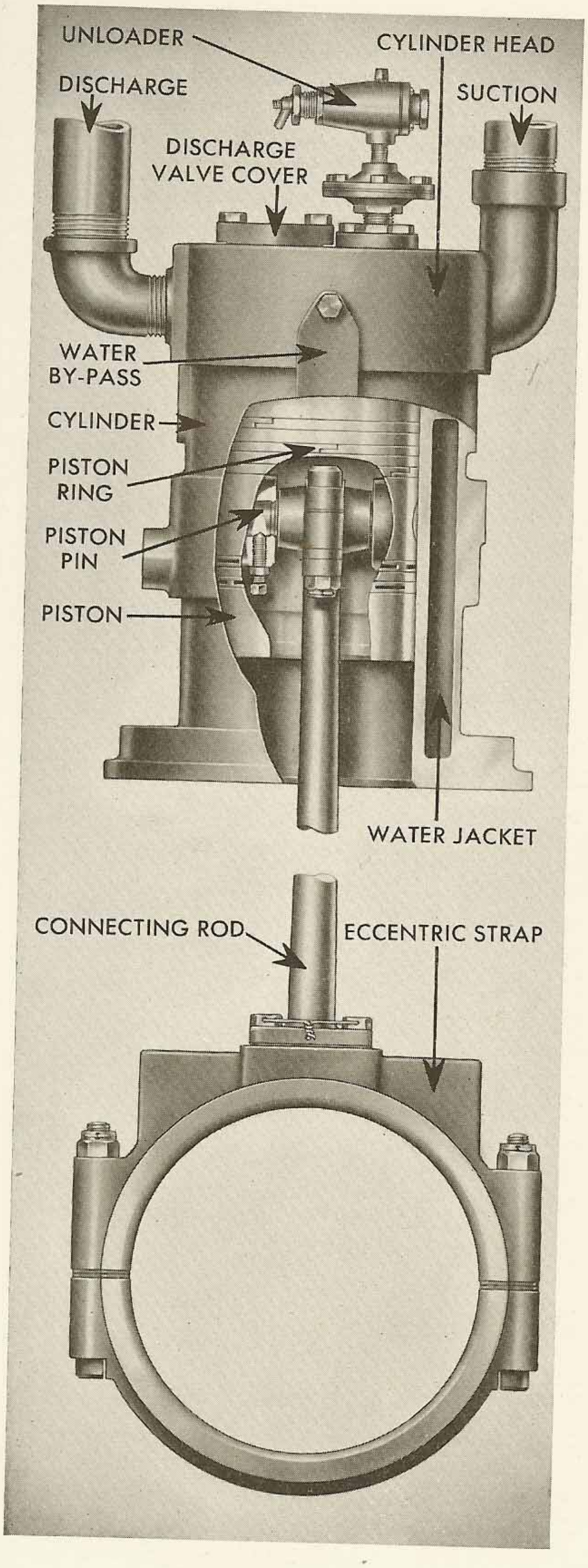


FIGURE 5-10

The stop also closes the center hole through the main valve. When the valve-operating linkage lifts as the rockers return to the running position, the valve spring closes both the pilot and main valve, shutting off the engine manifold from the air supply. When this master valve is open the starting manifold is charged with the same air pressure that is in the storage tanks. The air is delivered to the cylinders at the proper time by the air-start valves.

27. AIR COMPRESSOR: At the after end of the engine there is an air compressor driven by an eccentric, eccentric strap and connecting rod. The air compressor is single-acting; downstrokes draw air in by suction from the atmosphere, and upstrokes discharge air to the air tanks. Spring-loaded inlet and discharge valves are used. Figure 5-10 shows the construction of the compressor.

28. AIR-COMPRESSOR UNLOADER: As the amount of air in the storage tanks governs the number of engine maneuvers that can be made, it is necessary to keep the tank fully pumped up at all times. The air compressor piston can not be stopped while the engine is operating so it is necessary to have some means of stopping the pumping action of the compressor when the tanks are up to their limit pressure.

To make this control automatic a device called an unloader is supplied which will hold open the suction valve of the compressor as long as the tank pressure is up to the limit. With this valve held open, air drawn into the cylinder by the downstroke of the piston is forced back out of the suction opening and into the atmosphere by the upstroke. When the air pressure in the storage tanks drops below a fixed pressure, the unloader returns the compressor suction valve to its seat. The compressor will now function as an air pump and replenish the storage tanks. This unloader is shown in Figure 5-11.

It has a piston working against the air tank pressure at one end, and against an adjustable spring at the other. When the air pressure overcomes the spring tension, the piston moves away thereby allowing the air to pass to the top of a diaphragm. This diaphragm, being flexible, expands downward when the air pressure is applied. To this diaphragm is attached a four fingered prong, the ends of which are normally just above the suction valve. As the diaphragm and prong move downward the suction valve is held off its seat. When the air pressure in the tank drops lower than the spring tension, the piston is forced back onto its seat, cutting off the air supply to the diaphragm. The prong now follows the diaphragm to its normal position allowing the suction valve of the compressor to function.

This unloader is usually set to stop the compressor from pumping air from 15 to 25 pounds under the limit pressure of the tank safety valves. This is done to avoid the safety valves blowing continually. The amount of tank pressure drop which is necessary to start the compressor pumping again varies with each unloader but is usually around 25 pounds under the unloading pressure.

29. AIR TANKS: The air tanks are usually furnished by the shipyard, so we cannot tell you what size they will be, or how many will be installed. As a rule there will be several,

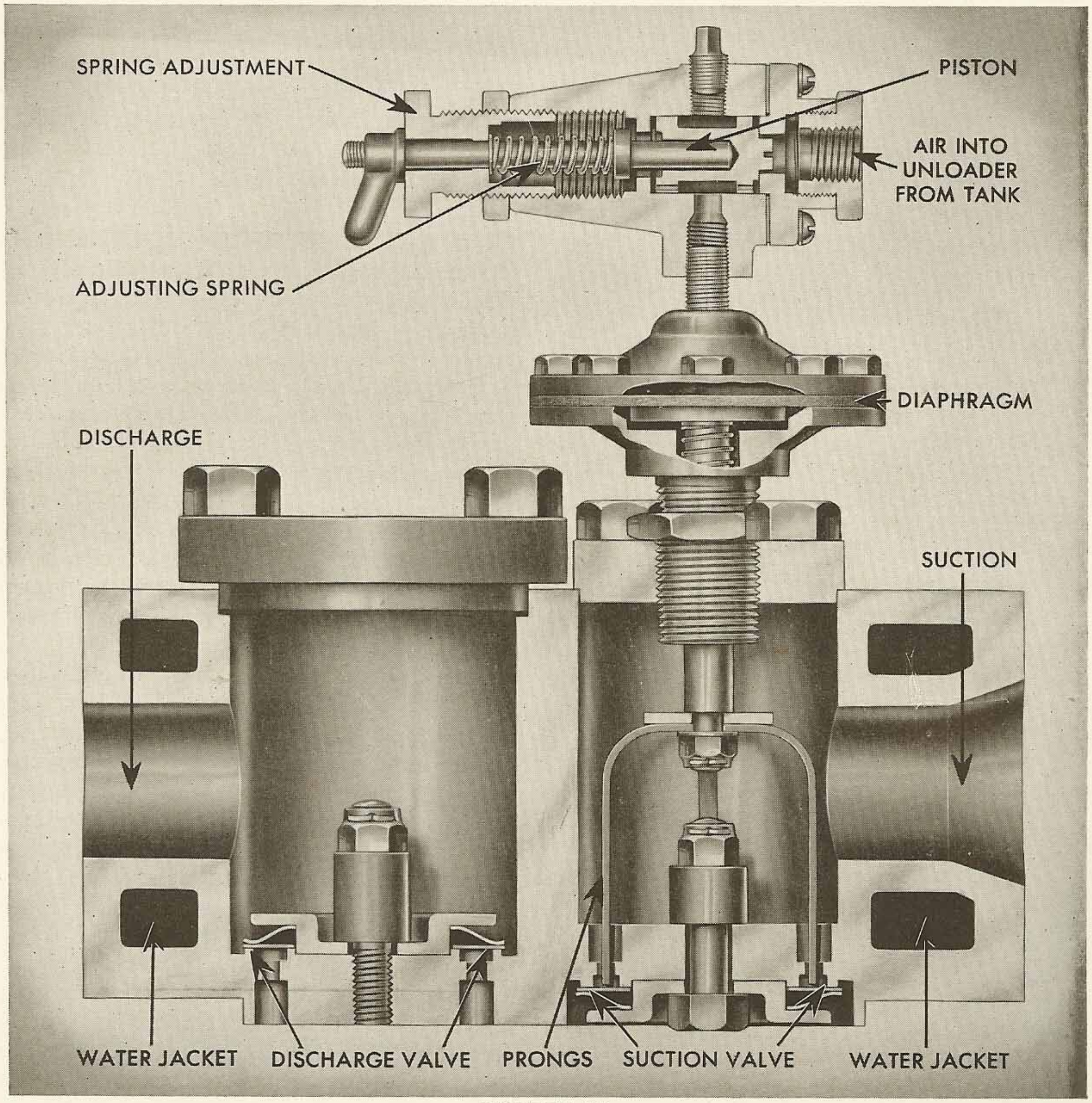


FIGURE 5-11

connected by suitable piping and valves. The tanks will have a drain valve and connection at the bottom to draw off accumulated oil and water. These various drains should be "blown down" once a day as accumulations of oil or water in the air supply are dangerous. Each air tank will probably have a safety valve, or spring-loaded valve, set to "pop" and release air at somewhere over 250 pounds, but well below the bursting pressure of the tank. Air tanks are sometimes called air bottles or air flasks. A diagram of a common air layout is shown in Figure 5-12.

30. INITIAL AIR SUPPLY: When starting up originally or after a long layup, you may have insufficient air pressure in the tanks. Sometimes the shipyard installs an auxiliary air compressor, driven by a small engine that can be cranked by hand. If so, this compressor is used for the initial tank filling. If the ship is at the yard, there probably is a compressed air supply that can be piped to the tank. Sometimes bottles of compressed air, similar to those used to supply soda-water fountains, are used. Bottles containing carbon-dioxide gas are satisfactory, but NEVER UNDER ANY CIRCUMSTANCES USE A BOTTLE OF OXYGEN, as oil and pure oxygen will result in a violent explosion.

31. BRAKE: When reversing from ahead to astern, or vice versa, you MUST WAIT UNTIL THE ENGINE STOPS BEFORE COMPLETING THE MANEUVER. Stopping is brought about quicker by means of a brake that brings a shoe against the flywheel rim as shown in Figure 5-13.

Air pressure admitted to the brake cylinder tends to push the piston and rod, but as the latter is already against the air-compressor

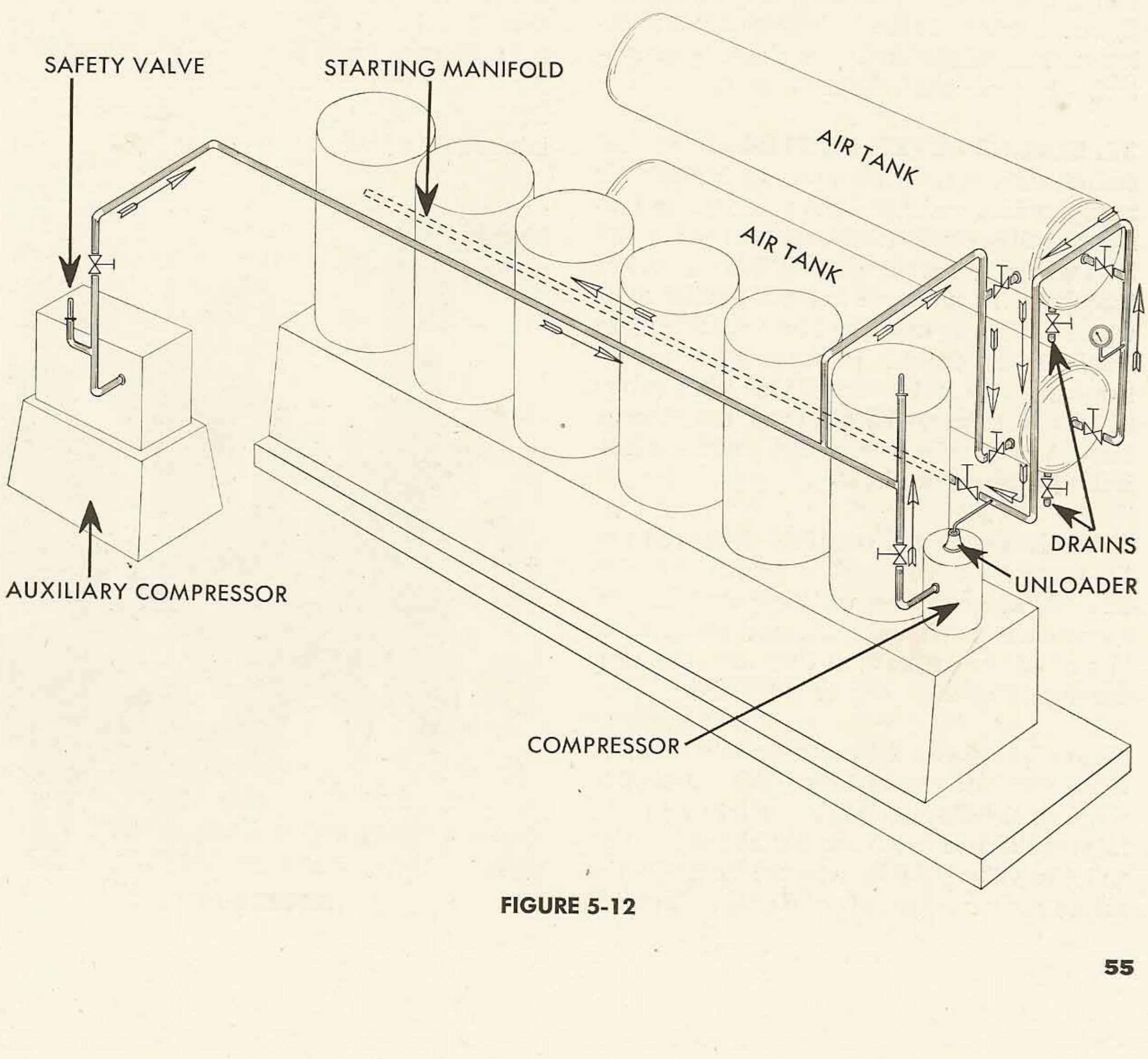


FIGURE 5-12

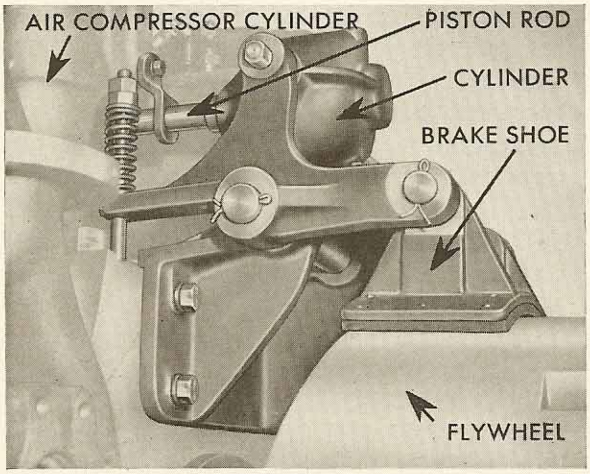


FIGURE 5-13

cylinder, it cannot move, and the cylinder backs away from it instead. The movement of the cylinder moves the brake lever, which causes the brake shoe to press against the flywheel. When the air pressure is released, the spring causes the brake shoe to lift from the flywheel. Air pressure is delivered to and released from this brake by the single-lever control, which we shall describe next.

32. SINGLE LEVER CONTROL: The fuel cutout, rocker shaft air ram, latch shaft air ram, flywheel brake and governor spring tension are all controlled from one unit on engines having a single lever control. The control of these various parts on engines having hand wheel control is described in Section 6. The single lever control operates pilot valves through cams and levers. These pilot valves distribute compressed air from the storage tanks to the cylinders of the various auxiliaries just mentioned.

The adjustment and complete description of the functions of this control are given in Section 18. However, we will now describe one operation in detail which should give a general idea of all the controls, as they are quite similar in principle.

Figure 5-14 shows the control unit with all of the tubing and some of the parts removed to simplify the illustration. The pilot valve (A) rotates the latch shaft to the ahead position and the valve (B) locates the shaft in the astern position. The lever (C) moves against the pilot valve (A) when the control lever is placed in the correct position for this operation.

Reference to Figure 5-15 which illustrates one of the four pilot valves in the control unit shows that the air supply is through the opening (a) and onto the head of the valve. Opening (b) is connected by tubing to one end of the cylinder of the latch shaft ram. It will be seen that this line is now open to the atmosphere through the holes (c) in the stem of the pilot valve, down the hollow stem and through the holes (d) in the vent valve (e).

The first action of the valve when the control lever is moved is to depress the spring under the vent valve. This closes off the holes (d) in the vent valve. As this valve travels into the pilot valve, the spring is compressed until the shoulder on the end of the vent valve strikes the end of the pilot valve. Further movement now lifts the pilot valve off its seat and permits the passage of the full air pressure into the tubing line through the opening (b) and finally through the tubing to one end of the latch shaft cylinder.

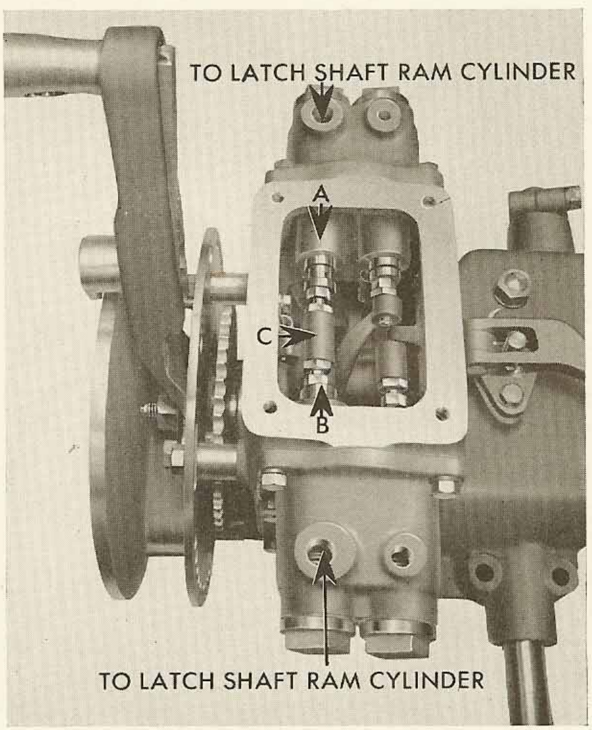


FIGURE 5-14

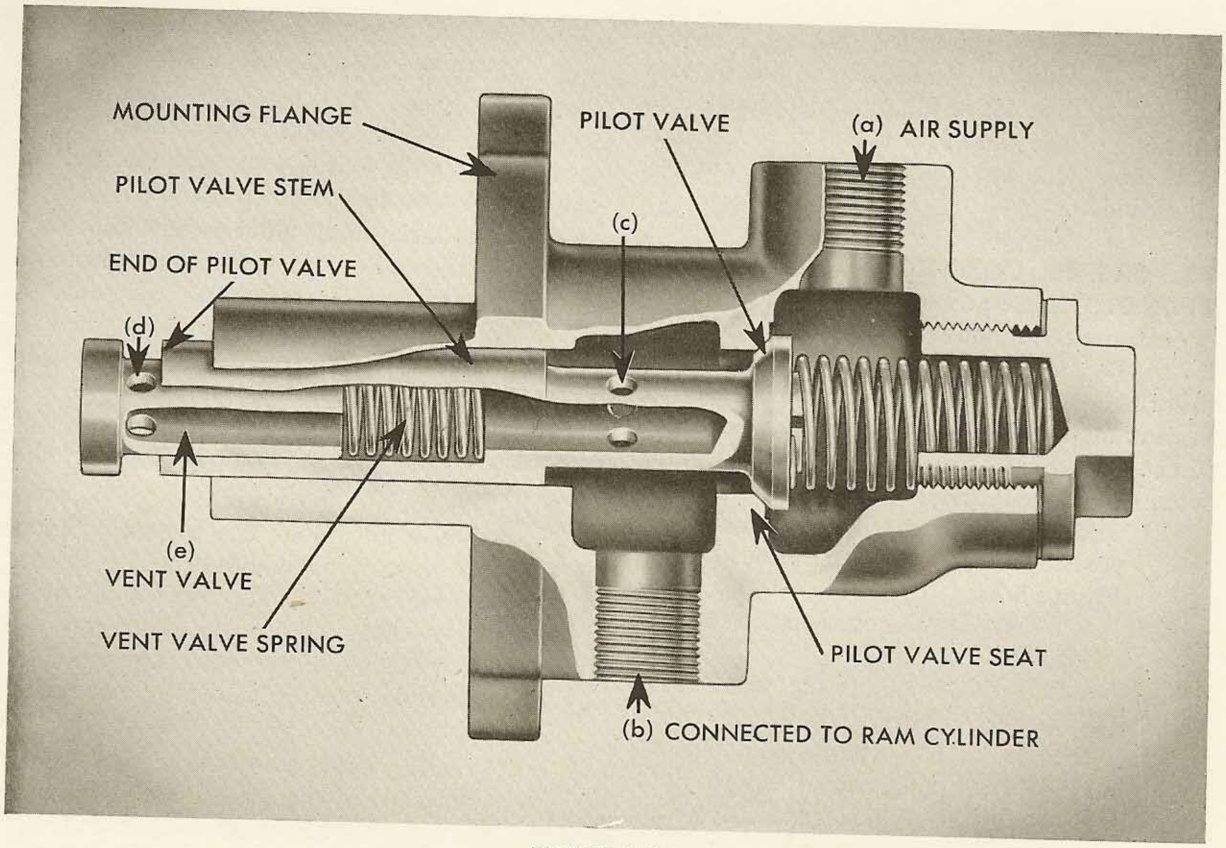


FIGURE 5-15

Pilot valve (B) Figure 5-14, is identical with the one just described but is connected to the opposite end of the latch shaft cylinder. As the lever was moved toward valve (A) Figure 5-14, the spring behind the vent valve in pilot valve (B) caused the vent valve to follow the motion of the lever. It will be seen that the holes in the vent valve would be exposed during this movement. Therefore, the end of the latch cylinder towards which the piston was traveling would be vented to the atmosphere.

When the latch shaft ram is moved into the reverse position the control lever is moved in the opposite direction and the action of valves (A) and (B) Figure 5-14, are just reversed. Valve (B) becomes the one which admits air to the latch cylinder and valve (A) now acts as the vent for its end of the cylinder.

33. LATCH SHAFT RAM: We have described how the air reaches the latch shaft ram and now a study of Figure 5-16 will show how the movement of the piston is used to rotate the latch shaft one half turn. The piston rod ends in a rack, which is simply a long piece of steel with teeth cut for part of its length.These teeth mesh with a gear on an intermediate shaft. On this intermediate shaft there is also a helical or angle cut gear which engages the same type of a gear on the latch shaft.

As the piston in the ram moves in either direction, the rack is drawn across the straight cut gear on the intermediate shaft, causing it to revolve. This movement, in turn, revolves the two helical gears and the latch shaft. The distance that the piston moves is such that the latch shaft turns to the correct ahead or astern position just as the piston reaches either end of its stroke.

34. CUSHIONING OF LATCH SHAFT RAM: Slamming of the piston against the ends of the cylinder is avoided by an air-cushioning arrangement. The air on the advancing side of the piston escapes through the vent valve, but when the boss, or enlarged portion of the rod just next to the piston, enters the cylinder head, it seals this escape and traps enough air to cushion the piston. This air escapes through a small adjustable bleeder valve very gradually. When air is admitted to that end of the piston for the next reversal, it can enter this cushioning space through a check valve.

35. OTHER CONTROL UNIT OPERATIONS: The method of controlling the other operations of maneuvering is in general similar to the control of latch shaft rotation, just described. The cams of the single lever control are arranged so each operation is performed in the proper sequence. For example, in going from slow-speed ahead to slow-speed astern:

(a) The control lever will be in the ahead position in the first running notch. "A" Figure 5-17.

(b) It is released and moved to the stop position, "B".

(c) The fuel cut-out cam operates a linkage system which turns the wedge shaft, withdrawing the wedges and cutting off the fuel supply to the cylinders. This occurs when the lever is anywhere between the two (x) marks.

(d) The brake pilot valve operates the flywheel brake. The brake is applied to the flywheel when the control lever is anywhere between the two (y) marks.

(e) After the engine stops, the control lever is moved to the astern starting position at "C."

(f) The brake pilot valve allows air to escape from the brake, releasing it as the lever passes the point "Y."

(g) The latch shaft pilot valves admit air to the end of the ram where the piston is, and open the other end to the atmosphere, driving the piston down the cylinder and rotating the latch shaft to the astern position.

(h) The control lever is then moved to "D" at the end of the starting slot.

(i) The rocker shaft air ram pilot valve admits air under the air-ram piston, the upward movement of which rotates the rocker shaft, forcing the air start valve lifter and latch down on the astern cams, also opening the air-start manifold master valve at the same time.

(j) Starting air is admitted to the engine, turning it in the astern rotation (some one cylinder will be on the power stroke so that its air-start valve will be open).

(k) After the engine has gotten up speed, the control lever is moved to "E," the first astern running notch.

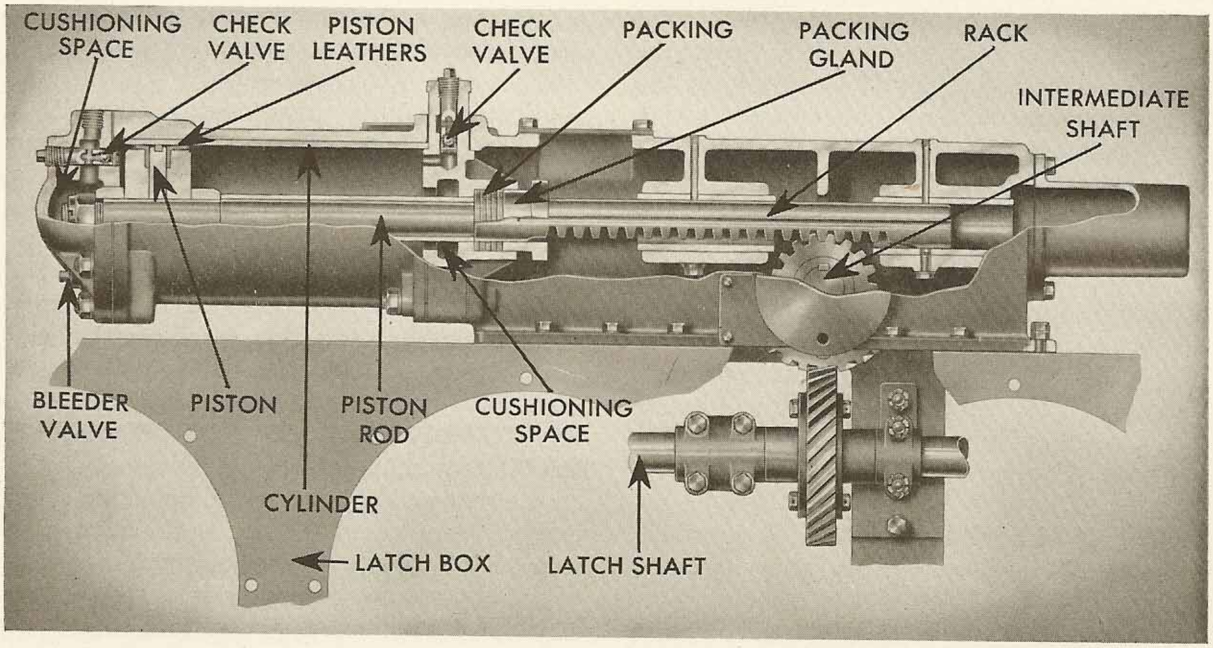


FIGURE 5-16

(l) While moving the control lever from "D" to "E" the rocker shaft air ram pilot valve exhausts air from the bottom of the cylinder, which returns the piston, lifts the air-start valve operating mechanism from the cams, and shuts off the air-start manifold master valve.

(m) This same movement releases the fuel-wedge shaft to control by the governor as the lever passes "X."

The engine is now running slow speed astern.

36. SLOW SPEED TO FULL SPEED: There are a number of notches beyond slow-speed astern or ahead. When the control lever is in one of these notches it compresses the governor spring, as explained in Section 4, and causes the governor to admit more fuel through the wedge shaft action. Full-speed ahead or astern corresponds to the maximum fuel feed.

37. EXHAUST MANIFOLD: We have already had occasion to discuss the exhaust manifold in Section 3. It collects exhaust gases from the individual cylinders so they can be piped to a muffler, usually located in the stack, or elsewhere on deck. The muffler is a tank-shaped affair, filled with baffles to break up the pulsations of the exhaust from the six cylinders. When the gases escape to the atmos-

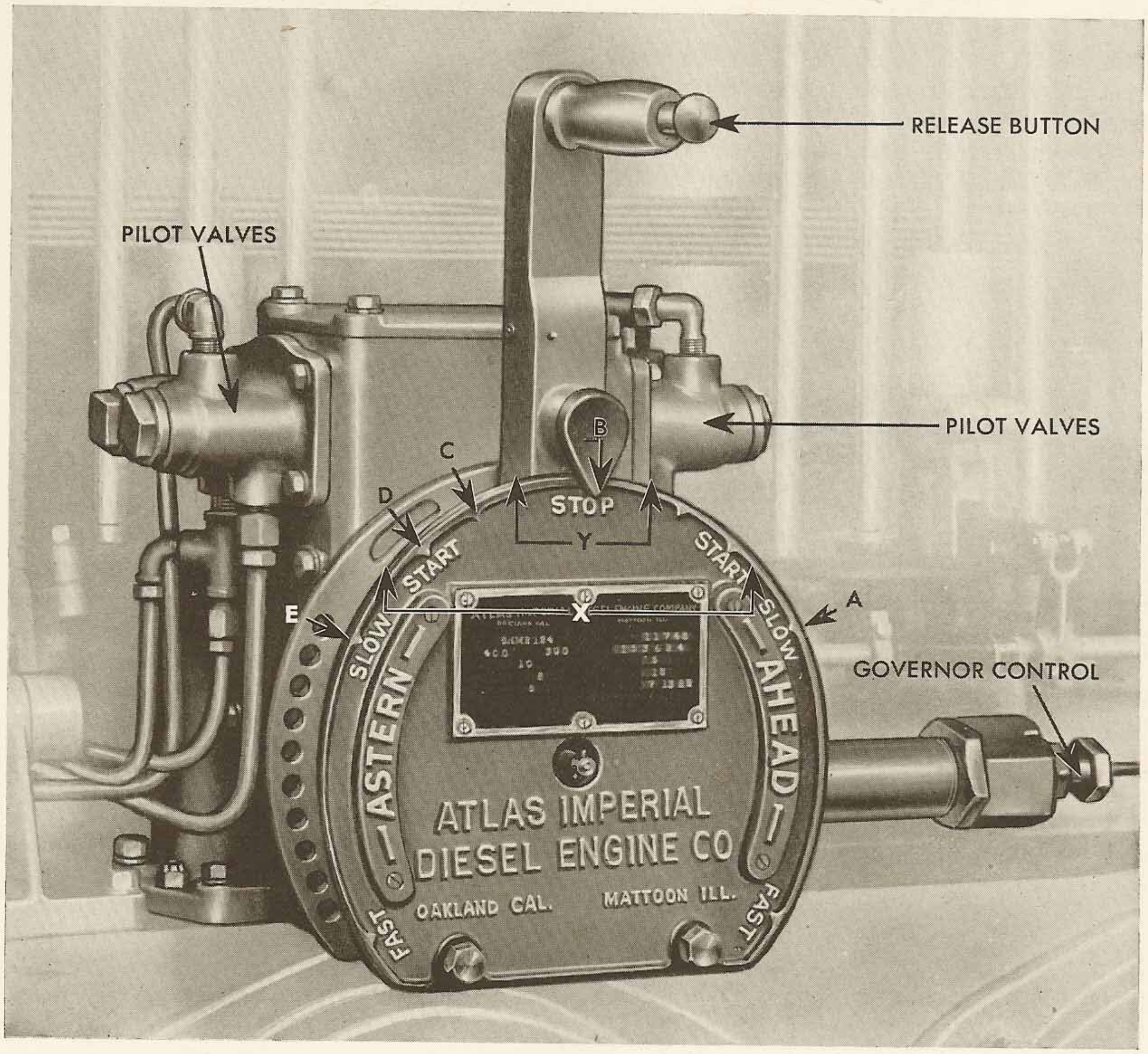


FIGURE 5-17

phere in a steady stream, less noise will be produced.

38. INLET MANIFOLD: The inlet air is led to the engine through a manifold connecting all cylinders. The two openings of the manifold to the atmosphere are each protected by a hood or large cap, which acts somewhat as a silencer, and also prevents articles being drawn into the cylinders.

39. CYLINDER RELIEF VALVES AND SNIFTERS: Screwed into each cylinder head is a fitting to which are attached two valves, either one of which, if open, will allow the escape of air or combustion gases from the clearance volume in the cylinder to the atmosphere.

The snifter valve is merely a needle valve opened by hand, to release compression when barring the engine over. The relief valve is a spring-loaded valve that opens when pressure in the cylinder exceeds the tension of the spring. The opening pressure can be adjusted by screwing the spring cap in or out. After the adjustment is made, the cap should be locked with the set screw. This assembly is shown in Figure 5-18.

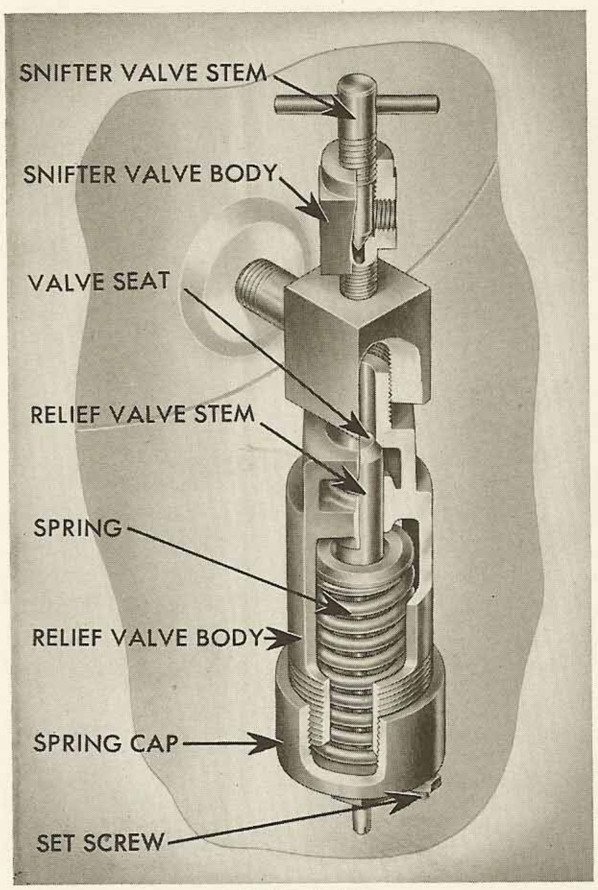


FIGURE 5-18

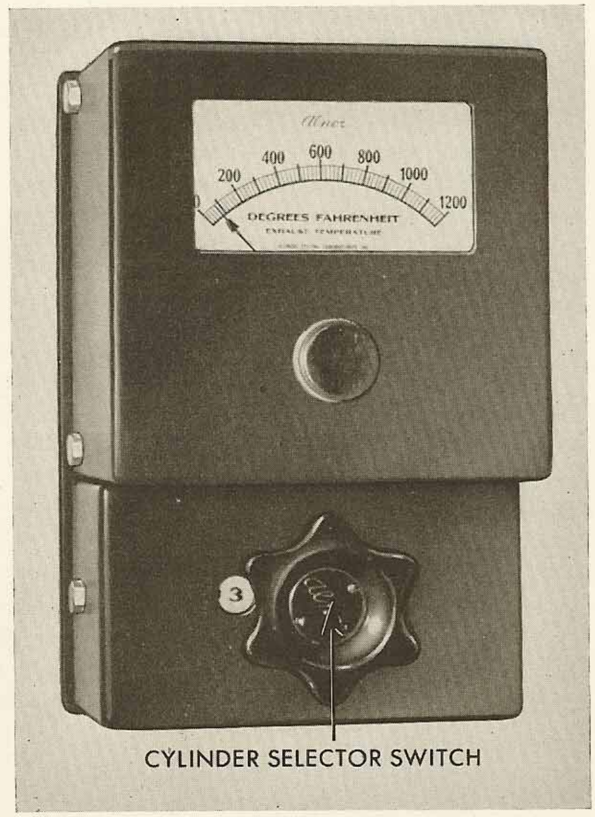


FIGURE 5-19

40. PYROMETER: Figure 5-19 shows a pyrometer, which is a device for determining the temperature of exhaust gases. The instrument is mounted on the gauge board and has a switch so that any one cylinder can be connected and its temperature read. Thermocouples are located in the passages from the cylinders to the exhaust manifold. Temperature is an indication of the work the cylinder is doing. The engine load should be divided evenly between cylinders for best results, so the exhaust temperatures should be about the same for all. If these temperatures are all within a range of 20 degrees, load can be regarded as well divided; a 50 degree spread is on the edge. Any cylinder showing a temperature more than 50 degrees below average is not doing its share; a cylinder more than 50 degrees above average is overloaded. How to adjust, so as to divide the load equally, will be told in Section 10.

SECTION 6
ENGINE OPERATION

1. NORMAL OPERATION: Study of Sections 1 to 5, inclusive, should give you sufficient knowledge of the principles of your engine for you to understand normal operation, or operation with the engine in good repair and adjustment. In this section we propose to describe such normal operation. How to make repairs and adjustments will follow in a series of sections.

2. CHECK OF ENGINE SYSTEMS: Very fortunate is the operator who is given charge of an engine while there is someone still aboard the vessel who is familiar with the entire power plant. The piping plan, the layout and functions of the various auxiliaries can be quickly determined if there is someone to explain them. Listen to such a man carefully, for the chances are that he has already solved many of the problems that will soon be yours.

However, there will be occasions when you will have to take charge of either a new engine or one that has been standing idle for a long period. In this event there are many things you will have to find out by yourself before the engine is started. For example: are the cooling, lubricating and fuel oil systems laid out properly and are they in working order? Trace each line of each piping system to its source and familiarize yourself with the location and purpose of each valve. Piping layouts can be quite tricky and apparently unnecessary valves often have very important jobs to do. Make sure the engine is in running order. The previous operator could have just started to take the engine apart for repairs.

3. COOLING SYSTEM: Be sure the sea valve is open, and go over the suction line to the pump to make sure that any other valves are likewise open. If the engine has been laid up for a long period, it may have been drained, and you should check to see that all drain plugs are in place and tight. If your engine has a raw-water cooling system, check over the oil-cooler valves, the valves controlling the water flow to and from the exhaust-valve cages, and trace the discharge line from the engine to the hull fitting to see that there are no closed valves or other obstructions.

If your engine is equipped with a fresh-water cooling system, inspect all valves on the heat exchanger, the discharge line valve in the raw-water circuit, and any other valves that may be in either the raw or fresh-water circuit. Make sure you have fresh water by checking the expansion-tank gauge glass.

4. LUBRICATING SYSTEM: Check the oil level in the lube service tank. If the oil does not show in the gauge glass, unbolt one of the covers on No. 6 crank pit and see if there is a quantity of oil in the sump. If there is, you should not add oil but wait to check the gauge level after the engine has been started. Then add enough oil to the lube service tank to show about ¾ of the gauge glass full. Fill the mechanical lubricator with NEW OIL until the level shows high in the glass. Give the crank of the lubricator several turns.

Check the thrust-bearing oil level by observing whether oil shows in the glass. If it does not, add oil until the correct level is reached.

Hand oil all points listed in the "FOUR-HOUR ROUTINE" described later in this section.

5. FUEL SYSTEM: Make sure there is fuel in the day tank. If the tank is empty or very low, fill it with a bucket or hand pump. See that the transfer pump is connected up with a storage tank containing fuel oil and that there are no closed valves in the suction or discharge lines that would stop pumping fuel from the storage tanks to the day tank. See that the day tank overflow is connected to the transfer-pump suction without obstruction.

6. HIGH-PRESSURE FUEL PUMP: Open the two vents, shown in Figure 6-1, on top of the outlet fittings of the high-pressure fuel

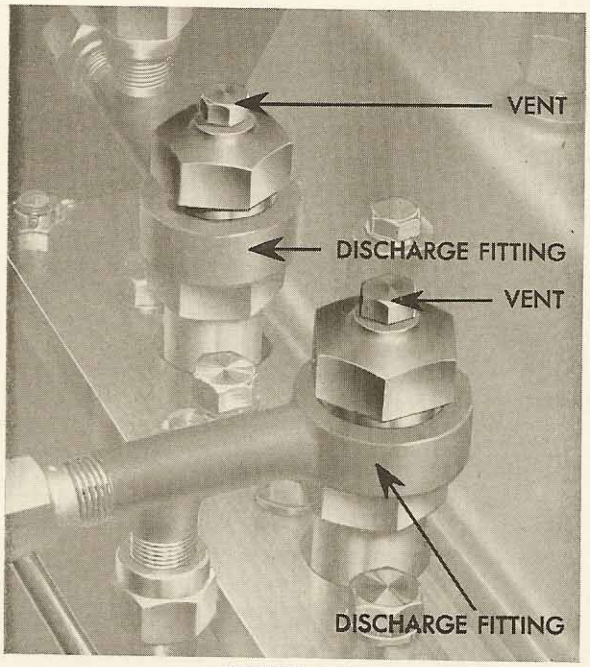


FIGURE 6-1

pump and work the hand-priming pump handle until solid fuel (fuel without air bubbles) flows from each vent. Then close the vents and work the handle until about 1000 pounds of fuel pressure registers on the gauge. BE SURE THE ENGINE IS NOT NEARER THAN 30 DEGREES OF ANY TOP CENTER, OTHERWISE A SPRAY VALVE MIGHT BE OPEN AND FUEL WOULD BE PUMPED INTO THE CYLINDERS.

7. AIR-STARTING SYSTEM: There should be at least 150 pounds air pressure in the tanks but full pressure of 250 pounds will assure quick, efficient starting and a greater number of maneuvers. Check the piping from the air compressor to the tanks, the tank valves, and the piping from the tanks to the engine, to see that all is clear.

8. TOOLS AND CRANKING BAR: Take a look to see that there are no tools lying on what will be moving parts when the engine starts. Be sure the cranking bar used for barring the flywheel over is not in the way. See Figure 6-2.

9. PRELIMINARY CRANKING: Close the fuel lines to the spray valves by closing the isolating valves on the common rail. Open the snifters, or cylinder-relief valves. Depress the latch button of the single-lever control until it releases the lever from the "stop" position, then release the latch button and move the lever to the ahead starting slot, "A." See Figure 6-3.

Wait in position "A" and give the latch shaft a chance to turn in the event the engine stopped with it in the astern position. The completion of this movement of the latch shaft ram can be checked by seeing that the dowel in the hub of the intermediate shaft of the latch ram points to the "ahead" position. Then after it turns, or has had time to turn, move on to "B" position and turn the engine over on air until all fuel, which might have leaked into the combustion chambers, has escaped from the snifters. This usually requires only one or two turns. Move the control lever back to "stop" in one motion without stopping at "A." IF YOUR ENGINE IS EQUIPPED WITH A HAND WHEEL CONTROL, REFER TO PARAGRAPH 17 THIS SECTION.

10. STARTING AHEAD: Close the snifter valves and open the isolating valves. You are now ready to start. Depress the latch button and move the lever to "A" Figure 6-3. Wait at "A" for latch-shaft rotation (we know you have just tested the engine running ahead on air, but waiting here is a good habit to form). Then move on to "B" position. When the en-

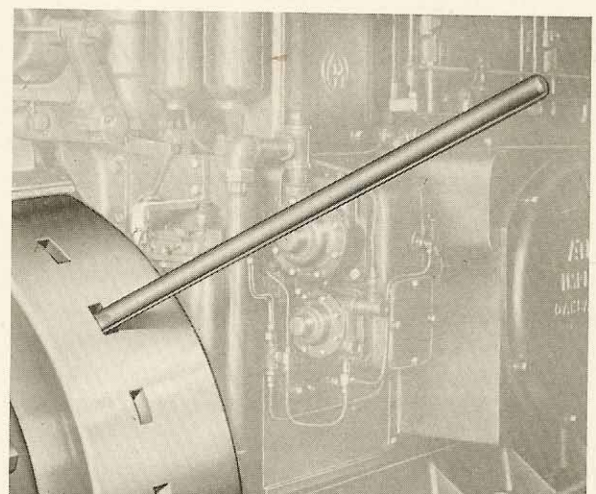


FIGURE 6-2

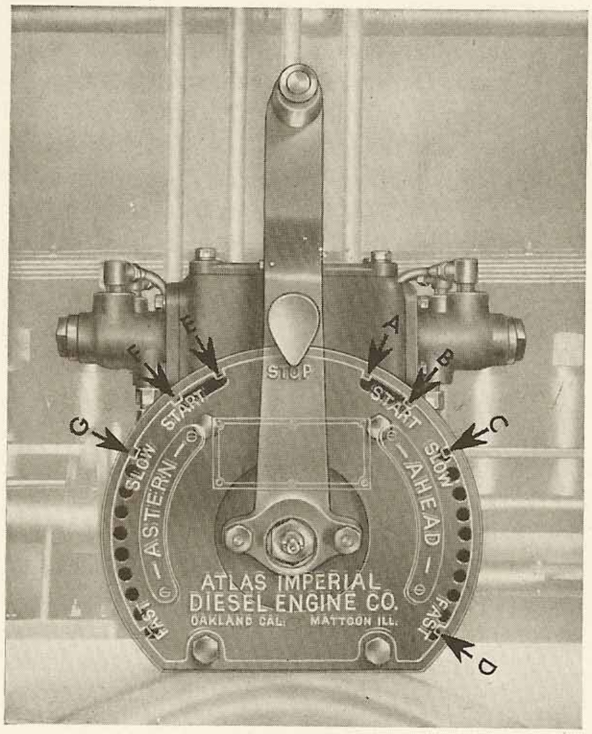


FIGURE 6-3

gine attains starting speed, depress the latch button to get out of the starting slot, release the button and move the lever on to the first running position, "C," or slow-speed ahead. With the engine at a slow idle, you are now off starting air and operating on fuel.

11. RUNNING CHECK-UP: Immediately the engine starts running on fuel in the slow-speed notch, check up on:

A. lubricating-oil pressure by the gauge on the board. It should read 40 pounds or over.
B. lubricating-oil level in the lube service tank. It should be approaching a level about four inches from the top of the glass.
C. fuel-oil level in the day tank. If the tank was only partly filled it should now be filling up to the level of the overflow pipe.
D. the mechanical lubricator to be sure all of the pumps are working.
E. cooling-water circulation. If the raw-water pump is not pumping, SHUT DOWN IMMEDIATELY and find the trouble. Check the fresh-water pump, if there is one.
F. oil or water leaks from pipes and fittings.
G. fuel-regulating valve, by shifting the handle up and down and watching the result on the fuel-pressure gauge on the board. If the fuel pressure increases as the handle is lifted and decreases when it is lowered the valve is free and working properly.

12. INCREASING ENGINE SPEED: Shift the control one notch into a higher speed and go through inspections (A) to (F), inclusive, again. If the engine has been started up from cold it is advisable to increase the speed gradually, going through the various checks each time the speed is raised until the engine has reached its rated number of revolutions per minute. In position "D," Figure 6-3, the maximum governor spring tension is applied.

When the speed is raised, the fuel pressure should be increased proportionately by the fuel- regulating valve shown in Figure 6-4. The regulation of this valve will come with experience. The rule governing this control is to always have sufficient fuel pressure to carry the load on the engine with a clear exhaust. The only exception is when the engine is just turning over with a very light load. The fuel pressure should then be around 1000 pounds and the exhaust might be slightly smoky.

13. REGULAR RUNNING INSPECTIONS: Regularly, while the engine is running, you should inspect:

(a) oil pressure. Now that the engine is warm it should be between 35 and 40 pounds. If it drops below 20 pounds, shut down immediately.
(b) oil level. If the lube service tank level does not get up to a point about four inches below the top of the glass, add oil.
(c) day tank level. The fuel should now be level with the overflow pipe opening.
(d) cooling-water temperature. If you cool with raw-water the temperature at the engine outlet should not be over 120 degrees Fahrenheit; if you cool with fresh-water it can be 160 degrees Fahrenheit.

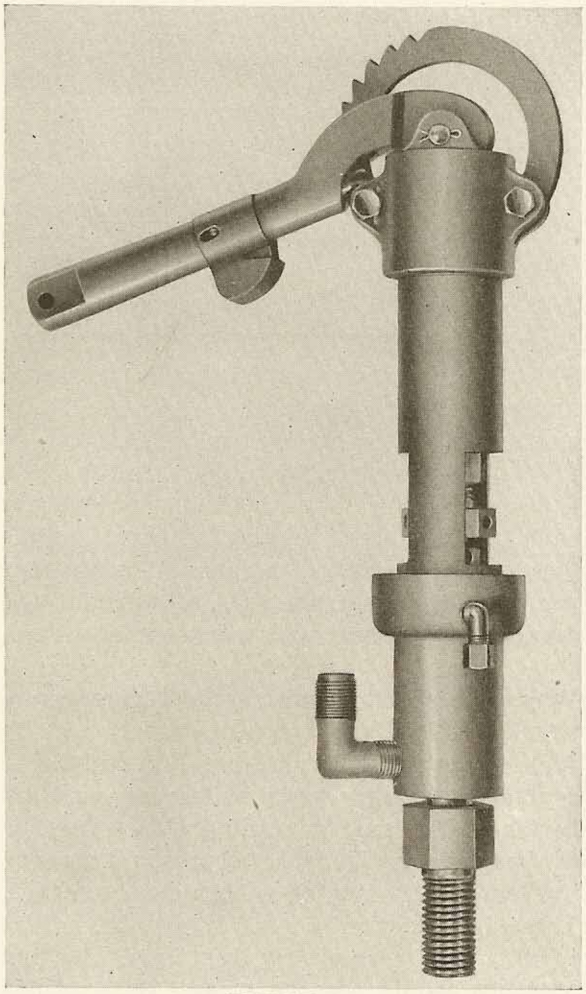


FIGURE 6-4

(e) fresh-water level in expansion tank (for fresh-water systems). If the level shows in the tank gauge the supply is sufficient.

(f) lubricating-oil temperature. It should not be over 145 degrees Fahrenheit at the oil-cooler outlet.

(g) mechanical lubricator. It should be well filled and feeding 15 to 20 drops per minute (25 to 30 drops for a new engine).

(h) bearings, this you can do by feeling the round pit covers on the manifold side (this should be done at least once each hour). If one cover gets hotter than the rest, it indicates that the oil being splashed against it is from a hot bearing.

(i) water jackets and manifolds. Feel them for even water circulation.

(j) fuel pressure. The fuel should be kept at a pressure which will permit the engine to turn its rated number of revolutions per minute. The amount of fuel required to maintain the rated revolutions will vary, especially in tugs, where the load on the engine is changed by towing conditions. The fuel pressure should never exceed 4500 pounds.

(k) exhaust temperature. Full-speed exhaust temperature should not be over 750 degrees Fahrenheit. If all cylinders are over that figure, the engine is being overloaded. If one cylinder is materially out of line in temperature with the others, adjustment is necessary. See Section 10.

(l) exhaust appearance. The exhaust should not smoke. A smoky exhaust may mean: excessive carbon on spray-valve tips; leaky spray valves; leaky exhaust, inlet or air-starting valves; buffer springs incorrectly adjusted; worn fuel cam or roller; leaky or stuck piston rings; or uneven cylinder loading. A few puffs of smoke while maneuvering or idling under light load, however, are nothing to be worried about.

(m) air pressure. If the air pressure drops below 150 pounds, because of air leakage or much maneuvering, you may have difficulty on the next maneuver. If the air pressure goes above 250 pounds, the compressor unloader requires adjustment.

(n) you should also carry out the four-hour routine. Be conscientious about it.

14. REVERSING THE ENGINE: When increasing or decreasing engine speed during maneuvers, remember to adjust your fuel pressure accordingly. When it is necessary to reverse the engine, depress the latch button and hold it, moving the control quickly to "stop" then release the button. WAIT UNTIL THE ENGINE STOPS. Depress the button to get out of the "stop" position, release the button and move the lever to the astern starting slot in position "E," Figure 6-3. Wait for the latch shaft to rotate, and then move the lever on to "F," Figure 6-3, which position admits starting air to the cylinders. After the engine attains starting speed, move the lever on to "G" or other astern positions depending on the speed required.

15. FOUR-HOUR ROUTINE: Each four hours take care of these things:

A. Using engine oil, hand oil the following:
   (a) rockers at rocker shaft
   (b) rockers at push-rod forks
   (c) inlet and exhaust valve stems
   (d) fuel wedges
   (e) fuel buffers
   (f) wedge-shaft bearings
   (g) tachometer drive
   (h) governor bearing and governor linkage, bilge-pump connecting rod, both ends of the eccentric strap of the mechanical lubricator drive
   (i) oil holes on control box
   (j) sight feed to pump
   (k) horseshoes
   (l) rocker shaft rollers
   (m) spray-valve rocker fulcrum

B. Using penetrating oil (or a mixture of equal parts of kerosene and engine oil, if no penetrating oil is available), hand oil the inlet and exhaust valve stems.

C. Check the oil level in the mechanical lubricator, adding oil if needed.

D. Give the handle of the lubricating oil filter one complete turn.

E. Give the handle of the fuel oil filter on the suction side of the high-pressure fuel pump one complete turn.

F. Check sight-feed oiler on circulating pump.

16. ONCE-A-WATCH ROUTINE: Once each watch, do the following things in addition to the four-hour routine:

A. Hand oil—
   (a) latch-shaft ram (oil holes)
   (b) flywheel brake (oil holes)
   (c) rocker-shaft ram (oil holes)
   (d) rocker-shaft ram linkage, including starting-air manifold master valve linkage

B. Drain the air tanks and any air traps of water

C. Drain lube service tank until oil runs clean (do this after the engine has been standing idle if possible)

D. Drain fuel day-tank until fuel runs clean (do this after the engine has been idle if possible)

E. Take pyrometer readings, and record in log

F. Take oil-temperature readings and record in log

G. Take discharge-water temperature readings and record in log.

17. WHEEL CONTROL ENGINES: If your engine is equipped with a hand wheel control for maneuvering, the various assemblies which make up the control unit operate as follows:

Familiarize yourself first with two shallow holes which are in the back of the wheel hub plate, Figure 6-5. Bolted to the latch box and in line with these two holes is a spring loaded pawl. When the hand wheel is turned back toward the stop position, about 90 degrees from either end of its travel, the spring pawl will drop into one of the holes in the hub plate and position the latch shaft in the correct "ahead" or "astern" position. The pointer will then be at either B or C, Figure 6-5.

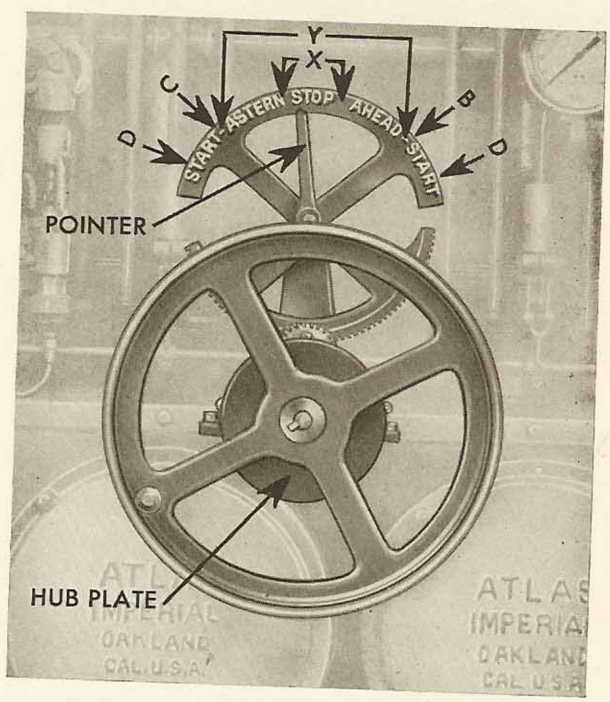


FIGURE 6-5

Movement of the wheel from either "ahead" or "astern" holes on to the end of travel is the equivalent of a movement of the pointer from either B to D or C to D, Figure 6-5, and is the starting maneuver.

As the pointer leaves either B or C on the way to the nearest D, the pilot valve shown in Figure 6-6 is opened by a cam on the latch shaft. This valve admits air to the rocker shaft ram which controls the rocker shaft and master air valve. When the rocker shaft is revolved a part of a turn, the air start valves are brought into action and the master air valve on the manifold is opened, permitting air to pass from the storage tanks into the starting manifold. This is fully described in paragraphs 21 to 25 of Section 5.

When the pointer is anywhere between the x marks, Figure 6-5, another pilot valve, identical with the one shown in Figure 6-6, is opened. This valve admits air to the flywheel brake cylinder. This explains why the operator must wait at or near the stop position, until the engine stops revolving before attempting to reverse the direction of rotation.

At any position between the two "Y" marks, Figure 6-5, the device shown in Figure 6-7 withdraws the fuel wedges, cutting out the action of the spray valves. The pawl is moved upward by a cam on the latch shaft and this movement is transferred to the wedge shaft through the lever and adjusting screw.

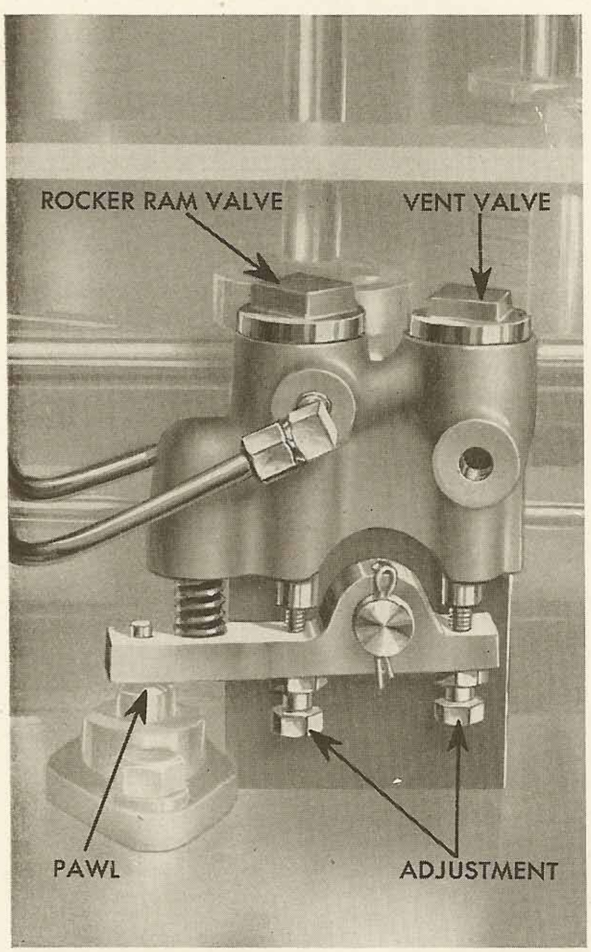


FIGURE 6-6

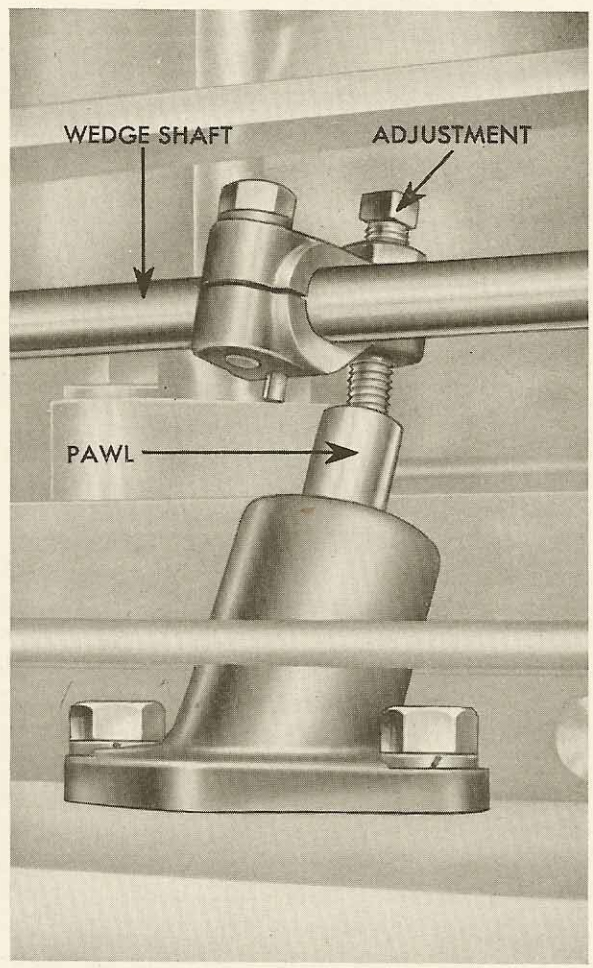


FIGURE 6-7

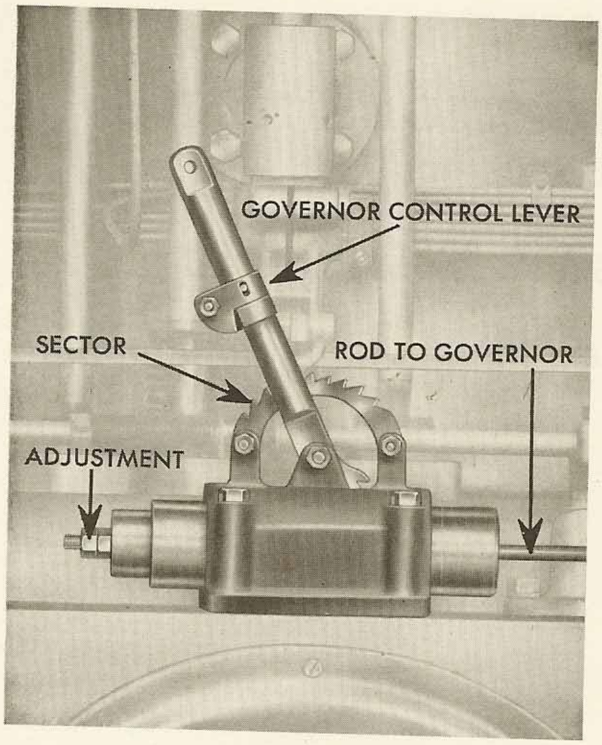


FIGURE 6-8

The governor control lever which is mounted on top of the latch box is shown in Figure 6-8. The movement of this lever acts through linkage shown in Figure 4-12, to increase or decrease the tension of the governor spring.

18. PRELIMINARY CRANKING: Close the isolating valves and open the snifters. Move the hand wheel to the end of its travel or pointer position "D," Figure 6-5. The engine will now revolve on air, and one or two turns should be sufficient to blow out any accumulation of fuel in the cylinders. Turn the wheel back to the stop position. Close the snifters and open the isolating valves.

19. STARTING AHEAD: Open the vents on the top of the high-pressure fuel pump and bleed the air as described in paragraph 6. Check the starting air pressure as in paragraph 7 and take the precautions outlined in paragraph 8. See that the governor lever and the fuel regulator handle are in the slow-speed positions. Turn the wheel so the pointer is at the ahead "D," Figure 6-5, position. As soon as the engine has attained starting speed, move the pointer back to "B." The engine should now be turning over slowly on fuel. Go through the running check-up described in paragraph 11.

20. INCREASING ENGINE SPEED: If the engine is cold, speeding up should be done gradually so that the engine will warm up evenly. The control of the fuel regulating valve is described in paragraph 12. The governor lever is advanced notch by notch at about the same rate as the fuel regulator. As the speed is increased, the check-up outlined in paragraph 11 should be repeated. When the engine is nearly up to the speed the operator desires, final close regulation can be made with the fuel regulating valve.

21. REVERSING THE ENGINE: Move the governor control lever and the fuel regulating valve to the slow-speed positions. Turn the hand wheel to the stop position and WAIT IN THAT POSITION UNTIL THE ENGINE STOPS REVOLVING. Turn the hand wheel to the astern "D" position, Figure 6-5. Wait until the engine attains starting speed. Turn the hand wheel back to "C," which is the astern running position. Adjust the governor control lever and the fuel regulating valve for the desired speed.

22. WARNING: The correct positioning of the latch shaft is important. When the control is in either the ahead or astern position the pawl must be in the proper hole in the hub plate. It is possible for the engine to run if this control is not located correctly but there is great danger of burning the valves or losing the complete supply of starting air.

SECTION 7

ENGINE SPECIFICATIONS AND CLEARANCES

FUEL AND LUBRICATING OIL

1. ENGINE SPECIFICATIONS

Number of cylinders	6
Bore	11½ inches
Stroke	15 inches
Maximum rated speed	325 revolutions per minute
Horsepower at maximum rated speed	320 horsepower
Firing order	1-5-3-6-2-4
Weight of engine including flywheel	38900 pounds approximately
Weight of one cylinder head assembly	530 pounds approximately
Weight of one piston and connecting rod	370 pounds approximately
Lubricating oil pressure minimum	30 pounds per square inch at rated engine revolutions per minute
Lubricating oil pressure	30 to 45 pounds per square inch when oil is hot
Lubricating oil, summer grade	S.A.E. Heavy or Light 40
Lubricating oil, winter grade	S.A.E. Light 30 (NOTE: subject to consideration for extreme cold)
Lubricating oil, capacity of engine	20 gallons
Lubricating oil for thrust bearing, grade	Heavy S.A.E. 30
Lubricating oil feed for mechanical lubricator, number of drops per minute	15 to 20 drops per minute
Lubricating oil feed from sight-feed lubricator on water pump, number of drops per minute	10 drops per minute (maximum)
Lubricating oil temperature before oil cooler	160 degrees, maximum
Lubricating oil temperature after oil cooler	145 degrees, maximum
Cooling water pressure at circulating pump discharge	20 pounds per square inch (maximum)
Cooling water temperature at exhaust manifold discharge	Raw water 120 degrees maximum Fresh water 160 degrees maximum
Fuel pressure at transfer pump discharge	10 pounds per square inch maximum
Fuel pressure in common rail—idling	1000 pounds per square inch
Fuel pressure in common rail—full load	4200 pounds per square inch
Exhaust temperature maximum	750 degrees
Starting air pressure	125 to 250 pounds per square inch
Air compressor type	single stage
Air compressor speed	engine speed
Air compressor bore	6 inches
Air compressor stroke	4 inches
Air compressor unloader setting	cut out 225 pounds per square inch
Air compressor unloader setting	cut in 210 pounds per square inch
Air compressor capacity per revolution	0.065 cubic feet per minute at rated engine revolutions

Raw water cooling: capacity of circulating pump at full speed	55.5 gallons per minute
Bilge pump speed	½ engine speed
Bilge pump bore	3½ inches
Bilge pump stroke	3¼ inches
Bilge pump capacity at full engine speed	20.3 gallons per minute
High-pressure fuel pump type	single stage—2 cylinder
High-pressure fuel pump stroke	1¾ inch
High-pressure fuel-pump bore	21/32 inch
High-pressure fuel pump speed	½ engine speed
Transfer pump make	Tuthill Pump Company
Transfer pump speed	536.5 revolutions per minute
Transfer pump capacity at full speed	2.16 gallons per minute
High-pressure lubricating oil pump make	Tuthill Pump Company (Internal Gear)
High-pressure lubricating oil pump speed	698 revolutions per minute
High-pressure lubricating oil pump capacity at full speed	11.5 gals. per minute at 50 lbs. per sq. in.
Sump lubricating oil pump make	Tuthill Pump Company (Internal Gear)
Sump lubricating oil pump speed	872 revolutions per minute
Sump lubricating oil pump capacity at full speed	15.2 gallons per minute
Lubricating oil cooler make	Ross Heater & Mfg. Co., Inc.

2. BEARING CLEARANCES:

	Minimum	Maximum
Main bearings	0.006	0.010
Crank pin bearings	0.005	0.007
Piston pin bushings	0.0035	0.005
Camshaft bearings	0.005	0.007
Rocker shaft bearings	0.001	0.003
Latch fulcrum bearings	0.003	0.005
High-pressure fuel pump Cross head bearings	0.0005	0.0025
Intermediate cam train bearings	0.002	0.005
Air compressor eccentric strap	0.005	0.010

3. MISCELLANEOUS CLEARANCES:

	Minimum	Maximum
Piston to cylinders (top)	0.065	0.071
Piston to cylinders (bottom)	0.010	0.012
Piston rings clearances in groove	0.003	0.005
Piston rings gap clearance (two top rings)	0.057	0.067
Piston rings gap clearance (all other rings)	0.035	0.045
Piston to top liner	$\frac{15}{16}$ inch	
Inlet and exhaust valves stem to bushing clearance (exhaust)	0.004	0.006
Inlet and exhaust valves stem to bushing clearance (inlet)	0.003	0.005
High-pressure fuel pump plunger to barrel		Lap fit
High-pressure discharge lift		⅛ inch

4. FUEL AND LUBRICATING OILS: As an operator of a vessel belonging to the Armed Forces, you will no doubt be supplied with the correct fuel and lubricating oil. However, should you require specifications of these supplies the following will enable you to select fuel and lubricating oils best suited to your engine.

5. RECOMMENDED FUEL OIL SPECIFICATIONS:

Viscosity	35 to 70 S.U. seconds at 100 degrees Fahrenheit
Gravity (A.P.I.)	Minimum 24 degrees
Conradson Carbon (A.S.T.M. D189)	Maximum 0.5%
Ash	Maximum 0.05%
B.S.&W.	Maximum 0.1%
Sulphur (A.S.T.M.D129)	Maximum 1.0%
Ignition Quality	40 to 60 Cetane Number

6. EFFECT OF FUEL PROPERTIES ON PERFORMANCE: As adjusted at the factory the engine will operate satisfactorily on fuels with viscosities per above specifications. It is possible to use thinner fuels but the operation is apt to be "snappy" and it may be difficult to maintain even cylinder load balance at varying loads. Fuels with viscosities less than 35 S.U.S. may also require special spray tips with smaller orifice holes than standard or the fuel pressure may have to be reduced. On the other hand fuels with high viscosities may require larger spray orifices than standard, increased fuel pressure and in extreme cases longer period of injection. To insure good operation it is recommended that the viscosity be held to the specification.

7. GRAVITY: The gravity is of secondary importance. A minimum of 24 degrees A.P.I. is merely given since heavier fuels generally require special treatment, such as heating and centrifuging, before they can be burned successfully.

8. CARBON: The Conradson Carbon or carbon residue in the oil is an index to the amount of carbon which will form in the combustion chamber. Fuels with high Conradson Carbon may cause carbon to build up on the spray valve tips to such an extent that the fuel sprays are deflected, causing poor operation and smoky exhaust. The higher the Conradson Carbon the more frequently will it be necessary to clean the spray valve tips. Experience also indicates that maintenance costs will be higher when fuel with high carbon residues is used.

9. ASH: The ash content of a fuel is a measure of the amount of mineral material it contains. After burning the mineral residues are abrasive and it is consequently important that the ash content be limited to 0.05%. If the content is higher rapid wear of cylinder liners, pistons and rings will result.

10. BOTTOM SEDIMENT AND WATER: The item B.S.&W. (Bottom Sediment and Water) is an index to the fuel's cleanliness. It is good economy to use clean fuel and store it in clean tanks.

11. SULPHUR: When the fuel oil is consumed in the engine sulphur burns to sulphur-dioxide. Under normal operating conditions most of this gas is ejected with the exhaust gases. If, however, temperature conditions are low enough, that is, if the engine is idling at low speed and under cold conditions, the sulphur-dioxide gas combines with condensed water vapors to form a corrosive acid which will attack metals used in the engine and exhaust system. It is consequently particularly important to hold the sulphur content low in fuels used for engines subject to variable loads with long period of idling and also for engines subject to frequent starting and stopping.

12. CETANE NUMBER: The cetane number of a fuel is an index of the ignition quality. Low cetane values produce excessive knocking. Excessively high cetane fuels cause high exhaust temperatures and smokiness of the exhaust.

13. FLASH POINT: Although the flash point does not affect the suitability of a diesel fuel it is well to specify a minimum of 150 degrees Fahrenheit, since state laws and Classification Societies generally require this minimum. The pour point of the fuel should be at least 15 degrees Fahrenheit below the lowest temperature to which the fuel storage tank is subjected.

14. LUBRICATING OIL: We recommend that a good grade of marine type pure mineral oil be used in these engines. The oil should be stable under the temperature conditions encountered in the engine and should be resistant to oxidation and sludging. In general, regarding quality of lubricating oil we refer you to a Lubrication Instruction Book which will be sent to any customer or operator requesting it. This book contains some good pointers on the selection and care of lubricating oils. It is not necessary to use compound oils, i.e., oils containing additives, inhibitors, anti-oxidants, carbon removers, etc. in Atlas Engines. There are, however, many good compounded oils on the market and these may be used providing extreme caution is exercised and the action of the oil in the engine is observed closely.

15. STRAIGHT AND COMPOUNDED OILS: When a pure or straight mineral oil is used some carbon or other deposits will generally be found in the crankcase and sump tank. The amount of these deposits depends greatly on the quality of the oil which has been used and for good grades of oil the deposits are not excessive and in any way harmful to the engine. The chemicals contained in the compounded oils enable these oils to carry the carbon and other constituents of the usual crankcase deposits in suspension. The compounded oils also have a strong tendency to break loose and carry away any existing crankcase deposits and since there is a limit to the amount that can be carried in suspension clogging of filters and oil lines may result. It is consequently of utmost importance to thoroughly clean out the crankcase, oil lines and sump tank before changing from a straight mineral oil to a compounded oil. As an added precaution we suggest that the first batch of compounded oil be used only for about 25 hours and then drained off. These precautions apply also when changing from one compounded oil to another compounded oil of different make or brand.

If a compounded oil is used the non-corrosiveness of this oil must be looked into very carefully. In this connection the Engineering Department of the Atlas Imperial Diesel Engine Co. is available for consultation and they will be glad to advise whether or not an oil is suitable for use in this engine.

16. VISCOSITY GRADE: With regard to viscosity grade our recommendations are that the viscosity at 130 degrees Fahrenheit be between 235 and 270 Secs. Saybolt Universal. This corresponds to an S.A.E. viscosity rating of 30 to 40. In other words, the oil to be used should be a heavy S.A.E. 30 or a light S.A.E. 40 oil.

17. CHANGING OIL: In regard to drainage periods we suggest that the first batch of oil be drained after 100 hours of service. Thereafter the suggested drainage period is 200 to 250 hours. This period may be lengthened somewhat on engines which are equipped with waste packed filters. In that case if the filter cartridge is changed before the oil is badly discolored and loaded up with insolubles or foreign particles, drainage periods of 400 to 600 hours can be used. In cases where no waste packed filters are used, the oil will not be worn out, of course, after 200 hours of service, providing a good grade of oil is used. It will, however, be dirty, and will contain insolubles which should be removed from the lubricating oil before it is re-used.

18. MECHANICAL LUBRICATOR: The same lubricating oil as used in the crankcase of the engine is also suitable for use in the mechanical lubricator. In the case of the mechanical lubricator, however, it is highly desirable that new oil be used.

SECTION 8
STANDARD TERMS, FITTINGS, AND TOOLS

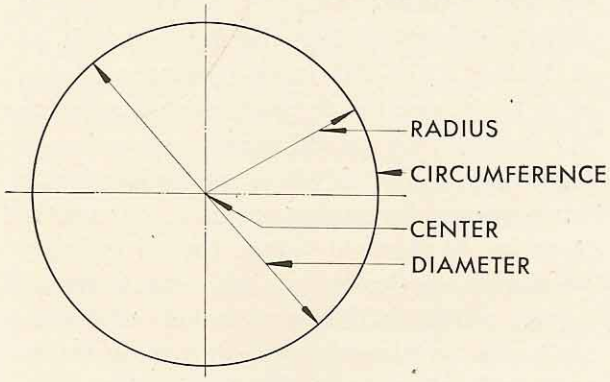


FIGURE 8-1

1. MEASUREMENTS OF CIRCLES: A circle has a center and a circumference. The distance from the center to the circumference is called the radius. Twice the radius, or the length of a line from circumference through the center and to the circumference, is called the diameter.

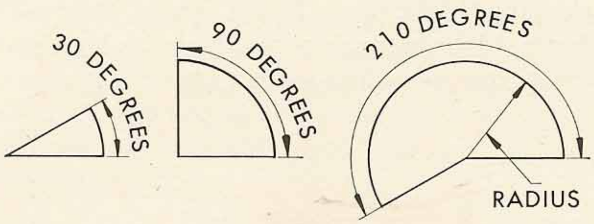


FIGURE 8-2

2. ANGULAR MEASUREMENT: To measure parts of circles, we divide any circle into degrees—360 degrees make a full circle, 180 degrees, a half circle, 90 degrees, a quarter circle, etc. Any part of a circle, comprised of part of the circumference (called an arc) and the two radii (the plural of radius) meeting the ends of the arc, is called a sector.

The number of degrees can be used to describe the size of an angle whether it is closed by an arc or not. A 90-degree angle is called a right angle, and two lines at right angles to each other can be said to be 90 degrees apart, whether there is a circle, or a part of one, in the picture or not. Two lines at 90 degrees are also said to be perpendicular to each other. A line may also be perpendicular to a surface, and two surfaces may be perpendicular to each other, as the walls of a room are perpendicular to the floor.

3. PARALLEL LINES: Two straight lines are said to be parallel if they could lie in the same flat surface and are always the same distance apart, never meeting. The lines of type on this page could be said to be parallel because any two run across the page at a constant distance apart, and they are on a flat piece of paper, or surface. However, if you should warp the page so that it is no longer flat, the lines cease to be parallel.

A line is said to be parallel to a surface if it stays the same distance away from the surface throughout its length. Two surfaces may be parallel. Thus a flat ceiling of a room is parallel to the floor, and the line of the picture moulding may be parallel to both the floor and the ceiling.

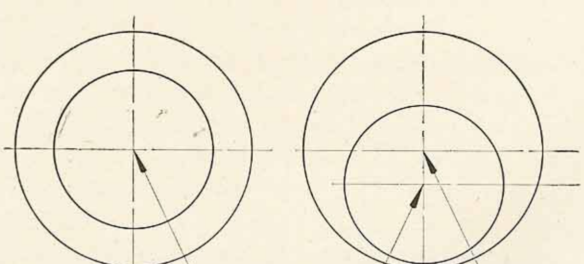


FIGURE 8-3

4. CONCENTRIC AND ECCENTRIC CIRCLES: Two circles are said to be concentric if they have the same center but different length radii. If the centers of both circles lie within the circumferences of both but do not coincide, the circles are said to be eccentric.

5. MEANING OF "TOLERANCE": If machinery builders had to make each part to exact dimensions, machinery would be terrifically expensive yet might perform no better. So each part that must fit in or around another part is made within a certain leeway, called a tolerance. For example, a round shaft made to fit in a bearing might have a nominal diameter of two inches, yet the builder knows from experience that the shaft will be satisfactory if it is made to any diameter between 1.995 inches and 2.005 inches. The drawings for the shaft will accordingly specify that the shaft diameter shall be 2.000 inches plus or minus 0.005 inch (usually shown on drawings as 2.000″±0.005″). Sometimes tolerance is expressed: 2.000 inches + zero, —0.006 inch, meaning that the shaft, or whatever it is, must not be over two inches on the dimension in question, but may be 0.006 inch smaller. Or a tolerance might be 6.000 inches + 0.010 inch, — zero.

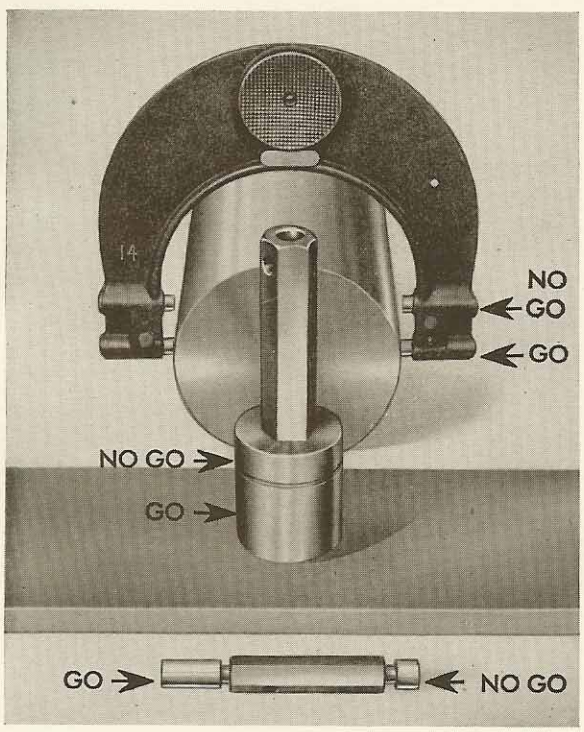


FIGURE 8-4

6. SNAP GAUGES: Whether or not parts have been finished within the dimensions allowed by the specified tolerances is checked by various kinds of tolerance gauges. A snap gauge is for measuring parts that can be spanned on the outside. It has two arms fitted with pads, called anvils, at the tips. The distance between the anvils is very accurately calibrated. If the part to be measured can be slipped between the anvils of the gauge, it is smaller than gauge dimension; if it cannot enter the gauge, it is larger.

To determine whether a shaft, for example, is finished 3.000 inches ± 0.005 inch, we should have two snap gauges, one 3.005 inches, the other 2.995 inches. If the larger gauge slips over the shaft, we know that the shaft is not over 3.005 inches in diameter; if the smaller gauge cannot be slipped over the shaft it is not less than 2.995 inches in diameter. The first gauge is called a "go" gauge, the second a "no-go" gauge.

7. OTHER GAUGES: Tolerance gauges may be made in various forms, depending upon the shape of the part to be gauged. Plug gauges are made for gauging holes. A "no-go" plug gauge should not enter the hole, and a "go" gauge should, if the hole is finished to the right dimension and tolerance.

8. CALIPERS: On shipboard you will seldom have tolerance gauges available, but you can measure parts if you have suitable calipers. The kind that should be used for any measurement will depend upon the accuracy you want. Measurements that need not be accurate beyond the nearest hundredth of an inch may be made with plain calipers such as are shown in Figure 8-5. The points of the calipers are brought against the part to be measured and the calipers are then withdrawn and laid against a scale to determine the dimension. In using calipers be sure you have the points across the dimension you want. Figure 8-5 shows how you could get an incorrect measurement if you were not careful.

In (A) of Figure 8-5 the calipers have not been checked for greatest dimension by passing them over the shaft. In (B) and (C) they have

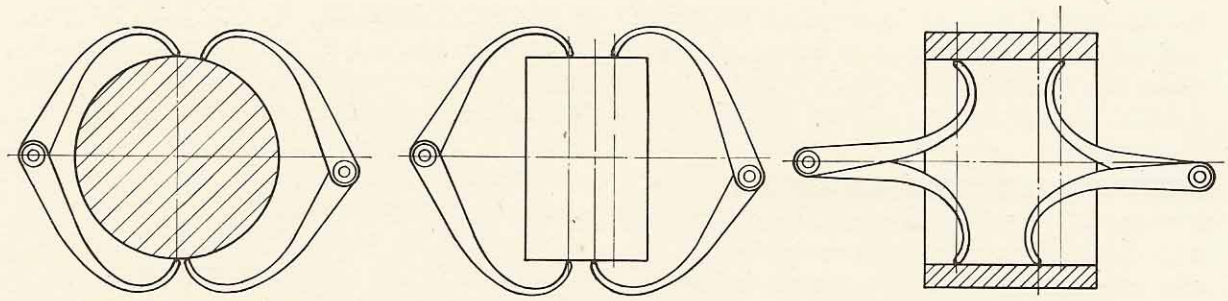


FIGURE 8-5

not been checked for least dimension by moving them up and down.

9. MICROMETER CALIPERS: More exact measurements require calipers of micrometer type. This type has anvils that can be moved in or out by turning a very accurately-made screw, using light finger action. The shaft of the moving anvil is marked off in inches, tenths of inches, and quarters of tenths (or, as we say, is graduated in inches, tenths and quarter-tenths). The dimension spanned by the anvils can be read directly on the shaft to the inch, tenth and quarter-tenth, and as a quarter-tenth is 0.025 inch, the reading is to twenty-five thousandths. In Figure 8-6, the shaft scale shows a gap between the anvils of 0.871 inch. One complete turn of the screw advances the moving anvil exactly one quarter-tenth or 0.025 inch. The circumference of the screw is graduated into 25 equal spaces, so that a turn of only one space advances the anvil $\frac{1}{25}$ of 0.025 inch, or 0.001 inch. In Figure 8-6, the circular scale indicates that the anvil has been moved 0.021 inch beyond the 0.850 inch we can read on the straight shaft scale, so that the anvils are apart by 0.871 inch.

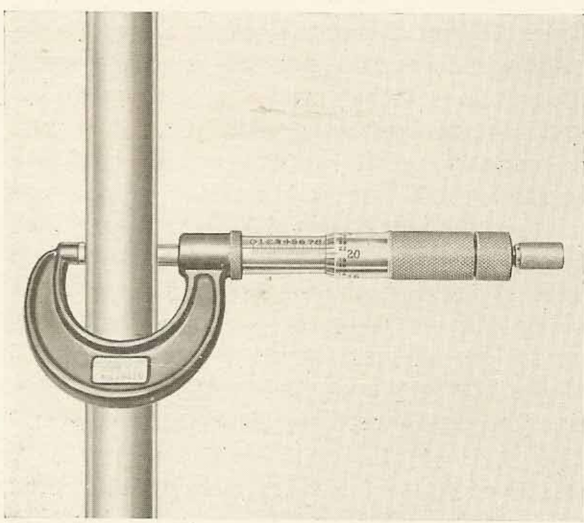


FIGURE 8-6

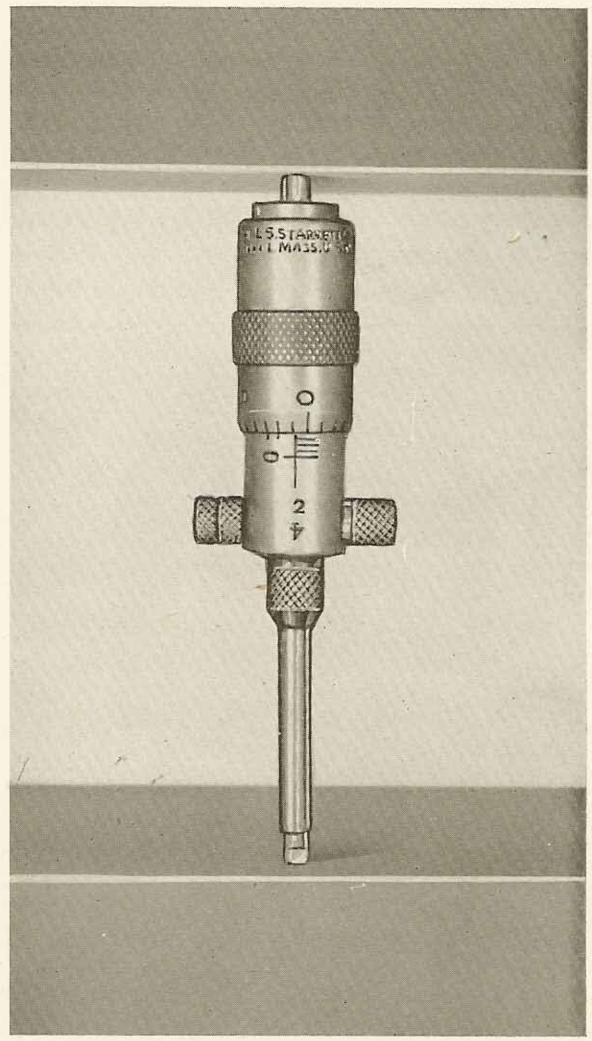


FIGURE 8-7

Micrometer calipers are commonly called "micrometers," and sometimes just called "mikes."

10. INSIDE MICROMETERS: The micrometer shown in Figure 8-6 is an outside micrometer. An inside micrometer is shown in Figure 8-7, with a reading of 0.101 inch. This measurement is added to the known length of the head and the stick which in this instance is three inches. The total measurement is therefore 3.101 inches.

11. DIAL INDICATORS: Another form of micrometer is the dial indicator. It is made with a dial and a pointer, geared so that a very small movement of the shaft in or out produces a large movement of the dial pointer. Suppose you wish to check a shaft to see whether it is parallel to a machined surface. You are not concerned, let us say, about the exact distance between the shaft and the surface, except to find whether it remains the same along the length of the shaft.

So you mount the dial indicator as shown at (B) in Figure 8-8, being careful to line the indicator shaft on the line of the diameter of the shaft being checked that is perpendicular to the surface. You move the indicator up until pressure of the shaft turns the pointer one revolution. You then set the pointer exactly at zero on the dial. Then move the indicator to position (A), as shown in phantom, being careful not to permit the indicator mounting to slip and change in height. At (A) the indicator will show whether the shaft is at the same height, or above or below it. In the figure, the indicator shows that the shaft is 0.010 inch higher than in position (B). Whether this is a serious difference will depend upon what the shaft does. If a shaft is correctly distanced from a surface at two points, and is straight, you may assume that it is correctly distanced at all points. If it is out 0.010 inch at points, say, one foot apart, and the shaft is straight, remember that it will be out 0.020 inch in two feet, 0.030 inch at three feet, etc.

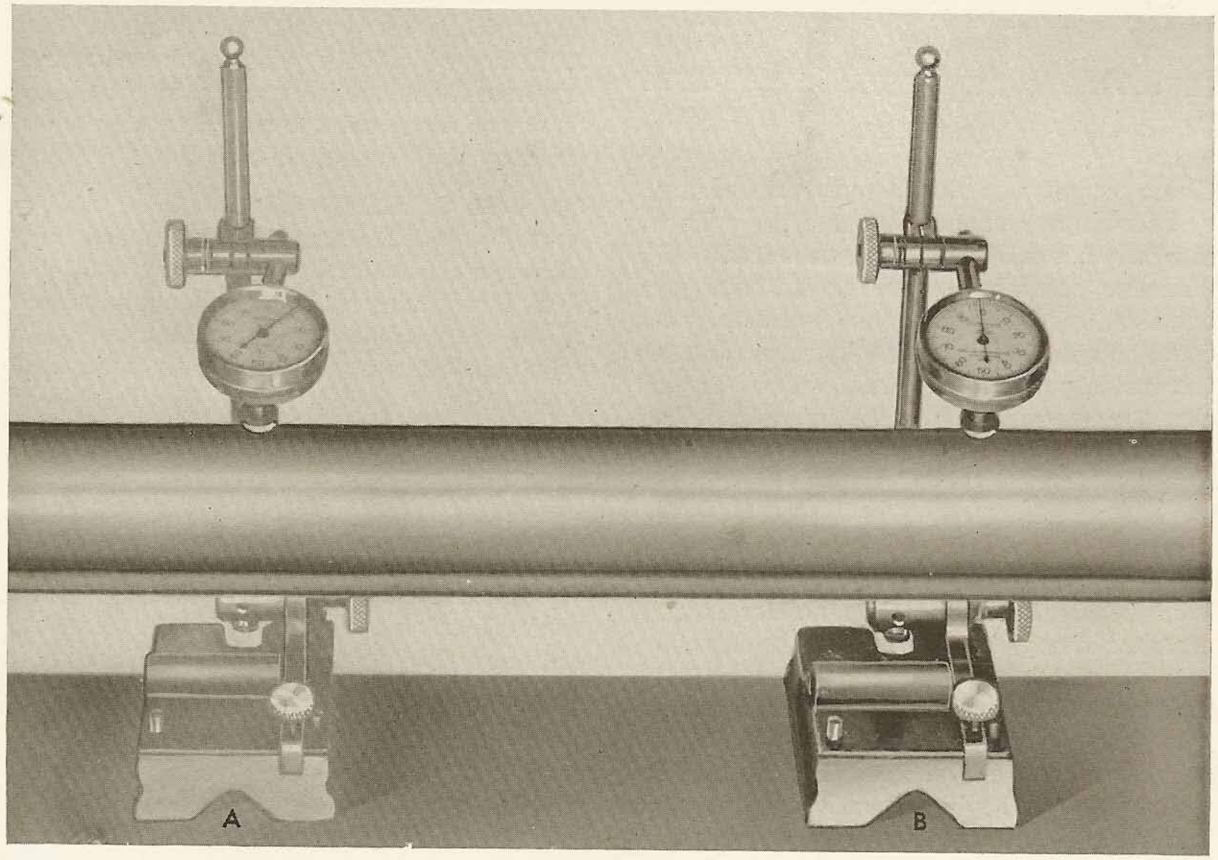


FIGURE 8-8

12. CLEARANCE: Parts that are to work against each other, or rotate within one another, must have clearance. For example, a shaft 2.000 inches in diameter would not turn in a bearing 1.980 inches in diameter. The bearing must be slightly larger than the shaft, say, for example, 2.020 inches, and the clearance in that case is 0.020 inch. Here again, we must have a tolerance, which will depend upon the size of the shaft and what it does in the machine. For example, the shaft might be 2.000 inches ± 0.005 inch, and the bearing 2.020 inches ± 0.005 inch, so that the tightest fit possible would be a 2.005 inch shaft in a 2.015 inch bearing, when the clearance would be 0.010 inch. The shaft could also be 1.995 inches and the bearing 2.025 inches, giving a clearance of 0.030 inch.

This could be specified as a clearance of 0.020 inch ± 0.010 inch.

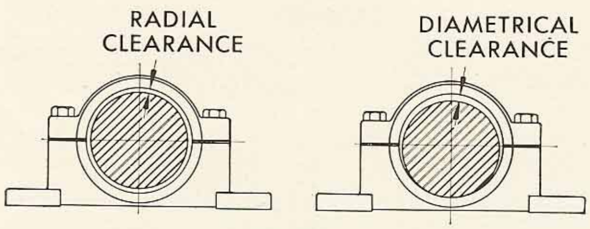


FIGURE 8-9

Clearance between shafts and their bearings, or between any round piece and the cylinder in which it is to fit, is usually measured on the diameter, or with the part inside touching at one side, as in (B) of Figure 8-9. Clearances could be specified as radial, however, or with the inside part centered, and the all-around clearance measured on the radius, as in (A) of the figure. When the kind of clearance is not specified, diametrical clearance is understood.

Clearance naturally is greater for large parts than for small ones. Sometimes this variation is so specified. For example, a builder of various sizes of engines may express the clearance between piston skirts and cylinders as 0.001 inch per inch of cylinder diameter. He means that when he makes an engine with 8-inch cylinders, he allows 0.008 inch clearance between skirts and cylinder walls; but on an engine with 11-inch bore, the clearance would be 0.011 inch.

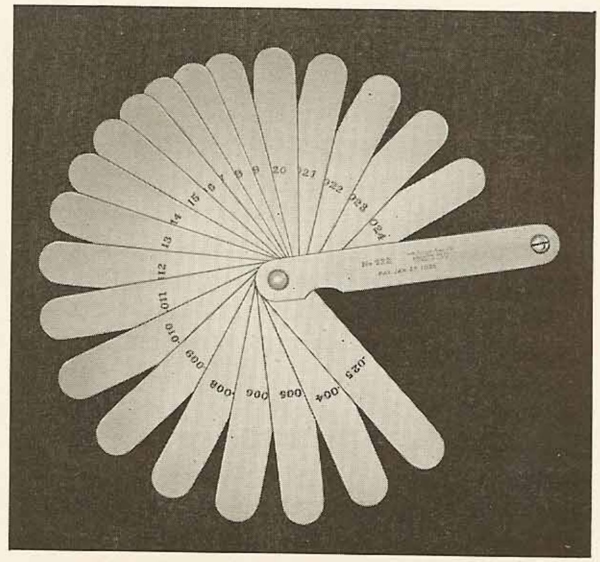


FIGURE 8-10

13. FEELER GAUGES: Clearance can sometimes be measured by feeler gauges, or thin strips of steel accurately made to exact thickness. For example, if a gap can be entered by three feeler gauges, side by side, one 0.005 inch thick, one 0.003 inch thick, and one 0.002 inch thick, we know that the gap is at least 0.010 inch wide. If the addition of another feeler gauge 0.002 inch thick makes the combined thickness too great for the gauges to enter, we know that the gap is less than 0.012 inch.

14. USE OF LEAD WIRES: Some fits are located so that feeler gauges cannot be inserted in the clearance. For example, the fit of a shaft in a bearing if the shaft has collars close to the sides of the bearing. Clearance in a split bearing can be measured by using lead wires. The top half is removed and soft lead wires known to be larger in diameter than the greatest clearance are laid on the top half of the shaft around the circumference. The top half of the bearing can then be bolted down to squeeze the lead wires to clearance thickness. The wires can then be micrometered, and the thickest flat on any wire will be the clearance of the bearing where the wire was located.

15. SHIMS: Split bearings often have the halves separated by shims, or thin strips of metal or paper. The clearance of the bearing when new will be increased by wear, but can be restored by removing shims. The same thickness of shims should be removed from

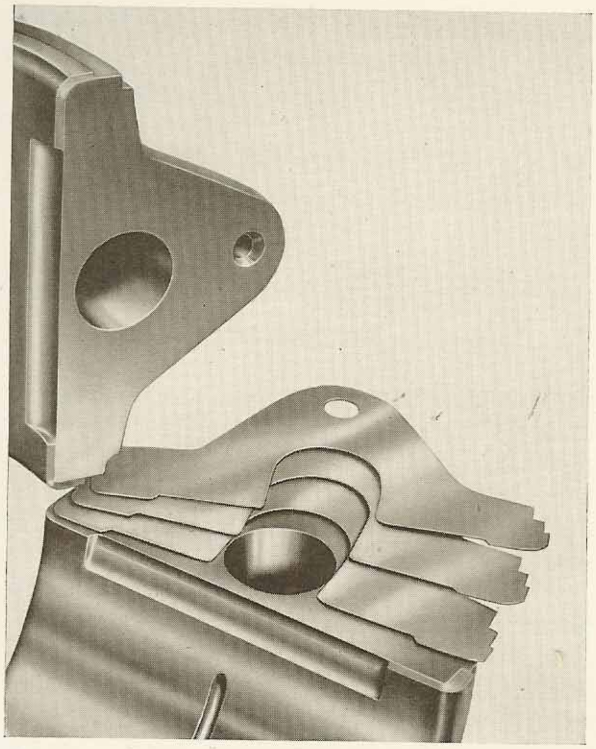


FIGURE 8-11

each side. For example, a bearing when new had a clearance of 0.020 inch but has worn to 0.030 inch clearance. If a shim, or combination of shims, 0.010 inch thick is removed at each side the original clearance will be restored. As bearings do not wear equally around the circumference, but in the sector that takes the load, which is usually the top or bottom of the bearing half-way between the shims, a bearing taken up by removing shims will no longer be exactly round. For a small take-up this makes but little difference, but removing shims to correct for a large amount of wear is unsatisfactory practice.

16. FITS: The fit of a shaft in a bearing may be loose, medium or snug, depending upon how precise the action of the shaft must be to do its work. The fit of a pin in a hole may be wringing, tight or force, depending upon what the pin does. A wringing fit is that of a pin in a hole of the same dimension. A tight fit is that of a pin in a hole just slightly smaller; in other words, the pin has a slight negative clearance. A force fit is one having considerable negative clearance: for example, the fit of a pin 1.000 inch in diameter in a hole 0.995 inch.

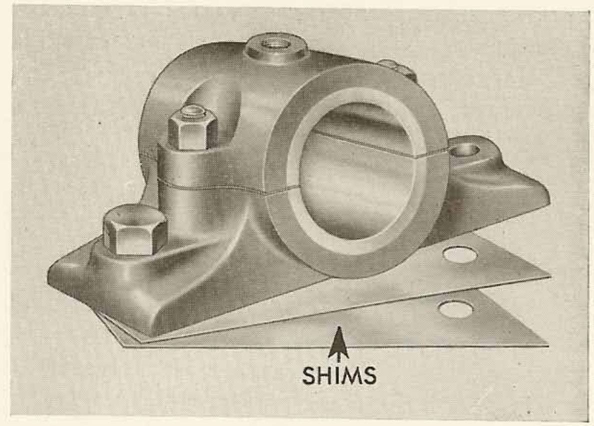


FIGURE 8-12

17. ALIGNMENT: Three points are said to be in alignment or "in line" if a straight line can be drawn through them. The bearings of a shaft are in line if one straight line could be drawn through all the bearing centers. A shaft is in line if one straight line could be drawn through its centers along its length.

Shims are used to facilitate alignment of bearings. Each bearing may be separated from its support by several shims. By removing or adding shims, the whole bearing can be moved nearer to or farther away from its support so as to be brought in line with other bearings.

18. SCREW THREADS: Many parts of machines are secured to each other by means of

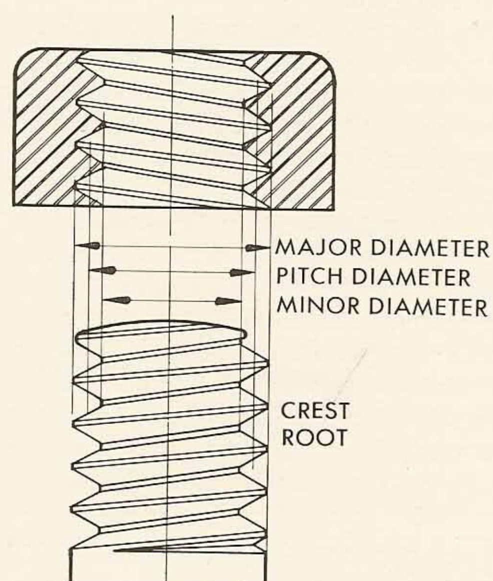


FIGURE 8-13

screw threads. A nut is threaded on a bolt, for example. In that case, the bolt has a ridge running spirally around it and this ridge fits in a spiral groove in the nut. The spiral ridge on the outside of the bolt is called the male thread; the spiral groove inside the nut is called a female thread.

19. THREAD MEASUREMENTS: The outside edge of the male thread on a bolt is called the crest, and the bottom of the valley between crests is the root. The diameter over the crests is the major diameter of the thread; the diameter from root to root is the minor diameter. The average of the two is the pitch diameter. The same names apply to female threads, but it is to be noted that the major, or greater, diameter of a female thread is measured from root to root.

20. PITCH: As the thread is spiral-shaped, turning the nut makes it move along the bolt. The distance it moves when given one complete turn is called the pitch of the thread. Pitch is also the distance between threads, and the number of threads per inch will be equal to one inch divided by the thread pitch.

21. RIGHT- AND LEFT-HAND THREADS: Generally to start a nut on a bolt, you turn the nut as the hands of a clock turn, and you keep turning that way to tighten the nut. To remove a nut, you turn the opposite way, or counter-clockwise. Such a bolt and nut are said to have right-hand threading. All screw threads are right-hand unless there is a special reason why they should not be. Some nuts secure wheels or gears, the rotation of which would tend to loosen a right-hand nut. In such cases, the nut is made with a left-hand thread, tightening when turned counter-clockwise. The propeller of a ship may turn right hand, or clockwise when looked at from a position aft of the ship. A right-hand nut holding it on the propeller shaft would have a tendency to loosen, or back off, so a left-hand nut would be used.

22. STRAIGHT AND TAPERED THREADS: Most machine parts that are threaded have straight threads; that is, threads that have the same diameter of root and crest throughout their length. Piping and pipe fittings, however, usually have tapered threads, or threads that gradually increase in diameter, each succeeding crest being a little more in diameter than the last. A male thread on the outside of a pipe will be at its smallest at the very end of the pipe, and will increase in diameter as it moves up the pipe. The coupling into which the pipe fits will have a female thread having its largest diameter at the entrance, tapering to a smaller diameter inside the coupling.

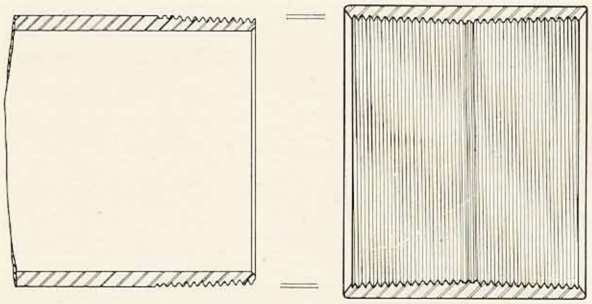


FIGURE 8-14

23. STANDARD THREADS: Pipe threads in the United States are usually cut to US Tapered-Pipe-Thread Standard. The normal taper is one in sixteen—namely, the diameter increases by $\frac{1}{16}$ inch in one inch of length. Straight threads are usually NC (National Coarse, formerly known as USS), or NF (National Fine, formerly known as SAE).

24. TAPS AND DIES: Round holes in iron, steel or other metal can be threaded by use of a tool called a tap. This tool looks somewhat like a bolt, but has grooves cut lengthwise to give the threads a cutting edge and provide space for the cuttings. The hole to be threaded must be smaller in diameter than the minor diameter of the female thread to be cut. Tapping is usually done with several taps. The thread is started with a tapered tap, then

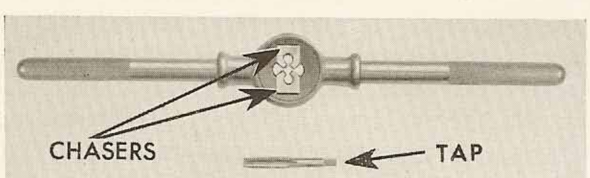


FIGURE 8-15

made straight with a straight tap, and sometimes the bottom threads are finished with a bottoming tap.

Male threads are cut with a die. The die, like a tap, is divided into several sections called chasers.

25. STUD, BOLTS, SCREWS: Figure 8-16 illustrates various parts having male threads.

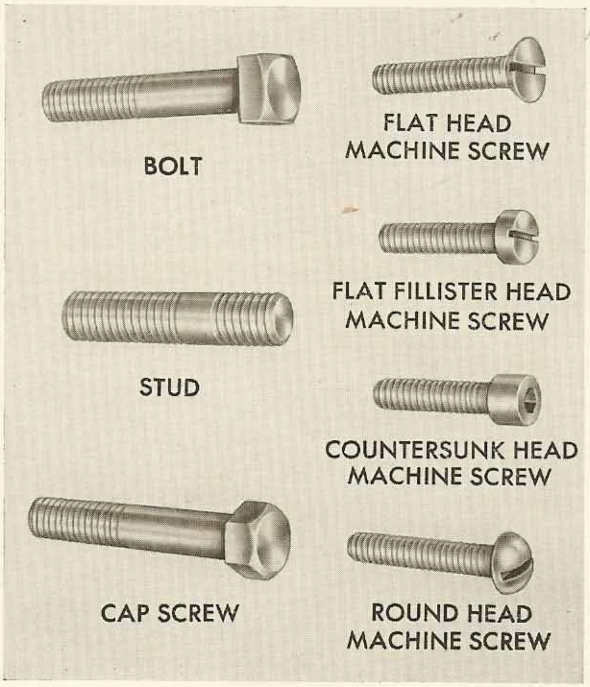


FIGURE 8-16

26. NUTS: Nuts may have four or more sides. A four-sided nut is a square nut, a six-sided nut is a hex nut, and an eight-sided nut is an octagonal nut. Most nuts are hex nuts.

27. WOOD SCREWS: Screws for use in wood are self-tapping: namely, they can be started with a hammer and then screwed home, displacing the wood to make room for the thread. Wood screws are tapered.

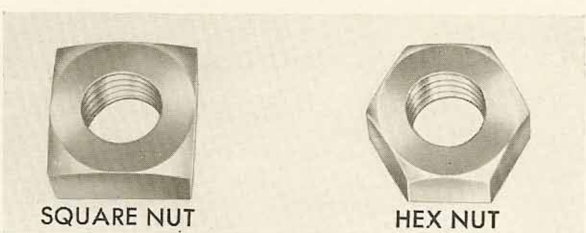


FIGURE 8-17

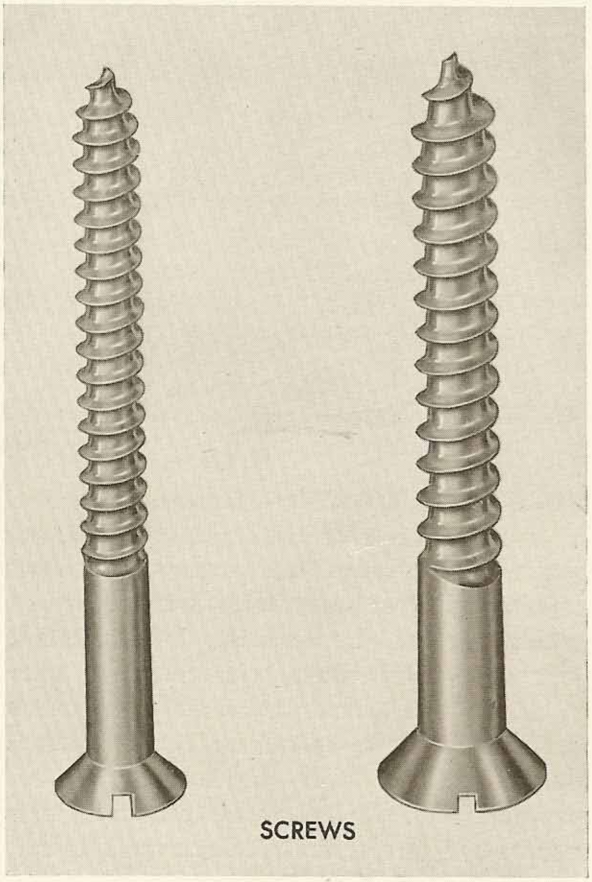


FIGURE 8-18

28. COUNTERSUNK AND SOCKET SET SCREWS: Sometimes it would be dangerous to have the head of a set screw protruding on a revolving wheel hub, so the screw is selected short enough to enter the hole completely. The head of such a set screw may be slotted, or may have a hex socket. In the latter case the screw can be tightened by using a bent rod.

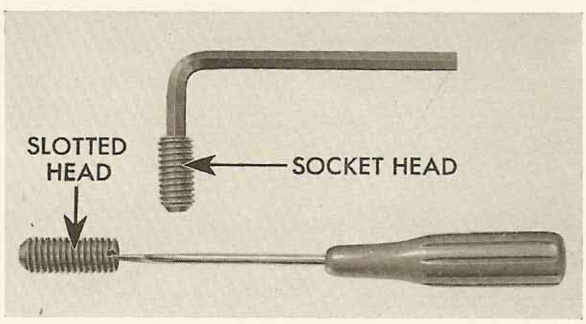


FIGURE 8-19

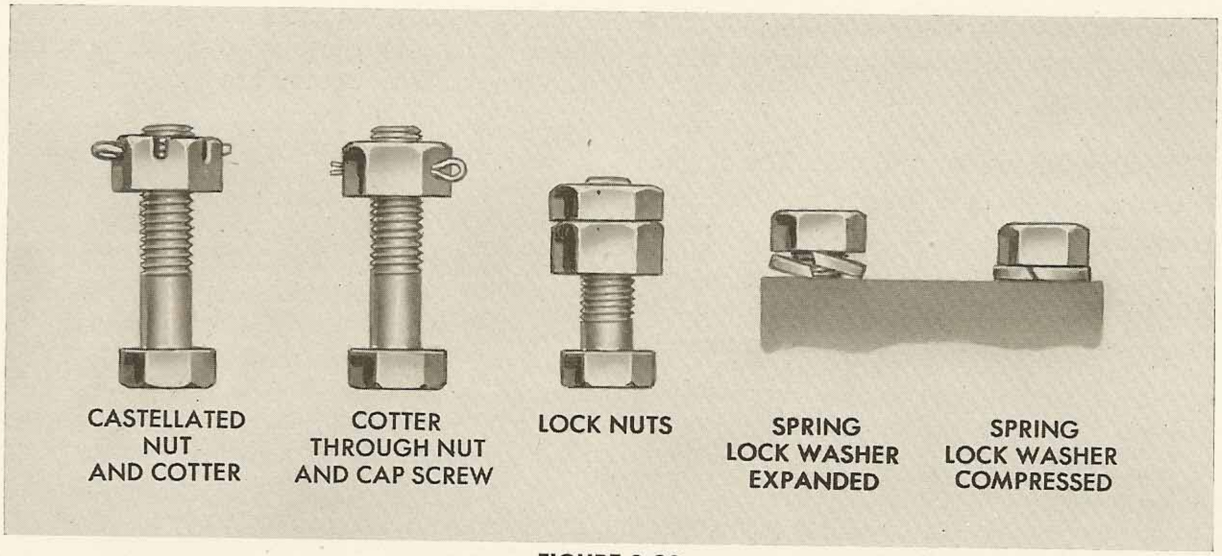


FIGURE 8-20

29. SECURING NUTS: Unless special provisions are made for locking nuts on studs or bolts, vibration or movement may loosen them and leave the part they hold insecure. Various means are used for securing nuts, including lock nuts, lock washers, wire and cotter pins. A lock nut is a second nut, screwed on the bolt behind the nut to be locked. The first nut is drawn up to the desired tightness and held in position, then the lock nut is drawn up to it and turned hard against it. Lock washers may be of spring type, tending to open up against the nut, or have edges that can be bent up against one or more flats on the nut.

When it is to be secured by a cotter pin, a nut is drawn up and a hole is drilled through both nut and bolt. A cotter pin is inserted in the hole and the split ends of the pin are separated to keep it from backing out. Securing nuts by cotter pins is facilitated by the use of castellated nuts, or nuts having slots already cut in various positions so that one of them will be in line with, or register with, a hole in the bolt. Sometimes a group of castellated nuts will be locked by locking wire.

Whenever a bent lock washer, cotter pin or locking wire is removed, it should be thrown away and a new washer, pin or wire used in reassembly.

30. SET SCREWS: A wheel or gear mounted on a shaft is sometimes secured to the shaft and forced to turn with it by means of a set screw. The hub of the wheel or gear is drilled

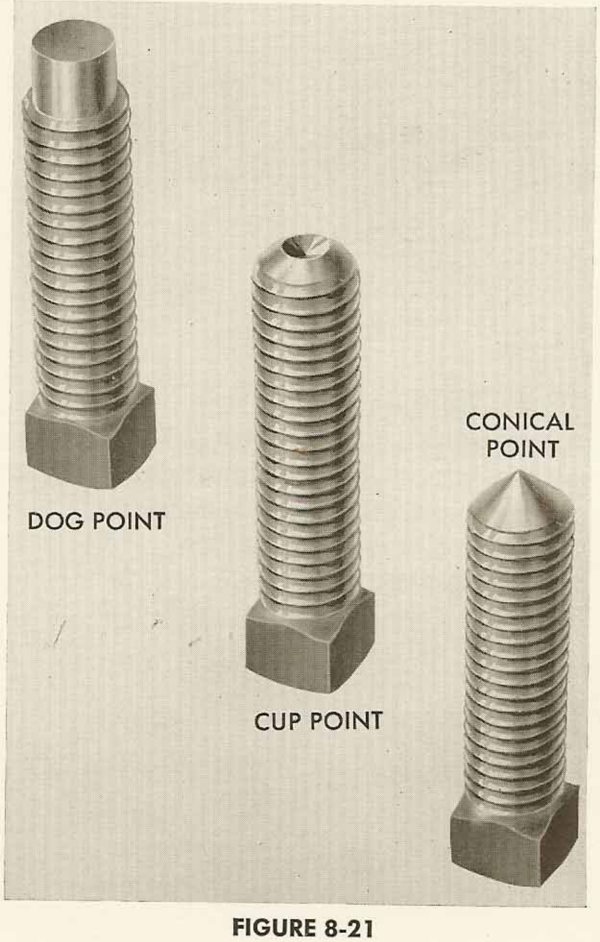


FIGURE 8-21

on a diameter, the hole is tapped and a screw is inserted and turned down against the shaft, which may have a shallow hole for engaging the point of the set screw. Set screws having various kinds of points are shown in Figure 8-21.

31. KEYS AND KEYWAYS: Set screws are not strong enough to hold heavy wheels or gears from turning on their shafts and keys are used for heavy duty. A key is a bar of steel that fits in a slot on the shaft and also in a slot in the hub of the wheel or gear. The hub cannot turn on the shaft without shearing the key. A key may be straight or semicircular (of Woodruff type). Both types are shown in Figure 8-22.

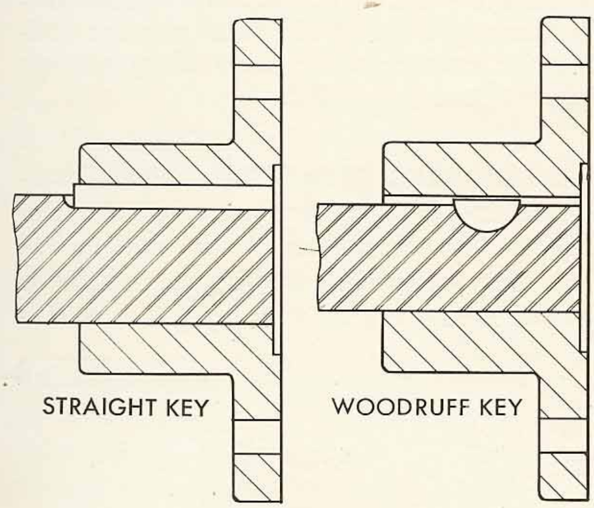


FIGURE 8-22

32. SPLINES: Sometimes ridges and valleys are cut in the shaft itself, with corresponding female cuts made in the inside of the hub of the wheel or gear. The shaft in that case is said to be splined. The fit is sometimes tight, and sometimes sliding, to allow movement of the gear along the shaft.

33. MACHINED FINISHES: A piece of metal is machined by cutting a surface on it using tools made of tool steel, a very hard, tough variety of steel. The cutting is done in a machine tool, which may mill, plane, bore, broach or turn, depending upon the type of machine tool. Machined surfaces may appear smooth but close examination will reveal the tool marks.

34. GROUND FINISH: A surface is ground by finishing it against a rotating wheel made of an abrasive, such as carborundum. Grinding is fine or coarse, depending upon the grain of the grinding wheel. Never use a grinding wheel without first putting on goggles.

35. LAPPING: A finish is lapped when the metal has been polished by rubbing it against an iron plate thinly covered with lapping compound, or abrasive mixed with kerosene or lard oil. Sometimes this lapping compound is compacted into a cake and is rubbed against the surface to be finished without any iron-plate backing. Parts that are to fit with very little clearance are sometimes lapped one against the other by using lapping compound in the clearance.

36. VALVE GRINDING: Valves are sometimes ground against their seats by coating the valve with lapping compound and working the valve on the seat. This is not true grinding, as when valve and seat are refaced against grinding wheels, but it is commonly called grinding.

37. REAMING: A hole can be enlarged by turning it to a larger diameter with a tool called a reamer. This is somewhat similar to a tap except that it cuts a smooth bore instead of a threaded one. Reamers may be straight, cutting a hole of constant diameter, or tapered, cutting a hole that slopes steadily to a decreased diameter. A parallel reamer opening up a hole in a shaft is shown in Figure 8-23.

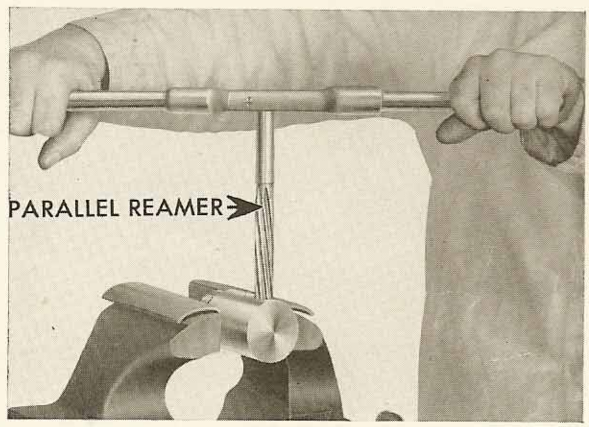


FIGURE 8-23

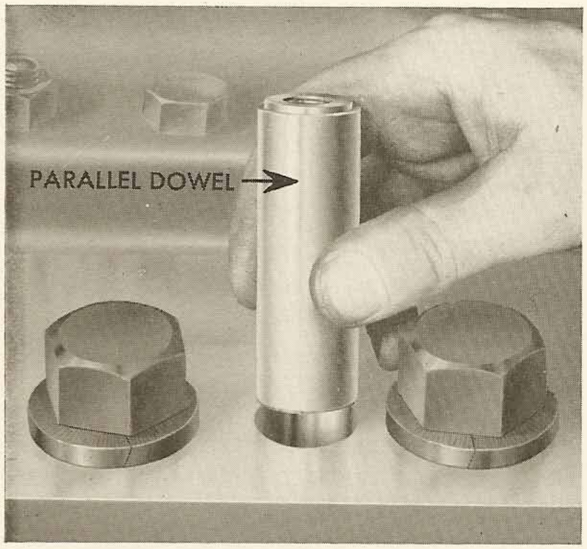


FIGURE 8-24

38. DOWEL PINS: When the alignment of two parts requires that they must not shift on each other, they are sometimes doweled. They are first lined up and then two holes are drilled through both parts in position, and at opposite sides. These holes may be taper reamed, in which case tapered pins called dowels are driven in; or the holes may be straight reamed with straight dowels used.

39. PIPE AND FITTINGS: Pipe comes in lengths, and to make up a pipe line there must be some way of joining one length to another. Piping smaller than two-inch diameter is usually made up with screwed fittings, with all screw threads tapered. The simplest form of screwed connection is a pipe coupling, shown in Figure 8-25. A more elaborate but more useful type is a union, also shown in that figure. Other fittings shown are 90-degrees long- and short-radius elbows, called ells, 45-degree ells, tees, crosses, reducers and return bends.

40. MAKING UP SCREWED FITTINGS: Before screwed fittings are assembled or made up, the male thread should be coated with a compound to insure tightness of the joint. For water pipe, use red lead; for low-pressure lubricating-oil or fuel pipe use shellac; for compressed air, use a sticky mixture of white lead and shellac.

41. FLANGED FITTINGS: Piping of two-inch diameter and larger is usually joined by flanges. The flanges may be screwed on the pipe ends for low and moderate pressures, or welded on for higher pressures. Flanges are

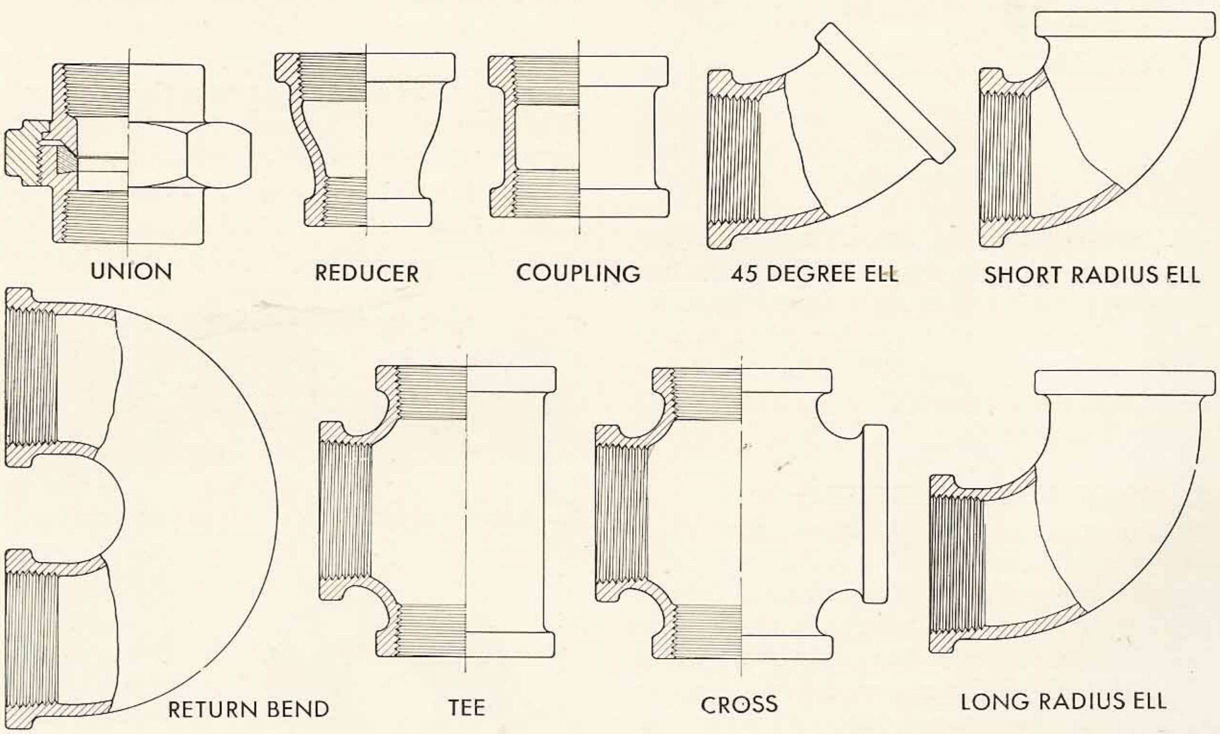


FIGURE 8-25

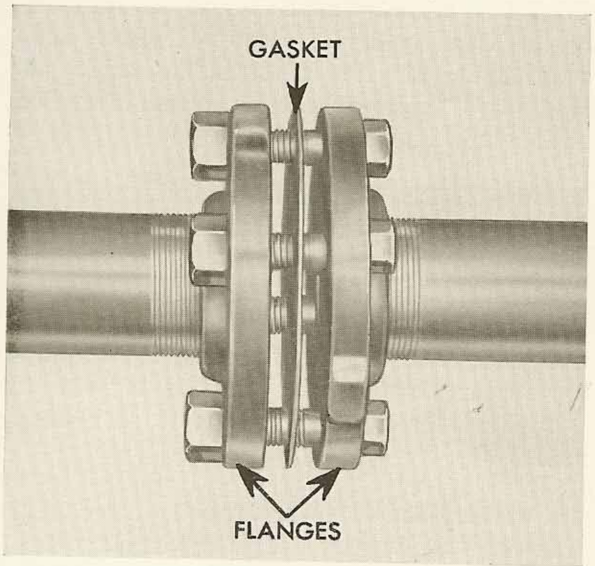


FIGURE 8-26

separated by gaskets, or rings of compressible material, for filling in surface irregularities in the flanges. Rubber, or rubber-impregnated material, is usually used for water or air lines. Oil-resisting material must be used for lubricating-oil or low-pressure fuel lines. Paper gaskets are often used if the flanges are well finished.

42. HIGH-PRESSURE FITTINGS: Fuel oil pressures of 1,000 pounds up to 20,000 pounds cannot be held by ordinary screwed or flanged fittings. Special compression fittings are used, with the joint made by a cone-shaped male nozzle in a conical seat, as shown in Figure 8-27. The high pressure tube is usually attached to the male member of the fitting by welding or brazing. Some joints, however, are made by bringing the tube through the male fitting and flaring the end of the tube over. The fitting should not be tightened

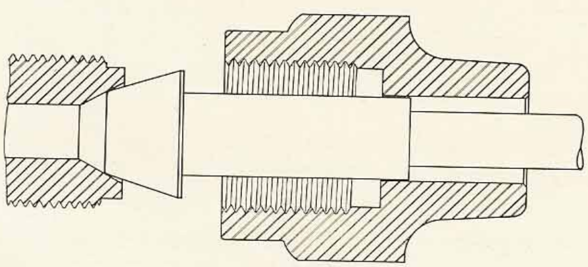


FIGURE 8-27

more than enough to stop leakage, as excessive tightening will spoil the conical seat.

43. WRENCHES: Nuts are tightened or loosened with wrenches, of which there are various types. Figure 8-28 shows several.

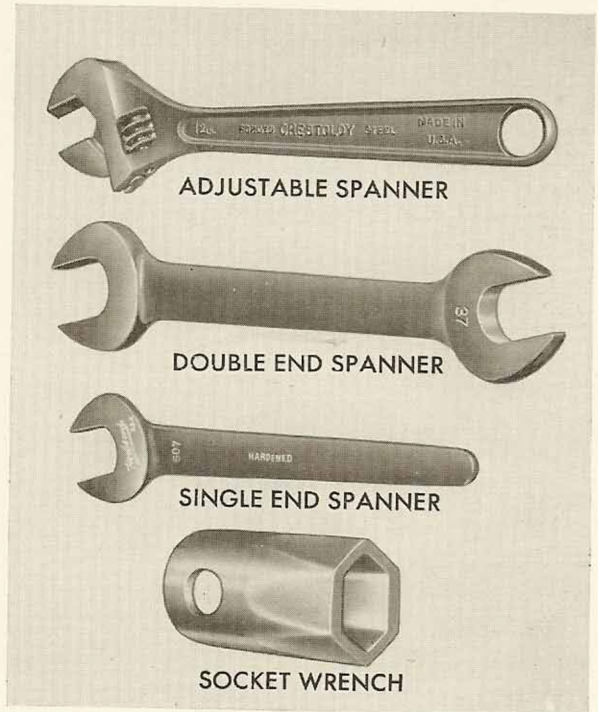


FIGURE 8-28

44. CORRECT APPLICATION OF A WRENCH: Figure 8-29 shows the right and wrong way to tighten a right-hand nut with a wrench.

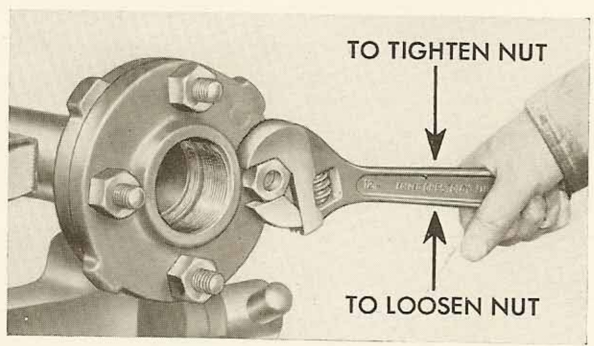


FIGURE 8-29

45. RATCHETS: Socket wrenches may be fitted with ratchets to enable the wrench to be applied to nuts located where the wrench handle could not be given a full swing. The ratchet turns the nut when the handle is turned in one direction but lets the handle slip in the ratchet on the back turn. Ratchets are usually reversible so they can be used to loosen as well as tighten.

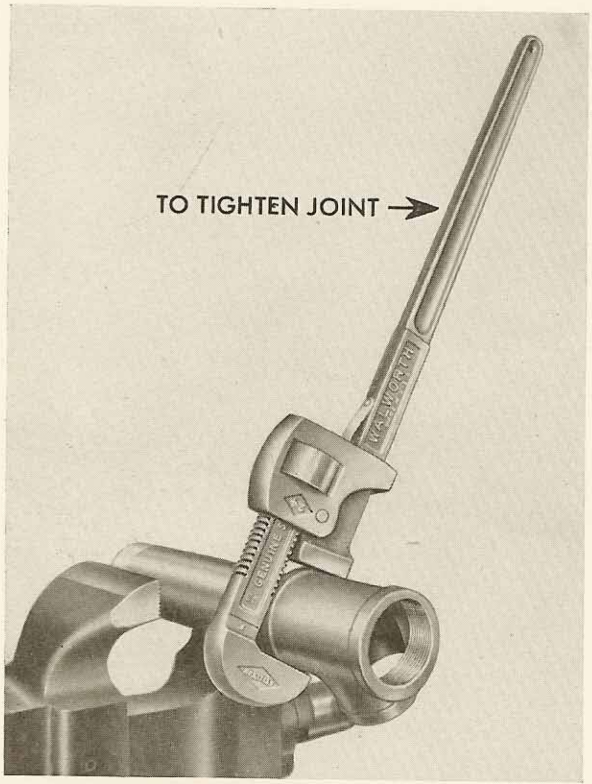


FIGURE 8-30

46. PIPE WRENCHES: Wrenches for turning pipe (also called Stillson wrenches) have roughened jaws and a moveable inside jaw that grips the pipe when the wrench is applied as shown in Figure 8-30.

47. WRENCH CAUTIONS: Don't pull on a large nut with a wrench without first thinking where you might land if the wrench slipped. Don't use a wrench a size too large for the nut. Don't try to back off a badly rusted nut without first trying to loosen it by applying penetrating oil or kerosene. Don't extend a wrench with a long pipe to work on a small nut.

48. VALVES: Flow is shut off or turned on in pipe lines by fittings called valves, of which there are several types as shown in Figure 8-31.

Any valve with a screw stem and a handle opens the line when the handle or wheel is turned counter-clockwise and closes the line by turning clockwise.

A valve used to close an air line will have a composition disc which closes against the seat. This disc will bed itself into the hard metal seat, and form a tight joint, with very little pressure. These discs are usually renewable. A valve used to close a water or oil line will have a metal plug, which closes on the seat, as liquids are not as difficult to hold as air or gases.

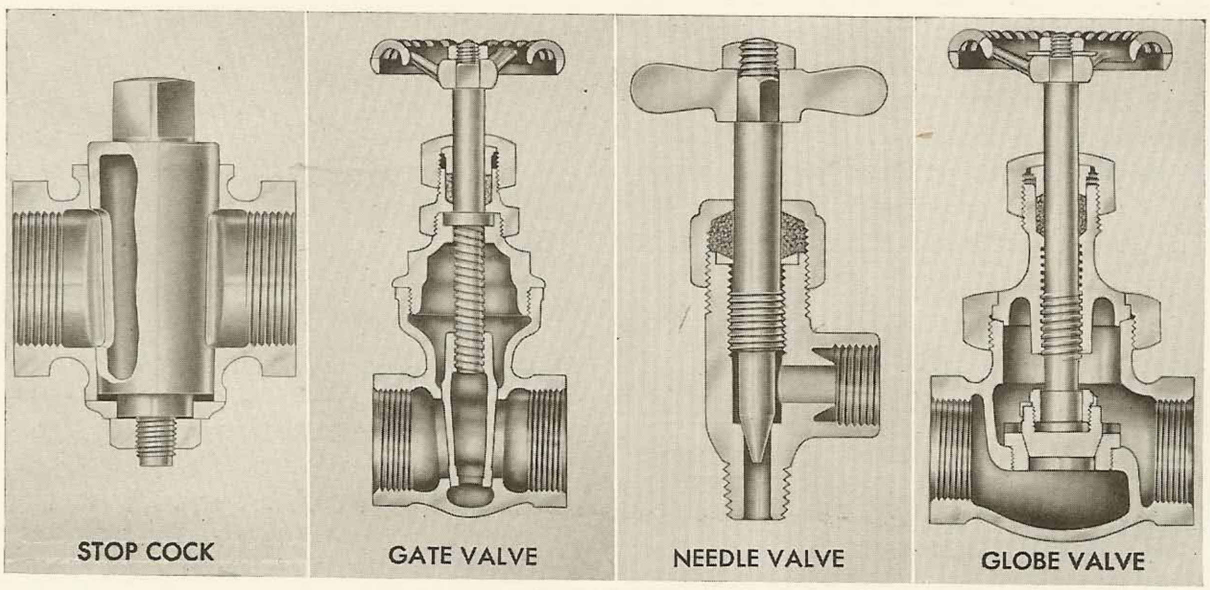


FIGURE 8-31

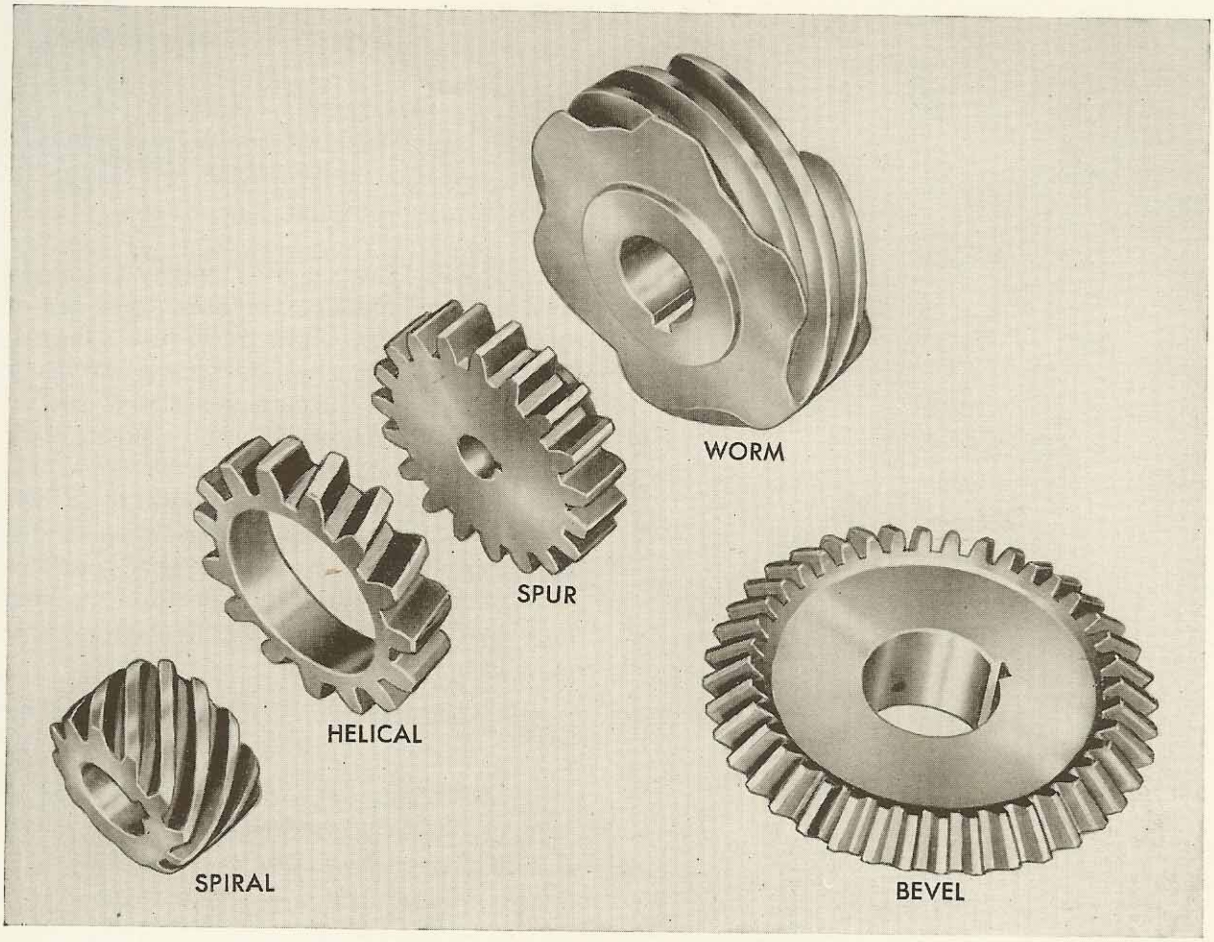


FIGURE 8-32

49. GEARS: One shaft may be made to turn another by means of gears. Various types of gears are shown in Figure 8-32. The speeds of the two shafts will be in inverse proportion to the number of teeth of their respective gears. For example, a shaft A with a gear having 30 teeth is driving a shaft B through a gear on that shaft having 90 teeth: shaft A will turn three times as fast as shaft B.

50. BACK LASH: The amount one gear can turn if the gear with which it is engaged is held fixed is the play or back-lash of the two gears.

51. DRIVING MACHINE PARTS ON OR OFF: Tight fits must often be driven loose or in place, yet the parts would often be irreparably injured if struck directly by a steel hammer or sledge. Sometimes a lead mallet will do the trick, but if the part is located so that a swing cannot be taken at it, a bronze drift pin may be held to the part and a hammer or sledge can be applied to the other end of the pin.

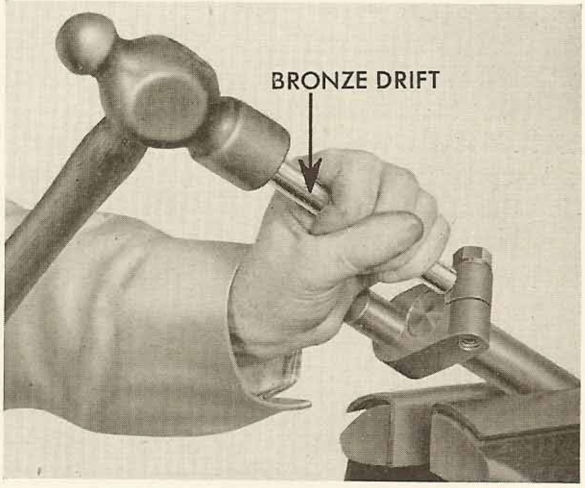
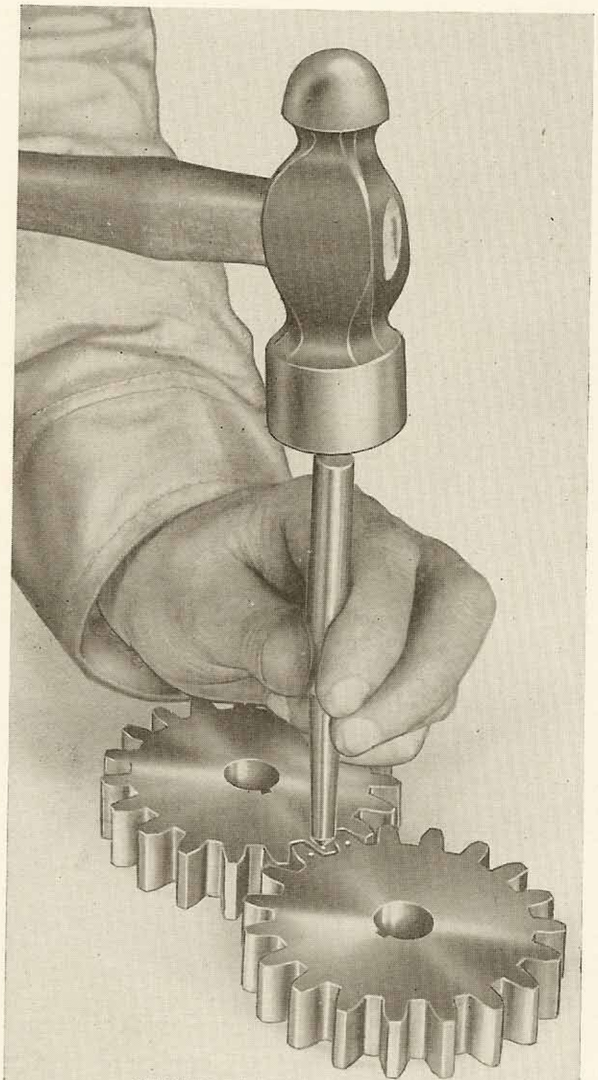


FIGURE 8-33

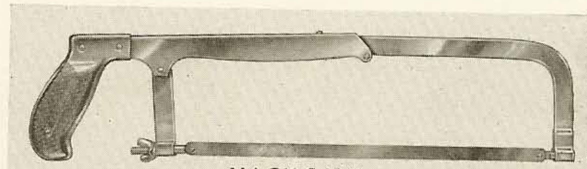


CENTER PUNCHING GEARS

FIGURE 8-34

52. CENTER PUNCHES: Center punches are used to make reference marks on metal, and to mark the center of a hole to be drilled as well as to make a small hole to start the drill point. When two shafts are timed in their rotation, the gears connecting them are sometimes center-punched at adjacent points, so they can be re-assembled in the same relation. If gears or other parts are marked for mating, in this way, great care should be taken that there are no former marks on the parts which could be confused with the new ones.

53. HACK SAWS: Sawing of metal is done with a hack saw, which has a saw blade of very tough steel. Frequently applying lubricating oil to the cut while sawing is helpful.



HACK SAW

FIGURE 8-35

54. FILES: Files are used to smooth roughened parts of metallic surfaces. They are of various shapes as shown in Figure 8-36. Always rub chalk on a new file before first using it. This improves the cutting action of the file and makes it last considerably longer. Bear down when pushing the file away from you, using no more than enough pressure for the kind of job. Use both hands, one on the handle, the other on the other end. See that your files have wooden handles. They protect you from the sharp end of the file.

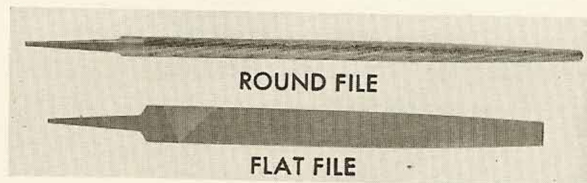
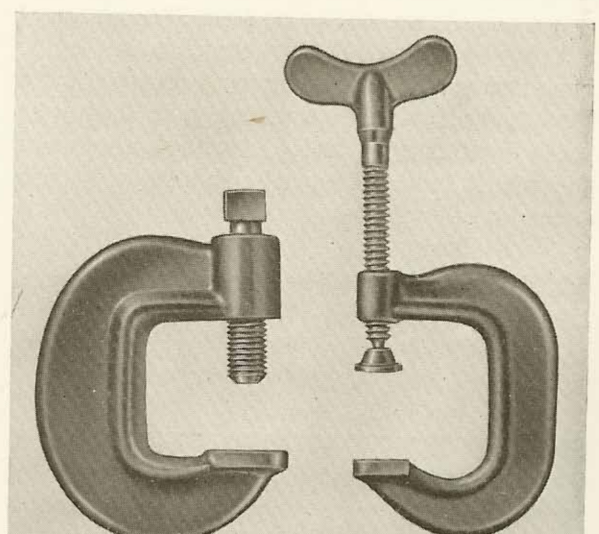


FIGURE 8-36

55. C CLAMPS: Parts can be temporarily held together with C clamps shown in Figure 8-37. Once located, the parts should be permanently assembled and the C clamps removed.



(C) CLAMPS

FIGURE 8-37

SECTION 9
MAINTENANCE ROUTINE

1. GENERAL RULES: Observing the following general rules will go a long way toward insuring satisfactory and trouble-free operation. Refer to the following sections for detailed instructions.

A. KEEP YOUR ENGINE CLEAN: Inspect the engine regularly and keep it wiped clean. It is much easier to keep the engine clean than to get it clean, and there is always less trouble with a clean engine than with one that is covered with oil and dirt.

B. LEAVE WELL ENOUGH ALONE: When the engine is running satisfactorily and smoothly, do not continually try to better the operation with minor adjustments.

C. NEVER ALLOW YOUR ENGINE TO SMOKE: When the exhaust from an engine is smoky it clearly indicates that combustion is not perfect and that residue, in the shape of smoke, is clinging to the oily surfaces of the cylinders, pistons, piston rings, valves, etc. When this happens you are creating trouble for yourself and doing an injustice to the engine. Therefore, the first thing in consideration of the operation of a Diesel engine is: DO NOT ALLOW YOUR ENGINE TO SMOKE.

D. KEEP A COMPLETE LOG OF ENGINE OPERATION: A complete log should always be kept of the engine operation, and back sheets should be consulted frequently and compared with present conditions. In this way gradual changes can be detected and investigated and insignificant troubles corrected before becoming real ones. Any unusual noises or other irregularities should be logged so that they will be investigated at the regular routine inspections.

E. INSPECTING REPAIRS: At completion of any adjustment or repair job, always make a thorough inspection to see that all parts have been correctly replaced, that bolts and nuts are tight, and that all cotter pins and locking wires are in place. If work involved rotating parts, bar engine around at least two full revolutions (so that the camshaft is turned one revolution) to be sure that all parts are clear. Be sure that no tools or rags are left inside the engine.

2. SMOKY EXHAUST: Smoky exhaust indicates defective combustion which usually is due to one of the following causes:

(a) Excessive carbon on spray-valve tips.
(b) Leaking spray valve.
(c) Leaky exhaust, inlet or air-starting valve.
(d) Buffer springs may be incorrectly adjusted.
(e) Fuel cam or roller may be worn.
(f) Leaky or stuck piston rings.
(g) Uneven cylinder-load balance.

If exhaust smoke is not even but occurs in the form of puffs it is likely that the combustion is defective in one or two cylinders only. Where the trouble lies can usually be determined by cutting out spray valves one at a time. When this is done, however, the engine should not carry more than $\frac{3}{4}$ load or the remaining cylinders will be overloaded.

3. INSPECTION AND MAINTENANCE ROUTINE: The following routine for regular inspection and maintenance work is suggested as a guide for the operator, but experience with the engine over a period of time may indicate changes that should be made in the schedule.

It will be noted in the following schedules that spray-valve cleaning has not been included. It is believed the spray valves should be cleaned only when necessary, rather than at definite intervals. The necessity for cleaning will be indicated by increased or uneven exhaust temperatures or smoky exhaust and at either of these indications the spray valves should be inspected and cleaned, if necessary. See Section 17 for spray-valve maintenance.

In the following, work to be done under each routine should include work listed under preceding routines. For example, work under "Annual Routine" includes everything listed under all other routines.

A. 4-HOUR ROUTINE:

(a) Hand oil the following points:

1. The inlet- and exhaust-valve stems
2. The rocker arms at their fulcrums and at their pushrod ends
3. Inlet and exhaust lifters, fuel wedges, lifter and buffers.
4. Wedge-shaft bearings
5. Tachometer drive
6. Governor bearing
7. Bilge pump connecting rod, both ends
8. Mechanical lubricator strap

For oiling the inlet- and exhaust-valve stems it is preferable to use penetrating oil. If this is not available a mixture of equal parts of engine lubricating oil and kerosene may be used. (A mixture of two-thirds engine fuel oil and one-third lubricating oil can be used in an emergency.) For all points in the above schedule use engine lubricating oil.

(b) Check the oil level in the mechanical lubricator. Fill the lubricator with clean engine oil of the grade used in the engine when necessary.

(c) Turn the handle of the lubricating-oil filter.

(d) Turn the handle of the fuel-oil filter. Always turn filter handles immediately after stopping the engine.

B. DAILY OR 24-HOUR ROUTINE:

(a) Clean out the sump tanks of the lubricating oil- and fuel-oil filters.

(b) Hand oil the flywheel brake.

(c) On engines equipped with pneumatic control, hand oil the air ram and interlock and grease the control unit shaft with cup grease.

C. 200 TO 300-HOUR ROUTINE:

(a) Check inlet- and exhaust-valve timing.

(b) Check spray-valve timing. (After starting the engine check cylinder-load balance.) See Section 10.

(c) Clean out lubricating oil day tank if lubricating oil is dirty or dark in color.

(d) Remove crankpit doors and inspect connecting rods. Be sure that all connecting-rod bolts are tight and that everything is in order. Inspect lower part of cylinder-liner bore.

D. SEMI-ANNUAL ROUTINE:

(a) Pull cylinder heads and pistons, remove rings and clean pistons and grooves thoroughly. Check rings for side and end clearance.

(b) Examine cylinder-liner walls. Watch for shoulders due to ring travel.

(c) Grind inlet and exhaust valves. Check valve springs for length and tension and for defects.

(d) Recondition spray valves. Inspect stem packing and repack if necessary. Inspect stem for wear and replace if worn. Inspect and clean spray-valve tips. Grind stem to tip.

(e) Inspect main and connecting-rod bearings. Check clearances and inspect bearing surfaces. Adjust clearances if necessary.

(f) Inspect gear train carefully, observing back-lash, indications of wear on teeth, and clearance, on intermediate gear bearings.

(g) Inspect camshaft and latch-shaft assemblies. Watch for worn or loose cams, loose or worn rollers or pins on the lifters. Be sure all keys and lock bolts are in place and tight.

(h) Inspect water pump and renew zinc plug if necessary.

(i) Inspect engine control parts, adjust and grind valves if necessary.

(j) Disassemble lubricating-oil cooler and inspect for corrosion. Clean thoroughly before reassembling. Renew zinc plugs if necessary.

(k) Check propeller-shaft coupling bolts and thrust-bearing and flywheel-clamp bolts.

(l) Check all hold-down bolts between engine and foundation. If they are loose check the engine alignment.

E. ANNUAL ROUTINE:

(a) Check crankshaft and thrust shaft alignment. If shaft needs realignment it is recommended that the work be done by an experienced and careful mechanic.

(b) Examine cylinder jackets and exhaust manifold water jackets. If scale is over $\frac{1}{16}$ inch thick it should be removed by scale remover solution.

(c) Remove and inspect lubricating oil and fuel oil transfer pumps. Note conditions of bearings, shafts and seals. Replace if necessary.

(d) Remove top cover and mounting plate on high-pressure fuel pump. Note condition of pump plungers and barrels. Disassemble crossheads and connecting rods and inspect for wear. Inspect suction and discharge valves and grind seats. Check valve lifts.

(e) Disassemble governor and inspect carefully all moving parts for wear and signs of distress. Inspect entire linkage between governor and wedge shaft for lost motion and wear. Fuel wedges, links and pins should also be inspected for wear and replaced if necessary.

(f) Inspect mechanical lubricator and connections to cylinder liners. Inspect ratchet mechanism for wear and proper functioning. Hand crank lubricator and observe the feed to each liner. Watch for water leaks at the nipples going through the water jackets.

(g) Clean out crankcase thoroughly. Be sure that all cleaning solution is drained out after cleaning is completed.

SECTION 10

ROUTINE TIMING OF ALL VALVES

1. RELATION OF ENGINE CRANKS: The procedure of timing an engine is not difficult if one is familiar with what is going on in cylinders other than the one being timed.

It is therefore recommended that the next few paragraphs be studied very carefully so that the sequence of events in the engine be thoroughly understood.

A familiarity with these events should enable the operator to reason his way out of any valve timing difficulty without reference to his manual.

A study of Figure 10-1 shows that the following pairs of cranks are always in the same position at the same time in a six cylinder engine.

Nos. 1 and 6
Nos. 2 and 5
Nos. 3 and 4

This means that when No. 1 piston is on top center, No. 6 piston is also on top center. The same rule applies to each of the other pairs of cranks.

2. POSSIBLE CYCLE EVENTS: Reference to Section 1, paragraphs 7-14, on the principle of the four stroke cycle engine shows that a piston can be doing only one of two things when it is on top center.

First: starting the power stroke, or,
Second: starting the intake stroke.

As two power strokes never occur at the same time, it is apparent that if No. 1 is on top center just starting the power stroke (a piston moving downward with both valves closed shows that it is a power stroke), No. 6 must be just starting the inlet stroke (a piston moving downward with the inlet valve open shows that it is an inlet stroke).

Or, if No. 4 is on top center just starting the power stroke, No. 3 must be just starting the inlet stroke. Or, if No. 5 is on top center just starting the power stroke, No. 2 is just starting the inlet stroke.

3. EACH CRANK OF ONE PAIR ONE REVOLUTION APART: As two revolutions are required to complete one cycle, one crank of any pair must be doing the same operation that the other crank of that pair is going to do one revolution later.

EXAMPLE: No. 5 crank and piston are at 40 degrees after bottom center on the compression stroke (both exhaust and inlet valves closed, and the piston moving upward shows that it is a compression stroke). On the next revolution No. 5 will be exhausting when it is at 40 degrees after bottom center, so this is the operation the other half of this pair of cranks (which is No. 2) is now doing. (No. 2 is now moving upward with the exhaust valve open, showing that it is the exhaust stroke.)

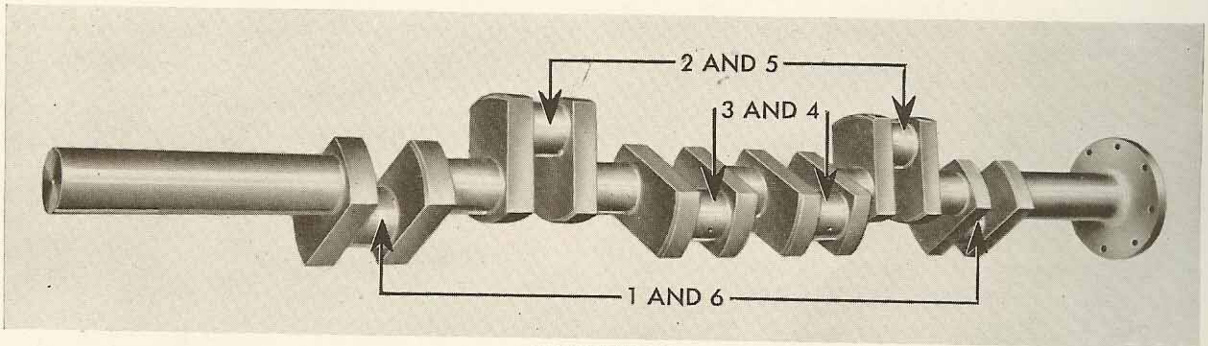


FIGURE 10-1

This pairing of the cranks, and the understanding of their function at any part of the cycle must be thoroughly understood before valves can be timed intelligently.

4. PRELIMINARY CHECKUP: Points to check before commencing to time the engine are:

A. If work has been done on the engine, make sure no tools have been left lying where they will come in contact with moving parts when the engine is turned over.

B. Starting air must be turned off at all air tanks.

C. All fuel wedges must move up and down freely, and be fully in (toward engine).

D. All buffer spring cages should be screwed nearly out.

E. Close all isolating valves.

F. Crank the mechanical lubricator 40 or 50 revolutions so the engine can be turned over more readily.

G. Open all snifter valves.

5. LATCH SHAFT POSITION: Insert a bar as shown in Figure 10-2 and turn latch shaft to AHEAD position. To check this position move the control handle into full-speed run-ahead position. If the latch shaft is not properly located, the control handle will not pass into the run position.

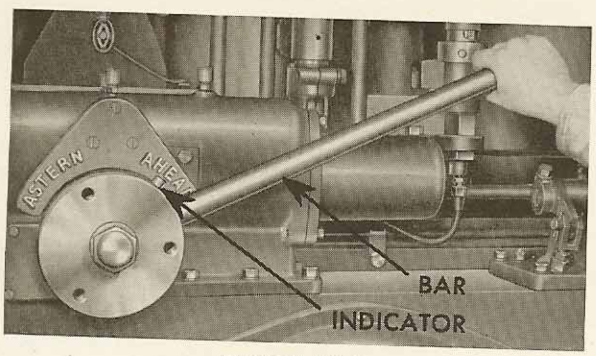


FIGURE 10-2

If the engine being timed has a hand-wheel control as shown in Figure 10-3, turn this wheel into the run-ahead position, B. Make sure that the spring pawl enters the notch on the back of the hub plate.

6. STANDARD AND OPPOSITE ROTATION: Standard six cylinder Atlas Imperial Diesel engines have the firing order 1-5-3-

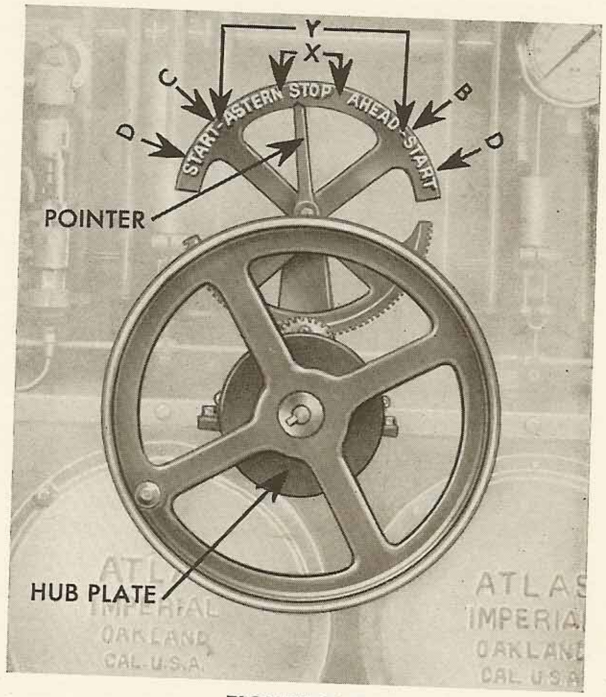


FIGURE 10-3

6-2-4. Opposite rotation engines have the firing order 1-4-2-6-3-5. Starting with No. 1 cylinder we will now give you all the moves necessary to time each valve in proper order on a STANDARD ROTATION engine. If your engine is OPPOSITE ROTATION, refer to paragraph 24 at the end of the section for instructions. Always check the firing order on your engine name plate to determine the rotation. These instructions are arranged in six groups, as several valves are timed at or near each top center.

7. NO. 1 TIMING GROUP: Turn the engine to ten degrees before No. 1 top center on the firing stroke. To determine a firing stroke when the valves are out of time turn the engine over and hold the fuel wedge of the cylinder being worked on. As this piston approaches firing top center the fuel wedge will start to lift.

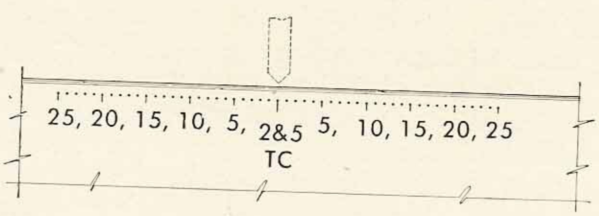


FIGURE 10-4

The outer rim of the flywheel is laid out with three groupings of centers spaced 120 degrees apart. See Figure 10-4. The space between each two dots equals one degree; the space between each two lines equals five degrees.

> **WARNING: If the flywheel is turned past the desired degree never back up just to the mark wanted. Always turn well past the mark in the opposite direction and return to the mark wanted by turning in the proper direction. This takes up the slack or backlash in the timing gears.**

8. NO. 1 TIMING GROUP continued: No. 6 **Cylinder Inlet**: Screw No. 6 inlet pushrod in or out of the fork until the roller in the opposite end of the rocker just touches the head of the valve stem. This means that as the camshaft moves ahead, the lifter roller will start to climb the lobe of the cam, opening the valve at ten degrees before top center, which is the desired opening.

9. NO. 1 TIMING GROUP continued: No. 1 **Spray Valve**: Turn the flywheel to eight degrees before top center. Open the isolating valve to No. 1 spray valve, one-half turn. Pump up about 1500 pounds of fuel pressure with the priming pump.

Adjust No. 1 spray-valve pushrod by screwing it out of the fork until it just opens the spray valve. This opening is indicated by the dropping of the needle on the fuel gauge, showing that the pressure in the system is being reduced by the open valve.

As soon as the needle starts to drop close the isolating valve to avoid excess fuel passing into the cylinder. Hold the pushrod with a pin as shown in Figure 10-5 and tighten locknut.

To check this setting, back up the flywheel to about 15 degrees before top center. Pump up 1500 pounds of fuel pressure. Open the isolating valve and pull the flywheel very slowly ahead and stop the instant the gauge needle starts to drop. Close the isolating valve and check to determine if the flywheel stopped at eight degrees before top center. If not make further adjustments and check again.

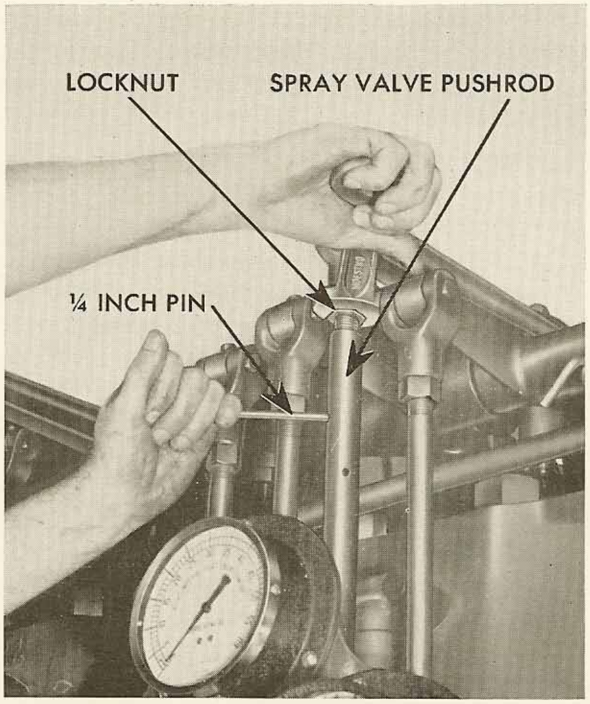


FIGURE 10-5

10. NO. 1 TIMING GROUP continued: No. 1 **Air-Start Valve**: Turn the flywheel to five

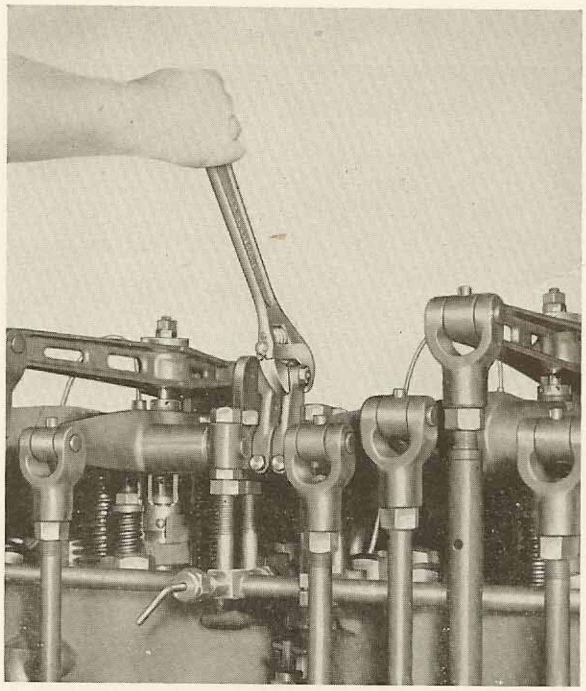


FIGURE 10-6

degrees before top center. With a wrench attached as shown in Figure 10-6, pull down eccentric rocker shaft to the full limit of its travel.

As the air-start valves are only in operation during the starting period, this eccentric shaft is used to bring the lifters down on the cams and return them to a point clear of the cam lobe, after the engine has started. Therefore, it is necessary to have these valve rockers in the operating position when timing the air-start valve.

Screw **No. 1 Air-Start** pushrod in or out of the fork until the end of the rocker just touches the head of the valve stem. As the camshaft turns ahead, the lifter roller will start to climb the lobe of the cam, opening the valve at five degrees before top center, which is the desired opening.

11. NO. 1 TIMING GROUP continued: **No. 6 Exhaust:** Turn the flywheel to five degrees after top center. Screw **No. 6 Exhaust** pushrod in or out of the fork until the roller in the opposite end of the rocker just touches the head of the valve. As the camshaft turns ahead, the lifter roller will leave the lobe of the cam, closing the valve at five degrees after top center, which is the desired closing.

12. NO. 1 TIMING GROUP continued: **Checking No. 1 Fuel-Valve Closing:** Turn the flywheel to about 25 degrees after top center. Open No. 1 isolating valve and pump up 1500 pounds of fuel pressure. Slowly turn the flywheel BACKWARD until the gauge needle begins to drop. Close isolating valve and check to determine if flywheel stopped at 18 degrees after top center. This check indicates the closing of the spray valve and if this comes within one degree of the proper closing point no further adjustment is necessary. If further away than one degree, see paragraph 22, this section. We have now covered the timing of No. 1 cylinder for spray valve opening and closing, and air-start valve opening, and No. 6 cylinder for inlet valve opening and exhaust valve closing.

13 NO. 5 TIMING GROUP: If you continue turning the engine in the forward direction, the next cylinder to come into firing position will be No. 5. Proceed to time No. 5 and No. 2 in the same way.

Stop at ten degrees before top center.

Time **No. 2 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 5 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 5 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 2 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 5 Spray-Valve Closing.**

14. NO. 3 TIMING GROUP: As you continue turning the engine, No. 3 will come next to the beginning of the firing stroke.

Stop at ten degrees before top center.

Time **No. 4 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 3 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 3 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 4 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 3 Spray-Valve Closing.**

15. NO. 6 TIMING GROUP: The next cylinder to come up to firing stroke position will be No. 6.

Stop at ten degrees before top center.

Time **No. 1 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 6 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 6 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 1 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 6 Spray-Valve Closing.**

16. NO. 2 TIMING GROUP: Next in rotation will be No. 2 at firing position.

Stop at ten degrees before top center.

Time **No. 5 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 2 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 2 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 5 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 2 Spray-Valve Closing.**

17. NO. 4 TIMING GROUP: After No. 2, No. 4 comes into firing position.

Stop at ten degrees before top center.

Time **No. 3 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 4 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 4 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 3 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 4 Spray-Valve Closing.**

18. TIMING ROUTINE STARTING AT ANY CYLINDER: This timing routine has been given as starting at No. 1 cylinder. The engine can be timed starting at any cylinder providing the firing order shown in Figure 10-7 is followed in rotation. This timing circle represents two crankshaft revolutions.

19. BUFFER SPRING ADJUSTMENT: The purpose of the buffer spring is to help overcome the upward movement of the spray-valve pushrod and to assist the spray-valve spring in returning the entire spray-valve

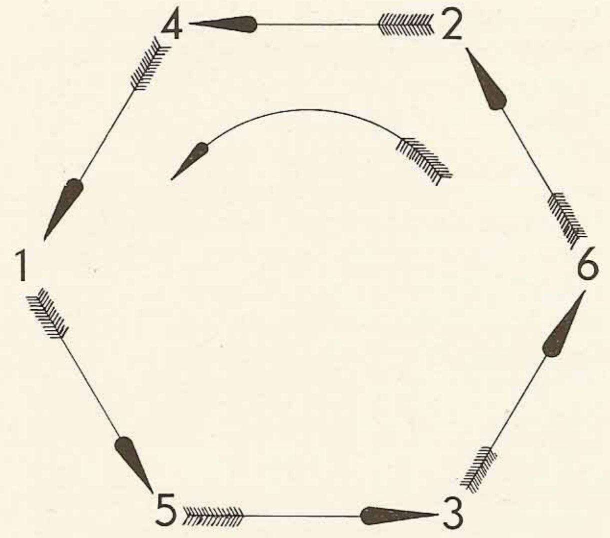


FIGURE 10-7

lifter mechanism to the base of the cam circle, after this equipment has been raised by the cam lobe. After all spray valves have been timed, the buffer springs can be adjusted without further turning of the engine, provided the flywheel is left 30 to 40 degrees from any top center. Adjust buffer spring cages as follows:

When the buffer springs are screwed out it will be found that the spray-valve rocker bears up against the horseshoe on the spray-valve stem. Screw the buffer spring cage in and down until this upward pressure is just released. (This can be checked by slowly turning the horseshoe between the thumb and finger while the buffer-spring cage is being screwed in. When the pressure is released the horseshoe will turn easily.)

Stop screwing the buffer-spring cage at the precise point the horseshoe turns freely. Screw out the cage one-half turn. This will allow the spray-valve rocker to exert a slight upward pressure against the horseshoe. Adjust all the buffer springs in this manner. Tighten the clamping cap screw sufficiently to prevent the cage from turning.

> **WARNING: The buffer spring cage should be adjusted each time a spray valve is removed or the spray valve timing changed.**

20. CHECKING FOR VALVE CLEARANCE: After the valves are timed it is necessary to check for clearance between the rocker-arm roller and the stem of the valve. This clearance must be about 0.025 inch for all exhaust and inlet valves when cold and allows for expansion of the valve stem when the engine warms up. The check is made with a feeler gauge inserted between the roller and the valve stem when the valve is fully closed. If the clearance is found to be greater than 0.025 inch do not alter, but if it is less, adjust the valve pushrod until the 0.025 inch feeler just slips through. To avoid turning the engine more than is necessary and to make sure that the valves being adjusted are fully closed, we suggest the following routine:

Spot the flywheel on **No. 1 Firing** top center and check the following valves for clearance:

No. 1 cylinder	Exhaust and Inlet
No. 2 cylinder	Inlet
No. 3 cylinder	Exhaust
No. 4 cylinder	Exhaust and Inlet
No. 5 cylinder	Exhaust and Inlet

Turn the flywheel to No. 3 firing top center and check the following valves for clearance:

No. 2 cylinder	Exhaust
No. 3 cylinder	Inlet
No. 6 cylinder	Exhaust and Inlet

21. BALANCING THE ENGINE WITH THE PYROMETER: The timing of the spray valve assures an equal amount of fuel being delivered to each cylinder. However, differences in the condition of the valves, the piston rings or even the spray valves may require the changing of the amount of fuel delivered to any one cylinder, in order to equalize the load between all cylinders. As the exhaust temperature is one of the most accurate indications of the amount of work a cylinder is doing, a means of taking these exhaust temperatures is provided by the Pyrometer, as shown in Figure 10-8.

The Pyrometer is connected to a thermocouple in each exhaust elbow by two wires. Turning the selector to the desired cylinder number gives a reading of the exhaust temperature in that elbow. These readings should never vary over 50 degrees between the highest and the

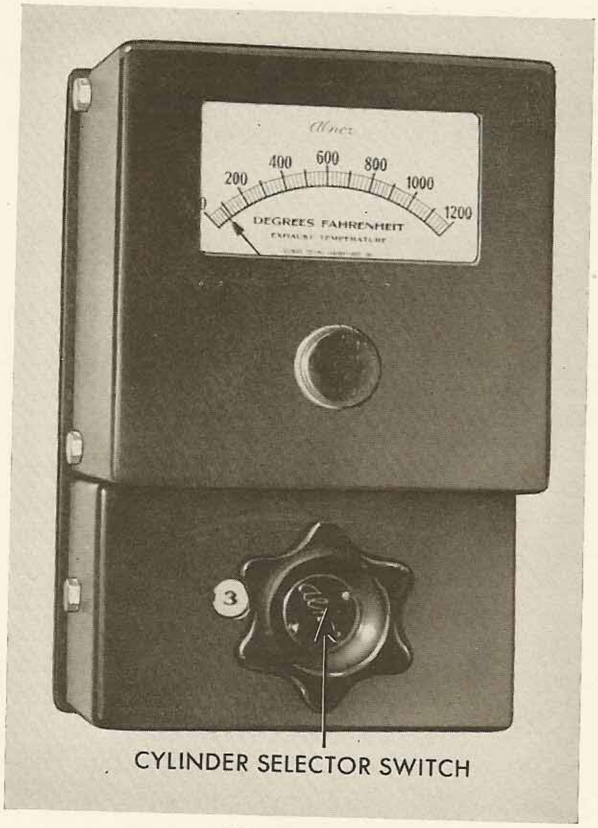


FIGURE 10-8

lowest cylinder when the engine is at full load. An engine operating with a 20-degree difference is considered to be balanced excellently. Check the temperatures at full load. If any cylinders are too high by comparison to the average, the temperature can be lowered by screwing in, or shortening, the spray-valve pushrod slightly. This shortens the length of time fuel is delivered to that cylinder. If any cylinder is too low the temperature can be raised by screwing out, or lengthening, the spray-valve pushrod. This increases the length of time fuel is delivered to that cylinder. Remember that exhaust temperatures vary according to the load on the engine. Adjustments should be made on one cylinder in comparison with all the others while running at a constant load condition. The adjustments should never be made by comparing the temperatures of a certain cylinder obtained at different times in the day.

> **WARNING: Do not depart from the correct timing of the spray valves by more than one-half turn of the push-**

rod in either direction. If more correction than one-half turn is needed to balance the load between cylinders there is trouble somewhere. See Section 24 on Trouble Shooting.

To avoid the spray valve timing getting too far away from its original setting, the spray valves should be checked for proper opening at least every 150 hours.

22. ADJUSTMENTS OF FUEL CAM IF CLOSING OF SPRAY VALVE IS LATE:

As an example, we will assume that No. 1 spray valve is closing at 22 degrees after top center. This means that the duration of opening is four degrees too long. The cam will have to be rolled ahead in the same direction the camshaft turns in order to bring the closing point under the spray valve lifter earlier. As the cam lobe has the same angle on both sides, it follows that whatever is taken from the closing period is added to the opening period. Therefore, to average out this condition one-half the number of degrees that the closing is late is the number of degrees the cam will be rolled ahead, namely two degrees. To adjust late closing proceed as follows:

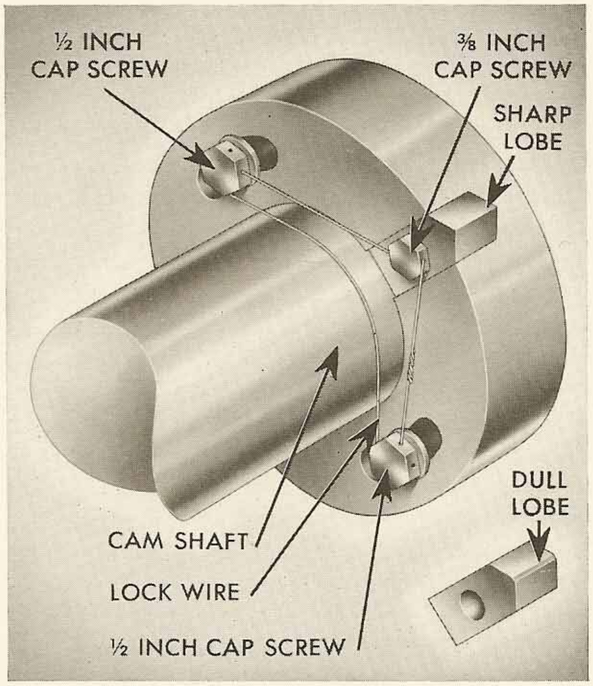


FIGURE 10-9

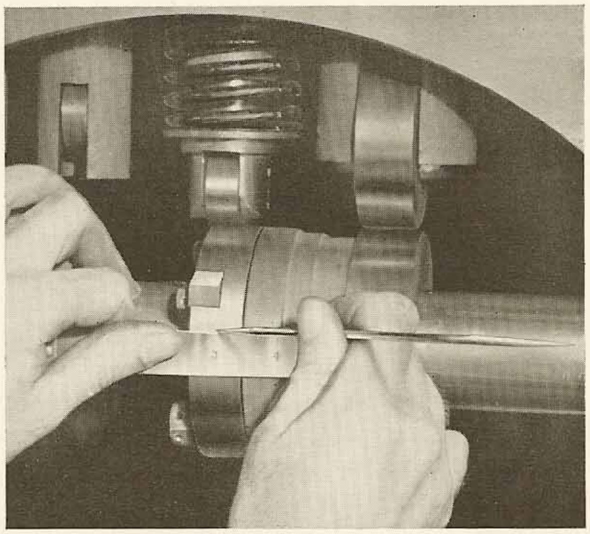


FIGURE 10-10

A. Remove the pit door and cut the lock wire on the fuel cam. See Figure 10-9.

B. With a scale or scriber draw a line across the face of the cam as shown in Figure 10-10. Loosen the two $\frac{1}{2}$-inch cap screws. Do not loosen the $\frac{3}{8}$-inch cap screw in the cam lobe. As $\frac{1}{64}$ inch of circumference on the face of the fuel cam equals one degree of crankshaft rotation, the cam should be rolled ahead (in the direction the camshaft turns) $\frac{2}{64}$ inch. The distance between the lines can be checked best with a pair of dividers.

C. Tighten the two $\frac{1}{2}$-inch cap screws. Turn the engine backwards until the cam lobe is on the inside of the spray-valve lifter. Time the spray valve in the normal manner as described in this section, paragraphs 7 to 11. Check the closing in the normal manner as described in paragraph 12. If the new closing point is within one degree of 18 degrees after top center no further adjustment is necessary. Replace the lock wire.

23. ADJUSTMENT OF FUEL CAM IF CLOSING OF SPRAY VALVE IS EARLY:

As an example, we will assume that No. 1 spray-valve closing is 12 degrees after top center. This means that the duration of opening is six degrees short. The cam will have to be rolled in the direction opposite the rotation of the camshaft in order to bring the closing point under the spray-valve lifter later. As the cam lobe has the same angle on both sides, it follows that whatever is added to the closing period is taken from the opening period; therefore, to average out this condition, one-half of the number of degrees that the closing is early, is the number of degrees the cam should be rolled back, namely three degrees.

A. Remove the pit door and cut the lock wire on the fuel cam. (See Figure 10-9.)

B. With a scale or scriber draw a line across the face of the cam as shown in Figure 10-10. Loosen the two ½-inch cap screws. Do not loosen the ⅜-inch cap screw in the cam lobe. As $\frac{1}{64}$ inch of circumference on the face of the fuel cam equals one degree of crankshaft rotation, the cam should be rolled back in the direction opposite the turning of the camshaft, $\frac{3}{64}$ inch. The distance between the lines can be checked best with a pair of dividers.

C. Tighten the two ½-inch cap screws. Turn the engine backwards until the cam lobe is on the inside of the spray-valve lifter. Time the spray valve in the normal manner as described in paragraphs 7 to 11. Check the closing in the normal manner as described in paragraph 12. If the new closing is within one degree of 18 degrees after top center no further adjustment is necessary. Replace the lock wire.

24. TIMING ROUTINE FOR AN OPPOSITE ROTATION ENGINE USING THE 1-4-2-6-3-5 FIRING ORDER: Read paragraphs 1 to 7 carefully for general instructions. Paragraphs 8 to 12 describe fully the timing of No. 1 cylinder group. The only difference in timing an opposite rotation is the order in which the cylinders are timed. This sequence follows:

25. NO. 1 TIMING GROUP: Turn the engine to 10 degrees before top center on the firing stroke.

Time **No. 6 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 1 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 1 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 6 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 1 Spray-Valve Closing.**

26. NO. 4 TIMING GROUP: Turn the flywheel to ten degrees before No. 4 firing top center which is the next cylinder group to time.

Time **No. 3 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 4 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 4 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 3 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 4 Spray-Valve Closing.**

27. NO. 2 TIMING GROUP: Turn the flywheel to ten degrees before No. 2 firing top center.

Time **No. 5 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 2 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 2 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 5 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 2 Spray-Valve Closing.**

28. NO. 6 TIMING GROUP: Turn the flywheel to ten degrees before No. 6 firing top center.

Time **No. 1 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 6 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 6 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 1 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 6 Spray-Valve Closing.**

29. NO. 3 TIMING GROUP: Turn the flywheel to ten degrees before No. 3 firing top center.

Time **No. 4 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 3 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 3 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 4 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 3 Spray-Valve Closing.**

30. NO. 5 TIMING GROUP: Turn the flywheel to ten degrees before No. 5 firing top center.

Time **No. 2 Inlet-Valve Opening.**

Turn the flywheel to eight degrees before top center.

Time and check **No. 5 Spray-Valve Opening.**

Turn the flywheel to five degrees before top center.

Time **No. 5 Air-Start-Valve Opening.**

Turn the flywheel to five degrees after top center.

Time **No. 2 Exhaust-Valve Closing.**

Turn the flywheel to 25 degrees after top center.

Back up and check **No. 5 Spray-Valve Closing.**

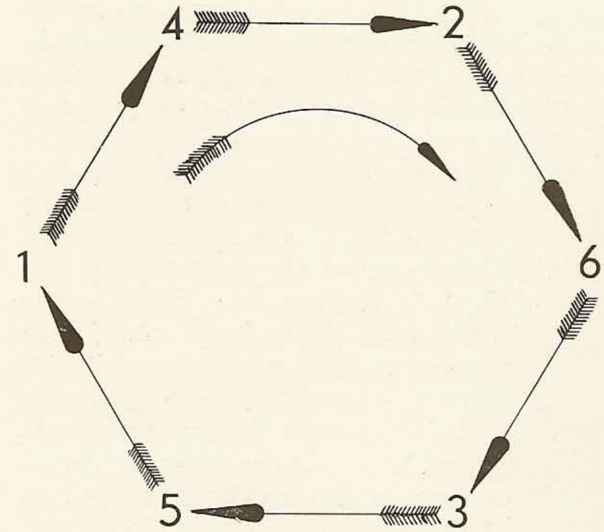


FIGURE 10-11

31. TIMING ROUTINE STARTING AT ANY CYLINDER: This timing routine has been given as starting at No. 1 cylinder. The engine can be timed, starting at any cylinder providing the firing order shown in Figure 10-11 is followed in rotation. This timing circle represents two crankshaft revolutions.

32. BUFFER SPRING ADJUSTMENTS: Read paragraph 19.

33. CHECKING FOR VALVE CLEARANCE: Read paragraph 20 but use the following table. Spot the flywheel on No. 1 firing top center and check the following valves for clearance:

No. 1 cylinder	Exhaust and Inlet
No. 2 cylinder	Exhaust
No. 3 cylinder	Inlet
No. 4 cylinder	Exhaust and Inlet
No. 5 cylinder	Exhaust and Inlet

Turn the flywheel to No. 2 firing top center and check the following for clearance:

No. 2 cylinder	Inlet
No. 3 cylinder	Exhaust
No. 6 cylinder	Exhaust and Inlet

Read paragraphs 21 to 23 for further adjustments.

SECTION 11
CYLINDER HEAD AND VALVES

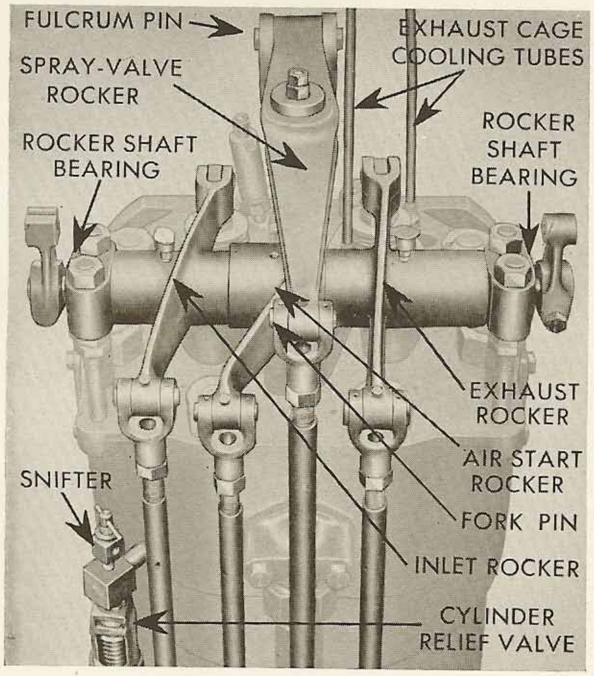


FIGURE 11-1

1. REMOVAL OF ROCKER ASSEMBLY: This assembly is shown in Figure 11-1 and is the first group of parts to be removed when work on the cylinder head is necessary. Remove the cotter pin and drive out the fulcrum pin in the end of the spray-valve rocker. Drive out the fork pin in the other end and lift off the spray-valve rocker. Drive out the fork pins in the inlet, exhaust and air-start rockers. Remove the four nuts which clamp the two rocker shaft bearings. Examine the forks on the ends of the rocker shaft. If these have pins in them the rocker assembly will lift off. If either one or both forks have pins extending into them from the next cylinder head it will be necessary to remove these pins before lifting off the rockers.

2. REMOVAL OF SPRAY VALVE: Disconnect the spray valve tube at each end. Loosen the spray valve clamp nut and remove the clamp. If the spray valve will not lift out easily, insert the point of a small pry bar (about 12 inches long) as shown in Figure 11-2. While prying up with one hand grasp the spray-valve strainer with the other hand and rock it back and forth.

When the valve is removed see if the gasket which fits under the tip nut is on the end of the spray valve or whether it has remained in the cylinder head. If the gasket did stay in the head a note of this fact should be made so that an additional gasket will not be used when the spray valve is installed. Handle the spray valve carefully. Avoid dropping it or bumping the tip, as the small holes damage easily.

If the engine is being overhauled, it is wise to service the spray valves before further dismantling is done as the fuel system will be still available for testing.

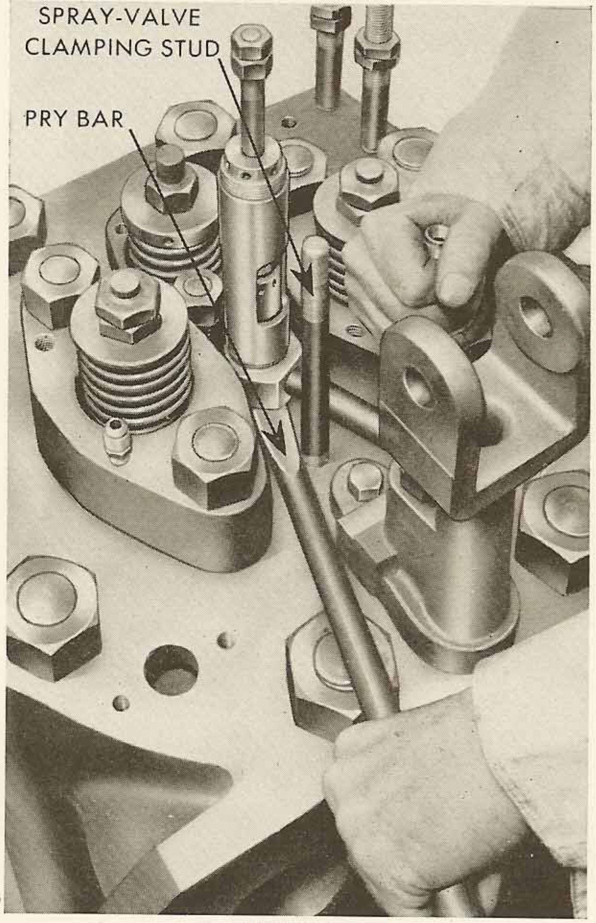


FIGURE 11-2

3. REMOVAL OF THE INLET AND EXHAUST CAGE: These two cages are identical and can be used for either exhaust or inlet. The exhaust cage, however, is water cooled and must be connected to the valve cage cooling manifold by the small copper tubes which are supplied.

As the exhaust valve is subjected to higher temperatures than the inlet valve a more durable steel is used for the exhaust valve. This means that the exhaust and inlet valves are not interchangeable except in an emergency when the proper valve is not available.

To remove these cages, disconnect the cooling tubes (if exhaust cage) and remove the two nuts on the cage flange. Jacking studs are supplied with the engine and these are used as shown in Figure 11-3 to withdraw the cage. It is important to apply pressure evenly to each jacking stud so that the cage will be removed without binding on the sides of the cylinder head.

If the copper cage gasket does not come out with the cage, remove it from the head before proceeding with the next valve. These gaskets can be used repeatedly providing they do not get too thin or broken. They can be annealed or softened by heating to a dull red and quenching in water.

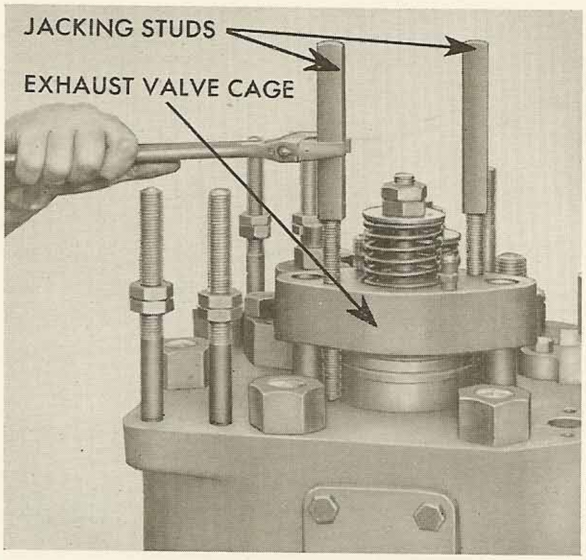


FIGURE 11-3

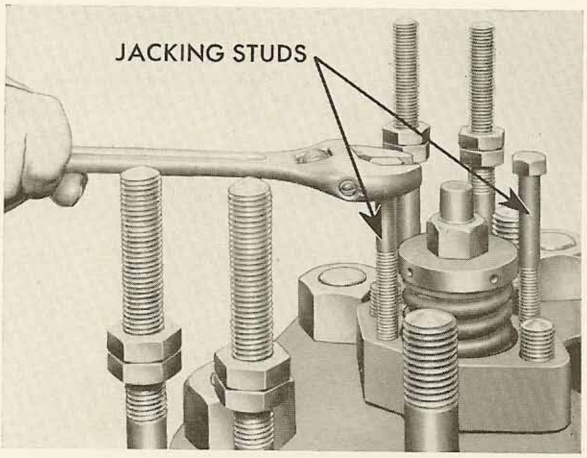


FIGURE 11-4

4. REMOVAL OF AIR-START VALVE: While these valves operate very little in comparison to the inlet or exhaust valves, they should be removed and cleaned thoroughly each time the other valves are worked on. The starting air always carries enough moisture to cause rust to form and if these valves are allowed to go too long without servicing, faulty maneuvering may result.

The air start cages are removed in the same manner as the other cages, that is, with jacking studs. Remove the two nuts on the flange of the cage and apply the pressure to the jacking studs evenly. Make sure that the gasket is lifted with the cage or if not, remove it from the head. Figure 11-4 shows the removal of the air-start cage.

5. REMOVAL OF CYLINDER HEADS: Unless a complete overhaul is being done never remove all the cylinder heads at one time. If one or two heads are left on to support the exhaust and inlet manifolds much time and trouble will be saved.

Drain the engine and remove all the cap screws that attach the inlet and exhaust manifolds to the head being taken off. Remove the section of water outlet manifold which is above the head. Remove the fuel rail clamps and the two cap screws which attach the air-start manifold. Remove all the cylinder head stud nuts. Disconnect the tube which carries the spray-valve cooling water. Attach a lift-

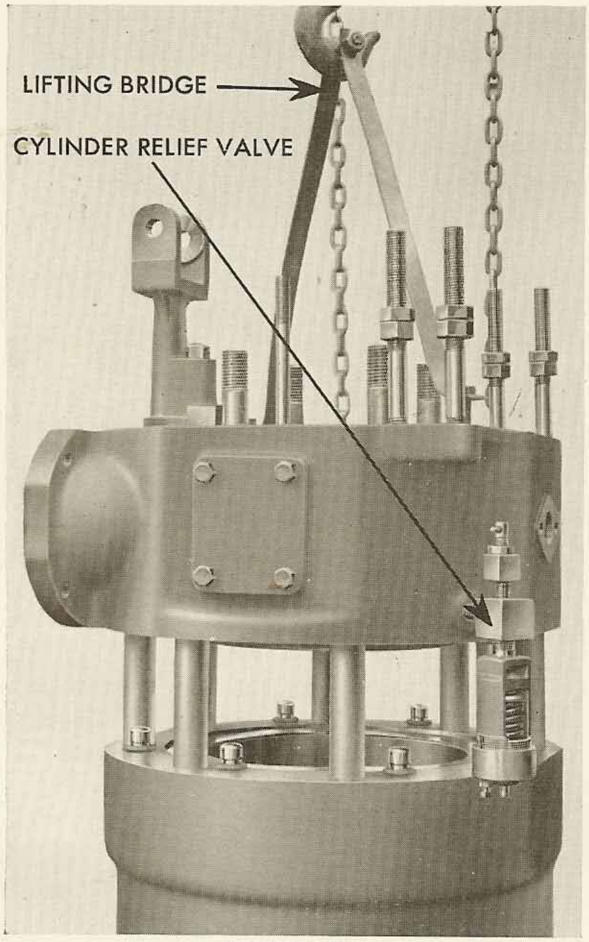


FIGURE 11-5

ing device as shown. This can be two pieces of 1/4 or 3/8 inch by one inch strap iron bent and drilled as shown in Figure 11-5. Hook a chain block into the lifting bridge and hoist the cylinder head off evenly. It may be necessary to shake the head to break it loose.

It is advisable to remove the cylinder relief valve shown in Figure 11-5 to avoid damage while the head is being handled on the floor.

6. DISASSEMBLY OF THE EXHAUST AND INLET VALVE CAGES: Figure 11-6 shows the various parts of an inlet or exhaust cage assembly.

While only the exhaust cage is cooled the inlet cage is interchangeable. The only alteration necessary is to equip the inlet cage with tubing fittings so that the exhaust cage cooling tubes may be attached. If there are signs of rust in the cage it should be tested for cracks by water pressure.

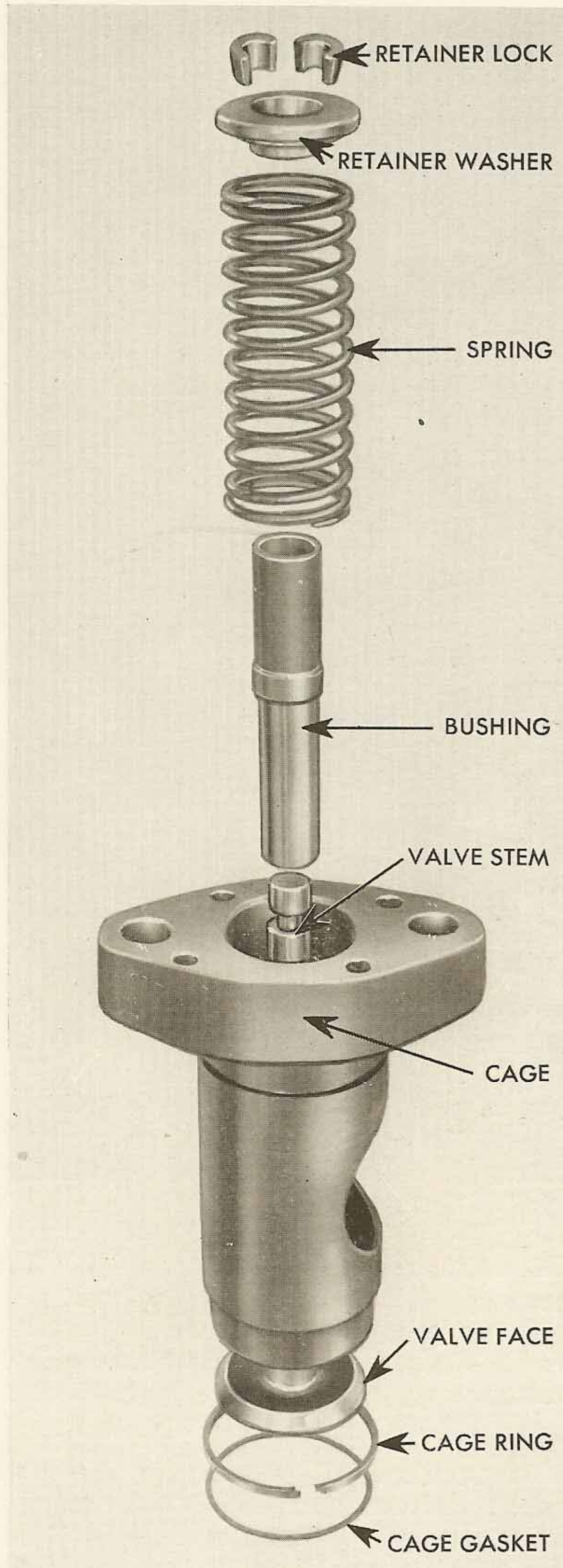


FIGURE 11-6

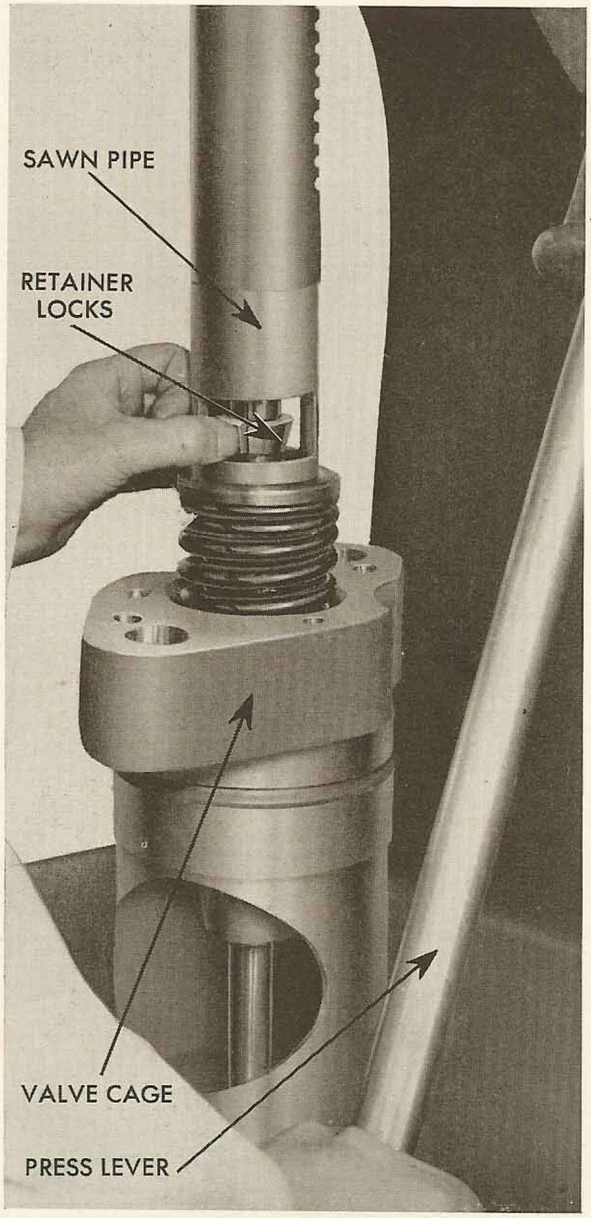


FIGURE 11-7

The retainer locks can be removed easily if a press is available, by sawing a piece of pipe and using it as shown in Figure 11-7. A lever can be rigged up that will exert the required pressure if necessary.

Older engines may be equipped with double nuts which lock against each other. These will take the place of the retainer locks and the valve stem will be threaded down for about three inches from the end. Care should be taken, when removing the last nut, that it does not fly off and injure the operator.

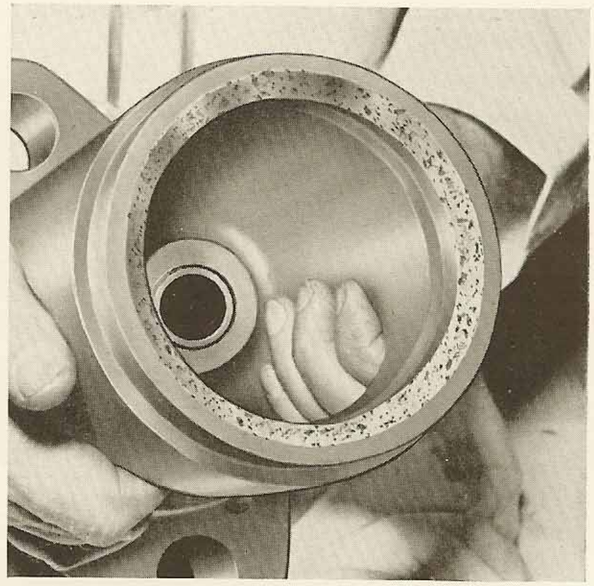


FIGURE 11-8

When the parts of the assembly have been cleaned examine them thoroughly for wear or damage. A pitted cage seat will look like the seat shown in Figure 11-8 while Figure 11-9 shows a valve face that needs grinding.

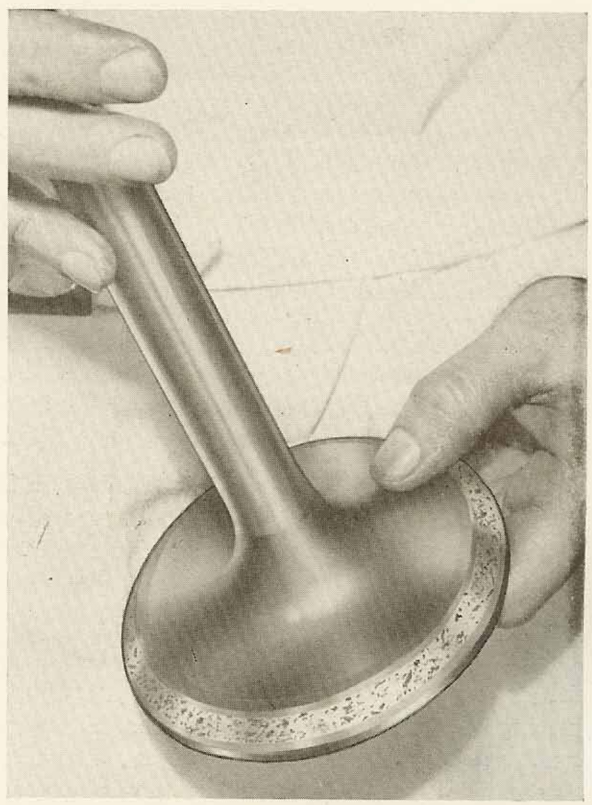


FIGURE 11-9

The clearance between a new valve stem and a new bushing should be between 0.004 and 0.005 inch. The bore of the bushing is 7/8 inch or 0.875 inch. So that there is the proper running clearance, the new valve stem should measure 7/8 inch less the clearance or 0.870 to 0.871 inch.

Use an outside micrometer and measure the valve stem in several places over its length. As 0.012 inch is the maximum wear permitted the valve should be renewed if the stem measures less than 0.858 inch.

To check the wear in the valve-cage bushing, insert a new valve stem and measure the clearance with a feeler gauge as shown in Figure 11-10. If more than 0.017 inch of feeler leaves can be forced between the bushing and the valve stem the bushing should be renewed. The normal running clearance is 0.005 inch and the maximum wear is 0.012 inch, making a total of 0.017 inch which is the greatest permissible clearance.

7. REPLACEMENT OF THE CAGE BUSHING: If renewal of the bushing is necessary set the cage upon blocks as shown

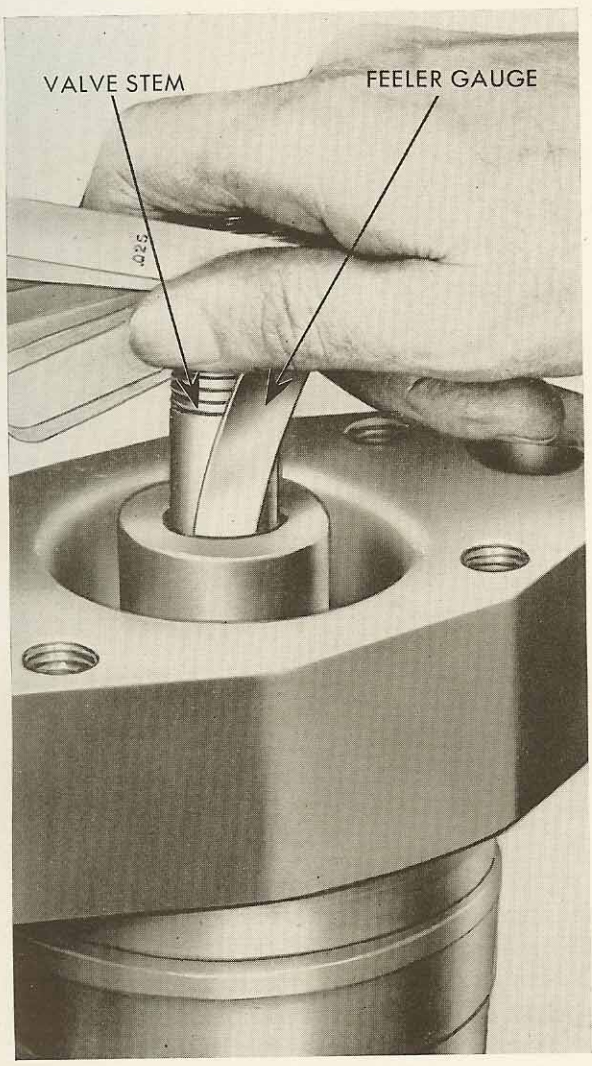


FIGURE 11-10

FIGURE 11-11

in Figure 11-11. Use a bushing driver made of a piece of 1¼ inch cold roll steel about 10 or 12 inches long and turned to $^{27}/_{32}$ inch diameter for about two inches on one end. If a press is available it can be used to force out the old bushing. Otherwise a heavy hammer can be used as shown in Figure 11-11.

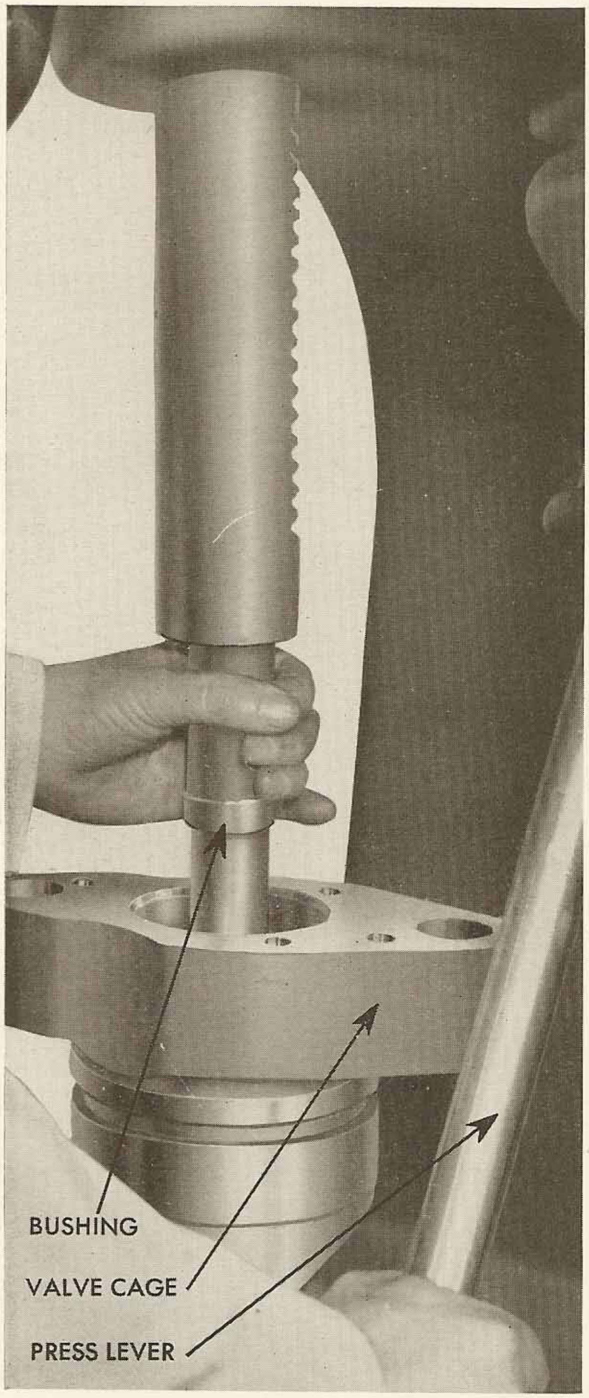


FIGURE 11-12

Before installing the new bushing smear the outside with a mixture of white lead and oil. Set the cage on the press as shown in Figure 11-12 and force the bushing in until the shoulder seats on the cage. The bushing can be driven in by using the bushing driver and a heavy hammer.

As the fit of the bushing in the cage is very tight the bore of the bushing is apt to be slightly distorted after installation. The hole should be reamed with a 0.875 inch parallel reamer as shown in Figure 11-13.

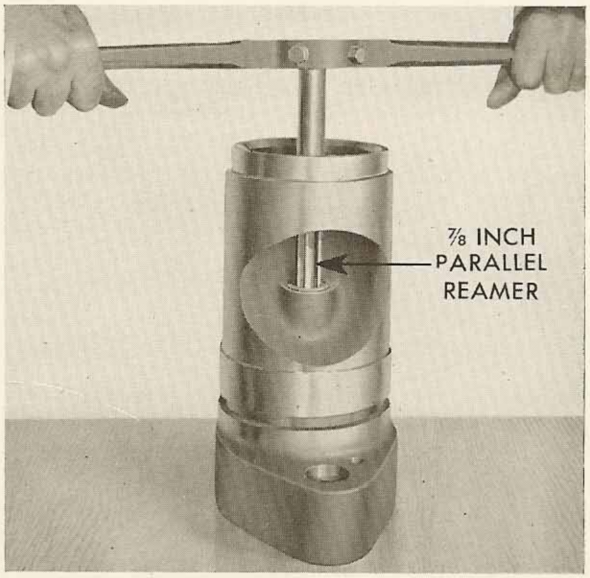


FIGURE 11-13

8. REAMING VALVE FACE AND SEAT: If the valve cage seat is pitted as shown in Figure 11-8, it should be reamed to avoid excessive grinding. A standard 45 degree seat reamer and a ⅞ inch pilot to fit into the bushing are the tools required. The reamer should be operated as shown in Figure 11-14. Do not remove any more metal from the cage than is absolutely necessary to obtain a clear seat.

If the valve face is pitted or burned as shown in Figure 11-9, the valve should be refaced in a valve machine or a lathe. If such equipment is not available we suggest using any spare valves on board. Keep the pitted valves until they can be serviced properly. However, if it is necessary, these pits, in either the valve or

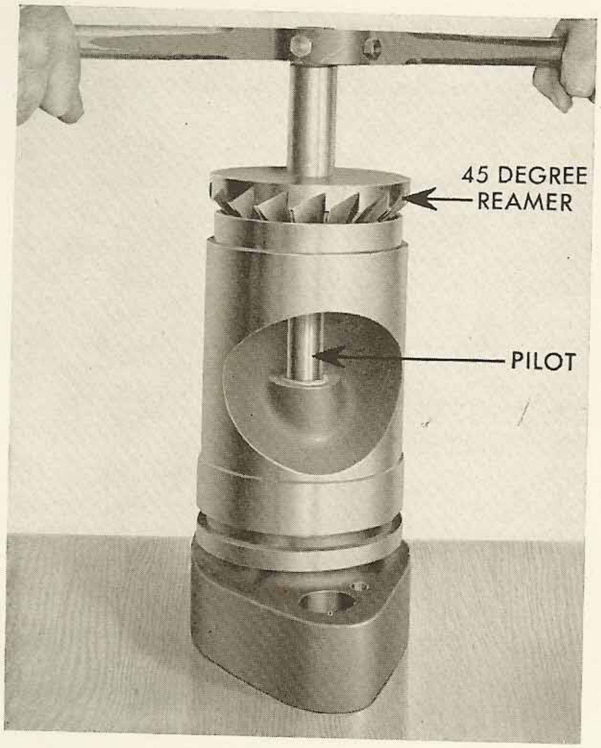


FIGURE 11-14

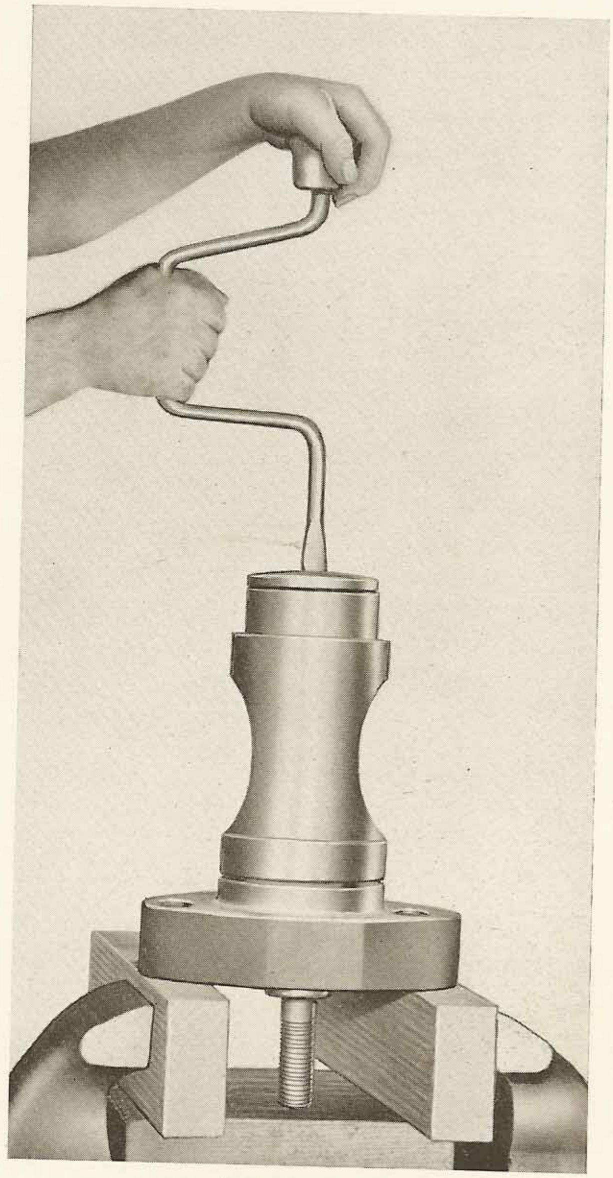


FIGURE 11-15

cage, can be removed by grinding, but much more work will be required than if they have been properly refaced.

9. GRINDING VALVES: The purpose of valve grinding is to obtain a gas or air tight fit between the valve face and the seat. Stand the valve cage on end and smear the valve face with coarse valve grinding compound. There are many valve grinding devices available but the most simple one can be made from an ordinary carpenter's brace and a wide screw driver bit. Use them as shown in Figure 11-15 and rotate the valve back and forth about 180 degrees. After 20 or 30 such movements, lift the valve off its seat to allow the grinding compound to reform on the grinding areas. Repeat these operations as often as is required to obtain a reasonably clear face and seat. Add more grinding compound when necessary.

There are many types of grinding compound available and most of them will do a good job. Some are already mixed in the form of a paste while others require a small quantity of water. A good grinding paste can be made by mixing emery powder and cylinder oil.

When the pits or scores have disappeared, change to fine compound and continue grinding until the seat is smooth and free from any marks as shown in Figure 11-16. The valve face should look like the one shown in Figure 11-17.

Wash the valve and cage thoroughly to remove all grinding compound. A simple check of the fit of the valve in the seat can be made as follows: Draw six or eight pencil lines across the face of the valve, spaced evenly around the circumference. Insert the valve in the cage. Press down firmly on the head of the

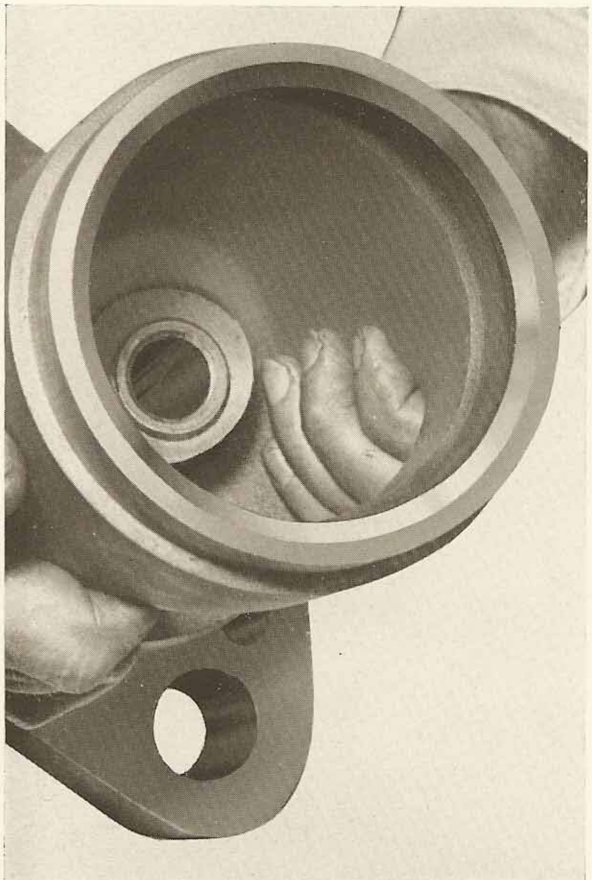


FIGURE 11-16

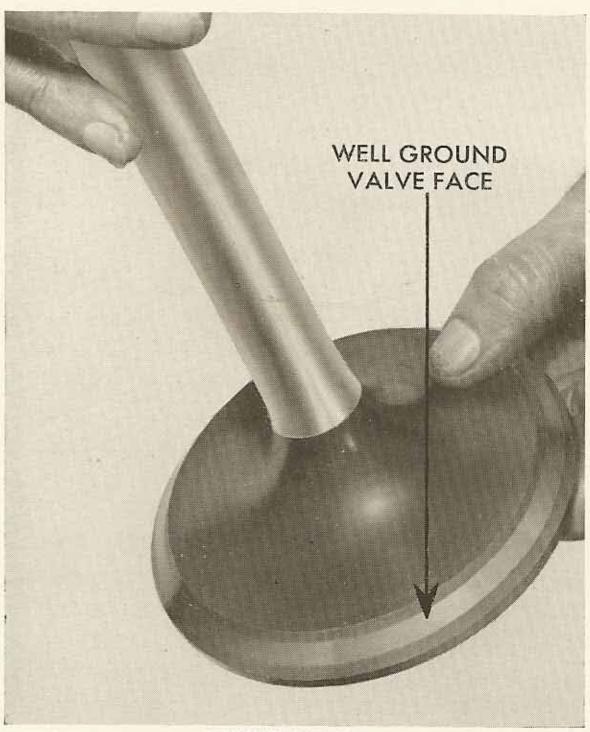


FIGURE 11-17

valve and turn the head approximately $\frac{1}{6}$ of a turn. Remove the valve and if the fit is proper, part of each pencil line should be erased.

10. ASSEMBLY OF VALVE AND CAGE: The cage sealing ring should be removed and the groove cleaned out. After replacing the ring, assemble the valve in the order shown in Figure 11-6. The retainer lock can be replaced by the same device used to remove it.

11. DISASSEMBLY OF AIR-START CAGE: Remove the parts in the order shown in Figure 11-18. Remove the balance bushing rings and the cage sealing rings and clean out the grooves. The valve stem and bushing of this assembly do not wear but they should be thoroughly cleaned and the valve face and cage seat ground if necessary. The bore of the cage where the balance bushing rings slide up and down should be cleaned.

If new balance bushing rings are fitted they should be checked for end gap clearance in the bore of the cage. This clearance should be at least 0.010 inch. The new rings should also be free in the ring grooves of the balance bushing. This clearance can be given to a ring by rubbing the ring over a piece of fine emery cloth laid on a flat surface. The rubbing motion should be circular.

12. ASSEMBLY OF THE AIR-START CAGE: All traces of grinding compound should be washed off thoroughly. All moving parts should be lightly covered with a penetrating oil.

Assemble the parts in the order shown in Figure 11-18. The end of the balance bushing with the rings, should be replaced nearest the head of the valve. The nut which holds the bushing against the shoulder on the valve stem should be well tightened. When the spring washer is screwed onto the stem it can be held by a pin while the locknut is being tightened.

After assembly is complete, support the cage flange on blocks so that the valve head is free to open. Strike the end of the stem several times and the action of the valve opening and closing can be watched.

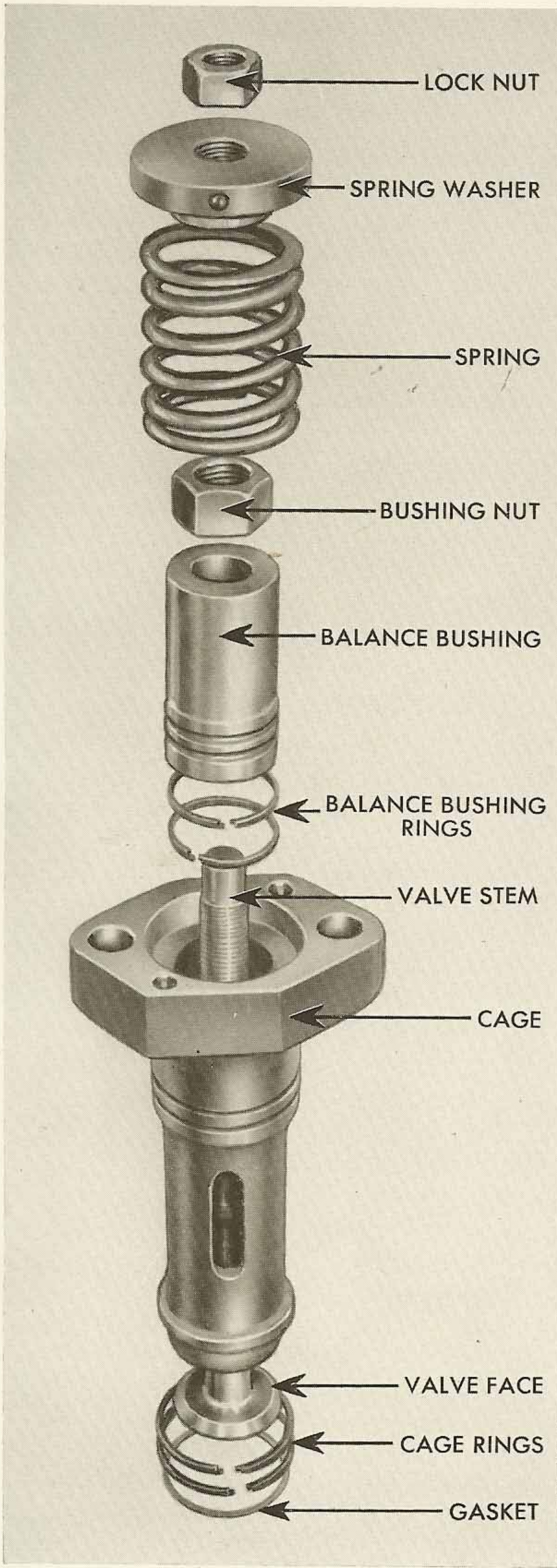


FIGURE 11-18

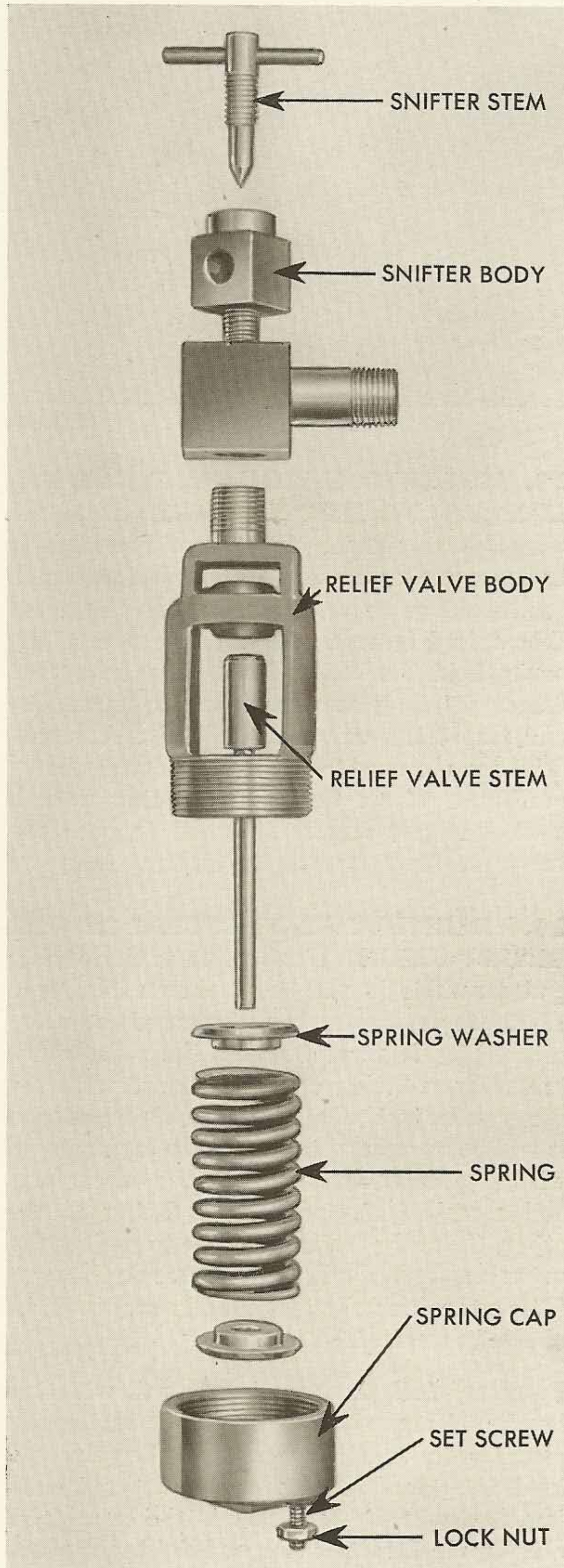


FIGURE 11-19

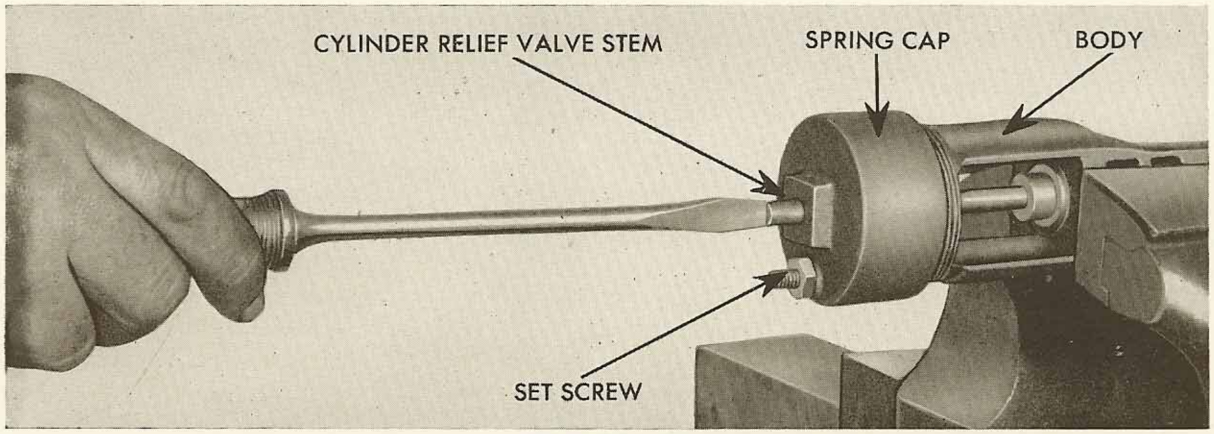


FIGURE 11-20

13. DISASSEMBLY OF CYLINDER RELIEF VALVE AND SNIFTER: It is not advisable to service this assembly unless it has been giving trouble. If the relief valve has been leaking, remove the parts in the order shown in Figure 11-19. After cleaning the parts, hold the body of the valve in a vise. Smear grinding compound on the valve face and insert the valve in the body. A screwdriver can be used to rotate the valve as shown in Figure 11-20. Continue grinding until a perfect ringed seat is obtained on both the valve face and the seat in the valve body.

14. ASSEMBLY AND SETTING OF THE RELIEF VALVE: Wash all parts thoroughly and assemble in the order shown in Figure 11-19. To set the spring tension of the valve proceed as follows: Connect the relief valve to the open fitting on the fuel rail with the spray valve test tube. To make this connection it will be necessary to have a fitting made up with a ½ inch female pipe thread on one end, and a male fuel compression fitting on the other. Close the isolating valve to each spray valve and open the isolating valve on the open fitting to which the test tube is connected as shown in Figure 11-21.

Pump up fuel pressure in the rail with the hand fuel pump. Screw down the spring cap of the cylinder relief valve until the valve will hold 800 pounds fuel pressure without leaking. Screw in the set screw in the cap, which acts as a lock for the cap, and tighten the lock nut. The valve is now ready for assembly on the engine.

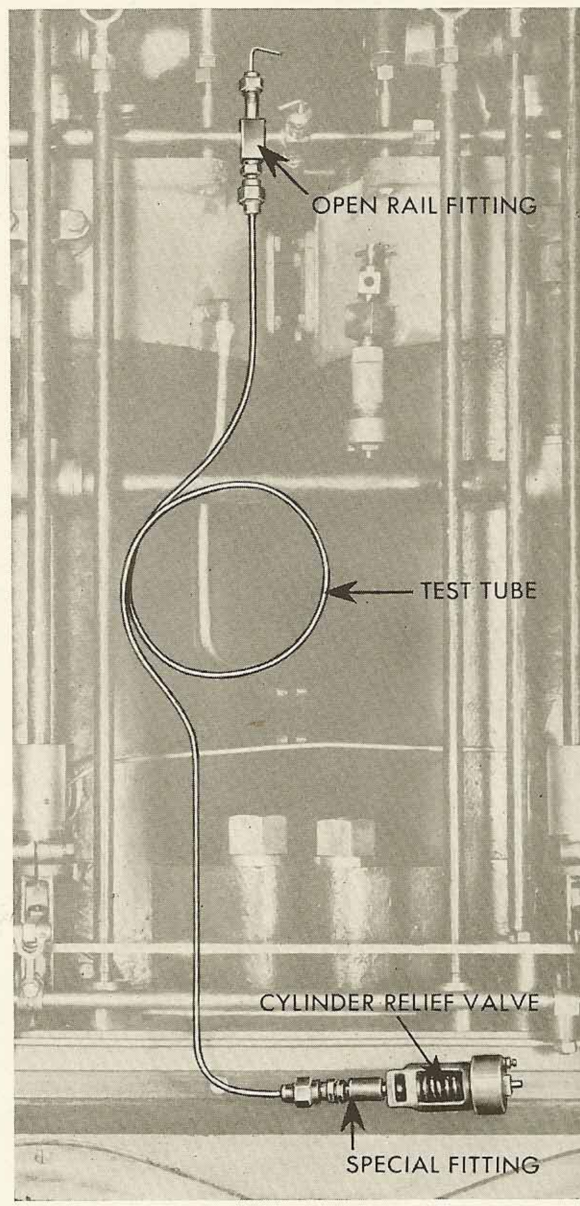


FIGURE 11-21

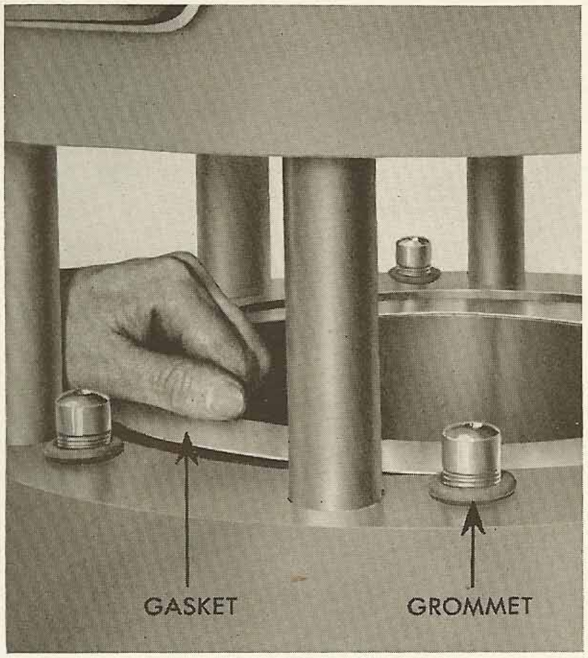


FIGURE 11-22

15. ASSEMBLY OF THE CYLINDER HEAD: Renew the rubber grommets, shown in Figure 11-22, which are around the by-pass pipes in the top of the cylinder. These grommets should not be coated with white lead or any sealing compound. Examine the copper cylinder head gasket and if it has become brittle it can be softened or annealed by heating to a dull red and quenching in water. If the gasket is thin or scored a new one should be used.

Clean the gasket groove which is formed by the top of the liner and the counterbore of the cylinder, and lay in the gasket. Make sure that the under face of the cylinder head is clean and lower the head onto the cylinder. Just before the head rests on the cylinder, lift the gasket as shown in Figure 11-22 to assure its being free and in place. Make sure that the head is setting evenly on the gasket. This can be done by checking with a feeler gauge the opening between the cylinder and the head all around the circumference.

Replace the exhaust elbows, inlet manifold, air-start manifold and water-outlet manifold gaskets. Start all the cap screws that attach these various manifolds to the head. Tighten these cap screws sufficiently to square the head to the flanges of the manifolds but do not give the final tightening until after the cylinder head nuts are drawn down.

Screw down all the head stud nuts by hand until they just touch the cylinder head. Using a box wrench and a four foot bar, tighten any one nut one flat or $\frac{1}{6}$ of a turn. Shift to the opposite side of the head and tighten one nut one flat. Proceed around the head in this manner, always tightening a nut as nearly opposite to the last one tightened as possible. All nuts should be tightened as much as it is possible for two men to pull on a four foot bar.

Tighten all manifold cap screws. Replace the fuel rail clamp. Connect the spray-valve cooling tube. Install the exhaust and inlet cage assemblies, making sure the gaskets are in their proper places. When tightening down the nuts which hold the valve cages, proceed the same as in tightening down the cylinder head. One flat at a time on each nut until a man pulling on a three foot wrench can tighten no more. Connect the exhaust valve cage cooling tubes.

Install the air-start cage assembly, being sure the gasket is in place. Replace the cylinder relief valve and the rocker assembly. Connect the rocker shaft forks and drive in the pins in the pushrod forks. The lock nuts on the pushrods should be loosened and the pushrods screwed well into the forks. They are then ready for adjustment when the engine is timed.

In installing the spray valve great care should be taken that there is only one gasket under the tip nut. Two or more gaskets will lift the valve up so that the value of the spray in the combustion chamber is changed. Connect the spray valve tube to the rail and the valve. This will locate the strainer after which the clamp nut can be tightened. Replace the spray valve rocker, being sure to put the cotter pin in the fulcrum pin.

As soon as the engine is started up, after a cylinder head has been off, an examination of all joints and gaskets should be made to determine if there are any leaks. All tools used in servicing the cylinder heads should be greased before laying away so that they will be in condition when they are again needed.

SECTION 12

CYLINDER AND LINER PISTON AND CONNECTING ROD

1. REMOVAL OF THE PISTON AND CONNECTING ROD: Remove the cylinder head as described in Section 11. Scrape the carbon from the top of the liner wall thoroughly, for if this surface is not clean it will be difficult to remove the piston.

Attach the piston lifting bar by two cap screws to the holes drilled and tapped in the top of the piston. This lifting bar can be any piece of iron $3/8$ inch thick by one inch or more wide and long enough to have a hole drilled in each end that will correspond to the tapped holes in the piston.

Remove the crankpit doors and bar the engine over until the crank is in the position shown in Figure 12-1. Remove the cotter pin and screw the nut almost off. Drive the connecting rod bolt down until it hangs on the nut.

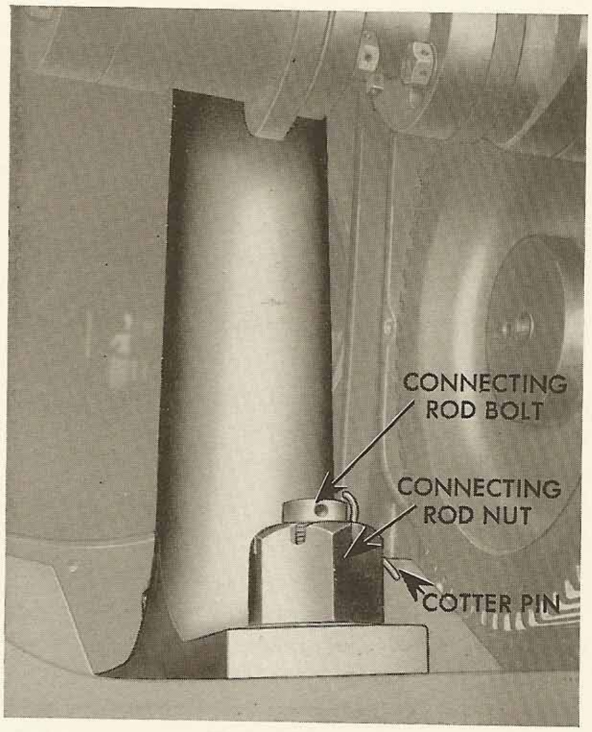


FIGURE 12-1

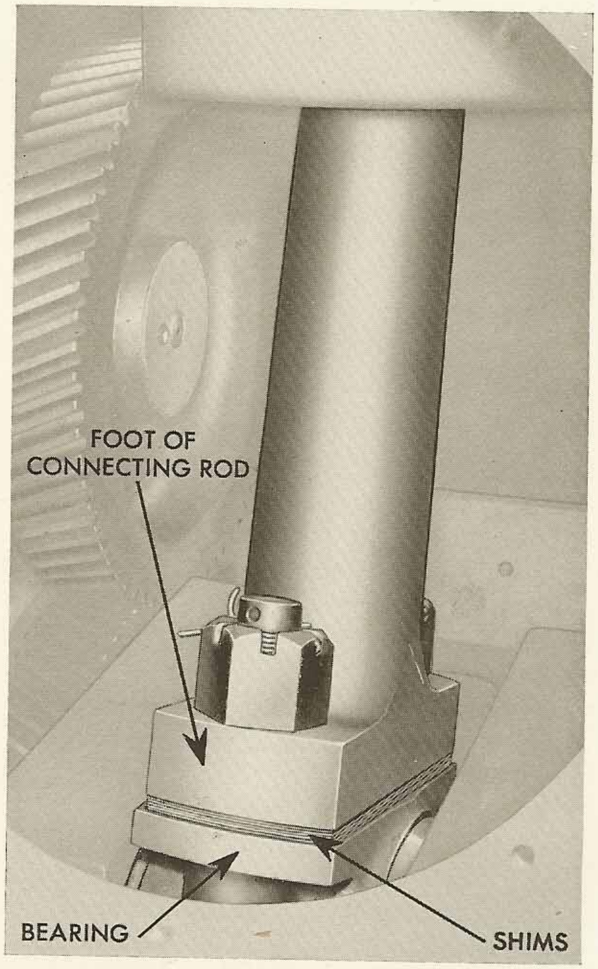


FIGURE 12-2

Bar the engine over until the crank is in the opposite position as shown in Figure 12-2. Remove the cotter pin and nut completely from the connecting rod bolt on the manifold side of the engine. Drive the bolt down with a three or four pound hammer. As the bolt is driven out the crank will have to be turned toward top center so the bolt will clear the pit wall.

Turn the crank back to the first position as shown in Figure 12-1 and remove the nut and drive out the bolt. Turn the crank to top center and hook a chain block to the piston lifting bar. Withdraw the piston and connecting rod. If the cylinder liner is worn badly there may be a slight ridge at the highest point of piston ring travel. As the piston is withdrawn, the rings may catch in this groove and it will be necessary to bump the foot of the connecting rod with a block of wood held between the foot of the rod and the crankpin. If the crankpin is turned down a few inches away from the block and then brought quickly back up against the wood block a sufficient force can be developed to push the rings past the ridge.

As the foot of the connecting rod leaves the top of the crankpin bearing, compression shims, as shown in Figure 12-3, will be exposed. Some shims may stick to the foot of the connecting rod while others may lie on the top of the crankpin bearing. It is important that none of these shims are lost or mixed with the shims from other cylinders. Collect all the shims from the cylinder being worked on and tie them in a bundle marked with the cylinder number.

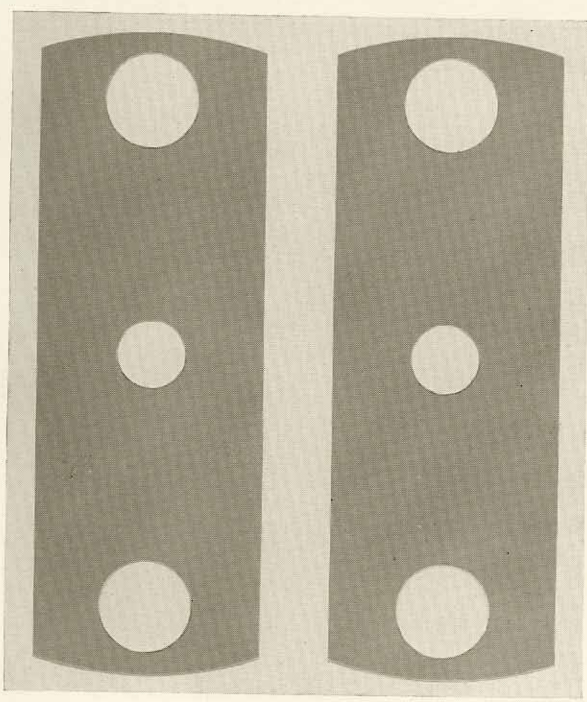


FIGURE 12-3

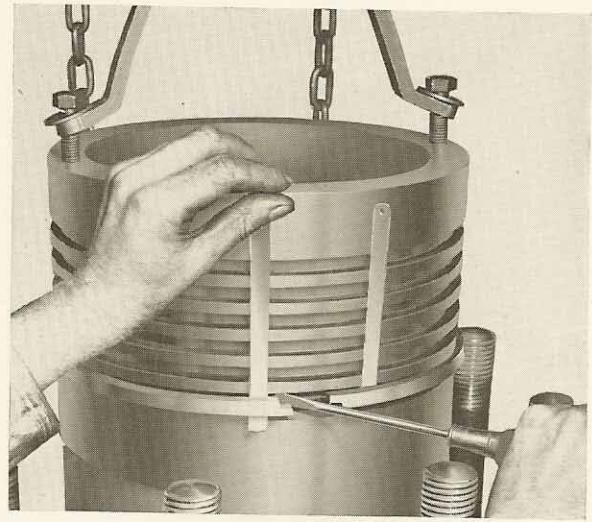


FIGURE 12-4

2. REMOVAL OF THE PISTON RINGS: It will be easier and safer to remove the piston rings while the piston is hanging from the chain block above the cylinder. This will avoid damage to the rings while the piston is being lowered to the floor. Grind off all the teeth of six or more used hack saw blades or cut similar strips of sheet metal.

Pry the end of the ring out as shown in Figure 12-4 and insert one of the metal strips. This strip can then be worked around the ring and another started in the end of the ring. When the ring is completely withdrawn from the groove and supported by the strips alone, slip the ring over the top of the piston. Repeat this operation until all the rings are removed. When the rings are stacked on the bench be sure that they are arranged in the same order they were removed as it is important to know which groove a ring belongs in when measurement checks are being made.

If some rings are stuck in the groove they may be loosened by the application of penetrating oil. If this treatment does not release the ring, it will be necessary to break the ring and remove it in pieces.

3. DISASSEMBLY OF PISTON AND CONNECTING ROD: Many of the service jobs described in this manual, such as removing bushings, pins and gears, can be done in a shop by presses or other equipment. How-

FIGURE 12-5

ever, these tools are seldom available on board ship, so we will endeavor to outline methods that can be employed with the facilities usually found in an engine room.

Stand the piston and connecting rod on end as shown in Figure 12-5. Loosen the lock nut (A) and remove the set screw (B) shown in Figure 12-11. With the piston and connecting rod still on end, tie a rope around the foot of the rod and attach the other end of the rope to some fixture overhead so the rope just takes the weight of the connecting rod.

The piston pin in your engine is step cut. That means that the bearing area and one end are the same diameter while the other end is smaller. This construction is shown in Figure 12-6 which explains why THE PIN MUST

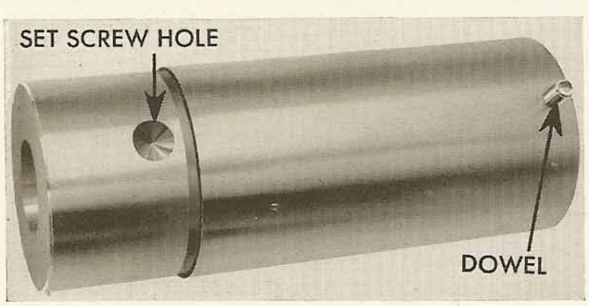


FIGURE 12-6

ALWAYS BE DRIVEN OUT FROM THE SMALL END. The small end is the one with the set screw in it. As the piston pin is hardened it will not stand direct blows of a sledge hammer. However, by using an old piece of bronze or brass shafting and a 12 to 16 pound sledge hammer, the pin can be driven out.

Wash the piston and connecting rod and clean out the ring grooves in the piston with a scraper made by sharpening a piece of broken ring. Remove the plug in the upper end of the connecting rod and the ball check from the foot. Clean out the drilled oil passage in the rod thoroughly. Clean and examine the ball check to see that the ball moves freely and is seating properly. If the lift of the ball exceeds $\frac{3}{32}$ of an inch the complete check valve should be replaced.

Stand the piston pin on end on the bench and with a micrometer take measurements of the diameter at four quarters of each end of the bearing surface. Next take at least eight or ten measurements at various places of the bearing area between the ends. If there is a variance of 0.005 inch or more in any of these measurements the piston pin should be reground or replaced. As regrinding is usually impossible on board ship, a worn pin will have to be replaced.

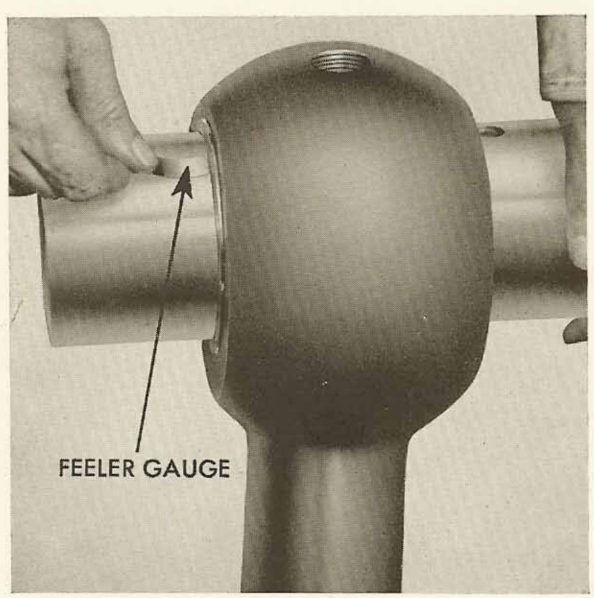


FIGURE 12-7

After a decision has been made on the condition of the pin the next step is a check on the clearance of the pin in the bushing. Grip the connecting rod in a vise and insert the pin in the bushing as shown in Figure 12-7. With a new piston pin and bushing, this clearance should be 0.004 to 0.005 inch. The maximum clearance should not exceed 0.010 inch and the bushing should be replaced if greater wear than this is found.

4. INSTALLATION OF PISTON PIN BUSHING: The worn bushing can be driven out with a drift and sledge in the same manner as the piston pin. The new bushing to be installed must be handled with more care to avoid damage. Set up a puller as shown in Figure 12-8. Any flat steel plate $\frac{1}{4}$ inch thick or over with a $\frac{3}{4}$ inch hole near the center will do. A $\frac{3}{4}$ inch bolt about 14 inches long with three or more inches of thread on one end, a small strongback and two pieces of $\frac{3}{4}$ or one inch square steel are all that is necessary to make up this layout. When everything is set up as shown, the new bushing can be forced into place by screwing down the nut above the strongback. As set up in Figure 12-8 the bushing can be pulled flush with the connecting rod. When this has been accomplished, loosen the nut and lay in the two square pieces of steel on the edge of the connecting rod, under the strongback, so that the bushing can be pulled through the correct distance. When in place the new bushing should protrude the same amount from each side of the connecting rod.

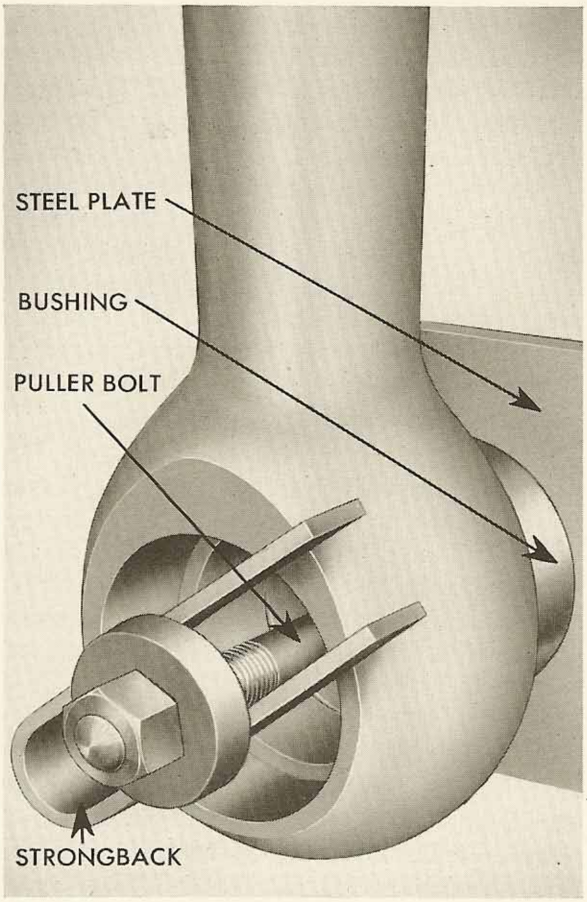


FIGURE 12-8

The clearance between the piston pin and the new bushing should be checked by again gripping the rod in the vise as shown in Figure 12-7. Insert the piston pin and measure the clearance with a feeler gauge. If a 0.004 or 0.005 inch gauge leaf cannot be inserted, the bushing should be opened up to this amount. A bearing scraper used carefully as shown in Figure 12-9 will scrape off any high spots in the bushing.

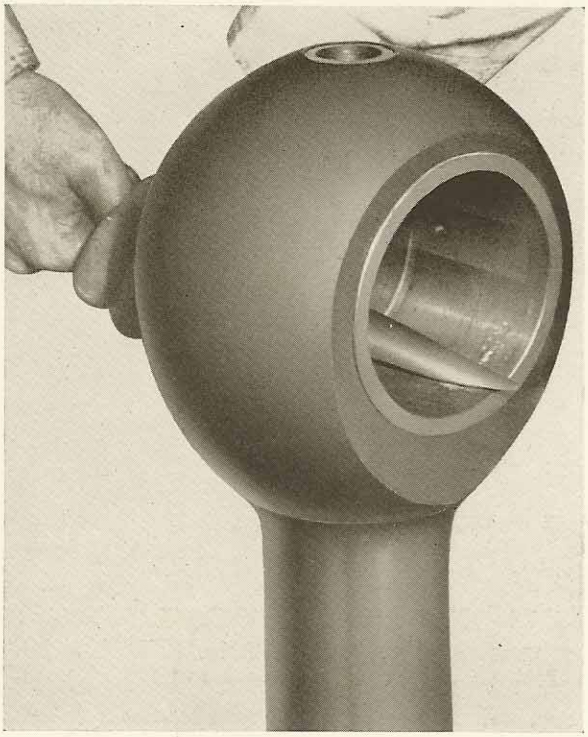


FIGURE 12-9

After the bushing has been installed, flush out the drilled passage in the rod to remove any particles of bushing material that may have been dropped through the hole or scraped off while pulling the bushing in. Replace the connecting rod check valve and screw the plug in the upper end of the connecting rod.

5. CHECKING AND FITTING THE PISTON RINGS: As the greatest wear in a cylinder liner occurs near the top ALWAYS CHECK THE RING CLEARANCES BELOW THE CENTER OF THE LINER. Insert each ring as shown in Figure 12-10 and measure the end-gap clearance with a feeler gauge. This end-gap clearance SHOULD NOT BE LESS than 0.005 per inch of the inside liner diameter for NEW RINGS in the top two grooves. Example: for $11\frac{1}{2}$ inch inside liner diameter: $11\frac{1}{2} \times 0.005 = 0.057$ inch total clearance.

The end-gap clearance should NOT BE LESS than 0.003 per inch of the inside liner diameter for NEW RINGS in the grooves below the top

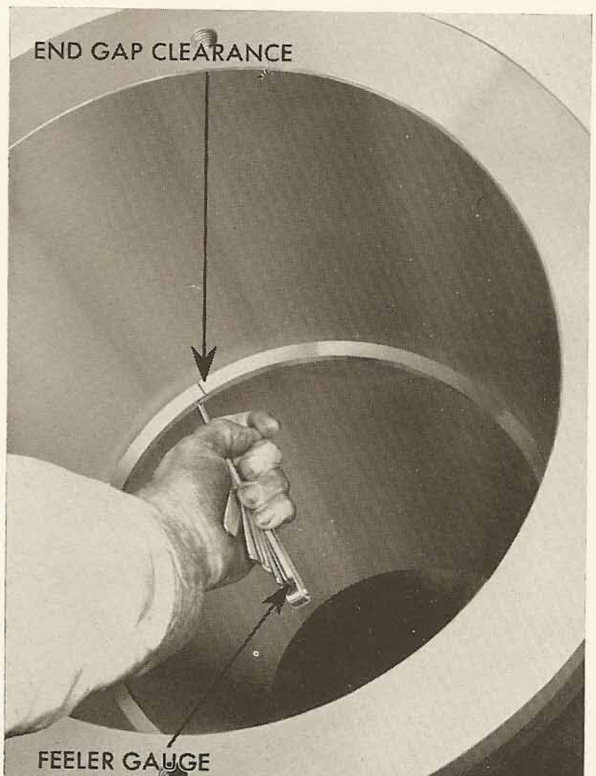


FIGURE 12-10

two grooves. Example: for $11\frac{1}{2}$ inch inside liner diameter: $11\frac{1}{2} \times 0.003 = 0.034$ inch total clearance.

If the gap clearance of any ring exceeds 0.008 per inch of the inside liner diameter, the ring should be discarded. When fitting new rings, the gap clearance can be increased by filing the ends of the ring. When fitting new rings, make sure that the clearance between the top of the ring and the top of the ring groove is at least 0.003 to 0.005 inch. This check should be made with the ring in the same groove it is to be installed in. These clearances are all shown in Figure 12-11.

The bottom ring and the first ring above the piston pin are oil scraper rings and should be installed RIGHT SIDE UP as shown in Figure 12-11. After the rings are fitted for gap clearance they should be carefully stacked so they may be assembled on the piston in the order they were fitted.

6. ASSEMBLY OF THE PISTON, CONNECTING ROD, AND RINGS: Make sure all parts are clean. Stand the piston on end, suspend the connecting rod as in Figure 12-5. When assembling the piston and rod remember that the marks on the foot of the connecting rod always go to the manifold side of the engine. The small end of the piston pin is always aft in the cylinder. These two facts will determine which way the connecting rod is turned before the piston pin is entered as shown in Figure 12-12.

Cover the pin with clean oil. Enter the piston pin as shown, with the small end in and the dowel in line with the dowel slot. Push in by hand as far as possible. There should now be about two inches sticking out. With a drift and a sledge drive the pin in as in removal, see Figure 12-5.

BE SURE THE DOWEL ENTERS THE DOWEL SLOT. When the shoulder (C), Figure 12-11, comes up against the piston, drive the pin BACK one or two blows with a sledge. This relieves any tension and should leave the shoulder on the piston pin about $\frac{1}{64}$ of an inch

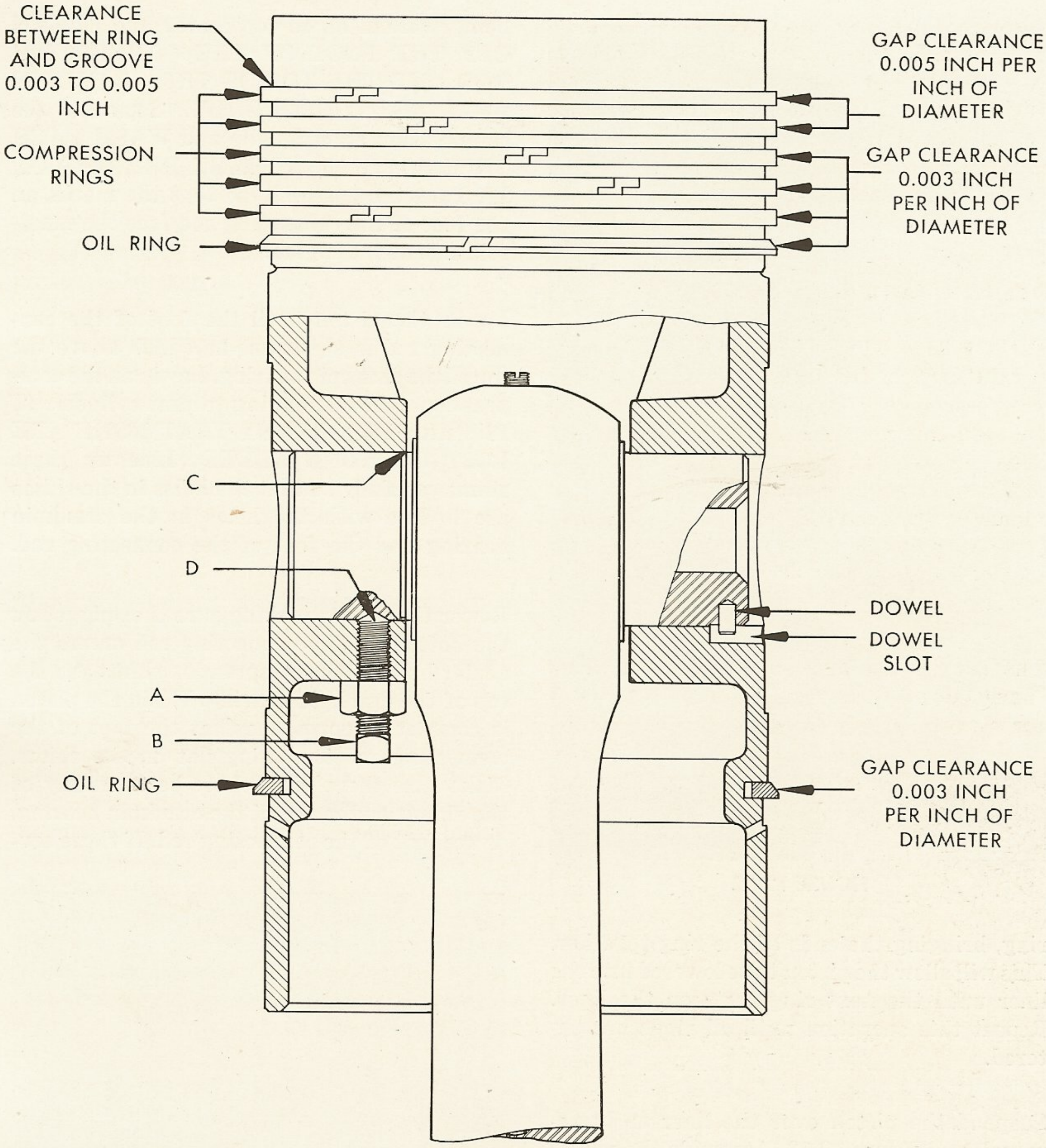


FIGURE 12-11

away from the piston. This measurement is not important as long as the shoulder does not touch the piston. Make sure the hole spotted in the piston pin (D), Figure 12-11, is directly under the set screw hole in the piston. Screw in the set screw tightly, and lock the lock nut.

7. ASSEMBLY OF THE PISTON AND CONNECTING ROD IN THE LINER: Clean the liner walls, piston and connecting rod. Smear oil over the walls of the liner. Set in the piston-ring compressor, as shown in Figure 12-13. This compressor ring is usually found among the engine room equipment and assists greatly in entering the piston rings in the liner without damage. If a compressor ring is not available, this job can be done by lowering the piston until the lower ring just rests on the top of the liner. Compress this ring by drawing a piece of strong cord around the

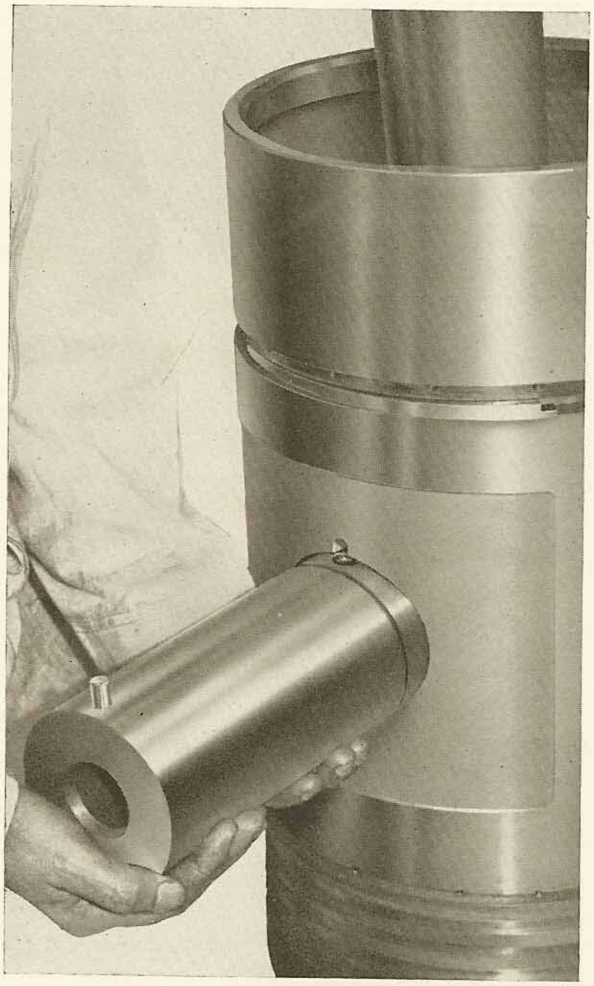


FIGURE 12-12

ring, bringing the ends of the ring together. This will allow the piston to be lowered into the liner until the next ring rests on the liner. Repeat this operation until all rings are entered.

Suspend the piston over the liner as in removal, see Figure 12-13. Assemble the piston rings on the piston as in removal, see Figure 12-4. The OIL SCRAPER RINGS MUST BE INSTALLED AS SHOWN IN FIGURE 12-11. THE TWO COMPRESSION RINGS WITH THE GREATEST GAP CLEARANCE MUST BE INSTALLED IN THE TOP TWO GROOVES.

Oil the ring compressor generously. Lower the piston until the piston top is level with the top of the liner. Turn the crank of the cylinder being worked on to top center and CLEAN OFF THE FOOT OF THE CONNECTING ROD AND THE TOP OF THE CRANKPIN BEARING THOROUGHLY. Separate the compression shim bundle and WASH EACH SHIM SO THAT NO DIRT REMAINS ON IT. Turn the assembly so that the marks on the foot of the connecting rod face the manifold side of the engine.

Lower the piston until the foot of the connecting rod is about one-half inch above the top of the crankpin bearing. Lay in all the compression shims belonging to that cylinder. IT IS VERY IMPORTANT THAT NONE ARE LOST OR NONE ADDED. Line up these shims carefully so that the holes in the shims are in line with the holes in the crankpin bearing and the foot of the connecting rod.

Lower the piston, making sure the spiggot on the bottom of the connecting rod enters the center holes in the compression shims and the top of the crankpin bearing. When the piston is completely down, see that the foot of the connecting rod is resting flat on the shims. Make sure there is no space between any of the shims, or the top of the crankpin bearing, or the foot of the connecting rod. If these sev-

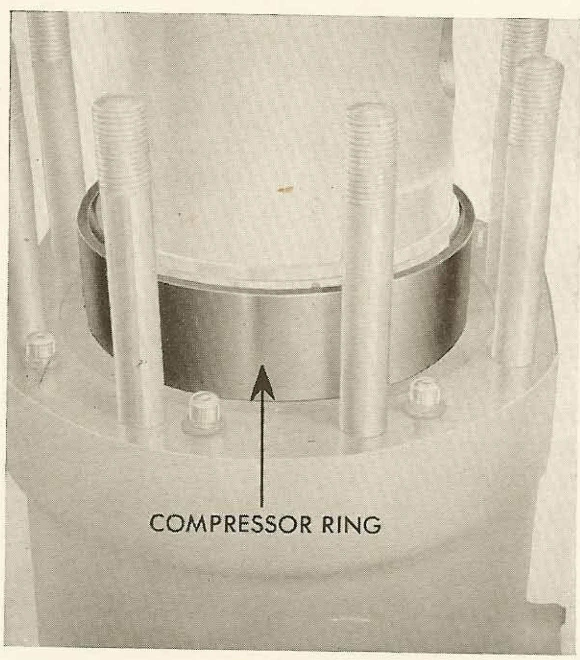


FIGURE 12-13

eral parts do not come together properly, DO NOT PULL THEM TOGETHER WITH THE CONNECTING ROD BOLTS. Find out what is holding them apart and correct it.

Turn the crank to top center and check the height of the piston by measuring from the top of the liner to the top of the piston. The following table gives the measurements for various engine sizes.

Engine Bore & Stroke	Measurement
10 x 13	13/16 in.
10½ x 13	13/16 in.
11½ x 15	15/16 in.
13 x 16	1 1/32 in.
14½ x 18	1 1/16 in.
15 x 19	1 3/16 in.

Make adjustments if necessary by adding or removing compression shims. If the liner has been removed do not take this measurement until the liner has been drawn into place. Drive the connecting rod bolts up, MAKING SURE THE FLAT ON THE CONNECTING ROD BOLT ENTERS THE RECESS IN THE BEARING. See Figure 12-14. Screw down the nuts until they touch the foot of the connecting rod. Tighten each nut only one flat at a time until both are as tight as one man can pull with a four-foot bar. There are two holes in the bolt for the cotter pin. These holes are so spaced that 1/12 of a turn on the nut will always line up a slot in the nut with a hole in the bolt. Insert the cotter pin and

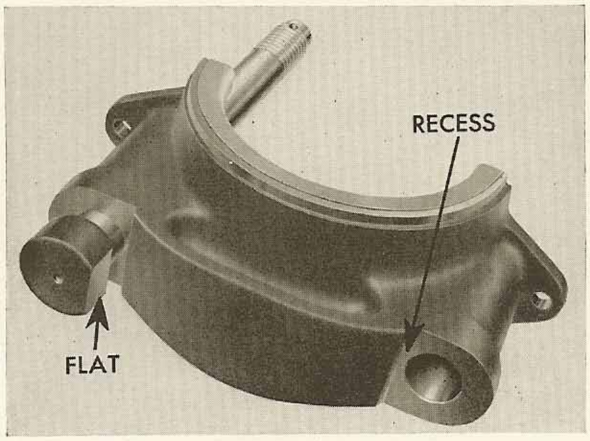


FIGURE 12-14

spread the ends. Always use a cotter pin that is nearly the size of the hole. SMALL LOOSE COTTER PINS ARE DANGEROUS.

8. REMOVAL OF THE LINER: Remove the cylinder head, the piston and the connecting rod. Disconnect the oil lines from the mechanical lubricator. Screw out the packing nut, Figure 12-15, and remove the rubber grommets. Screw out the oil pipe.

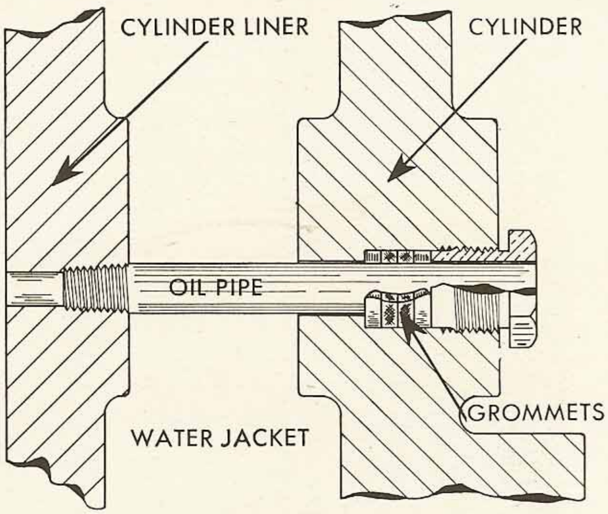


FIGURE 12-15

Set up as shown in Figure 12-16. The puller bolt C should be about 1½ inch diameter and threaded on both ends.The two blocks A shown resting on the cylinder can be any two pieces of metal, of equal thickness, which will raise the strongback up enough to allow the liner to clear its spiggots. The strongback B can be heavy plate with a hole bored in it for the bolt to go through or it can be two pieces of metal, one laid each side of the bolt. Whatever is used it must be strong enough to stand the pull of the bolt without bending. The washer under the top nut F should be heavy and well greased. The puller bar D which fits on the bottom of the liner can be either a plate or a heavy bar. In either case it must be cut round and the outside diameter cannot be any larger than the diameter of the outside of the liner at the bottom. Otherwise it would foul on the cylinder when the liner G was withdrawn.

If the liner is not stuck too tightly, screwing down on the nut on top of the strongback should release the liner, but it may be neces-

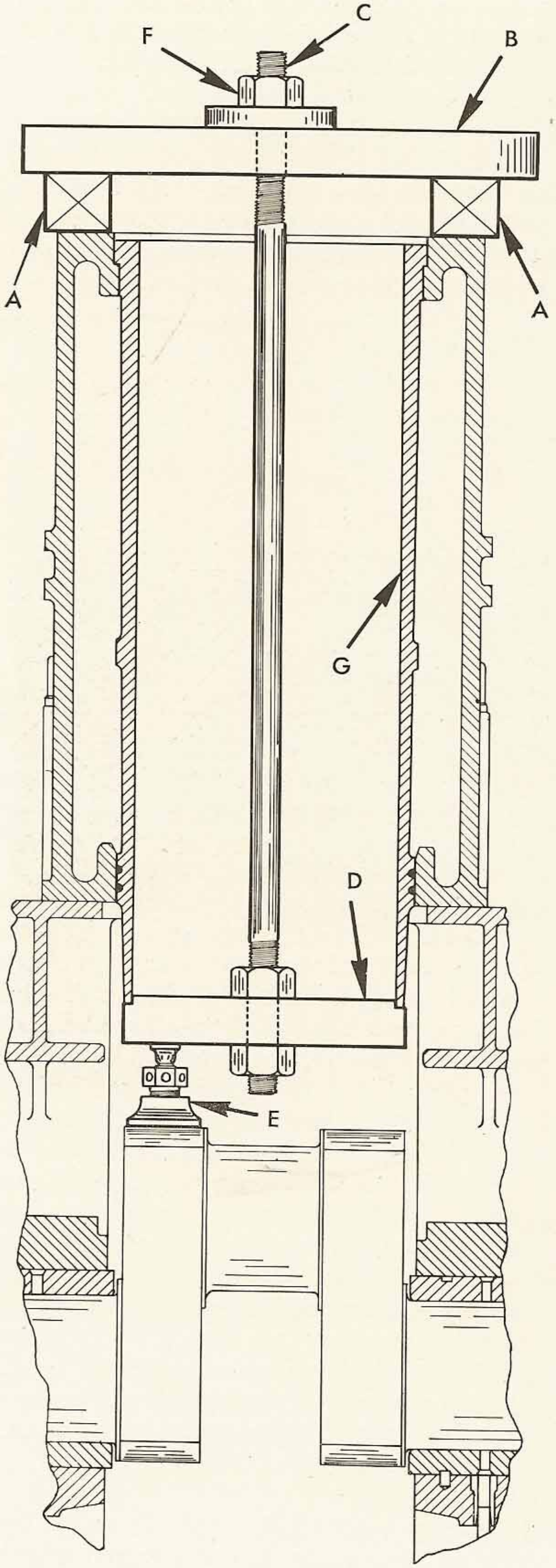


FIGURE 12-16

sary to use a jack E as shown to start it. After the liner is started, remove the pulling gear and attach the lifting bar which can be any strap iron $3/8$ inch thick with a hole bored in each end to correspond with the two cap screw holes in the top of the liner. Hook the chain blocks to the lifting bar and withdraw the liner from the cylinder.

Remove all scale from the outside of the liner and remove all scale and mud deposits from the inside of the cylinder. Remove and discard the two rubber grommets at the bottom of the liner. Remove and discard the paper gasket at the top of the liner.

Measurements of the liner can be taken either before or after the removal from the cylinder in the manner shown in Figure 12-17. Inside micrometers, which are used for this job, are described in Section 8.

Measurements should be taken at the top of the ring travel (where the greatest wear occurs) and about six inches below the top of the ring travel. All measurements should be taken both fore and aft and thwartships. A record of each cylinder should be kept.

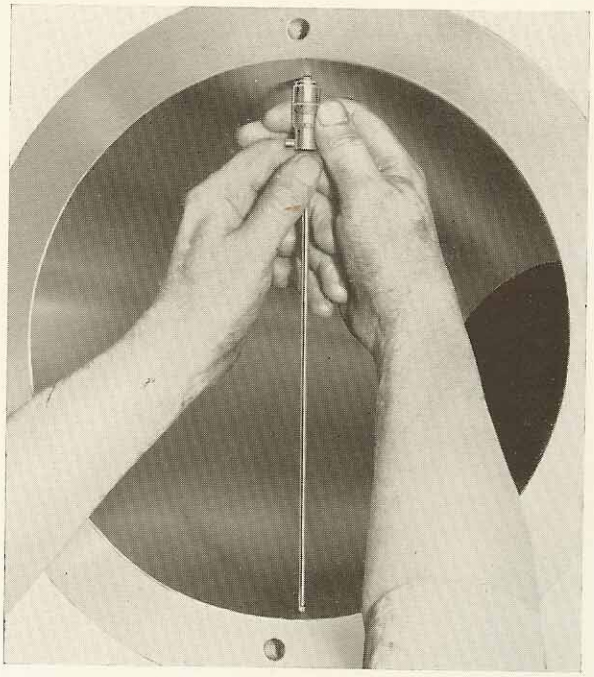


FIGURE 12-17

9. ASSEMBLY OF THE LINER: Clean the liner thoroughly, giving special care to the grommet grooves at the bottom and the gasket face at the top. Clean the gasket seat in the cylinder. Smear clean, soft grease over the NEW paper liner gasket. Slip the gasket over the bottom of the liner and press it lightly up to the gasket face.

Suspend the liner over the cylinder by chain blocks and smear the NEW liner grommets with clean gasket shellac.

Roll these grommets into the liner grooves, taking care not to twist or wind them up (see Figure 12-18). Cover the grommets with more gasket shellac just before installing in the engine. Lower the liner into the cylinder, taking care that the liner dowel enters the slot in the cylinder (see Figure 12-19), and also that the paper gasket is not damaged during lowering. Make sure the liner is setting on the paper gasket. The liner will be tightened down into place by the cylinder head when it is put on.

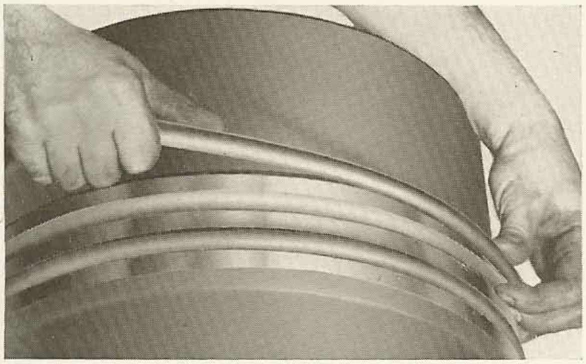


FIGURE 12-18

Screw in both cylinder-lubricating pipes (see Figure 12-15). Use NEW rubber grommets to pack these lubricating pipes. Screw the packing nuts in and connect the mechanical-lubricator tubes.

After a liner has been installed and the engine started up for the first time, run a few minutes and stop. Remove both pit doors and examine both the inside and the outside of the liner skirt for water leaks. If water is leaking down inside of the liner wall, the cylinder lubricator pipes are leaking. If water is leaking down the outside of the liner, the rubber liner grommets are leaking. If the grommets were installed and handled carefully, no such leak should occur.

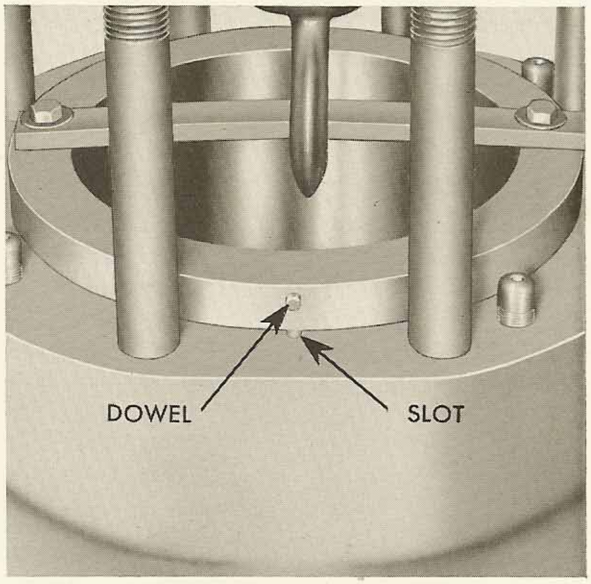


FIGURE 12-19

SECTION 13

CRANKPIN BEARING

1. GENERAL: Crankpin bearings are usually the first spot where trouble will occur if there has been a failure of the oiling system from neglect or stoppage. The first indication of a hot crankpin bearing will be a hot crankpit cover. The oil which is thrown from the overheated bearing will make the cover warmer than those on the other pits. If the bearing is loose there will be a dull knocking, especially, just as the engine is stopping. A burned out crankpin bearing will knock badly and may also cause a low temperature reading on the pyrometer. There will also be traces of babbitt in the crankpit. These bearings should be inspected every six months and their clearances adjusted if necessary.

2. DISASSEMBLY OF THE CRANKPIN BEARING: Remove the cylinder head as described in Section 11 and the piston and connecting rod, see Section 12. Remove both the clamp bolts, being careful not to allow the bearing halves to fall into the pit and damage the oil manifold. Collect the shims from each side of the bearing and tie them in two bundles marked with the cylinder number. If the shims are kept intact as they are removed from the bearing much time and trouble will be saved during assembly. Figure 13-1 shows a crankpin bearing.

Wash out the crankpit thoroughly as well as the crankpin, and the crankpin bearing. Remove the main bearing cap (see Section 14) of the first journal aft of the crankpin being worked on. This will be the journal which supplies the crankpin with oil. With a clean rag, NOT WASTE, tied on to a piece of wire or heavy cord, wash out the drilled passage in the crankweb which extends from the journal to the crankpin.

If there are signs of an oil failure the bottom half shell of the journal should be rolled out for inspection.

3. EXAMINATION OF THE CRANKPIN: Examine the crankpin carefully for damage. The roundness of the crankpin can be checked by outside micrometers. If the pin is slightly scored as shown in Figure 13-2 a new bearing can be fitted providing the crankpin is cleaned up. Use a whetstone and fine emery cloth to remove any rough projections which are above the bearing surface. When using any abrasive

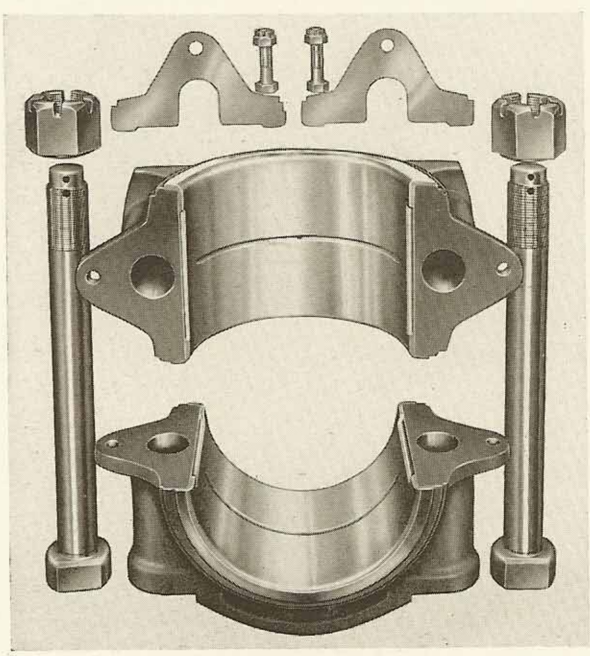


FIGURE 13-1

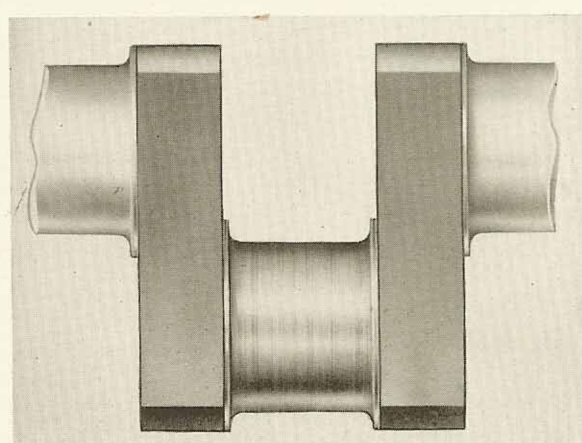


FIGURE 13-2

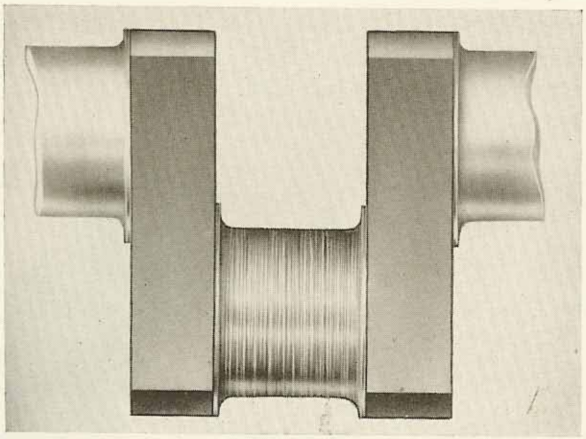


FIGURE 13-3

substance on a crankpin or main journal be sure and plug the drilled oil passage in the crankshaft.

If the crankpin is badly scored as shown in Figure 13-3, emergency repairs are not practical and every effort should be made to have the pin trued up at a shipyard or repair base. If it is impossible to reach such a place, an emergency method of bringing your ship home is suggested in paragraph 10 of this section.

4. EXAMINATION OF THE BEARING: After the crankpin bearing has been washed, examine the babbitt. Loose or cracked babbitt will look like Figure 13-4. Such a bearing should be replaced. A burned out bearing will look like Figure 13-5 and should be replaced.

Sometimes a bearing will have fine hair cracks and as long as these do not cause the babbitt to be loose the bearing can be used in an emergency. Spots on a bearing may have small deposits of babbitt which have been wiped from some other area. These should be scraped off. Babbitting and reboring a bearing on board ship is not practical unless all the equipment necessary is available. It is customary to carry several spare bearings and these should be used in case of accident. The damaged bearings should be kept for reconditioning at a base or service depot.

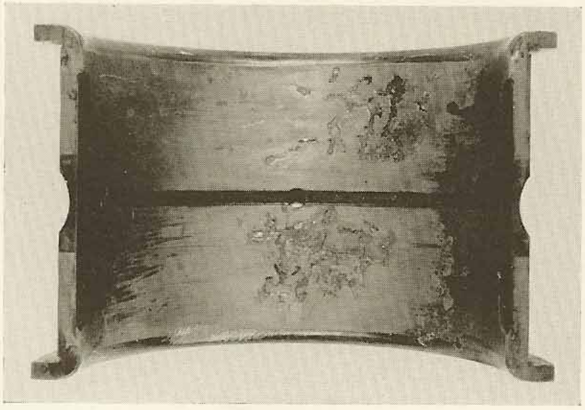


FIGURE 13-4

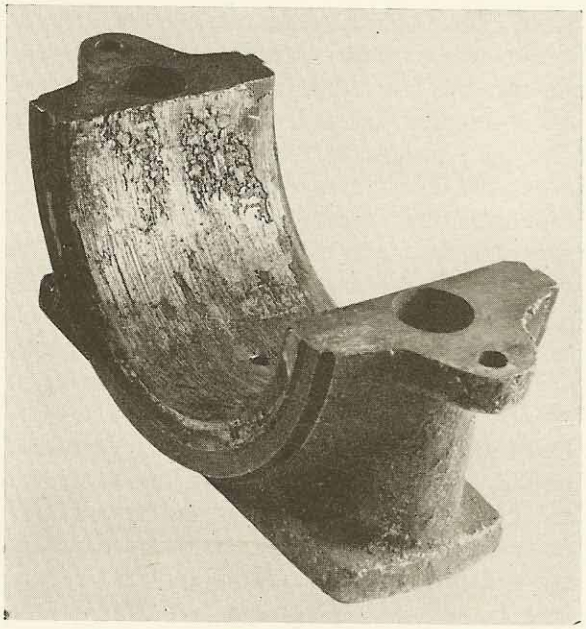


FIGURE 13-5

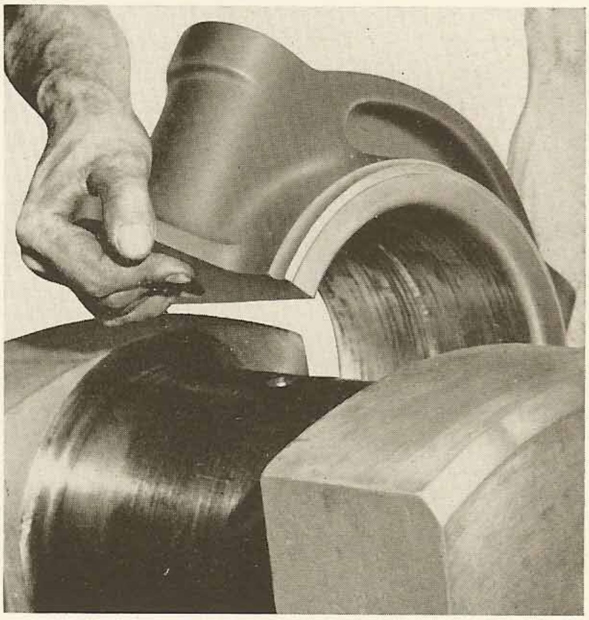


FIGURE 13-6

5. FITTING A BEARING: The ability to fit a bearing properly comes only from experience but we will point out what is wanted in the finished job and rely on the operator's own good judgment to achieve the requirements as nearly as possible. The object of bearing fitting is to obtain a sure contact between the majority of the babbitt area on the bearing and the surface of the crankpin. If 3/4 of the babbitt touches the crankpin, a bearing is considered well fitted. The spare crankpin bearing will be bored and machined to within a few thousandths of an inch of size. Coat the crankpin very lightly with Prussian Blue. Press down on the bearing half as shown in Figure 13-6 and move to and fro several times. Lift off the bearing half and the babbitt will probably look like Figure 13-7.

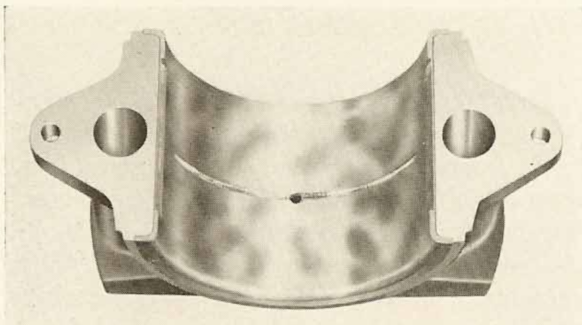


FIGURE 13-7

Here is the real object of bearing fitting. To remove, by light scraping, these high spots, which have picked up blueing from the crankpin. The next trial fit should show additional areas marked with blueing. This process is repeated until at least 3/4 of the babbitt is marked after a trial fit as in Figure 13-8. A bearing scraper is handled very lightly as in Figure 13-9.

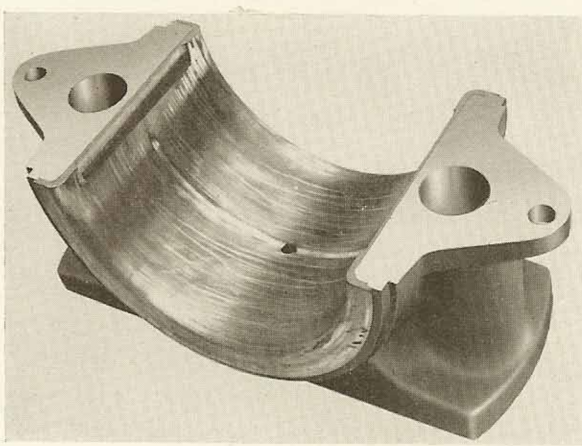


FIGURE 13-8

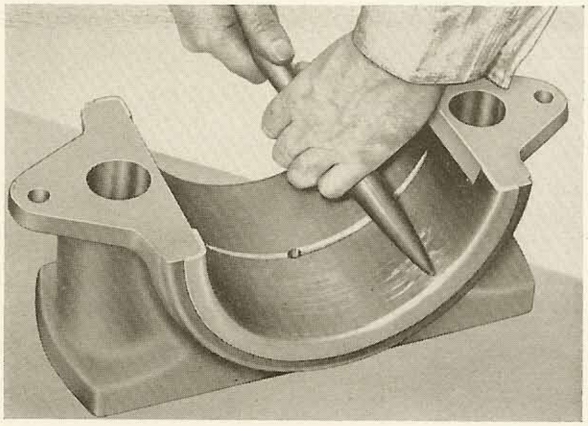


FIGURE 13-9

Fit each half of the bearing in this manner. Thoroughly clean the crankpin and the bearing halves. Assemble the bearing and the shims on the crankpin using the crankpin bolts and heavy spacers to clamp the halves together as shown in Figure 13-10.

When using these spacers the crankpin bolts must be drawn up as tightly as they would be in the final assembly so that the shims will be fully compressed.

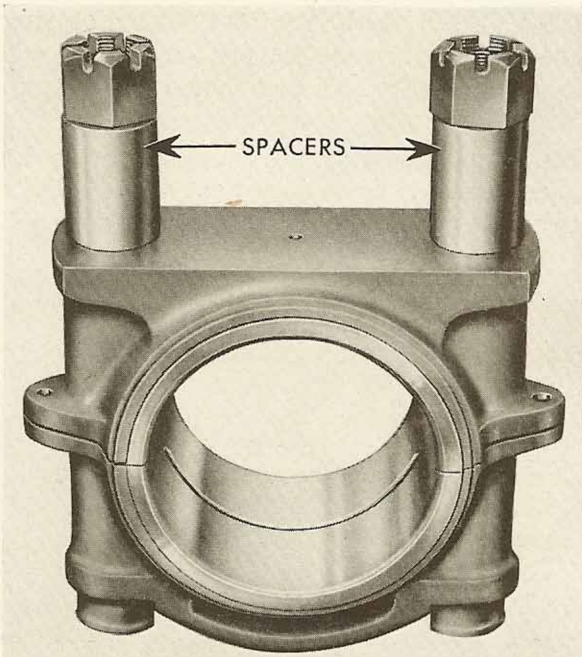


FIGURE 13-10

6. SHIMMING FOR RUNNING CLEARANCE: Add or remove enough shims at each side so that the bearing can just be rotated by hand when the halves are firmly clamped together. Always keep both shim bundles the same thickness. If the shim bundles have been mixed, measure each shim with a micrometer and add up the total thickness of each bundle. In this way the bundles can be evened up. After the bearing has been so adjusted that it will just turn on the pin, select shims for both sides that will give a clearance of 0.001 per inch of crankpin diameter. Example: for a 7-inch pin, $7 \times 0.001 = 0.007$ inch, total clearance. These shims are now added to those already in the bearing.

7. END CLEARANCE: While the bearing is assembled, move it fore and aft on the crankpin with a pry bar. The amount of end clearance can be measured by inserting the leaves of a feeler gauge between the end of the bearing and the crankweb. If this end clearance is less than 0.007 inch the babbitt should be scraped from the end of the bearing until this clearance is obtained.

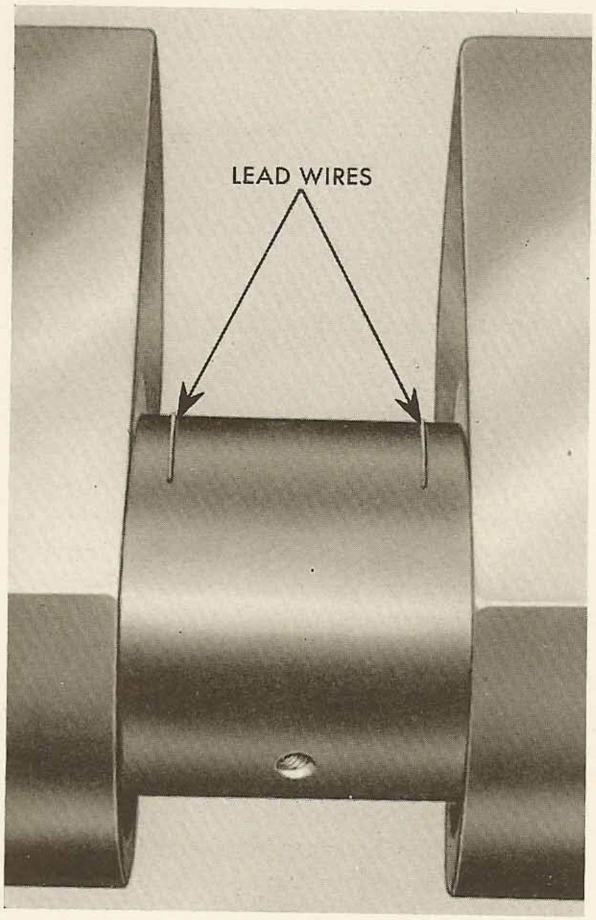


FIGURE 13-11

8. FINAL ASSEMBLY: When the proper end and running clearance has been obtained and adjusted, clean the crankpin, the drilled passage in the crankshaft and the bearing halves. Lower in the piston and connecting rod. Be sure to have the numbers which are stamped on the foot of the connecting rod facing the manifold side of the engine.

During this final assembly it is advisable to again check the running clearance between the bearing and the crankpin. This can be done in the following manner:

Before the bearing halves are again assembled on the crankpin, lay two pieces of lead wire, about 0.025 inch diameter and 2 inches long, across the crankpin as shown in Figure 13-11. These should be placed about one inch in from each end of the crankpin.

Lay the top half of the bearing on these lead wires carefully and assemble the bearing, the connecting rod and the piston. By tightening the connecting rod bolts, and drawing the entire assembly together, the lead wires will be squeezed to the exact clearance left in the bearing by the shims.

Remove the bearing and measure the now flattened lead wires with a micrometer. If the proper running clearance has not been obtained, add or take away shims, of proper thickness, from each side and assemble and check the clearance again.

Example: 0.005 inch running clearance desired.

The lead wire when removed measures 0.003 inch. Add a 0.002-inch shim to each side and assemble and check again. When the correct clearance has been obtained, oil the bearing surfaces and crankpin with clean oil and assemble the bearing with its correct shims on the pin. The bearing halves are held together by the two small clamp bolts until the crankpin bolts are driven through.

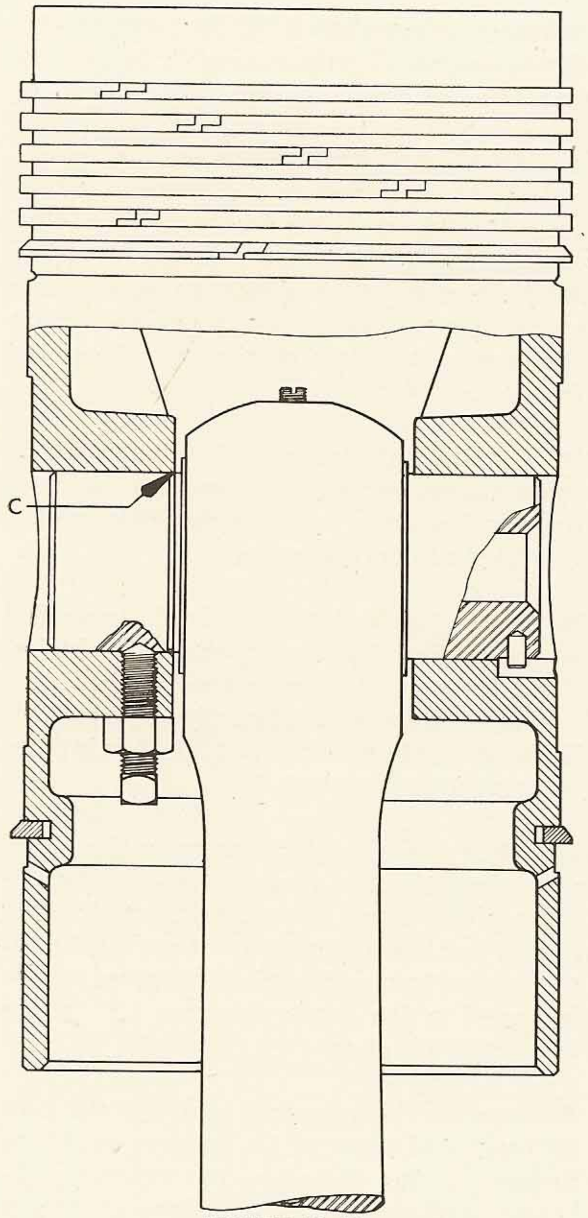


FIGURE 13-12

The flats on the heads of the connecting rod bolts must enter the recess in the lower bearing. See Figure 12-14. After the nuts are tightened, BE SURE THE COTTER PINS IN THE CONNECTING ROD BOLTS ARE IN PLACE AND PROPERLY SECURED.

9. SERVICE NOTE: If there has been trouble in obtaining the proper end clearance on the crankpin bearing or if the lead wires from each end of the bearing halves have been showing different thicknesses, the alignment of the assembly should be checked as follows: Refer to "C" Figure 13-12.

The clearance between the piston pin boss, and the bushing in the connecting rod should be nearly the same on both sides. The total clearance of both ends may vary from 1/16 inch to 3/32 inch but while this measurement is not important, there MUST BE A CLEARANCE SHOWING ON BOTH ENDS. This can best be checked by looking at the upper end of the connecting rod with a flashlight. The piston-pin bushing and the piston bosses will be dark while the piston pin will show bright and this bright streak at either end of the bushing will indicate sufficient clearance. If no bright streak shows, the piston-pin bushing must be crowding the piston boss. A slight variance here does not matter but if the piston-pin boss is hard up against the bushing, the crankpin bearing will be kept from sitting squarely on the crankpin.

In this case disconnect the foot of the connecting rod from the bearing. Turn the rod and the piston one-half turn. This will bring the marks on the foot of the rod to the operating side of the engine. Bolt the rod tightly to the bearing again and check the clearance between the piston-pin boss and the bushing. If the clearance remains as before, that is, the piston-pin boss is still crowding the SAME end of the bushing, the connecting rod and piston are properly aligned. If this clearance changes from one end of the bushing to the other when the rod is turned one-half turn, either the rod is bent or there is dirt stuck on the under side of the rod foot.

If the clearance does NOT change, proceed as follows: Disconnect the rod and bearing and turn the bearing one-half turn.This brings the bearing marks to the operating side of the engine. Bolt the rod and the bearing tightly together and again check the clearance between the piston-pin boss and the bushing. If the clearance remains the same as through all previous checks, the alignment of bearing, connecting rod, and piston is correct.

If after making this last check, the clearance DOES change from one end of the bushing to the other, the bearing has been improperly fitted and should be scraped so as to bring the top of the bearing parallel with the crankpin.

If these various checks have proved that the assembly is in alignment, clearance at either end of the piston pin bushing can be obtained in the following manner: Loosen all the studs or cap screws, attaching manifolds or flanges to the particular cylinder and cylinder head. Loosen the four nuts on the cylinder mounting flange. The holes in the mounting flange are large enough to permit slight movement fore and aft. If the piston-pin bushing is hard up on the FORWARD end, wedge the cylinder FORWARD far enough to give some clearance. Tighten down the mounting flange nuts. Tighten all studs and cap screws in the manifolds. If the piston-pin bushing is hard up on the AFTER end, wedge the cylinder AFT. After proper clearance has been obtained, assemble the connecting rod and the bearing in the proper manner.

10. EMERGENCY MEASURES IN CASE OF IRREPARABLE DAMAGE TO THE CRANKPIN, CRANKPIN BEARING, CONNECTING ROD, OR PISTON: If any of the above mentioned parts have been damaged in any one cylinder so that repairs cannot be made, it is still possible to operate the engine but only in the case of extreme emergency. Proceed as follows: Remove the cylinder head. Remove the piston, connecting rod, and crankpin bearing. Replace the cylinder head so that the water manifolds will all be connected. DO NOT REPLACE THE VALVE PUSHRODS. Drive a wooden plug into the oil hole in the crankpin so that no oil can escape. Wrap the crankpin with canvas and very small rope so that the wooden plug can not blow out.

The engine can now be operated as a five cylinder engine but ONLY AT HALF SPEED OR LESS. DO NOT RELY ON THE ENGINE TO MANEUVER. IT MAY NOT START EITHER AHEAD OR ASTERN. To start the engine ahead, spot the flywheel 25 degrees after top center on the first cylinder to fire after the dead cylinder.

Example: Firing order ahead 1-5-3-6-2-4.
No. 3 cylinder dead.
Spot the flywheel at 25 degrees after No. 6 cylinder firing center.

To start the engine astern spot the flywheel 25 degrees after top firing center of the first cylinder to fire after the dead cylinder.

Example: Firing order astern 1-4-2-6-3-5.
No. 3 cylinder dead.
Spot the flywheel at 25 degrees after No. 5 cylinder firing center.

This procedure should only be used if it is impossible to get your vessel to port any other way. The isolating valve to the dead cylinder must be closed. The engine must be run at half speed or less, as the unbalanced condition brought about by the removal of the piston will cause damage if full revolutions are attempted.

SECTION 14
CRANKSHAFT AND MAIN BEARINGS

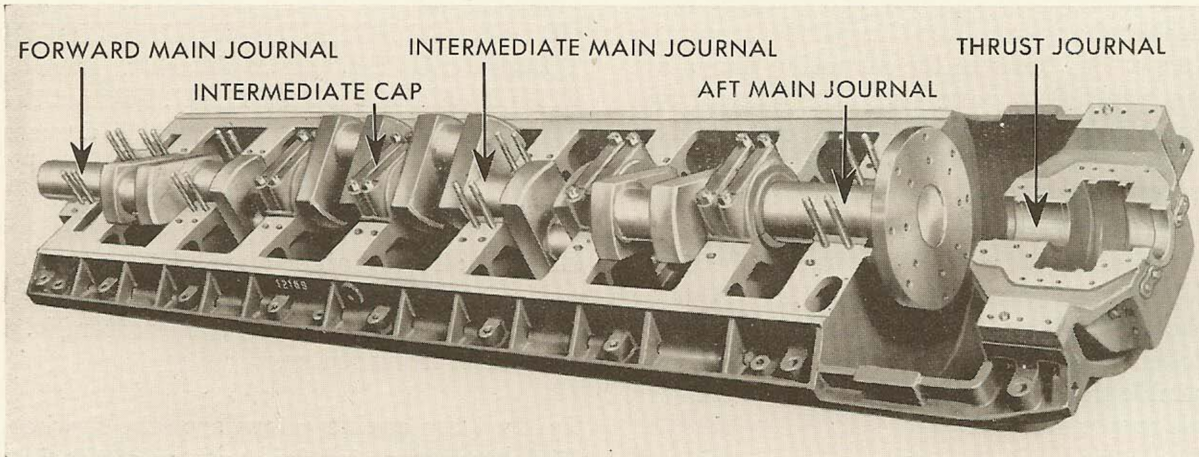


FIGURE 14-1

1. POSSIBILITY OF REPAIR: Most crankshaft work should be undertaken at a repair depot by experienced mechanics who have the knowledge and equipment to carry on a job of this type. However, certain minor repairs and inspections can be made at sea with the equipment usually found on board ship.

2. INSPECTION OF MAIN BEARINGS: Bearings should be examined regularly as outlined in Section 9. However, the operation of the engine prior to these inspections should govern special points to be watched during inspection. If there has been trouble maintaining sufficient oil pressure and the oil pumps, oil filters, oil pressure regulating valve, sump screen and the condition of the oil were known to be correct, it is possible that some of the bearings are too loose and allowing excess oil to escape. This can be checked by connecting up a hand or small power pump to the high pressure oil line after it leaves the high pressure oil pump. Remove all the crankpit covers and force oil through the system with the auxiliary pump. The operator can quickly spot any bearing that is passing more oil than the others. Leaks in the distributor manifold or other piping of the oil system can be found in this way also.

All main bearings can be examined by removing the main bearing caps and rolling out the bottom shells. This can be done without dismantling the engine. Figure 14-1 is a base and crankshaft stripped to show the various main bearings. Some of the bearing caps have been removed to illustrate the bearing studs.

3. REMOVAL OF INTERMEDIATE MAIN BEARING CAPS: After taking off all crankpit doors remove the nuts from the main bearing studs. Lift off caps and top half shells, taking care to observe markings so each part can be replaced where it belongs. Shims from each side of each bearing should be bundled and marked.

4. INSPECTION OF SHELLS: These top half shells should be examined carefully as they are removed and before cleaning. Their appearance is usually a good indication of the general condition of the lower shell. A dark, oil stained top half shell is a sure sign that the bearing is too loose and needs adjustment. A top half shell with small flakes of babbitt on its bearing surfaces or in the oil reservoirs will demand an inspection of its lower shell, as it is no doubt wiping or bearing too hard. The top half shells will always be darker and have less bright bearing areas than the bottom shells.

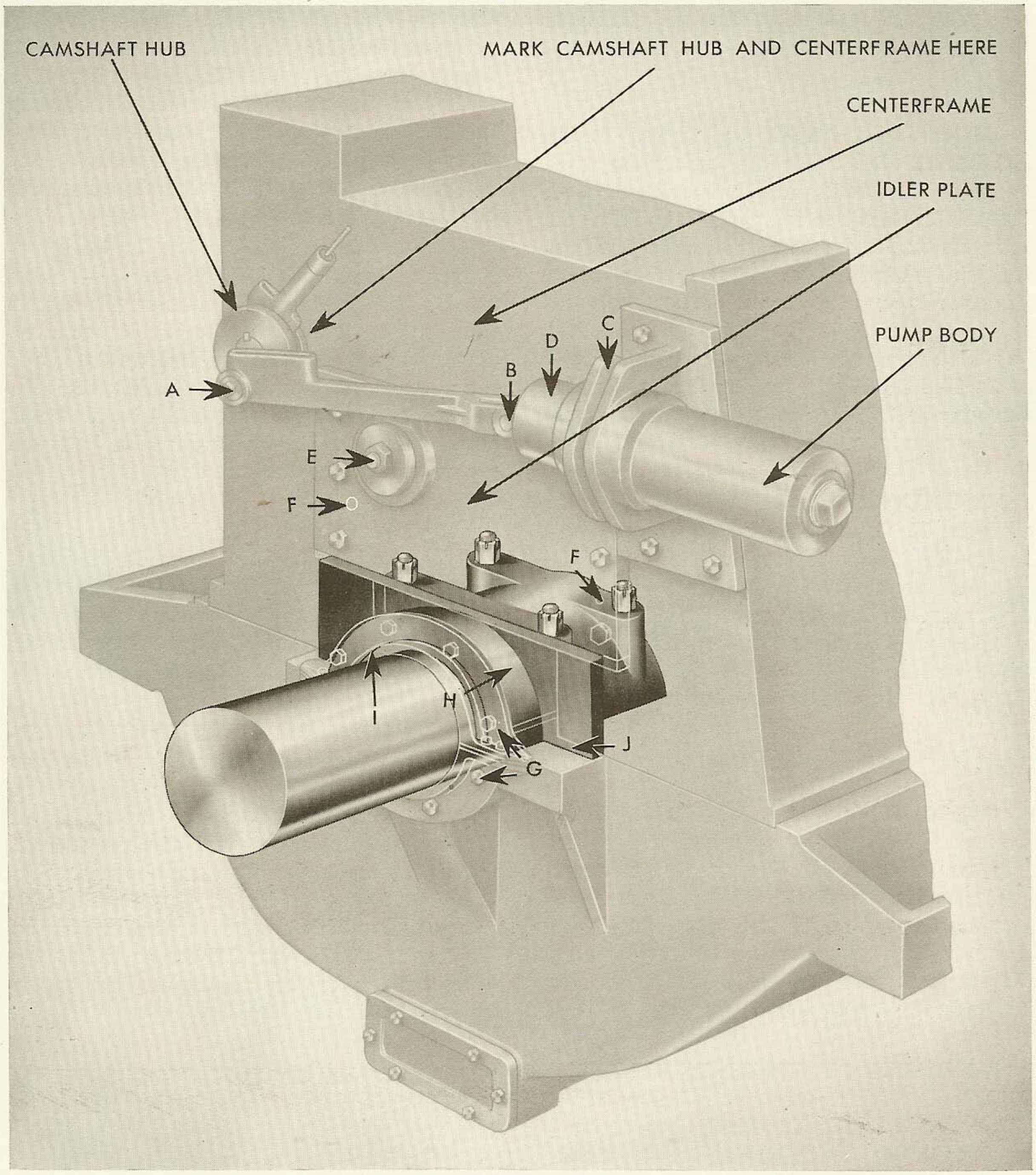


FIGURE 14-2

All shells whether upper or lower should be handled very carefully as the babbitt lining bruises easily and the steel backs of the shells will not fit properly in their saddles or caps if they have been dropped or bumped.

5. TESTING SHELLS: If the shell is held up and struck sharply with a hammer it should have a pronounced "ring" to it. This indicates that the babbitt lining is tight and correctly bonded. If the shell sounds "dead," the bonding has probably failed and further inspection will show that the babbitt is loose over a large area. This can usually be proven by pressing the babbitt firmly and watching to see if oil squeezes out around the edges of the shell between the babbitt and the steel back. Shells with loose babbitt should not be used except in an emergency.

6. REMOVAL OF THE FORWARD MAIN BEARING CAP: The idler gear, idler plate, and part of the bilge pump have to be removed before the main bearing cap can be lifted off. It is also necessary to mark the camshaft so that the engine can be correctly timed when the idler gear is replaced. THIS MUST BE DONE BEFORE THE IDLER GEAR IS REMOVED, otherwise the operator will have to go through the lengthy procedure outlined in paragraph 13 of Section 19 to re-time the camshaft properly.

7. MARKING THE CAMSHAFT: Turn the engine to No. 1 top center on the firing stroke. This will be No. 1 top center with both inlet and exhaust valves closed. Refer to Figure 14-2 and with a center punch mark the hub on the end of the camshaft and the centerframe so that the marks are directly in line. These two marks must be accurate as they have to be mated perfectly when the idler gear is assembled on the engine later.

8. REMOVAL OF THE BILGE PUMP: Remove the cap screw and washer (A) and drive out the pin (B) Figure 14-2. The connecting rod can now be lifted off. Remove the packing gland (C) and the pump plunger (D). The packing may be removed from the pump body as new packing should be used during assembly.

9. REMOVAL OF IDLER PLATE AND GEAR: The idler plate has a hollow shaft fastened to the back of it which forms a bearing for the idler gear. The bolt (E) extends through this shaft and has a large washer on the inner end which holds the idler gear in place. Remove the nut and this bolt can be pushed into the crankpit after the engine has been rolled away from top center.

As the idler plate controls the mesh of the idler gear and the crankshaft and camshaft gears, the plate is positioned accurately by the two dowels (F) Figure 14-2. Reference to this figure will also show that there is a space between the idler plate and the flange of the bearing cap. This space is taken up with a cork gasket. So that a new cork gasket of the proper thickness can be selected for assembly, measure this gap before the plate is removed and mark the measurement down for future reference.

Remove the oil seal (G) Figure 14-2 from around the crankshaft. Examine the felt in this seal to determine whether it needs replacing or not. Withdraw the dowels (F) and remove all the cap screws which attach the idler plate to the centerframe. The plate can now be removed. The idler gear can be taken out through the crankpit door.

Remove the four bearing stud nuts and the cap (H) and the shell (I) can be lifted off. Where the flange of the bearing cap faces against the centerframe a coating of sealing compound is used and these two faces should be scraped clean in preparation for assembly.

10. REMOVAL OF AFTER MAIN BEARING CAP: The circulating pump is driven from a crankpin which extends through the centerframe at the after end of the engine. This crankpin is on one end of a short shaft that is supported by the plate shown in Figure 14-3. The other end of this shaft carries a large gear which engages a smaller gear on the crankshaft. Many of these parts have to be removed before the after main bearing cap can be taken off.

11. REMOVAL OF THE CIRCULATING PUMP: Disconnect all pipe lines to the pump. Sling the pump from a block and tackle or chain block so that the weight is just taken. Remove the two cap screws (A) and the cap screw and washer (B) Figure 14-3 from the pump connecting rod. Care should be taken not to lose the shims which adjust this bearing. Remove the four cap screws which attach the crosshead guide to the centerframe. The entire pump unit can now be set aside. Remove the bolt (C) from the crankpin. Carefully drive a wedge in the gap (D) Figure 14-3 and the crank can be pulled off.

12. REMOVAL OF THE PLATE, SHAFT AND GEAR: Open up the door of the eccentric pit on the manifold side of the engine. Disconnect the foot of the air compressor connecting rod from the eccentric strap. Do not lose any of the shims that may be under the foot of the rod, as these govern the height of the piston in the air compressor cylinder. Tie the rod over to one side of the pit. Remove the bolts (A) Figure 14-4 and the gear can be taken out.

The brass plate (B) Figure 14-4 is the retainer ring for the ball bearing (C) and is removed next. This ring is held on by large countersunk machine screws. After this retainer ring has been taken off, the shaft and gear hub can be pushed into the eccentric pit and removed through the door. Do not lose the spacer collar which fits around the shaft and lies between the cone of the after ball bearing and the crank.

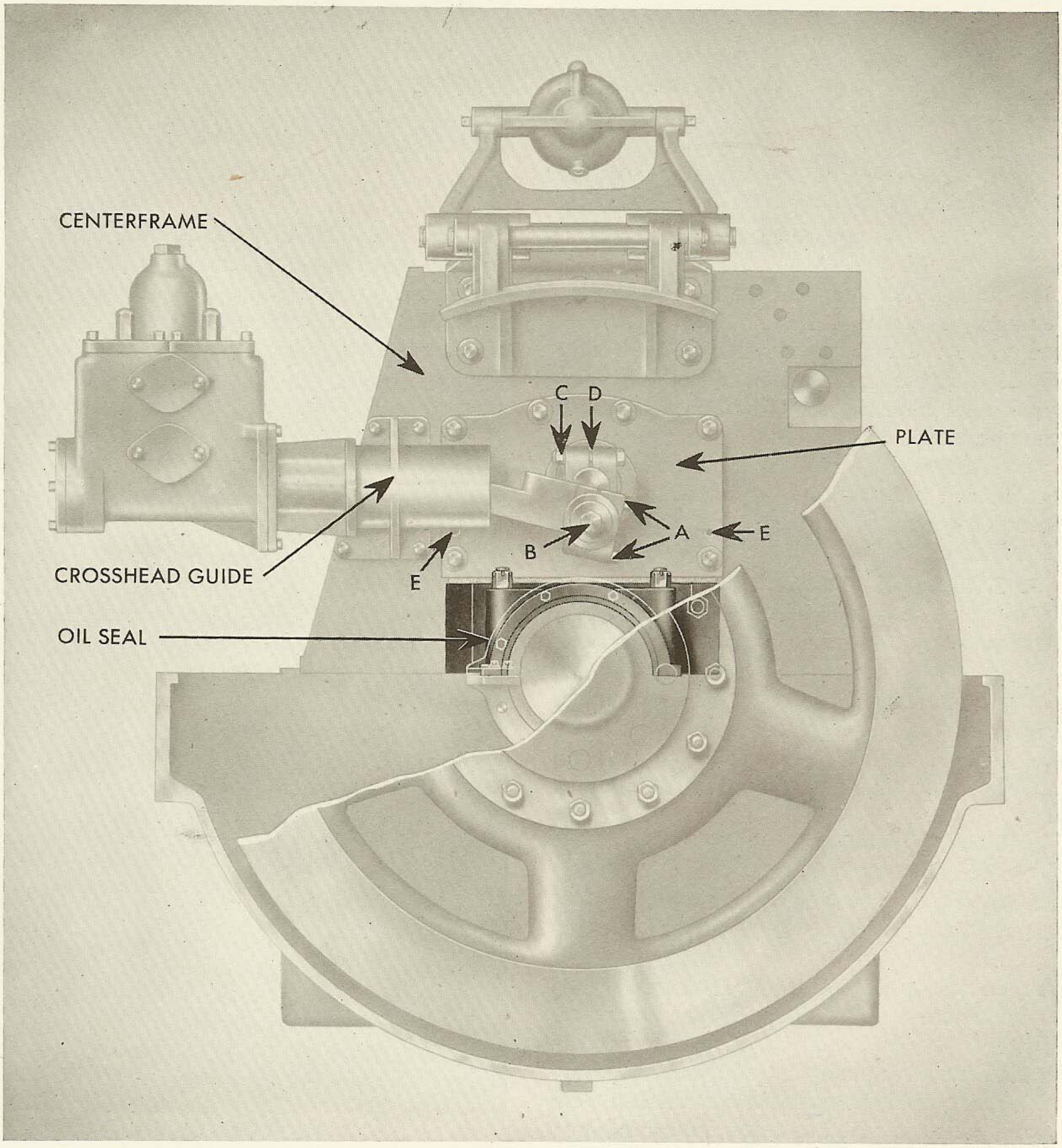


FIGURE 14-3

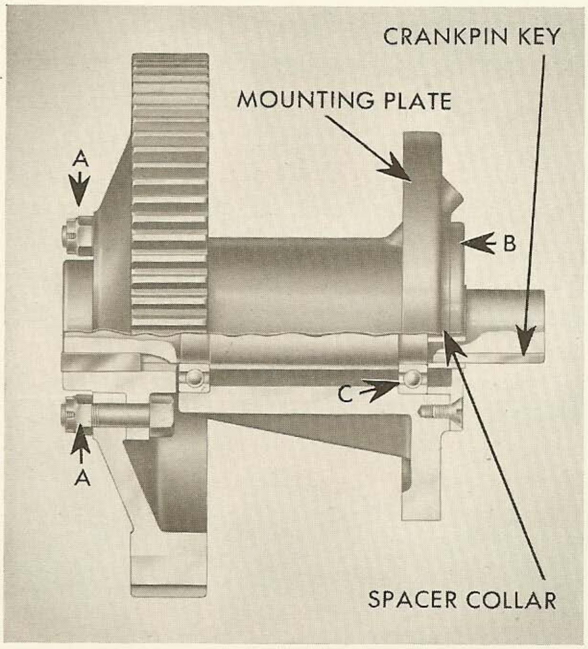


FIGURE 14-4

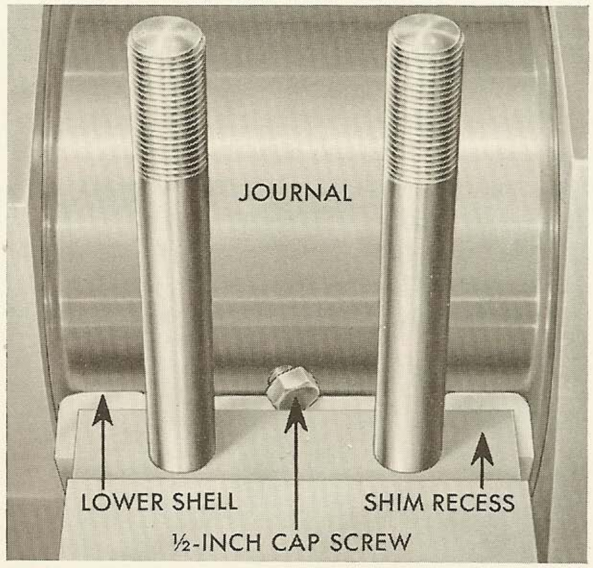


FIGURE 14-5

The plate which supports the shaft and gear assembly is positioned by two dowels and is sealed to the aft bearing flange by a cork gasket in the same manner as the camshaft idler gear plate on the forward end of the engine. This gap should be measured and recorded before the plate is removed. Remove the oil seal and examine the felt. Remove the four bearing cap stud nuts and the cap and top half shell can be lifted off.

13. REMOVAL OF BOTTOM SHELLS: Never remove two adjoining bottom shells. Always leave one in between to support the weight of the crankshaft. Drop a ½ inch cap screw into an oil hole in the journal, as shown in Figure 14-5. Slowly turn the flywheel and the head of the cap screw will roll the shell to the top of the journal where it can be lifted out.

Examine the babbitt lining of the shells as described in paragraph 4 of Section 13. If the babbitt is found to be badly cracked or burned the shell will have to be replaced but remember that it is better to try and reach port even at reduced speed rather than attempt bearing replacement or crankshaft alignment at sea. However, if the condition of the bearing or crank journal is such that additional damage will occur if the engine is operated, a new bearing can be fitted and aligned as follows:

14. FITTING NEW SHELL: Examine the journal carefully for damage. Remove all roughness or scores that project above the bearing surface, with a whetstone and fine emery paper or cloth. Plug the hole in the

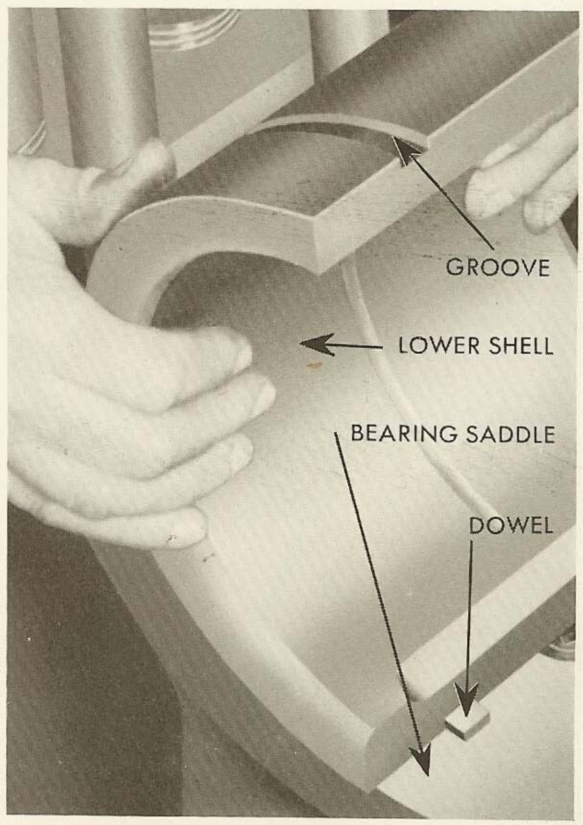


FIGURE 14-6

journal whenever abrasives are being used on the shaft. Roll the new shell in by entering it between the shaft and the bearing saddle and pushing it in as far as it will go. Drop a cap screw into the oil hole in the journal and slowly turn the flywheel to roll the shell into place. There is a groove around the back of the shell and this groove has to be lined up with a dowel in the bottom of the saddle as shown in Figure 14-6.

Cut and bore four pieces of ½ inch iron in the shape shown in Figure 14-7, so that they will lie partly on the shim recess and partly on the shell. With a piece of pipe for a spacer as shown, draw down on the shell, with the bearing cap nuts, from each side. Make sure that the shell is lying tightly in the saddle along the edges. Smear the top of the journal lightly with Prussian Blue and turn the crankshaft two or three turns. Roll out the shell and examine the markings on the babbitt.

Proceed to fit the bearing as described in paragraph 5 of Section 13.

WARNING: THE STEEL BACKS OF THE SHELL AND THE BEARING SADDLES MUST BE ABSOLUTELY CLEAN WHEN THE SHELL IS ROLLED IN EACH TIME. Any dirt in this area will either tip or lift the shell and produce a false reading when the blueing marks on the babbitt are examined. Each succeeding fit should show additional areas of babbitt marked with blue. When a showing of about 75% of the bearing area is obtained the bearing can be considered as fitted and the alignment of the crankshaft should now be checked.

15. BRIDGE GAUGES: Most new engines are supplied with bridge gauges. This is the device shown in Figure 14-8 and it is simply an arched piece of metal which sets into the shim recess on each side of a main bearing.

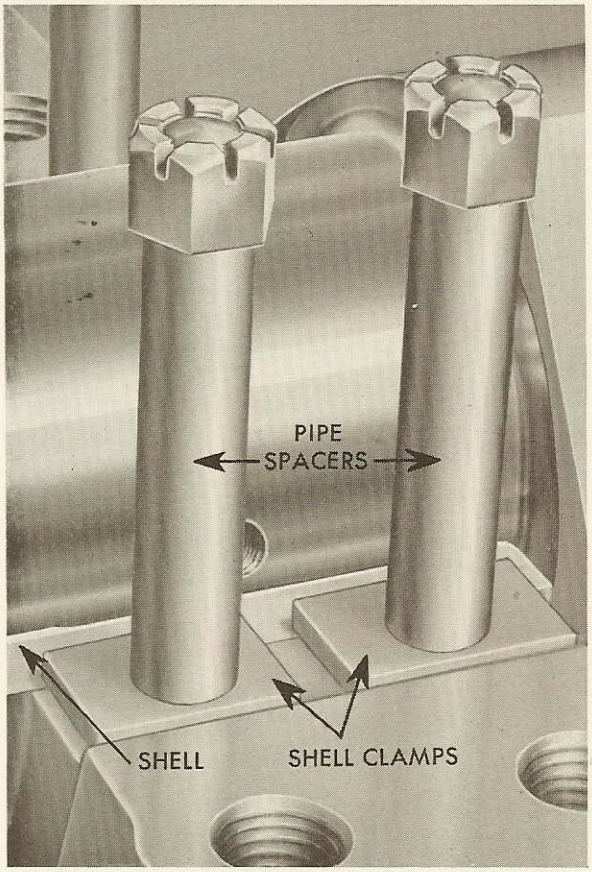


FIGURE 14-7

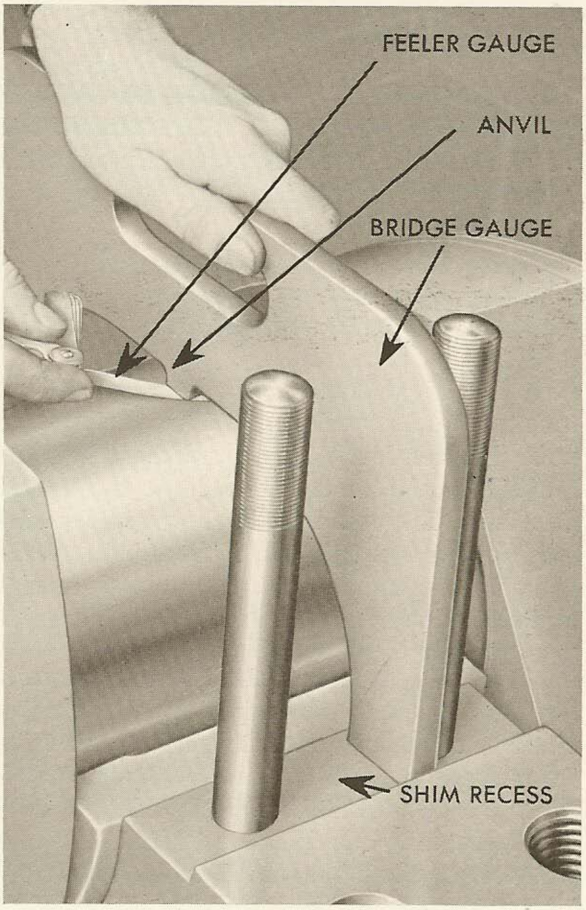


FIGURE 14-8

There is a small anvil which extends down almost to the top of the journal. During construction, after the crankshaft has been bedded in, the measurements of the gap between the anvil and the journal are taken with a feeler gauge. The record of each journal is stamped on the bridge gauge.

At any future date the bridge gauge can be applied to any journal and the difference between the recorded reading and the new one is the amount the shaft has dropped due to the wear of the bearing. This normal wear down should be about the same on all journals in older engines. If adjacent bearings are found to be 0.004 inch or more high or low, from the recorded measurement after due consideration has been given to normal wear down, alignment of the crankshaft should be undertaken. This should only be done at a repair depot where skilled mechanics are available. However, the bridge gauge can be used to check the alignment of a main bearing which has been installed in an emergency.

16. USE OF BRIDGE GAUGE TO CHECK THE ALIGNMENT OF REPLACEMENT SHELL: As an example, we will assume that No. 4 main bearing has been replaced and fitted. With No. 4 bottom shell out, install a jack as shown in Figure 14-9, on No. 3 journal.

The bridge gauge is stamped to show that the original clearance for No. 3 journal was 0.087 inch. The wear down of the bearing is 0.003 inch, so No. 3 now shows 0.090 inch clearance with the jack forcing the crankshaft into the bottom of the shell. Mark down the actual clearance. The wood block shown in the picture is to prevent the shaft from being damaged. Repeat this operation on No. 5 journal and mark down the clearance.

Roll in No. 4 bottom half shell. Install the wood block and jack on No. 4 journal, forcing the shaft into the bottom of the shell. Again take bridge gauge readings on No. 3 and No. 5 journals. IF THESE READINGS HAVE DECREASED IT SHOWS THAT NO. 4 BEARING IS TOO HIGH AND IS LIFTING THE SHAFT FROM THE ADJACENT BEARINGS. For example, No. 3 journal did read 0.090 inch. It now reads 0.086 inch, which means that No. 4 bearing has lifted No. 3 journal out of its bearing by 0.004 inch. This means that No. 4 bearing has to be carefully scraped in order to lower it 0.004 inch. GREAT CARE MUST BE TAKEN WHEN THIS FINAL FITTING IS BEING DONE SO TOO MUCH CLEARANCE IS NOT SCRAPED OUT. This would result in the bearing being too low and would show up as follows:

After No. 4 shell has been fitted and rolled in, apply the jack to No. 4 journal so as to force it into the bottom of the shell. The bridge gauge reading is 0.003 inch or 0.004 inch greater than the stamped figure for this journal plus the average wear down. This indicates that the bearing is now too low for safety and should not be used.

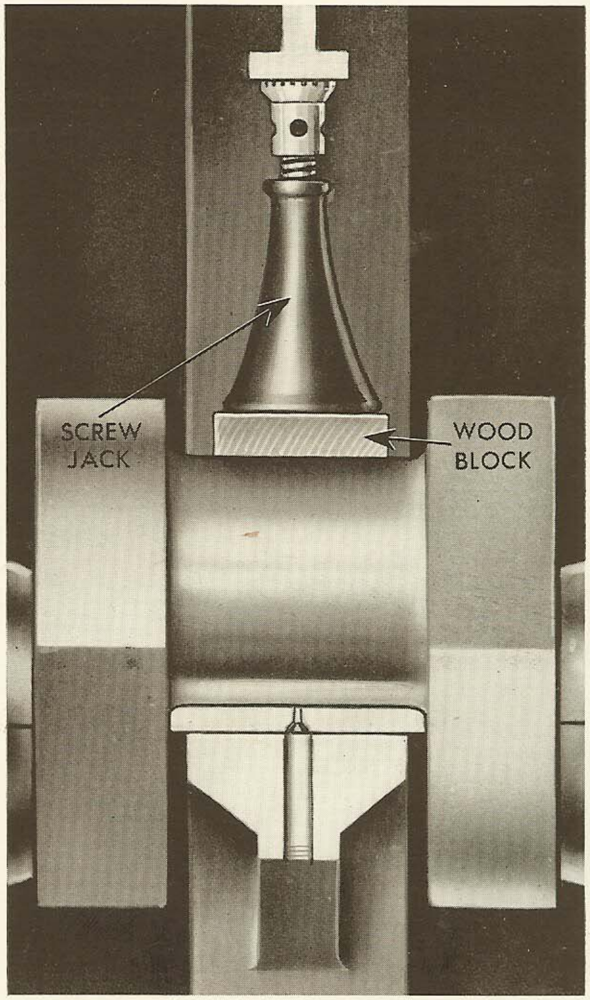


FIGURE 14-9

17. SHIMMING OF BEARING CAPS: After any bearings requiring fitting have been finished, wash all parts thoroughly.

Clean out drilled oil passages in the crankshaft. Check and shim all main bearings to proper clearance by using lead wire as described in Section 13, paragraphs 6, 7, and 8.

The clearance allowed should be 0.001 inch per inch of crankshaft diameter. It will be found that the lower half shells usually project from 0.002 to 0.003 inch above the base when installed. When the main bearing cap nuts are drawn down the shims will force the shells tightly into the saddles.

18. ASSEMBLY OF FORWARD BEARING CAP: The after side of the flange of the forward main bearing cap faces against the centerframe. This joint must be oil tight. Apply Permatex or gasket seal compound to these faces and just before tightening the cap nuts force the cap aft as far as possible. Tightening the cap nuts will now hold these two faces together.

When this cap has been shimmed it will be found that the lower edges of the flange are held away from the base at point (J) Figure 14-2. This gap will vary according to the thickness of shims used in the bearing. Select cork gaskets of the correct thickness and cut them so they will lie along the lower edge of the flange and out to the after side of the oil seal. These gaskets are on both sides of the bearing. Smear them with Permatex just before drawing the cap down.

Examine the felt in the oil seal. If this is hard it can be softened by "working" between the fingers. Apply Permatex to the after face of the seal and attach it to the end of the bearing.

19. INSTALLATION OF IDLER GEAR: Put the idler gear and idler gear plate in position but do not fasten with cap screws or dowels. Turn the flywheel to No. 1 top center. Lift the idler gear out of mesh so that the camshaft can be turned by hand. Turn the camshaft so that the scribe mark on the hub of the camshaft and the one on the centerframe mate exactly in the same position they were when the marks were made. Drop the idler gear into mesh with both crank and camshaft gears. Check again to make sure the scribe marks on the camshaft and centerframe are in the right position and the flywheel is on No. 1 top center.

Refer to the measurement taken at disassembly of the distance between the idler plate and the bearing cap flange. Select a gasket cork of a thickness which will allow for some compression. Cut the cork to the proper size and apply Permatex or gasket seal compound. Place the cork between the idler plate and the bearing cap flange and force down the idler plate until the dowels can be driven in. Screw in and tighten the cap screws which hold the idler plate to the centerframe.

Turn the flywheel away from top center. Install the idler-gear keeper bolt and make sure the dowel in the washer facing the idler gear, enters the dowel hole in the end of the shaft. Tighten the keeper bolt nut and fit the cotter pin. Test the idler gear for a slight fore and aft movement which is proper. Install the various pump parts in the order they were removed.

20. INSTALLATION OF THE AFTER BEARING CAP: The after main bearing cap is prepared for assembly in the same way as the forward cap. Gaskets under the edge of the flange and Permatex on the face that fits against the centerframe. When the bearing cap is secured, attach the oil seal to the end using Permatex on the face.

21. INSTALLATION OF THE PUMP PLATE AND GEAR: Thoroughly wash the shaft bearings. Hold the plate up against the centerframe and push through the shaft and gear hub from the eccentric pit. Put on the after bearing and spacer collar. Attach the brass retainer ring and tighten the countersunk machine screws well. Wedge open the crank slightly and drive it on at the same time forcing the gear hub and shaft aft as far as possible.

The shoulders on the shaft, the ball bearing recesses in the plate and the length of the spacer collar are so arranged that when the spacer is driven home against the ball bearing cone, by the crank, the bearings are positioned correctly. Tighten the crank bolt and attach the gear to the hub.

Select a cork gasket material of a thickness that will allow for some compression. Cut a gasket to fit the top of the bearing flange. Smear this gasket with Permatex and lay it on the top of the flange. Make sure the pump gear is in mesh with the crankshaft gear and press the plate down until the dowels can be driven in. Screw in and tighten the plate cap screws.

22. INSTALLATION OF THE CIRCULATING PUMP: Sling the pump into place and attach it to the centerframe by the cap screws which go through the crosshead guide. Make up the pump connecting rod bearing on the crankpin. This bearing should be shimmed so that it will have about 0.002 inch clearance. This can be checked with a feeler gauge. After the washer and cap screw (B) Figure 14-3 have been installed there should be a slight fore and aft movement to the connecting rod. This will indicate that nothing has been sprung or is under tension.

Connect the air compressor connecting rod to the eccentric strap, being sure to replace any shims that were under the foot of the rod. Connect up all the piping to the circulating pump.

WARNING: Before closing up the crank or eccentric pits, go over every part that has been removed to make sure that all nuts and cap screws are tight and that all locking wires and cotter pins are in place.

To locate the fore and aft position of the crankshaft read paragraphs 4 and 5 of Section 15.

SECTION 15

KINGSBURY THRUST BEARING

1. FUNCTION: This bearing absorbs the thrust of the propeller which is transmitted through the propeller and intermediate shafts to the engine. Its principal parts are:

- A frame or housing
- A thrust shaft and collar
- Two ahead-thrust shoes
- Two astern-thrust shoes
- Adjusting studs
- A main or journal bearing
- Oil seals

2. DESCRIPTION OF PRINCIPLE: The bottom part of the thrust collar is submerged in oil which lies in the sump. As this collar revolves in either direction, it picks up a heavy coating of oil. On either side of the thrust collar are a pair of thrust shoes, so attached to the housing that the faces of these shoes can find their own position in relation to the face of the thrust collar.

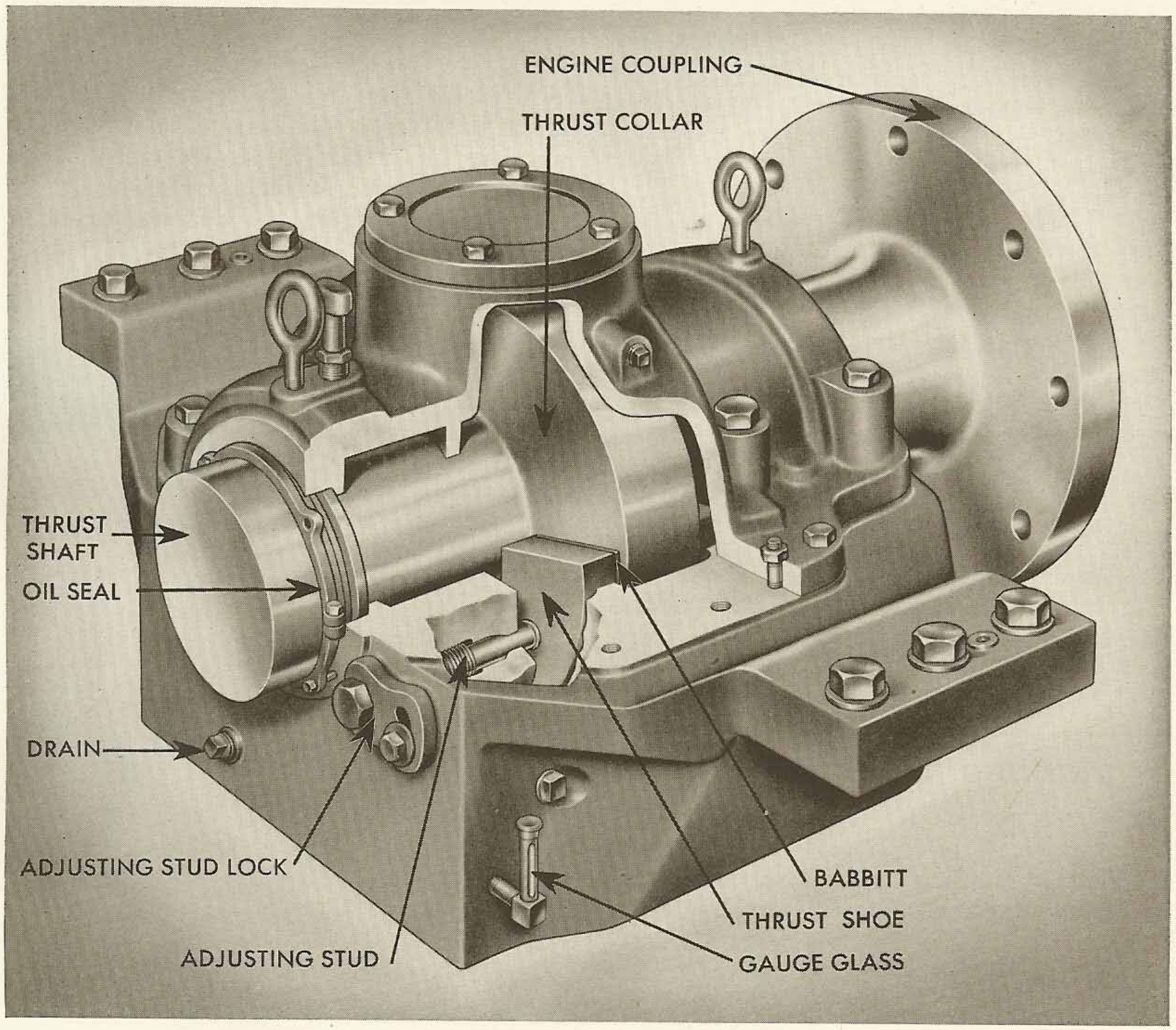


FIGURE 15-1

As the film of oil on the thrust collar comes in contact with the leading edge of each thrust shoe, it forces the edge of the shoe away from the thrust collar. As this oil film moves across the face of the thrust shoe, it is gradually squeezed thin, causing the thrust shoe to lie at a slight angle to the face of the thrust collar. This means that the oil film is actually a wedge of oil which prevents the thrust or pushing effort of the propeller forcing the crankshaft against the ends of the main bearings, thus causing damage.

When the engine is reversed and the thrust force is exerted in the opposite direction, the other pair of shoes takes up the load.

3. CARE OF THE BEARING: If, through neglect, the oil level in the sump is allowed to drop to a point where the collar will not pick up enough oil to form an oil wedge, the two metal surfaces will come together and the babbitt on the faces of the thrust shoes will be burned off almost immediately.

This bearing will need little attention except a supply of clean oil and occasional adjustment. The oil level should be checked every day. Figure 15-1 shows the location of the gauge glass. The oil should be drained off every 1000 hours. The sump should be thoroughly washed out and new clean oil put in to the proper level. Always use an oil that meets the specifications stamped on the plate of the bearing.

The main journal is located ahead of the thrust ring and is oiled by the scraper and oil passage as shown in detail in Figure 15-2.

4. ROUTINE ADJUSTMENT IS MADE AS FOLLOWS: Remove the cover of the bearing.

NOTE: As the crankshaft is connected directly to this thrust bearing, it will be seen that any adjustment of the thrust in a fore or aft direction will have a direct action on the location of the crankshaft and the position of the cranks in the pits.

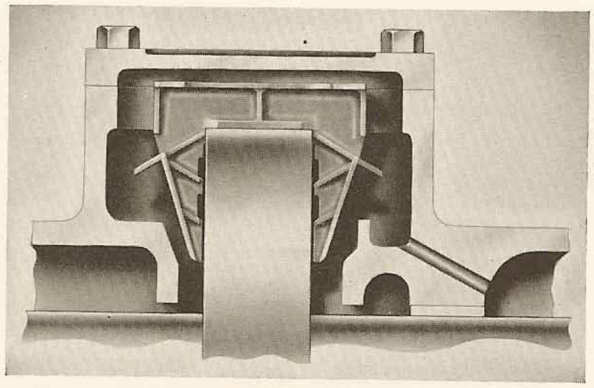


FIGURE 15-2

Slack off all four thrust adjusting studs, see Figure 15-1. The rake or slope, that most engines are installed on, will cause the crankshaft to slide aft until some one of the crank webs stops against the end of a main journal bearing.

With either a jack or a pry bar move the crankshaft forward to the limit of its travel. To measure the length of this movement lay a straight edge across the face of the thrust collar and scribe a line across the edge of the thrust housing as shown in Figure 15-3.

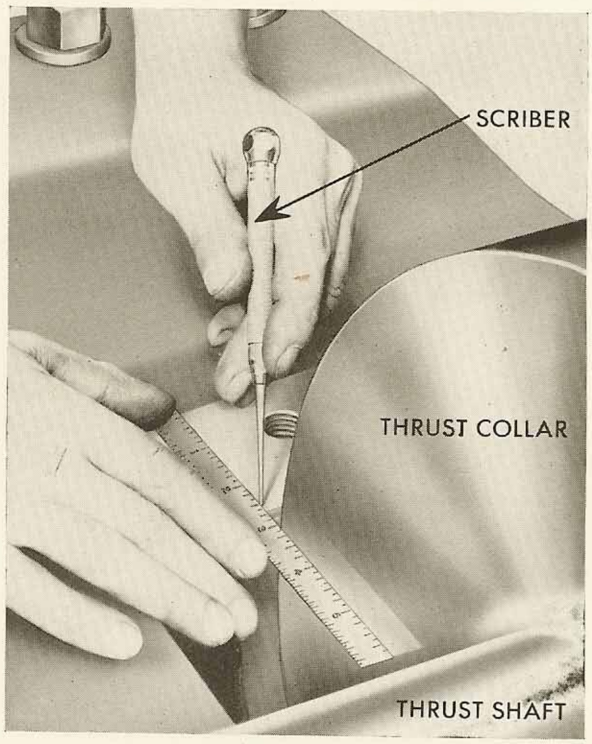


FIGURE 15-3

If two lines are scribed, one at each end of the crankshaft travel, the distance between the lines is the amount of fore and aft travel of the crankshaft. Screw the after two adjusting studs in so that the two after thrust shoes move the crankshaft ahead one-fourth of the total end travel.

BE SURE BOTH AFTER THRUST SHOES ARE BEARING TIGHTLY AGAINST THE THRUST COLLAR.

Use the following table and select a piece of sheet or shim metal of the proper thickness and large enough to about cover the face of one thrust shoe.

End Clearance Allowance for Atlas Engines

Engine Bore	Thrust Bearing End Clearance
14½" and 15"	0.017
13	0.015
11½	0.014
10	0.012

Insert the proper thickness shims between the forward side of the thrust collar and the forward thrust shoe. Tighten up the adjusting stud until the shim can just be removed by hand. Repeat this operation on the other forward thrust shoe. When the shim is removed there will now be the proper clearance in the thrust bearing.

ATTACH ALL FOUR STUD LOCKS (SEE FIGURE 15-1) TO THE FOUR ADJUSTING STUDS.

5. CHECKING FORE AND AFT LOCATION OF CRANKSHAFT: Remove all pit doors. Check end clearance of each piston rod and piston pin as described in Section 13, paragraph 9. If any of these clearances are not proper, the thrust bearing will have to be adjusted again so that the crankshaft is moved far enough ahead to give sufficient clearance between any connecting rod and its piston-pin boss.

This readjustment should never position the crankshaft further ahead than half its total fore and aft movement.

FIGURE 15-4

6. OIL SEALS: After all adjustments are completed, examine the packing in the oil seals. If this has become worn or hard, it should be renewed. The packing is laid in as shown in Figure 15-4.

DO NOT TIGHTEN OIL SEALS MORE THAN IS NECESSARY TO STOP OIL LEAKS.

7. STANDARD THRUST BEARINGS: A few Atlas engines are equipped with the type of thrust bearing shown in Figure 15-5. The thrust shaft has several lands or collars which are bedded in babbitt. These collars absorb the thrust effect of the shaft by bearing against the babbitt faces of the grooves. There is no adjustment to this type of bearing and when the babbitt grooves are worn so that the thrust shaft can be moved fore and aft, 1/16 inch, the entire bearing should be rebabbitted. This is work which should be undertaken only at a service depot.

The bearing housing is water cooled and water is drawn off the cooling system just after it leaves the circulating pump. It is piped to the bearing housing where it passes through the water jackets and is usually led overboard in a separate discharge pipe. This is done so that the amount of circulation can be checked at all times. CAUTION: BE SURE TO DRAIN THIS BEARING when laying up the engine during cold weather.

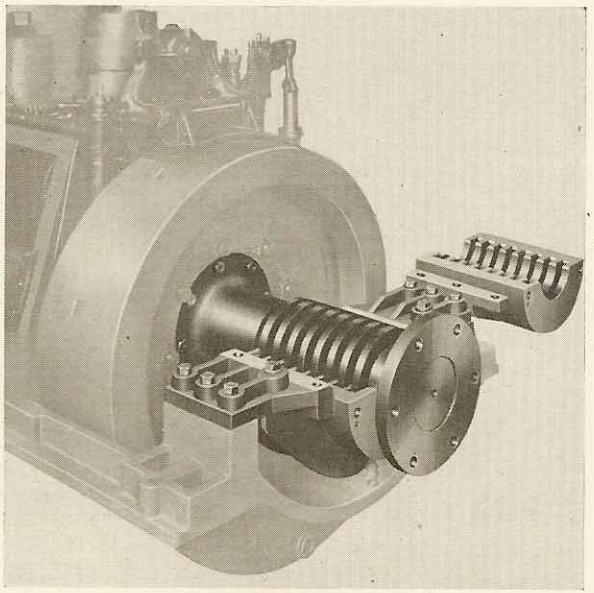


FIGURE 15-5

The bearing is lubricated by oil led through a tube from the mechanical lubricator. The pump should be set to deliver 30 to 40 drops of oil per minute.

8. REBABBITTING THRUST BEARING: In the erection of the engine at the factory, the thrust bearing is treated as if it were an additional main bearing. After all the lower main bearing shells have been scraped into alignment the thrust shaft is bolted to the crankshaft and tested for trueness. It is required that the total run out of the thrust shaft at the aft end does not exceed 0.002 inch. In the meantime the thrust bearing (lower half) is installed temporarily on the base. The thrust shaft is then coated with blueing and the whole shaft assembly lowered into position. The bearing is then shimmed up or down, moved forward or backward, to one side or the other and scraped until the bearing is satisfactorily located.

The finished bearing must be in line with the main bearings. The thrust collars on the shaft must be a close fit in the grooves but at the same time have clearance. An end play of approximately 0.005 inch to 0.010 inch is desirable. The location of the bearing should be such that the crankshaft is slightly aft of its central position in the base since the normal wear on the thrust bearing will allow the crankshaft to move forward.

When the foregoing conditions have been met, the thrust bearing (lower half) is doweled to the base. The thrust bearing cap is then scraped in and adjusted for clearance with shims.

There are several ways of doing this work in the field and the one most suited to the equipment available should be selected.

SECTION 16

HIGH PRESSURE FUEL PUMP & REGULATOR

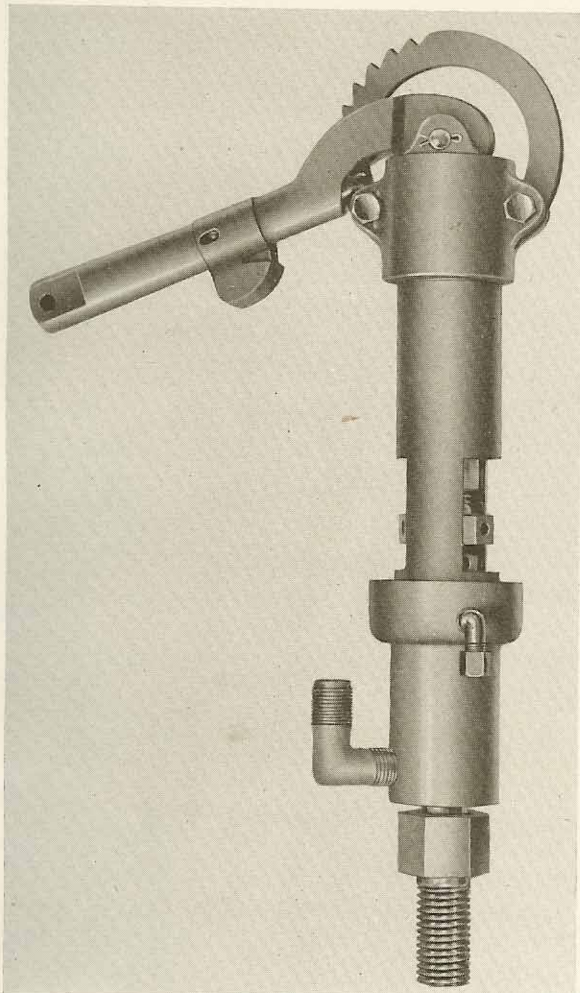


FIGURE 16-1

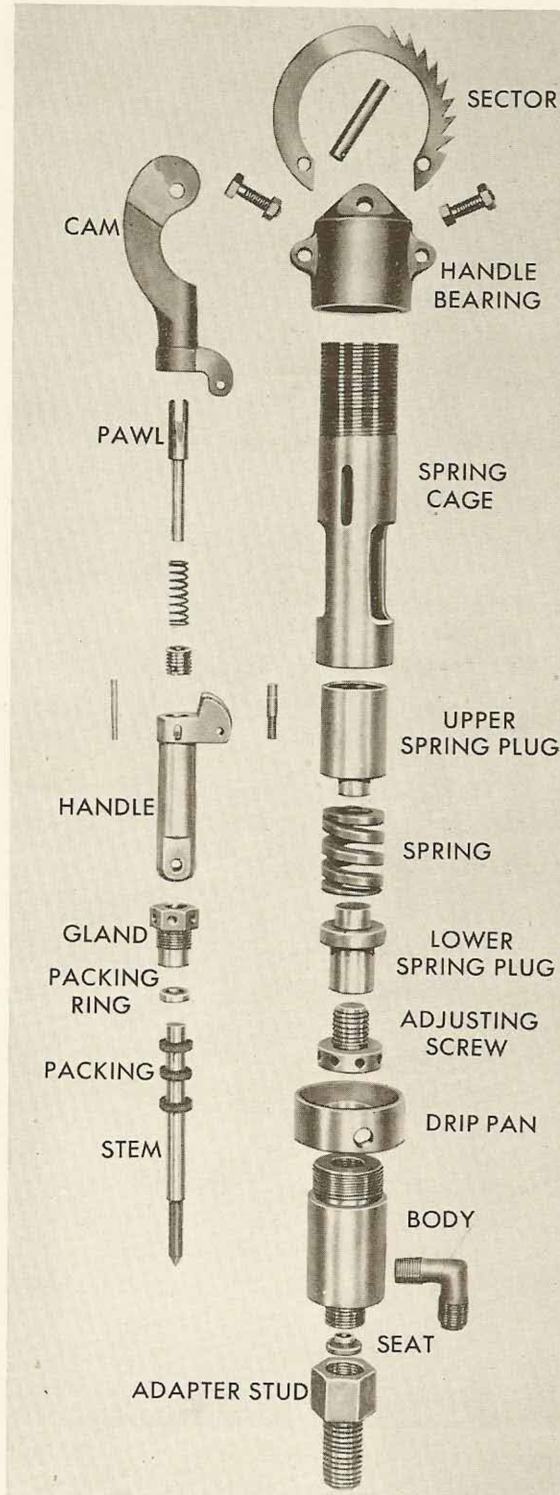


FIGURE 16-2

1. FUEL REGULATING VALVE IN GENERAL: This valve, shown in Figure 16-1, requires very little servicing but nevertheless is an important part of the fuel system. It should not be dismantled or tampered with during routine inspections or overhauls. However, when trouble develops, the valve should be taken apart immediately and serviced. A leaky regulating valve will cause faulty starting and maneuvering and also makes the accurate timing of the spray valves impossible. A leak in this valve will often lead an operator to believe that other parts of the fuel system are at fault.

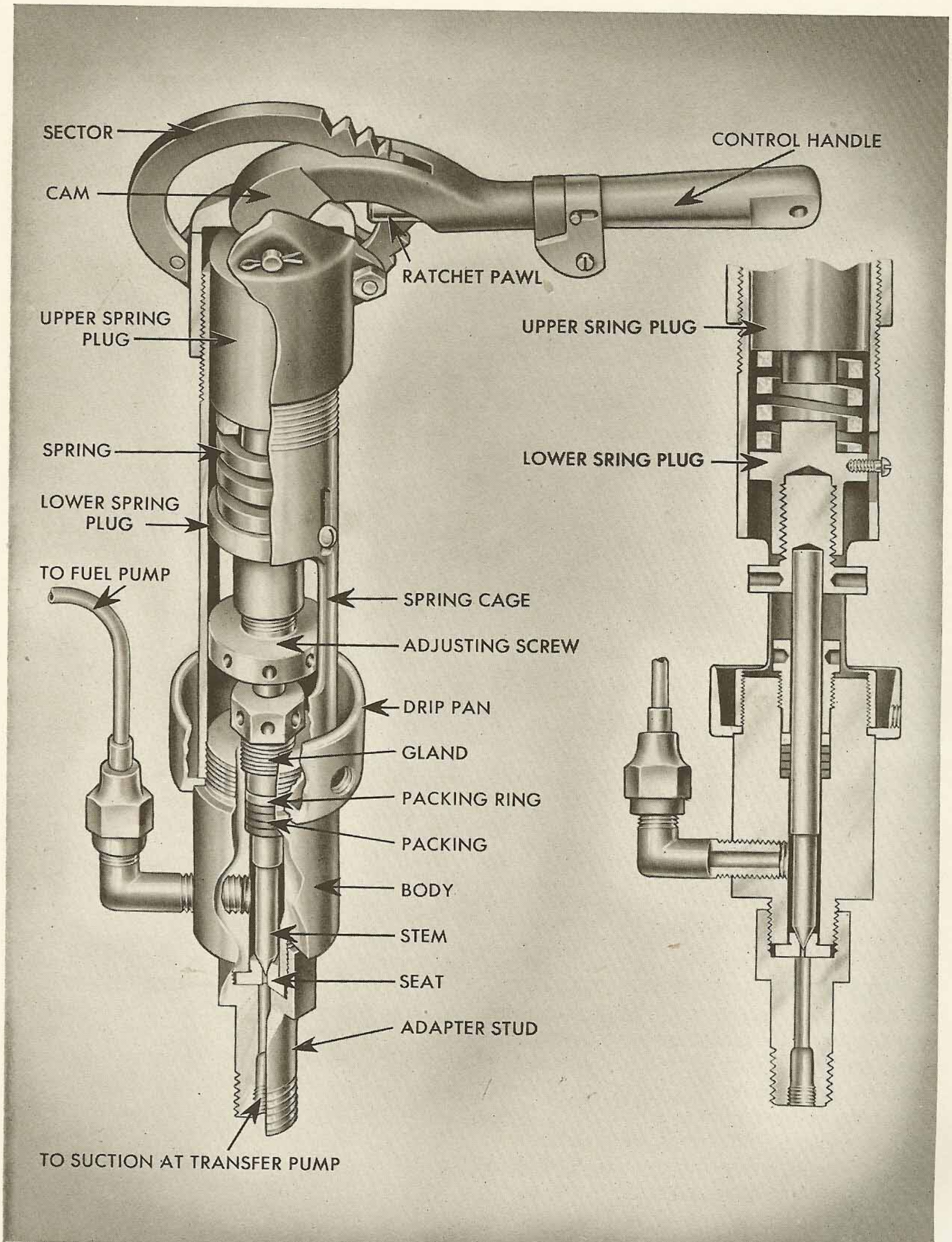

SECTOR
CAM
CONTROL HANDLE
RATCHET PAWL
UPPER SPRING PLUG
SPRING
LOWER SPRING PLUG
TO FUEL PUMP
SPRING CAGE
ADJUSTING SCREW
DRIP PAN
GLAND
PACKING RING
PACKING
BODY
STEM
SEAT
ADAPTER STUD
TO SUCTION AT TRANSFER PUMP
UPPER SRING PLUG
LOWER SRING PLUG

FIGURE 16-3

2. TESTING FOR LEAKY VALVE: If it appears that the valve is not holding pressure, make the following check before dismantling: Shut off all the isolating valves and pump up two or three thousand pounds fuel pressure with the priming pump. Disconnect the discharge line of the regulating valve. If the discharge opening continues to drip after the valve has bled off any excess pressure, the valve requires servicing. If the pressure does not hold and the regulator is not leaking, the discharge valves in the high pressure pump are not holding tightly and need attention. See paragraphs 14 and 15, this section.

3. DISASSEMBLY AND INSPECTION: Remove the parts of the valve in the order shown in Figure 16-2. Remove the packing and clean the assembly thoroughly. Examine the stem in the packing way. If this is worn or rough, the stem should be replaced. Examine the valve face on the end of the stem. A valve which has been leaking for some time will have bright streaks or channels across the face where the escaping fuel has burnished the ground finish of the valve. These channels will most likely show on the removable valve seat as well.

While such marks can be ground out it is usually better to renew both the stem and seat when this channeling condition is found. If either the stem or the seat requires replacing, it is advisable to discard both. These parts are inexpensive and much time will be saved by installing the set.

4. ASSEMBLY: Grip the body of the valve in a vise and insert several rings of packing. On top of the packing place the brass packing ring. Screw in the packing gland until it just touches the packing ring. At least half of the threads on the packing gland should be engaged. These parts can be seen in Figure 16-3.

Remove the gland and the packing ring and force the stem through the packing. Replace the packing ring and the gland and screw the packing gland as tightly as possible with a twelve-inch wrench. Slacken gland a turn or two and grip the top end of the stem in the vise as shown in Figure 16-4. The jaws of the vise should be protected with copper facings.

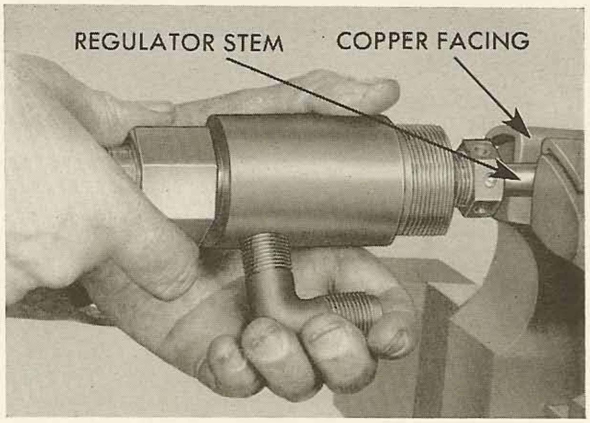


FIGURE 16-4

Revolve the body of the valve around the stem until the stem works freely in the packing. Light oil can be applied to the packing and stem. Replace the body of the valve in the vise again and tighten the gland nut. After slacking off the gland nut, place the stem back in the vise and again work the body around and up and down the stem.

The purpose of this procedure is to "kill" the packing so that there is no expansion left in it. A tight joint must be obtained with very little friction on the stem. If the packing retards the movement of the stem, faulty fuel pressure control will result. The amount of "kill" required by the packing will be best determined through experience but we suggest at least two operations. After these are completed the gland should be left finger tight and will require very little tightening even in operation, as the fuel pressure under the packing will exert sufficient force to squeeze the packing tightly to the stem.

Assemble the entire valve as shown in Figure 16-3 but do not attach the adapter stud and seat. The drip pan is held in place by the spring cage which should be left about one-quarter turn loose. This allows the drip pan to be turned so that the opening can be lined up with the fitting on the engine when the valve is installed.

As outlined in Section 4, the operation of this valve is governed by spring tension. There are three ways of controlling this spring tension: (a) by lifting the handle which causes the cam to force down the upper spring plug. This decreases the distance between the upper and lower spring plugs, thereby compressing the spring; (b) by screwing the handle bearing up or down the spring cage. This action can compress the spring somewhat even before the cam takes effect; (c) by screwing the adjusting screw in or out of the lower spring plug.

To position these various parts properly during assembly, proceed as follows: Locate the stem in such a way that the flange of the seat will bear on the end of the valve body when the stem face is on the seat. Screw the adjusting screw into the lower spring plug so that about one-half of the threads are engaged. (This will provide further adjustment when the valve is assembled.) With the handle in the lowest position, screw the handle bearing down the spring cage until the cam just touches the upper spring plug. The valve is now ready for final assembly.

5. FLUSHING AND ADJUSTMENT: When the stem was forced through the packing, small particles of graphite may have been carried down into the body of the valve so it is necessary to clean the valve body thoroughly before attaching the seat. Connect the spray valve test tube to the open fitting on the fuel rail and to the inlet of the regulating valve. Close all isolating valves and pump up fuel pressure with the priming pump. Open the isolating valve to the test tube quickly. This will allow a rush of fuel to pass into the regulating valve and carry off any dirt. Repeat this several times and then grip the valve body in the vise.

The end of the valve stem will be just protruding through the body, so place the seat over the stem and screw on the adapter stud. Leave this stud about one-quarter turn from being fully tightened. You will notice that the seat is a very loose fit in the adapter stud. The purpose of this is to allow the seat to find its own position with relation to the stem.

Lift the handle as high as possible which will force the stem into the seat with considerable pressure. This will assure a proper alignment between the stem and the seat. Tighten the adapter stud with a heavy wrench while the pressure is still on the stem and the seat will be held permanently in its correct position.

Connect the valve to the test tube on the engine and with the handle in the highest position pump up two or three thousand pounds pressure. There should be no leakage at the discharge opening of the valve. If the valve is not holding pressure, drop the handle quickly, several times. This will allow a rush of fuel to pass out which may carry off any dirt which is under the valve face or on the seat. If this fails, the valve needs grinding.

6. GRINDING: Remove the adapter stud and seat and dry off the fuel from the stem and seat. Smear very fine grinding compound on the face of the stem. Hold the seat between the thumb and finger and rotate it against the stem which should be positioned so that the flange on the seat just misses the end of the valve body. This will assure the seat being held square with the stem. After this grinding process has been continued for five or ten minutes (these parts are very hard), wash out the valve as described in paragraph 5, and assemble and test again.

7. SETTING THE VALVE: After testing shows that the valve will hold fuel pressure without leaking, move the handle to the lowest position. By screwing the adjusting screw in or out of the lower spring plug, set the valve so it will hold 1000 pounds fuel pressure without leaking. If pressure in excess of this figure is pumped up, the fuel should discharge out of the valve but as soon as the pressure drops to 1000 pounds, the valve should hold without any discharge. The valve is now ready to be installed on the engine.

8. ISOLATING VALVES: There are eight of these valves on your engine. One for each spray valve, one to control the fuel gauge and one open valve for making any tests which require high fuel pressure. These valves need very little servicing and should be taken apart

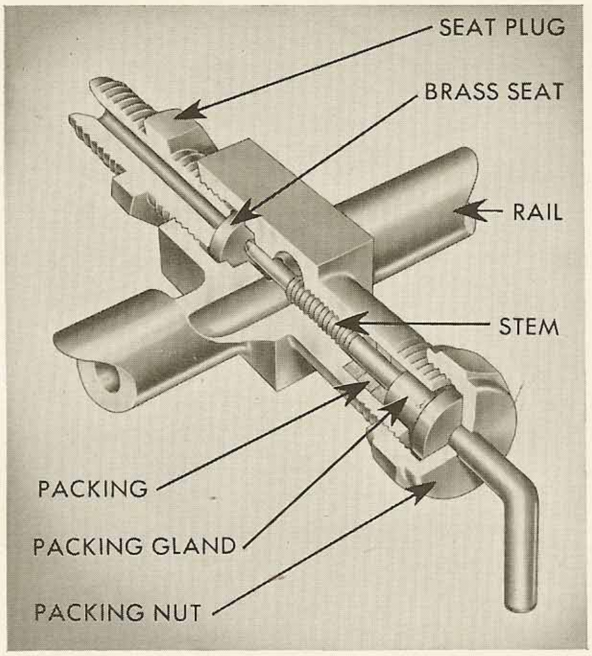


FIGURE 16-5

only if trouble develops. They should never be tightened or closed with a wrench. If the stem is broken through accident, proceed as follows:

9. DISASSEMBLY: Reference to Figure 16-5 will show that the stem is turned to a smaller diameter from the end of the threads onto the valve face. This piece is hardened and is usually the location of a break. Disconnect the tube and screw out the seat plug. Remove the brass seat. Screw the broken stem out and remove the packing nut, gland and packing.

10. ASSEMBLY: After the broken piece of stem has been removed, flush the rail and valve out well with fuel oil. Insert sufficient packing rings (the same rings as used to pack the spray valve) so that the packing gland flange is held away from the end of the body of the valve. Screw on the packing nut and the stem. Replace the brass seat and screw in the seat plug but leave it about one-fourth of a turn from tight.

The recess in the body that holds the seat in place is larger in diameter than the brass seat. The purpose of this large recess is to allow the seat to align itself with the stem. The plug is left just loose enough so that the seat can move around and find its own center when the tapered end of the stem is screwed into it. After the seat is correctly positioned, tighten the plug so that the seat is held securely in place. This final tightening of the plug will force the hardened steel end of the stem into the brass seat, assuring a tight valve.

11. HIGH PRESSURE FUEL GAUGE: This gauge is a delicate instrument and should be returned to the nearest service depot if repairs are necessary.

12. HIGH PRESSURE FUEL PUMP: The greatest problem in maintaining the high pressure fuel pump is keeping it free of dirt and water. The valves and their cages are hardened and the clearances are so slight that foreign matter in the fuel will cause sticky or leaking valves. Salt water will corrode these hardened parts quickly and should therefore be kept out of the system if possible. Efficient strainers are supplied and these will protect the pumps from dirt and water providing they are cleaned frequently and kept in condition.

The plunger and barrel of each pump are of a type which requires no packing. The fit between these two parts is so carefully made that pressures up to 10,000 pounds can be reached with only sufficient leakage for lubrication purposes. This close fit requires that these two parts should always be treated as a unit. If both pumps are removed, the plungers and barrels should never be mixed. When ordering replacement parts always order a plunger and barrel as a set.

13. DISASSEMBLY: Reference to Figure 16-6 will show that the suction chamber is formed by the cover, which is shown in phantom, and the pump mounting plate. The suction valves are reached by removing this cover while the discharge valves are outside of the cover and directly under the bleeder valves. The two pumps and the priming pump are assembled to the mounting plate which, when removed, exposes the entire assembly. The connecting rod and crosshead guides are reached by the removal of the door in front of the after end of the camshaft.

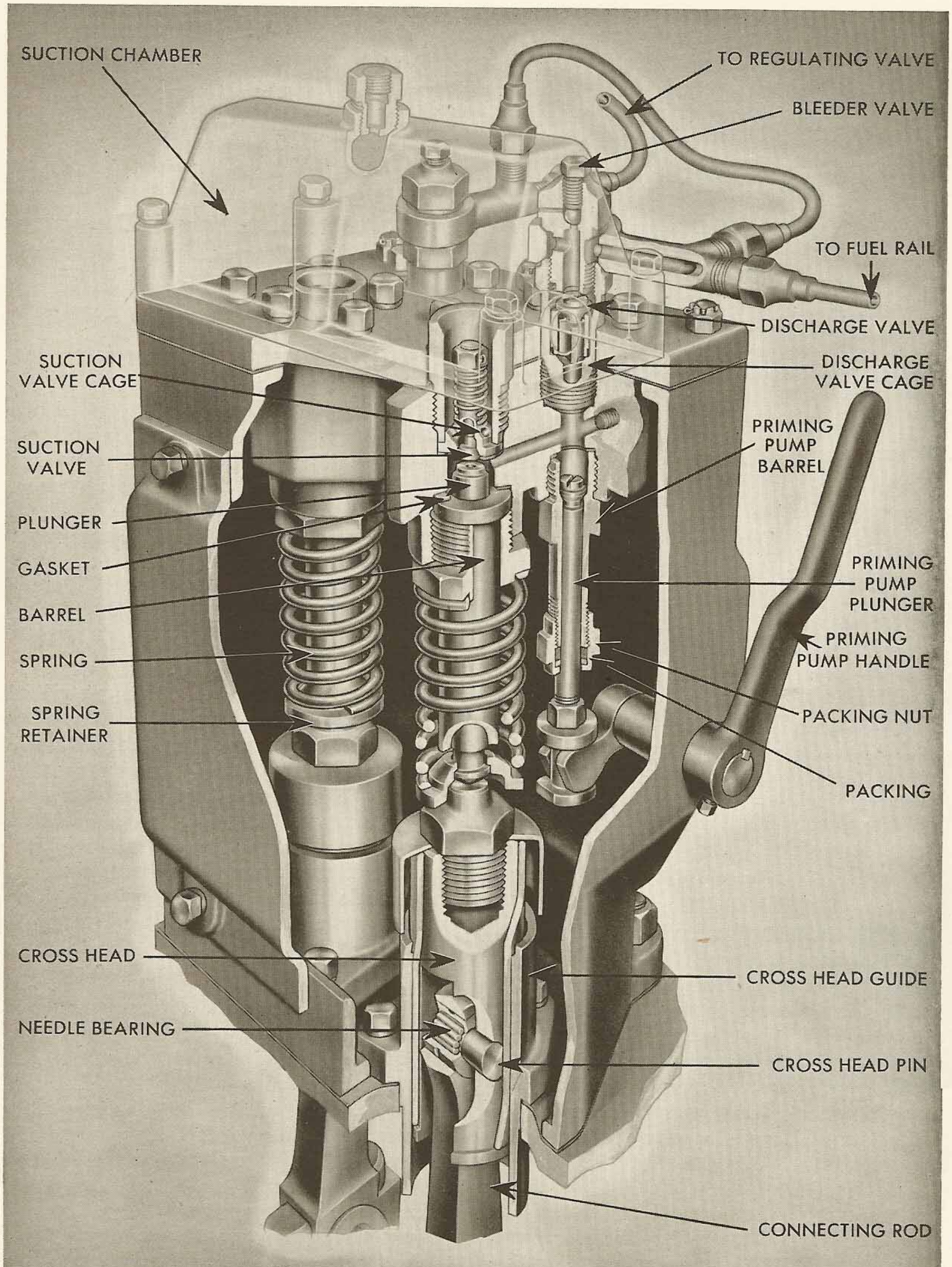

SUCTION CHAMBER
TO REGULATING VALVE
BLEEDER VALVE
TO FUEL RAIL
DISCHARGE VALVE
SUCTION VALVE CAGE
DISCHARGE VALVE CAGE
PRIMING PUMP BARREL
SUCTION VALVE
PLUNGER
GASKET
BARREL
PRIMING PUMP PLUNGER
SPRING
PRIMING PUMP HANDLE
SPRING RETAINER
PACKING NUT
PACKING
CROSS HEAD
CROSS HEAD GUIDE
NEEDLE BEARING
CROSS HEAD PIN
CONNECTING ROD

FIGURE 16-6

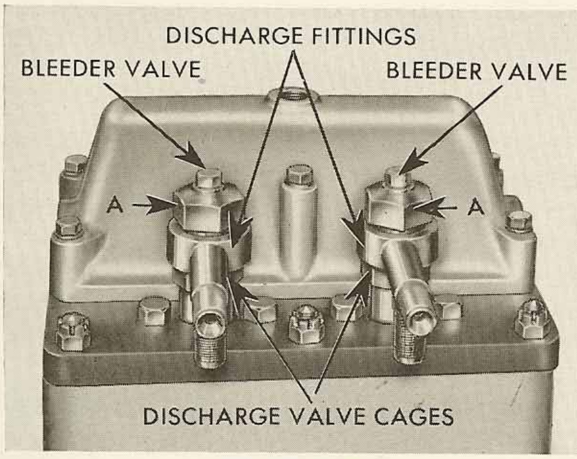


FIGURE 16-7

14. REMOVAL AND SERVICING OF THE DISCHARGE VALVES: The discharge valve cages, shown in Figure 16-7, screw directly into the pump block and can be removed after the high pressure tubing has been disconnected. The indications of a leaky discharge valve are the same as those described for a leaky regulator in paragraph 2, this section. Both the valve and the seat are very hard so they are seldom scored. A leak more often comes from dirt lodged between the valve and seat. This dirt can usually be removed by a thorough cleaning. If this fails, the valve can be ground in the normal way with very fine grinding compound. If either the cage or valve seat is badly scored, the assembly should be replaced, as grinding out deep scores is a lengthy job.

The two nuts, A, Figure 16-7, release the discharge fittings. The valve cages are next unscrewed from the pump mounting plate. Figure 16-8 shows the discharge valve and cage.

CAUTION: The nut, A, Figure 16-7, forms a stop which governs the lift of the discharge valve. When the unit is assembled the total lift should be $\frac{3}{32}$ inch. If, upon removal, the end of this nut is found to be unduly hammered up where it comes in contact with the head of the discharge valve, it is almost a sure sign that the hardened seat and guide, shown in Figure 16-8, is loose.

In this case it will be necessary to renew the cage and seat assembly. The hammered condition can also be caused by the lift of the valve being less than $\frac{1}{16}$ inch.

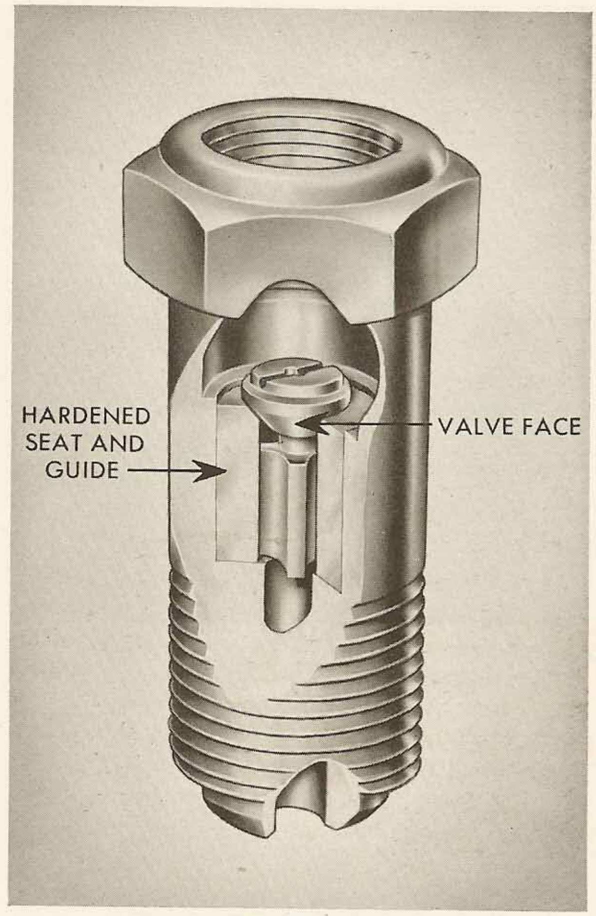


FIGURE 16-8

15. REMOVAL AND SERVICING OF THE SUCTION VALVES: Take off the cover and the suction valves will be exposed as shown in Figure 16-9. Unscrew the two suction valve retainer nuts and lift the assemblies out. Remove the cotter pin and unscrew the valve stem nut. Inspect the valve face and cage seat and grind or renew if necessary. Wash all parts thoroughly before assembly. When the stem nut is replaced it should be screwed down so that the total lift of the valve does not exceed $\frac{1}{16}$ inch. When these cages are assembled in the pump, be sure that the copper gaskets are in place under each cage. This cage assembly is shown in Figure 16-10.

16. DISASSEMBLY OF THE PUMPS: Remove all the cotter pins and nuts from the studs which hold the mounting plate, Figure

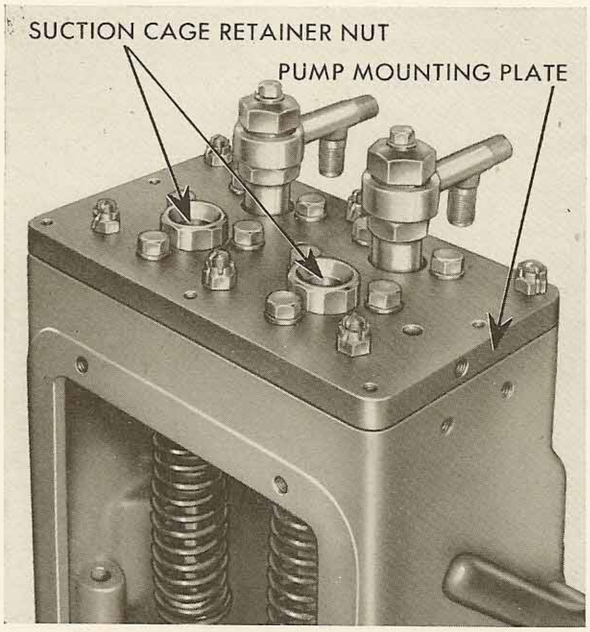


FIGURE 16-9

16-9, to the housing. Lift off the mounting plate, the two high pressure pumps and the priming pump. The two high pressure plungers and springs rest on top of the crosshead and care should be taken that the plungers do not fall out as the mounting plate and pumps are lifted off.

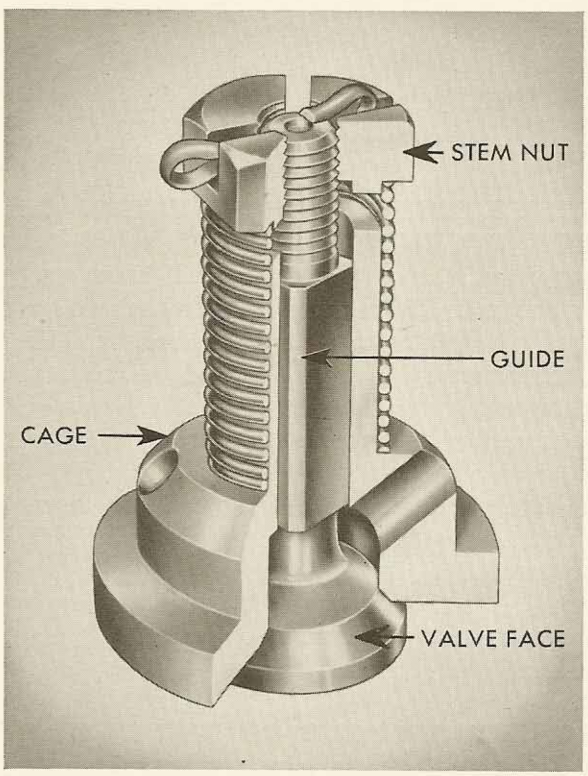


FIGURE 16-10

The high pressure pump barrel is held into the pump block by the large nut just above the spring shown in Figure 16-6. If this barrel is replaced be sure a new copper gasket is used between the flange of the barrel and the pump block. The retaining nut must be well tightened.

17. REMOVAL AND SERVICING OF PRIMING PUMP: The priming pump, Figure 16-11, attaches to one of the pump blocks. The head of the priming pump plunger has an inverted valve face which seats in the barrel of the pump. In Figure 16-11, the plunger is withdrawn sufficiently to show the valve face and the seat is in the barrel about the center of the hex portion next to the threads. The other end of the barrel has a packing nut. When this gland is repacked, the nut should never be tightened up so as to retard the movement of the plunger.

The valve can be reground, if leaking, by using fine grinding compound. To pack the stem use two or three turns of $\frac{1}{8}$ inch twisted graphite packing. When screwing the pump barrel into the block, be sure that the copper gasket is in place.

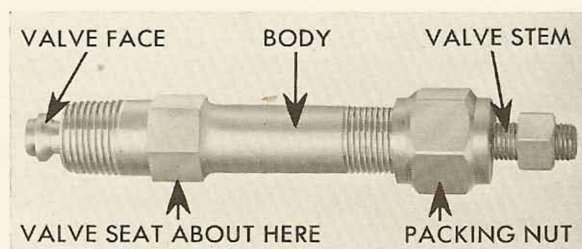


FIGURE 16-11

18. REMOVAL OF CROSSHEAD GUIDES: Figure 16-6 shows a metal shield over the crosshead. This shield prevents any fuel leakage going into the base and mixing with the lubricating oil. Under the shield and around the guide is a sleeve which can be replaced if worn or scored.

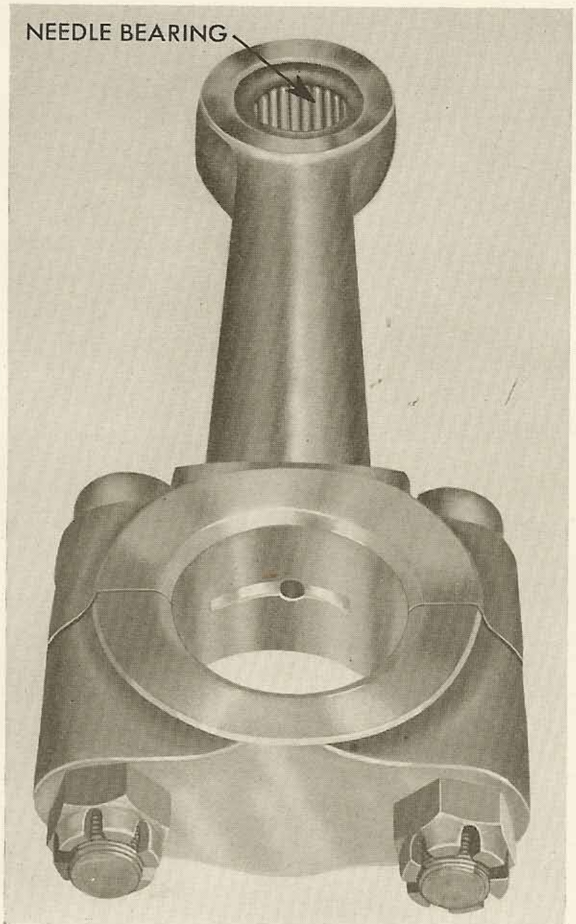


FIGURE 16-12

The shield and sleeve can be removed by unscrewing the large nut in the head of the crosshead. The guide is attached to the pump housing by two cap screws.

19. REMOVAL OF CROSSHEAD AND CONNECTING ROD: The connecting rod shown in Figure 16-12 is removed by taking the crank pin bearing apart. Do not lose the shims and be sure to mark the bearing halves so they can be assembled in their correct positions. Drive out the crosshead pin and inspect it and the needle bearing for wear. The bearing is a press fit in the connecting rod.

When fitting the crank pin bearing, the clearance should be adjusted to 0.002 to 0.003 inch, and the end clearance at least 0.007 inch. The shim bundles should be kept to equal thickness on both sides of the bearing. The connecting rod nuts must be well tightened and cotter pins installed during assembly.

20. AIR BLEEDING: Whenever the high pressure pump assembly has been drained of fuel, it is necessary to bleed off all the air before the pump will function properly. Open up the supply line to the pump and open the vent on the suction chamber. Do not close this vent until solid fuel runs out of the opening. Next open the two bleeder valves on the discharge fittings and work the priming pump handle until solid fuel (fuel without air bubbles) escapes from these valves. Next open the fitting on the fuel rail which is farthest away from the pump and work the priming pump until solid fuel runs from the end of the rail. Close this fitting and it should now be possible to pump up pressure in the rail. During this procedure, all isolating valves should be closed.

SECTION 17
SPRAY VALVES AND OPERATING MECHANISM

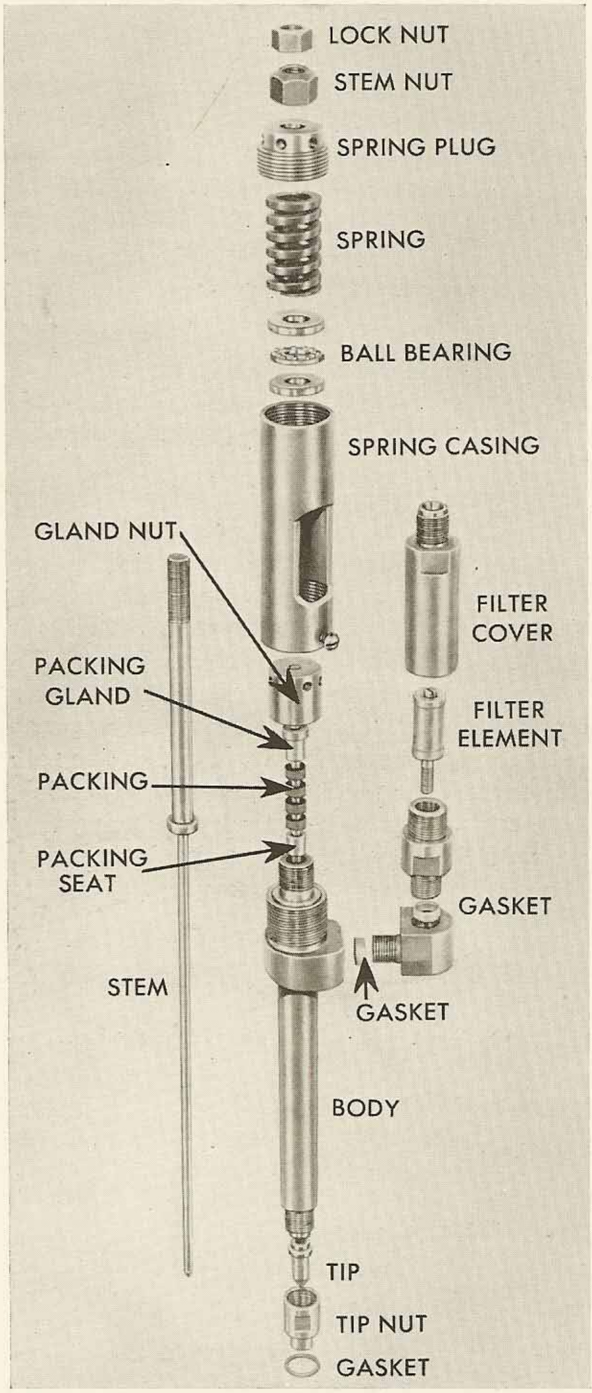


FIGURE 17-1

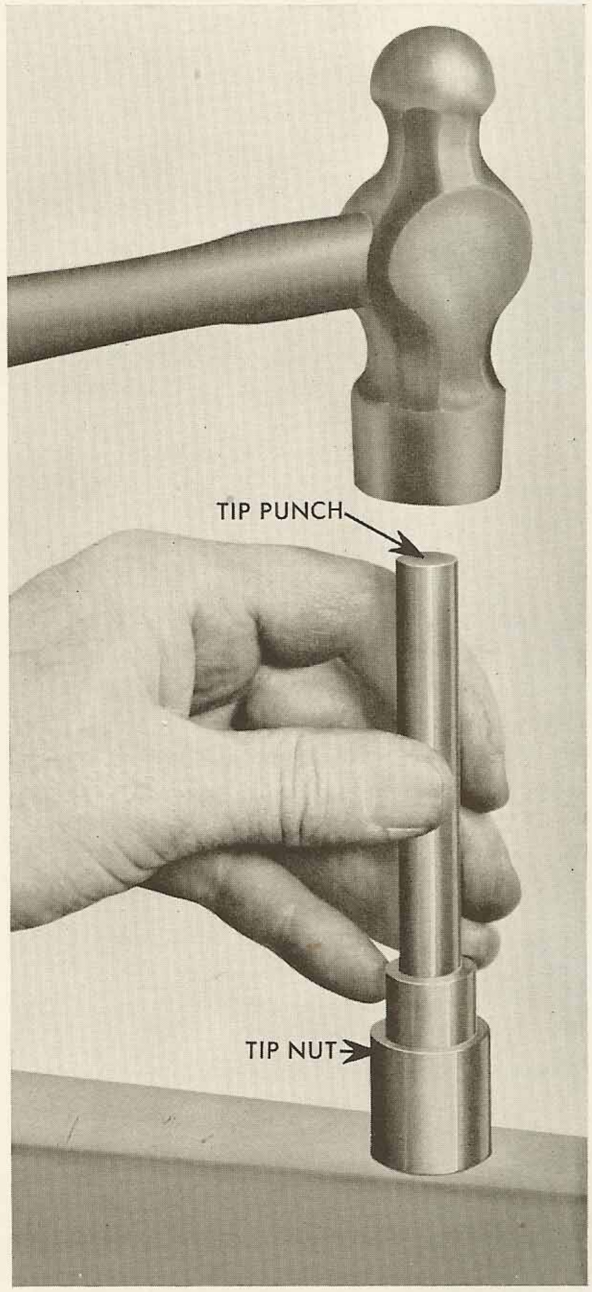


FIGURE 17-2

1. DISASSEMBLY OF SPRAY VALVES: Remove parts in the order as shown in Figure 17-1. When removing the tip from the tip nut

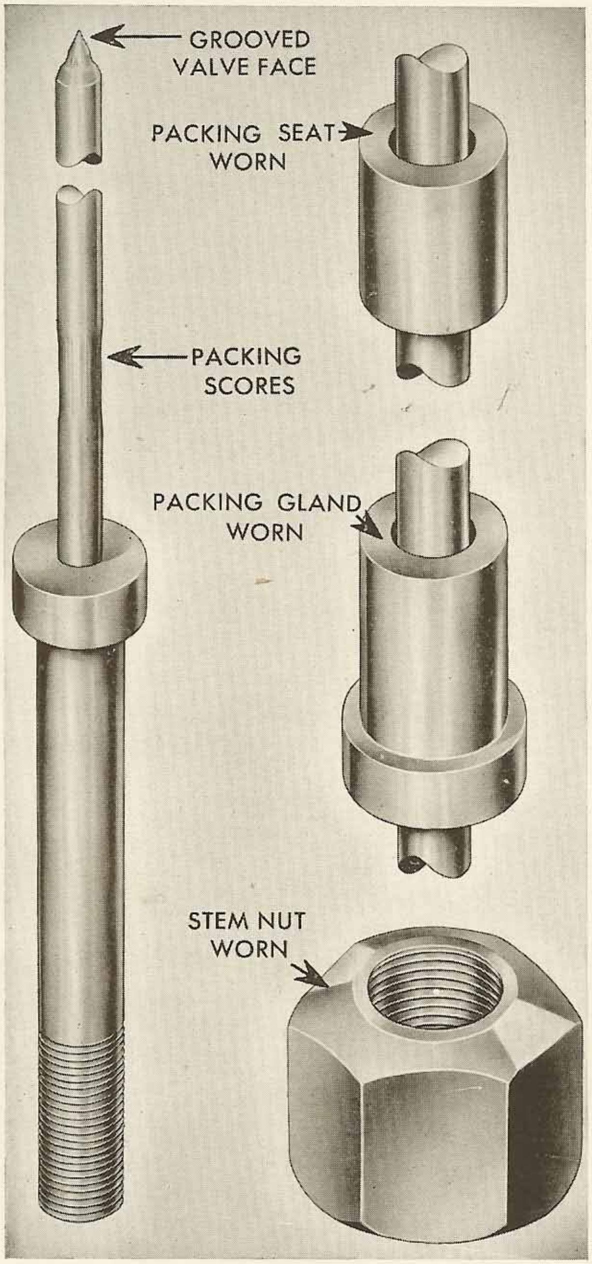


FIGURE 17-3

use the tip punch as in Figure 17-2, to avoid damage to the tip. Wash all parts thoroughly.

2. EXAMINATION: The stem nut will become worn through contact with the horseshoe and if the seating area is rough the nut should be renewed. The packing gland and seat should be renewed if they are loose enough to permit packing to find its way down the stem. The stem will bind or seize in the packing if it is rough in the packing way. Continual grinding may form ridges on the face of the stem which will make it difficult to obtain a good seating in the tip. Experience will tell when these parts should be renewed, but if any of them are worn so as to look like the parts shown in Figure 17-3, they should be renewed immediately.

3. SPRING TESTING: The point to remember in testing or adjusting spray valve springs is that the tension of all the springs must be equal. Several weak and several strong springs in an engine will cause more trouble than all weak springs, as any great difference in the tension will cause the engine to run unevenly at low speeds.

A simple test can be made by placing a new and a used spring in a vise as shown in Figure 17-4. As the vise is closed both springs should compress alike. If the coils of the used spring collapse, while coils of the new one are well separated, the old spring should be discarded unless the used spring tests out about the same with all the other spray valve springs in the engine.

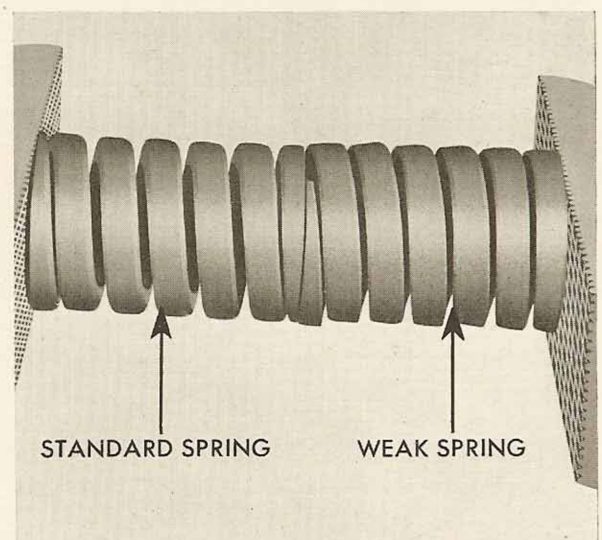


FIGURE 17-4

4. TESTING SPRAY VALVE TIPS: If the tips are marked 5-13-30, this means that there are five holes of 0.013 inch in diameter at 30 degree angles. These hole sizes are very important, as a tip with holes worn 0.001 oversize will deliver approximately one-eighth more fuel each time the valve opens.

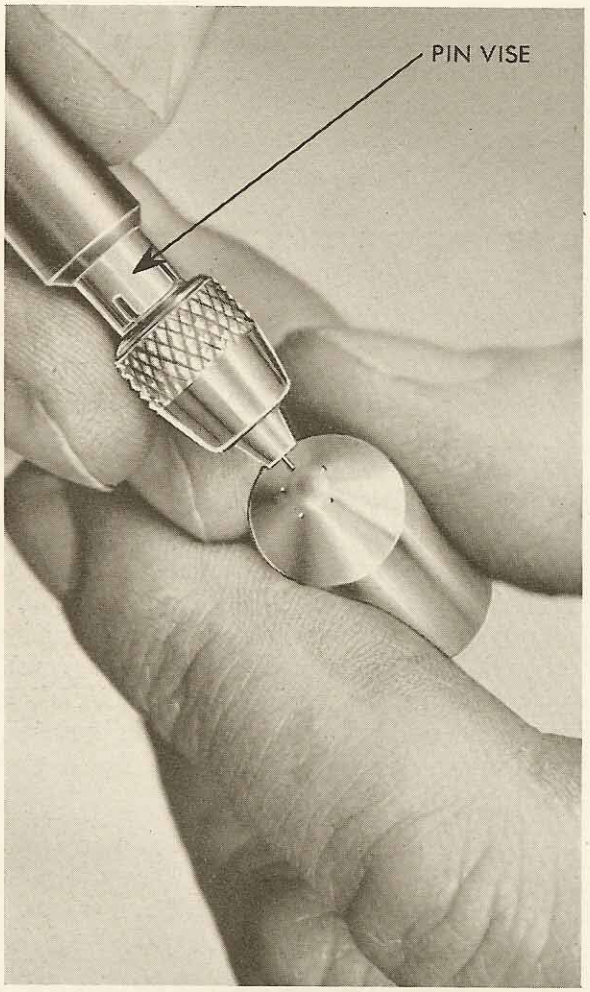


FIGURE 17-5

Insert 0.013 inch wire in a pin vise and clean all the holes thoroughly as shown in Figure 17-5. Change the wire to 0.014 inch and WITHOUT FORCING try all the holes again. If the 0.014 inch wire will go through any of the holes, the tip should be discarded.

5. SPRAY VALVE FILTER: Remove the filter cover, see Figure 17-6, and screw out the element. HANDLE THIS ELEMENT CAREFULLY TO AVOID DAMAGE as the openings between the discs are only 0.001 inch and any enlargement of these openings will allow dirt to pass into the spray valve. Wash all parts thoroughly in fuel oil and assemble filter to the spray valve body.

6. ASSEMBLY: After all parts are inspected and thoroughly cleaned, grip the spray valve body in a vise. Press in as many packing rings

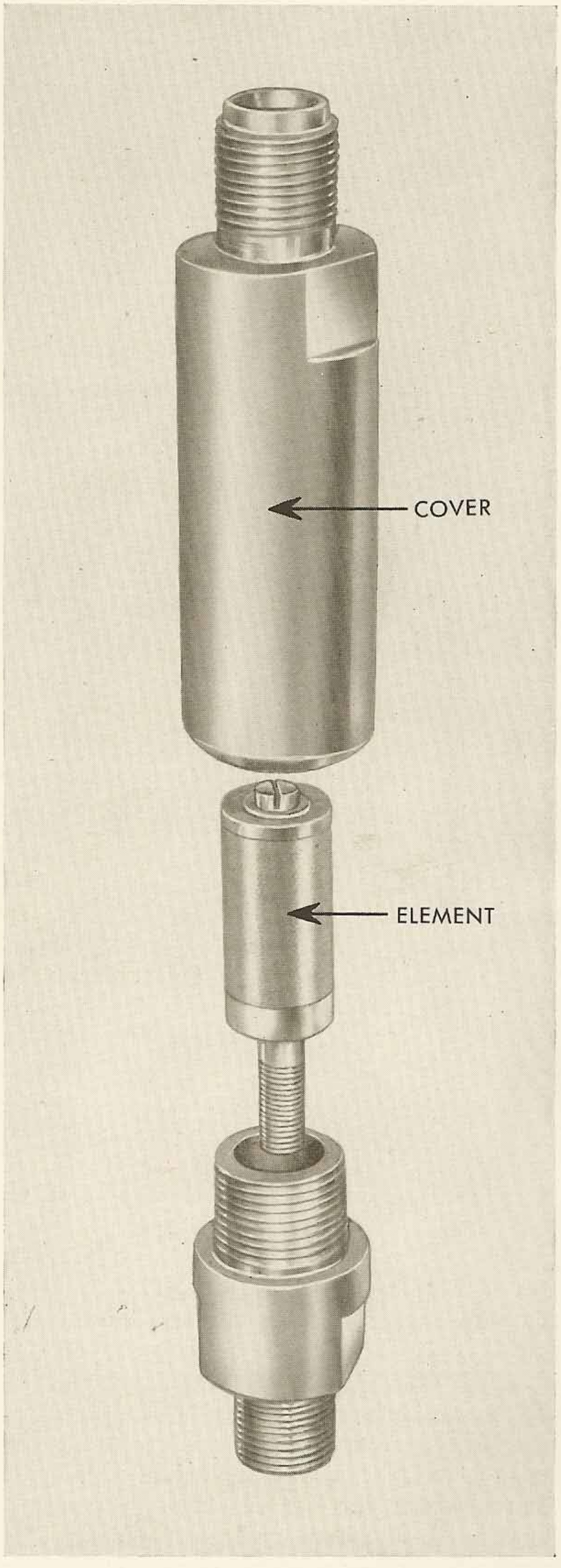


FIGURE 17-6

as will leave the gland extended about one-quarter inch. ALWAYS USE NEW PACKING RINGS.

The joints of the packing rings should be staggered and an easy way to do this is to imagine the packing hole as the face of a clock. Put the joint of the first ring at 12 o'clock, the next one at 3 o'clock, the next one at 6 and the next at 9 until sufficient rings have been installed. Put in the gland and screw down the gland nut until it just touches the gland. DO NOT TIGHTEN THE GLAND NUT.

Oil the stem well and push it through the packing until the thrust ring of the stem nearly touches the gland nut.

Put on the ball bearing and then the spring. Screw on the spring cage until the set screw hole in the cage lines up with the hole in the body. Insert and tighten the set screw. SPRAY VALVE BODIES AND SPRING CAGES ARE NOT INTERCHANGEABLE. The spring plug should be screwed in but only two or three threads, as it will be adjusted later.

7. FLUSHING AND TESTING: Attach the spray valve to the test stand on the engine as shown in Figure 17-7 and close all isolating valves. THIS IS IMPORTANT, for if these valves are left open, fuel may be pumped into the cylinders.

Connect the test tube to the spray valve and to the open isolating valve on the rail. Pump up about 1500 or 2000 pounds fuel pressure in the rail with the hand priming fuel pump.

Open the isolating valve quickly. Close the valve and repeat this operation several times so as to wash out any dirt or particles of graphite off the packing, which may be in the spray valve body.

Using a pan of clean fuel oil, wash the tip out thoroughly. A pipe cleaner is very handy for cleaning the inside of the tip. Fill the tip with fuel oil and insert the tip plunger, see Figure 17-8. Force the plunger into the tip which will

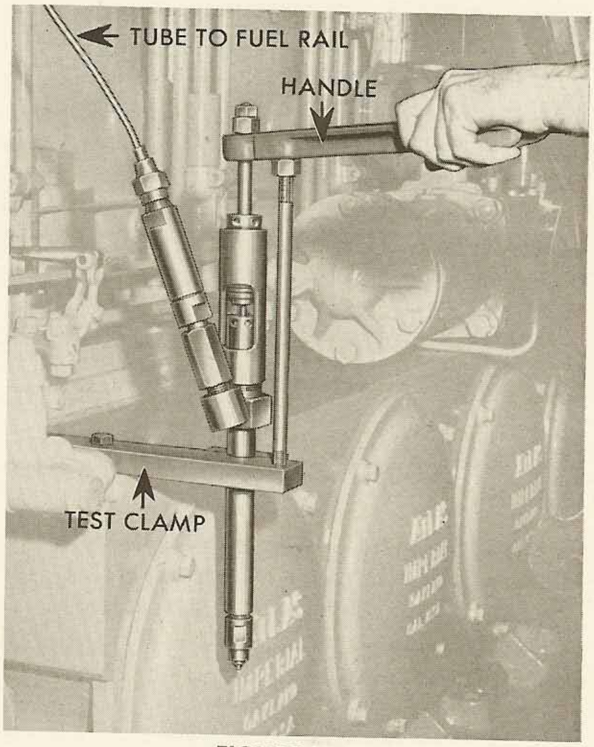


FIGURE 17-7

FIGURE 17-8

spray the fuel out of the tip holes. Each hole should discharge a full stream. Place the tip over the end of the stem and screw the tip nut on tightly.

Screw down the spring plug until pressing down on the test handle will lift the stem only $\frac{1}{16}$ of an inch. This means that the spring is $\frac{1}{16}$ of an inch from being fully compressed. WARNING: KEEP TRYING THE LIFT AS THE SPRING PLUG IS SCREWED DOWN, FOR THE STEM CAN BE FORCED THROUGH THE TIP IF THE PLUG IS SCREWED DOWN AFTER THE SPRING IS FULLY COMPRESSED.

Pump up 2000 or 3000 pounds pressure with the priming pump and open the isolating valve to the test stand. Press the test handle down quickly several times and watch the action of the fuel spray from the tip. WARNING: DO NOT GET FACE OR HANDS NEAR THE TIP OR IN THE WAY OF THE SPRAY AS THIS CAN RESULT IN SERIOUS INJURY. The spray from all holes should look alike as in Figure 17-9.

If any holes are plugged remove and clean the tip. After the proper spray is obtained, pump the fuel pressure up to 4000 pounds, wipe the tip off dry and let it stand for a few seconds. Draw the back of your hand across the end of the tip. No fuel moisture should show. If the tip is leaking it will be necessary to grind the seat.

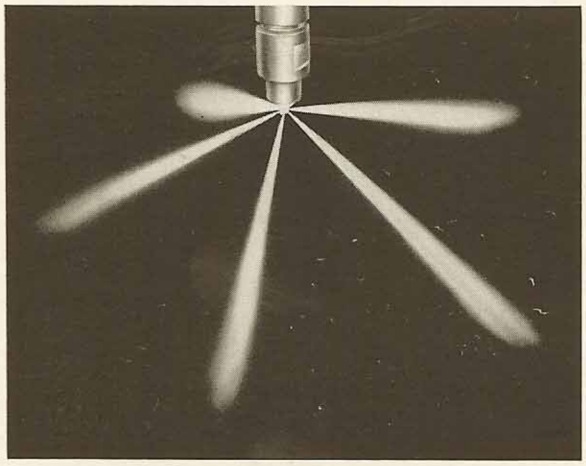


FIGURE 17-9

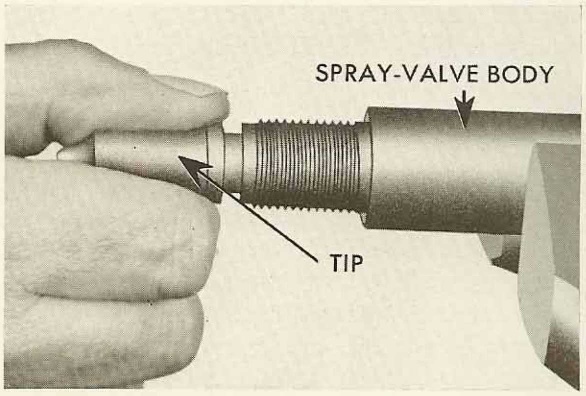


FIGURE 17-10

8. GRINDING SPRAY VALVE: Screw out the spring plug releasing the spring pressure. Remove the tip nut and punch out the tip. Smear a VERY SMALL QUANTITY of extra

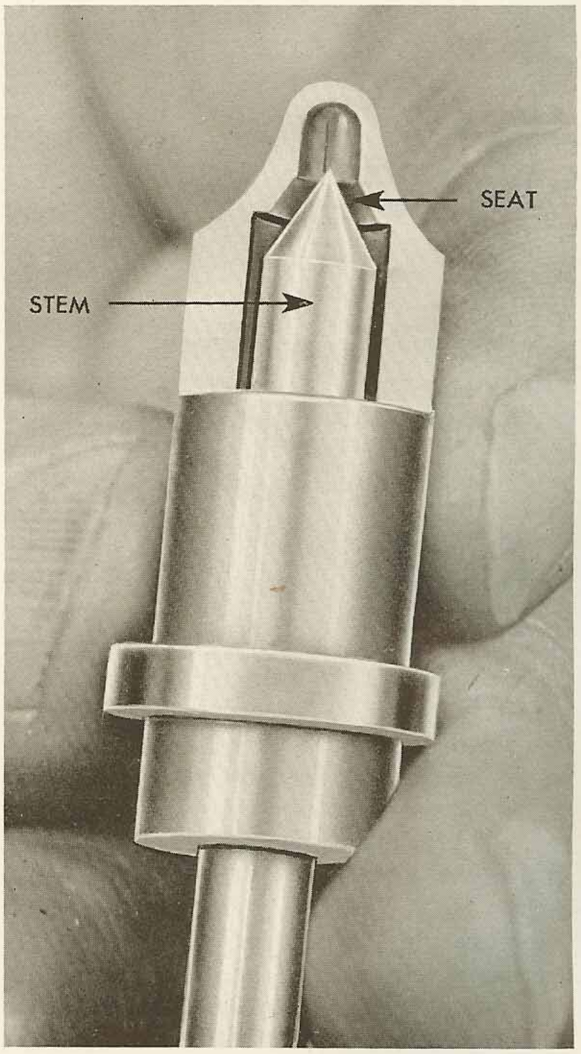


FIGURE 17-11

fine valve grinding compound on the valve face area of the stem. Place the tip over the stem and so adjust the position of the stem that the flange of the tip is about one-thirty-second of an inch away from the end of the spray valve body as in Figure 17-10.

Rotate the tip back and forth as in grinding engine valves. Repeat this operation until a well ground ring appears around the stem face. Figure 17-11 shows a tip cut away to illustrate the seat and stem face which may require grinding. Clean out the tip and stem thoroughly and test the tip with the plunger to assure yourself that all holes are clear. Assemble and test the valve on the test stand.

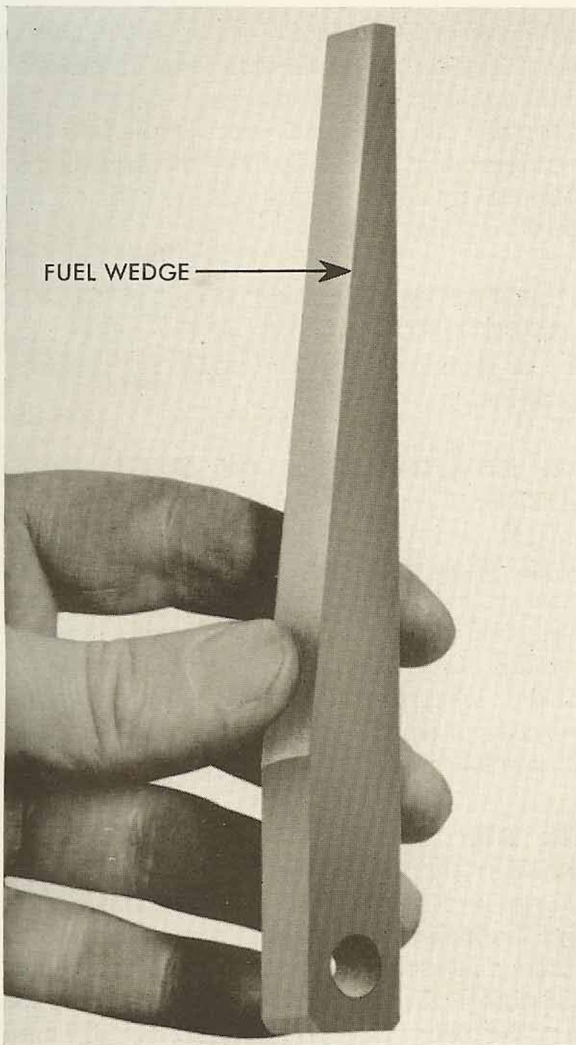


FIGURE 17-12

If several grindings fail to produce a tight seat examine the stem face and the tip seat for scores or ridges. Renew either or both parts if necessary. Remember that each time the grinding process is repeated, the spray valve should be flushed out on the test stand before assembly. The spray valve is now ready for installation in the engine.

9. EXAMINATION OF SPRAY VALVE LIFTING MECHANISM: Examine the fuel wedge shown in Figure 17-12. If the wedge feels rough at points where the lifter wedge pin and the ball end of the pushrod are in contact with it, the wedge should be replaced.

10. REMOVAL OF THE SPRAY VALVE LIFTER: Loosen the buffer-spring clamp nut and unscrew the buffer spring cage. Remove the pushrod and examine the lifter wedge pins. Remove the crankpit door and examine the roller on the lower end of the lifter. If either the pin or the roller is flat or damaged as shown in Figure 17-14, repairs should be made as follows:

Remove governor linkage to the wedge shaft (A) and bearing block nuts (B) from all wedge shaft bearings. Remove wedge shaft (C) and two cap screws which hold the spray valve lifter guide to the centerframe. Remove the two cap screws marked (D) which will release the fuel latch (E). All these references will be found in Figure 17-13. Remove the latch, allowing the spray valve lifter to rest on the camshaft.

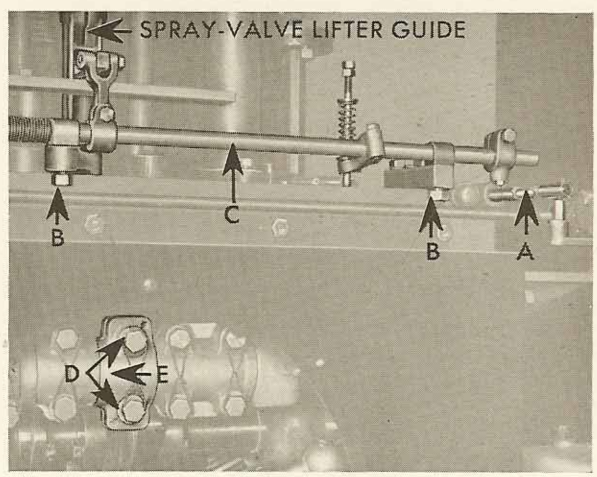


FIGURE 17-13

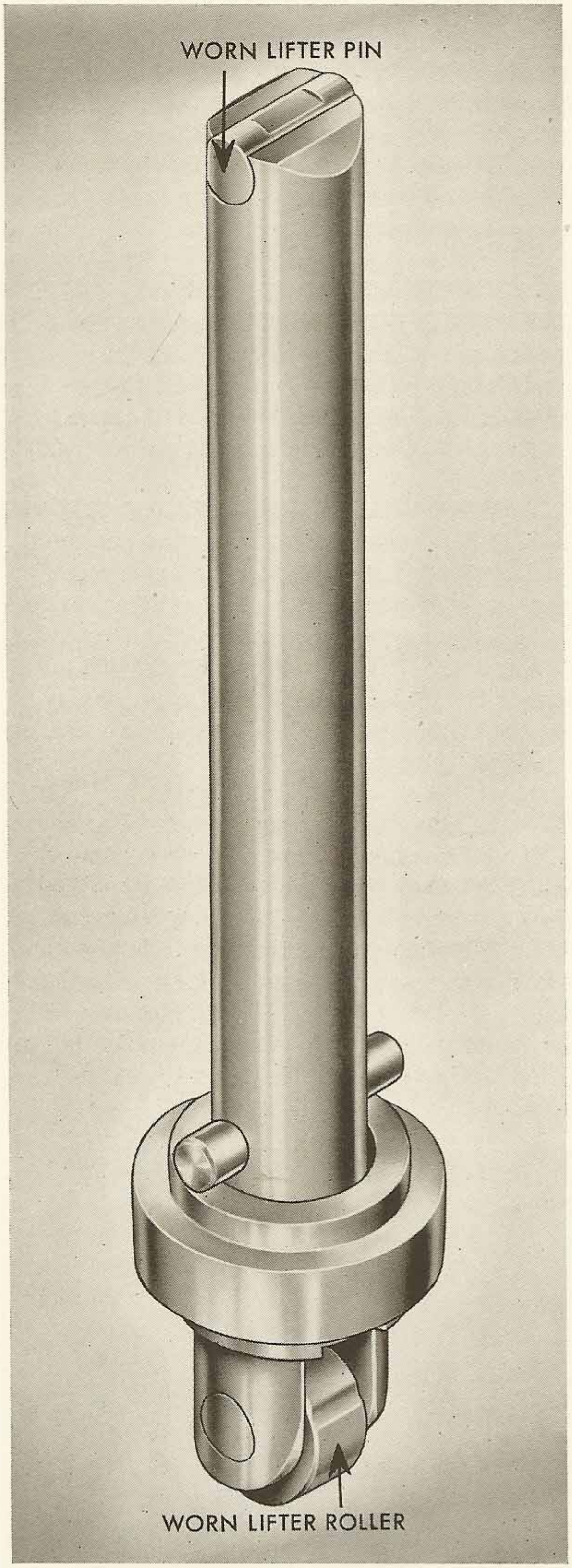


FIGURE 17-14

Pry up the spray valve lifter guide, at the same time holding the spray valve lifter so that it does not fall into the pit. Grip the spray valve lifter in a vise and drive out the pin, then turn it so that the flat spot is not exposed and drive in and rivet the edge of the hole over so that the pin can not come out.

To remove the roller pin mark the exact center with a punch. Drill in with a 5/8 inch drill just far enough to clean out the countersink in the lifter body. Select shim stock of the proper thickness to make up the space between the roller and the lifter body and insert it between the two parts so that the lifter will not be bent when the roller pin is driven out. Drive out the pin and replace the worn parts.

File the ends of the new pin until they follow the shape of the body, but leave the pin about one-thirty-second of an inch long. Insert the shim again to take up the space between the roller and the body and rivet the pin into the countersink at EACH END of the lifter body. Remove the shim and smooth the ends of the pin with a file.

11. EXAMINATION OF SPRAY VALVE LATCH AND ROLLER: If the rollers are flat or damaged see Section 19, for replacement instructions.

12. EXAMINATION OF FUEL CAM LOBES: Cam lobes gradually wear down until the points are dulled as shown in Figure 17-15. Their replacement is governed by the same rule that applied to the renewing of spray valve springs. One sharp lobe among five dull ones will be more troublesome than all dull lobes providing the dull ones are all worn down equal. It is a good rule to replace all cam lobes rather than one or two.

13. REPLACEMENT OF FUEL CAM LOBES: Cut and remove the locking wire shown in Figure 17-15. Remove the three-eighths inch cap screw and pry out the lobe. Insert the new lobe, screw in the cap screw and tighten lightly. Drive the lobe well down into the slot with a two or three pound hammer and a bronze or brass drift. Tighten the

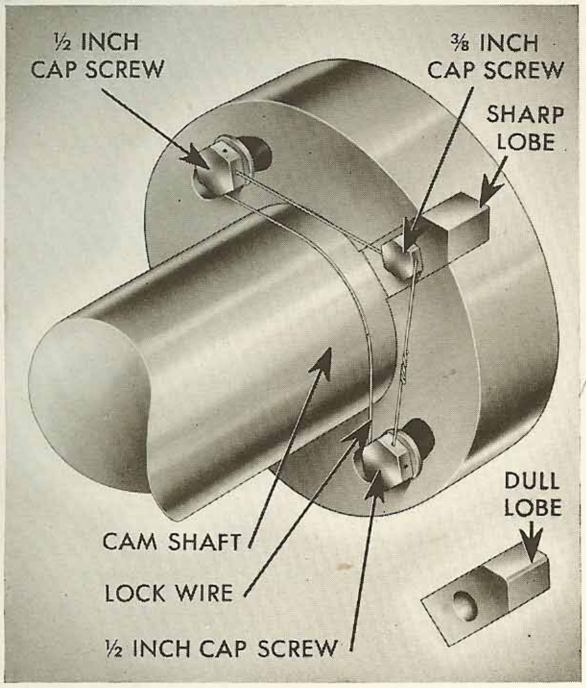


FIGURE 17-15

cap screw but DO NOT USE OVER A SIX INCH CRESCENT WRENCH. Use new locking wire to secure the cap screws.

14. INSTALLATION OF THE SPRAY VALVE: Before placing a gasket on the end of the spray valve make sure that there has not been one left in the spray valve opening in the cylinder head. These gaskets may be used several times providing they do not become too thin or hard. Before replacing the spray valve clamp, make sure the spray valve is well seated on the gasket. Attach the tube from the rail to locate the strainer and tighten the clamp nut.

Put on the spray valve rocker and place the horseshoe between the stem nut and the rocker. Loosen the lock nut under the fork of the spray valve pushrod and screw the pushrod into the fork until no threads show under the lock nut. This shortens the rod. Install the fork pin in the rocker and fork.

NOTE: Make sure the fuel wedges are in toward the engine as far as their travel permits and that the flywheel is not within 30 degrees of any top center.

If only one or two spray valves have been removed, proceed as follows:

Screw down the stem nut until the rocker is held to the level of the other spray valve rockers. This can be checked by sighting along the top of the rockers from one end of the engine.

If all the spray valves are being replaced, proceed as follows:

Screw down the stem nut on No. 1 spray valve until the top of the rocker is held level with the top of the cylinder head. Repeat this procedure on No. 6 spray valve. Screw down the stem nuts on all the other spray valves so that the rockers sight level and even with No. 1 and No. 6 rockers. Screw down all lock nuts and tighten them against the stem nuts.

Great care should be taken that the STEM IS NOT TURNED WHEN LOCKING THESE NUTS, as damage to the valve seat can occur if the stem is even slightly turned. The spray valves are now ready for timing. See Section 10 for procedure.

SECTION 18
CONTROLS

1. CONTROL GROUP: The control group consists of the following parts which are covered in this section: Hand Wheel, paragraph 7; Pilot Valves, paragraphs 8 and 9; Rocker Shaft Ram, paragraph 10; Flywheel Brake, paragraph 11; Master Air Valve, paragraph 12; Fuel Pressure Regulator, paragraph 13; Fuel Cut-out, paragraph 15; Wedge Shaft Spring, paragraph 16; Single Lever Control Unit, paragraph 17; Latch Shaft Ram, paragraph 34; Latch Shaft Interlock, paragraph 26; Governor Control Handle, paragraph 14.

2. CONTROL: We will deal with the engine controls in two parts, the first part covering engines having a hand wheel control and the second part, engines having single lever control.

3. HAND-WHEEL CONTROLLED ENGINES: Figure 18-1 shows the various parts of the control system.

A. The wheel for shifting the latches and applying the starting air.
B. The fuel-pressure regulator.
C. The governor control handle.
D. The flywheel brake pilot valve.
E. The rocker-shaft ram.
F. The rocker shaft ram pilot valve.
G. The fuel cut-out device.
H. The master air valve.

4. TO START THE ENGINE AHEAD: We will first briefly review the maneuvering operations so that the functions of the various units, to be serviced, will be more clearly understood. The hand wheel is geared to the pointer, shown directly above it. To start the engine ahead, this wheel is turned forward to the limit of its travel, which places the pointer at the word "start." This movement revolves the latch shaft and places the proper cams in action as well as opening the pilot valve (F). This valve permits air to pass into the rocker-shaft ram (E) which brings the air-starting valves into action by turning the eccentric rocker shaft. On the after end of this rocker shaft there is a bell crank and a link which operates the master air valve (H). When this valve is opened, air from the storage tank passes into the air-starting manifold and through the proper air-start valves to the cylinders.

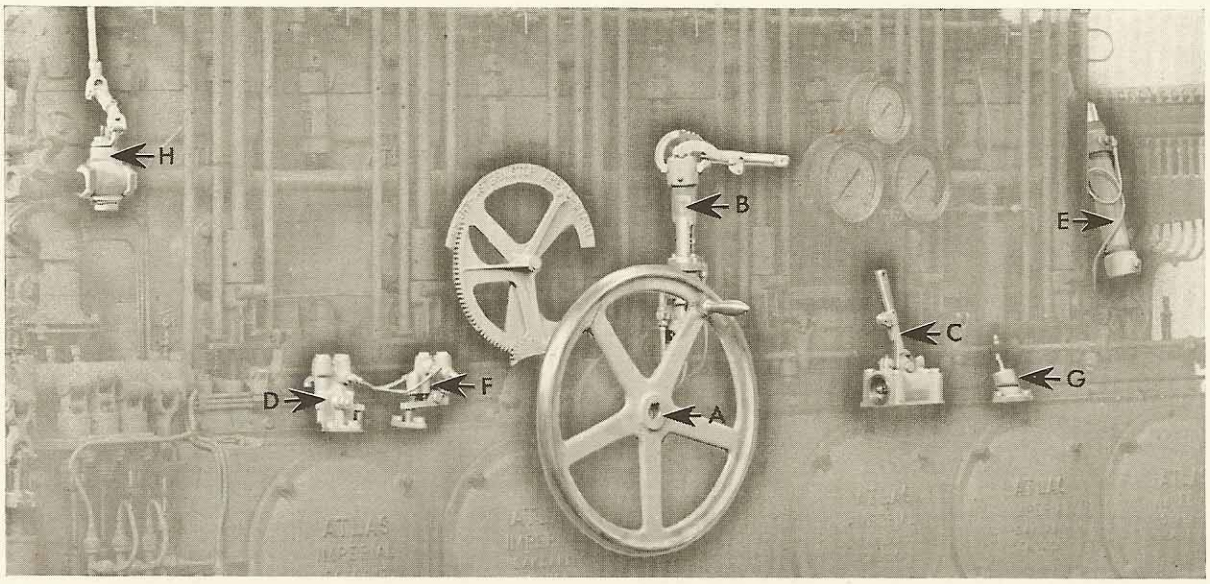


FIGURE 18-1

After the engine has gained speed on air, the hand wheel is turned back about 90 degrees until the spring loaded pawl on the latch box drops into the shallow hole in the back face of the hub plate of the wheel. This slight movement closes the pilot valve (F) which returns the air-start valves to their original position and closes the master air valve (H).

Once the engine has started, speed is controlled by the governor handle (C) and the fuel-pressure regulator handle (B). The fuel pressure should be increased gradually to full speed and should always be decreased when maneuvering to about 2000 pounds.

5. TO STOP THE ENGINE: Decrease the fuel pressure and return the governor control to the idling position and turn the hand wheel to the stop position. The first part of this movement will operate the fuel cut-out (G) and the latter part will open the pilot valve (D) which will supply air to the flywheel brake. If an immediate reverse is required, ALWAYS REMAIN IN THIS POSITION UNTIL THE ENGINE HAS STOPPED REVOLVING before attempting the reverse maneuver.

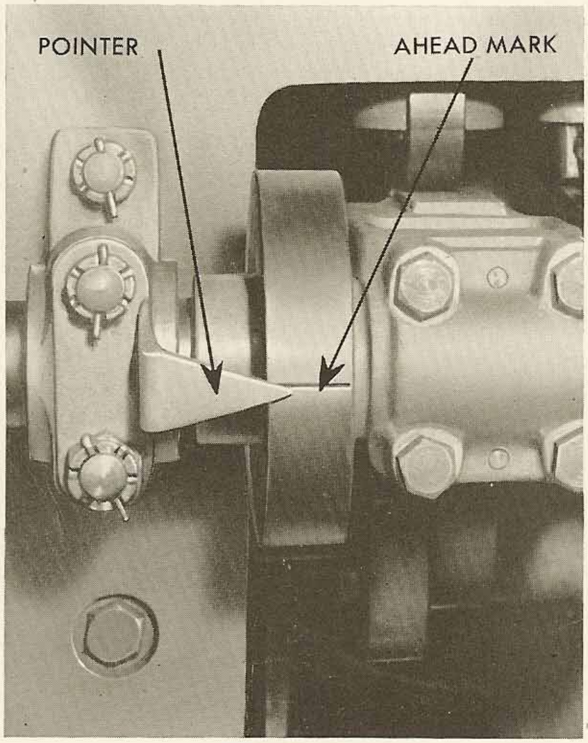


FIGURE 18-2

6. TO REVERSE THE ENGINE: All the operations for reversing the engine are the same as for going ahead except they are carried out in the astern positions.

7. ADJUSTMENT OF THE HAND WHEEL: If this assembly has been removed, the proper timing for replacement follows: Remove the No. 4 crank pit door. On the latch-shaft coupling between the No. 4 and No. 5 cylinders are scribed marks which come under a pointer shown in Figure 18-2. These marks are made after the correct position of the latch shaft is determined during manufacture.

Roll the latch shaft out (the ahead position) until the ahead mark comes directly under the pointer. Turn the hand wheel until the spring loaded pawl, attached to the latch box, lines up with a hole in the hub plate. Lower the wheel assembly into place, which meshes the gears. Screw in two or three of the cap screws which hold the assembly to the latch box. Turn the hand wheel into the reverse position and check the astern mark on the latch-shaft coupling with the pointer. Now see if the pawl has dropped into the reverse hole in the hub plate. If this hole does not come right when the pointer is on the mark, lift the assembly and turn the wheel until the other hole lines up with the pawl. (There are two holes in the hub plate.) After attaching the assembly, again turn the hand wheel ahead and check to see if the pawl drops into the hole when the ahead mark is under the pointer. When this adjustment is complete and with the hand wheel in the run-ahead position, attach the pointer stand with the pointer located between Ahead and Start.

8. PILOT VALVES: These two valves (D) and (F), Figure 18-1, are operated from cams on the latch shaft. They are in operation only when the engine is maneuvering and yet they must hold full air pressure all the time the engine is operating. Therefore, it is essential that they are kept in perfect condition so that the starting air will not be wasted. Fine grinding compound can be used to grind leaking pilot valves. The procedure is the same as for grinding any other valves in the engine. Absolute cleanliness is necessary during assembly, as the parts of these valves are very small and will stick if not cleaned thoroughly.

9. PILOT VALVE ADJUSTMENT: Figure 18-3 shows that each pilot valve is really two valves. One to admit air to the device the pilot valve is connected to, and the other valve to release the air when it has done its work. The air pressure is constantly on the head of the pressure valve (A), Figure 18-3. It will be seen that the passage (B) connects the chamber under the head of the pressure valve to the space above the head of the vent valve (C). As this valve is now open, the opening (D) is vented to the atmosphere through the passage (B), and the open vent valve (C). When the pressure valve is opened, the lever, working on the fulcrum shaft, closes the vent valve and the full air pressure is passed out of opening (D) and on to either the

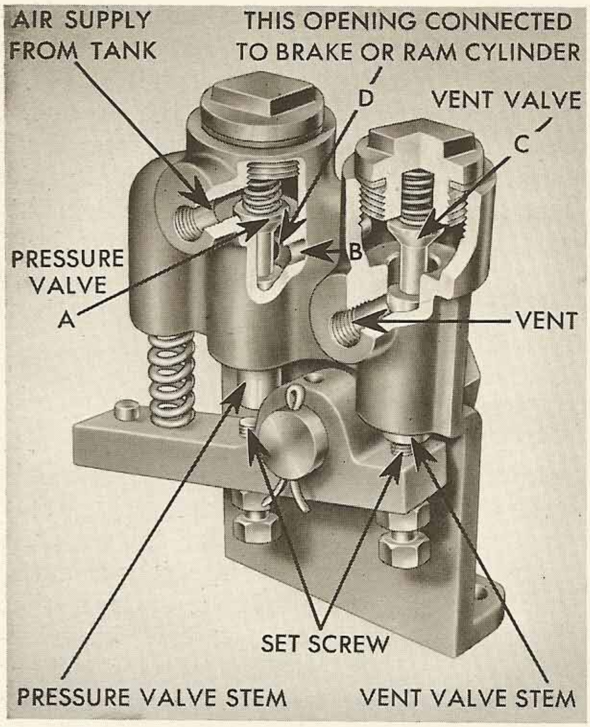


FIGURE 18-3

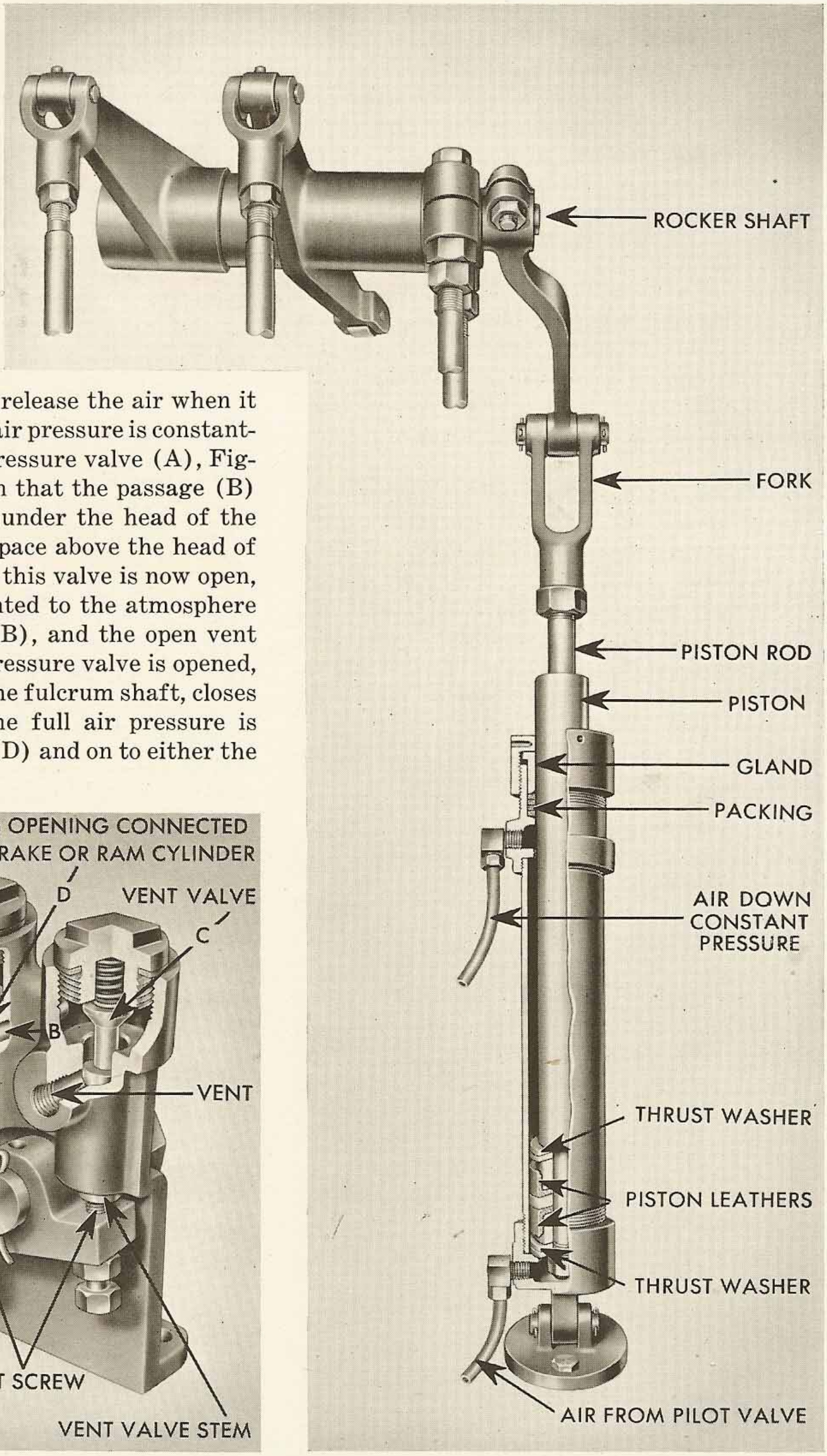


FIGURE 18-4

brake cylinder or the rocker-shaft ram, depending on which pilot valve we are considering.

The adjustment of the pressure valves in both pilot valves is made with the hand wheel in the run position. The clearance between the valve stem and the set screw in the lever (see Figure 18-3) is adjusted to 1/16 inch. The adjustment of the vent valve in the pilot valve (D), Figure 18-1, is made with the hand wheel in the stop position. The clearance between the valve stem and the set screw in the lever is 1/16 inch. The adjustment of the vent valve in the pilot valve (F), Figure 18-1, is made with the hand wheel in the start position, and the clearance between the valve stem and the set screw in the lever is 1/16 inch.

10. ROCKER-SHAFT RAM: The various parts of the ram are shown in Figure 18-4. The two piston leathers require replacing when they get very hard or scored. They can be softened somewhat by soaking in a neatsfoot type oil. The gland is packed with a well lubricated twist packing. Care should be taken that this packing is not drawn too tightly, or seizure of the piston may occur.

The travel of the piston is limited by contact of the thrust washers with the upper and lower cylinder heads and the total stroke should be 9⅝ inches. The position of the rocker-ram piston, relative to the rocker shafts, can be adjusted by lengthening or shortening the piston rod. This is done by screwing the fork on or off the rod. The rocker shaft position should be adjusted so that the forks connecting the various rocker shafts point straight up when the air-ram piston is down.

11. FLYWHEEL BRAKE: The various brake parts are shown in Figure 18-5. The leather should be replaced if it becomes hard or scored. All pins and rockers should be kept well lubricated. If oil, grease, or water is allowed to collect on the flywheel rim, the efficiency of the brake will be ruined and slow maneuvering will result.

12. THE MASTER AIR VALVE: Figure 18-6 shows the master air valve and the link-

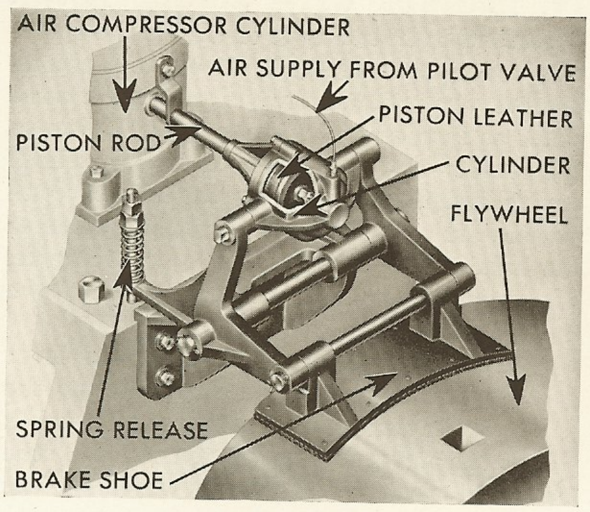


FIGURE 18-5

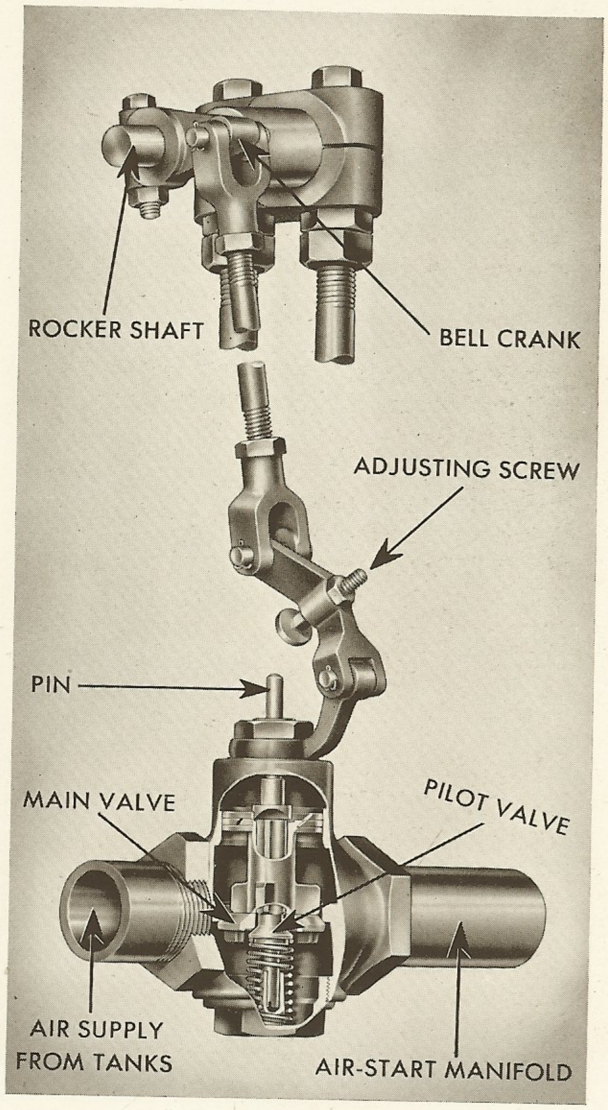


FIGURE 18-6

age which operates it by rotation of the rocker shaft. The valve may be ground with fine compound in the normal way. The linkage that connects this valve to the rocker shaft should be so adjusted that the valve is about $\frac{1}{2}$ inch open when the rocker-shaft ram is at the extreme length of its travel.

13. THE FUEL-PRESSURE REGULATOR: The care of this valve is covered in Section 16, paragraphs 1 to 7. The adjustment should give about 1000 pounds fuel pressure when the handle is in its lowest position.

14. THE GOVERNOR CONTROL HANDLE: The adjustment of this control and the care of the governor are covered in paragraph 28 of this section.

15. THE FUEL CUT-OUT: The fuel cut-out is shown in Figure 18-7. The adjustment of this control is made with the hand wheel in the run position. The clearance between the pawl that comes through the latch box and the adjusting screw in the wedge shaft arm should not be less than $\frac{1}{16}$ inch with the wedges full in.

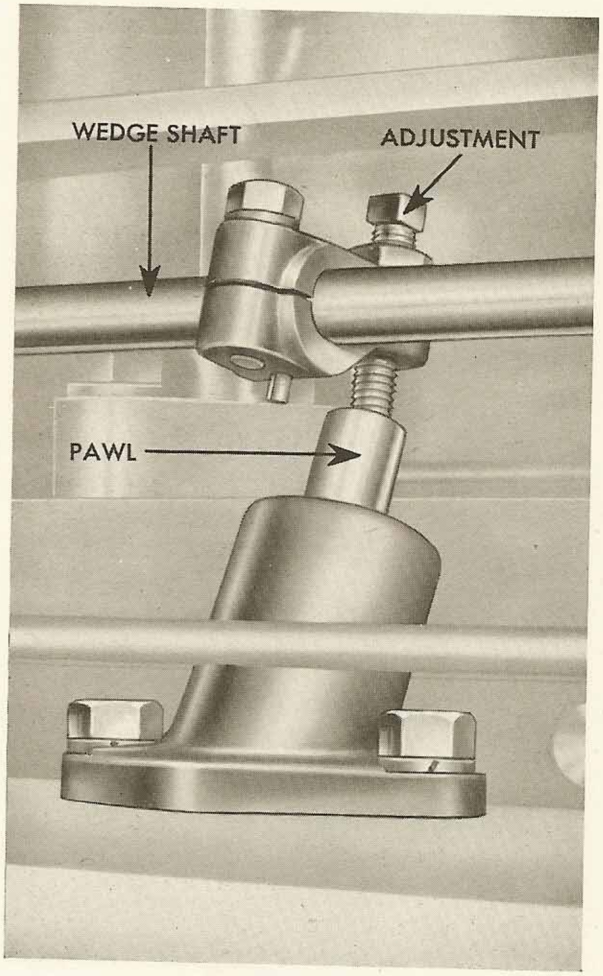


FIGURE 18-7

16. THE WEDGE SHAFT SPRING: The adjustment of this control is made with the hand wheel in the run position. The tension of the spring may be increased by rolling the clamp on the wedge shaft so that the spring will return the wedges to full speed position if they are pulled out by hand. This adjustment should be made with the flywheel at least 30 degrees from any top center. If the wedge shaft has been removed from the engine, be sure that it is turning freely in its bearings before adjusting the wedge shaft spring. Figure 18-8 is a close-up view of the spring and clamp.

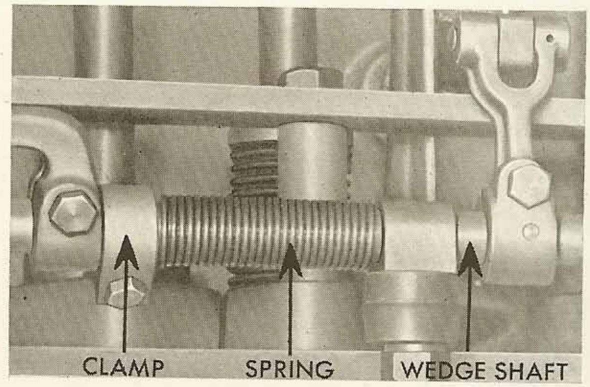


FIGURE 18-8

17. ENGINES WITH SINGLE LEVER CONTROL: In this type of engine the operation and maneuvering of the engine is accomplished by the same devices and in the same order as in the hand wheel engine. However, the control of these various devices has been centralized in one unit by the use of compressed air to shift the latch shaft instead of the hand wheel on the other type of engine. The single lever control is divided into two units.

1. The control box with its hand lever which operates the fuel cut-out, the brake and rocker-shaft ram pilot valve, the governor spring tension rod, the interlock and the valves which operate the latch-shaft ram.

2. The latch-shaft ram which is simply a double-ended air cylinder and piston connected to the latch shaft through a rack and gearing. Its purpose is to rotate the latch shaft from ahead to astern or back, by air pressure, which has been delivered by the control unit and lever at the proper time.

18. STARTING THE ENGINE BY SINGLE LEVER CONTROL: Refer to Figure 18-9, which shows the control lever with various positions marked off by numbers. As the lever is moved ahead to start the engine, the following events take place:

Position 1: The pilot valve to the flywheel brake is closed and the vent valve opened, which releases the flywheel brake. (This brake is on while the lever is in any position between No. 1 ahead and No. 1 astern.) At the same time the pilot valve controlling the latch-shaft ram starts to open, causing the ram to roll the latch shaft to the ahead position.

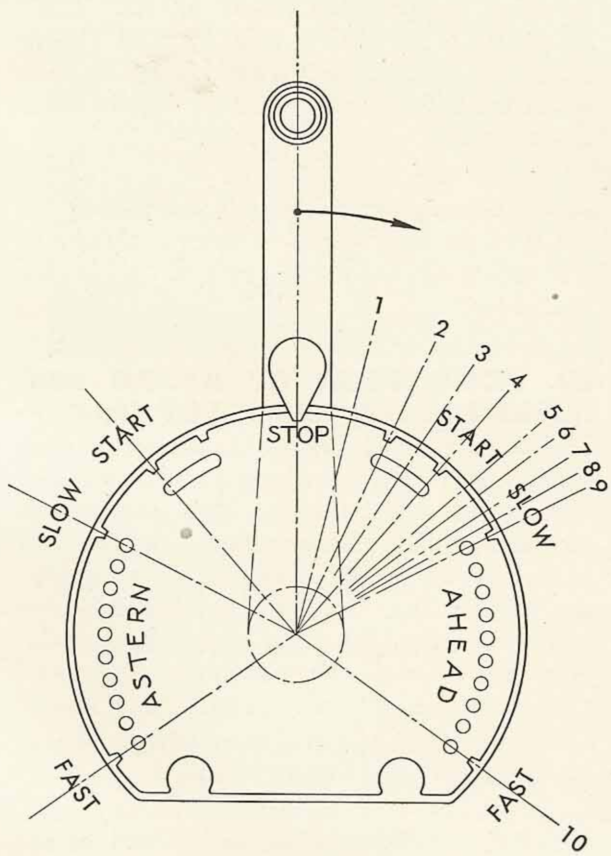


FIGURE 18-9

Position 2: The lever is held in this position until the latch shaft is located for ahead operation. This can be checked by the indicator pin on the turning hub of the ram, Figure 18-10.

Position 3: At this position there is a safety interlock mechanism which prevents the lever moving further ahead until the latch shaft is properly positioned.

Position 4: The pilot valve controlling the rocker-shaft ram opens here. This brings the air-start valves into action and also opens the master valve admitting air from the storage tank. The engine is now rotating on air in the ahead direction and when sufficient speed is attained, the lever should be moved through positions 5 and 6, 7 and 8 to 9, where the engine will be operating on fuel.

Position 5: The fuel cut-out is gradually released here so that fuel is admitted to the cylinders.

Position 6: The rocker-shaft ram pilot valve closes here, taking the air-starting valves out

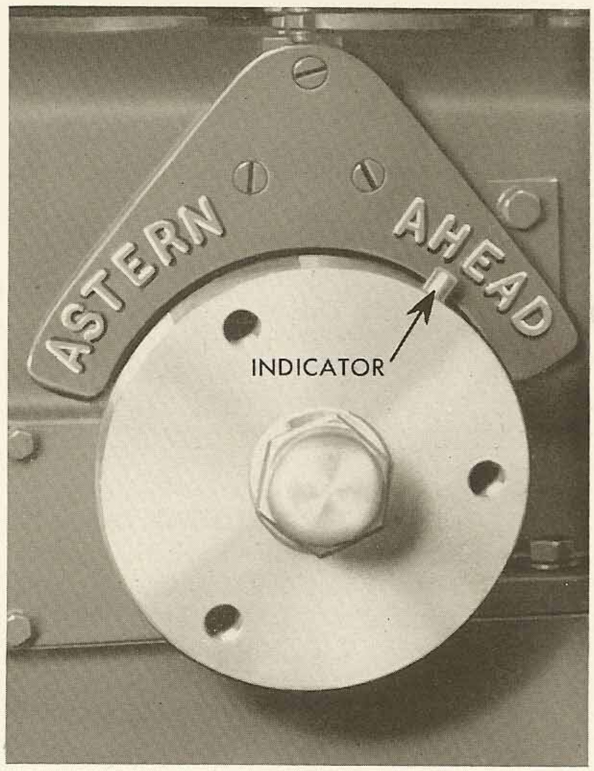


FIGURE 18-10

of action, also closing the master air valve. The engine is now revolving by momentum and is ready for fuel.

Position 7: The fuel cut-out is entirely released and the fuel wedges are under the control of the governor.

Position 8: This position closes the pilot valve to the latch-shaft ram and opens the vent valve, which unloads the air pressure in the ahead cylinder of the ram.

Position 9: This is the slow position for engine operation, at which point the engine will be adjusted to turn around 100 revolutions per minute.

Position 10: Each succeeding notch between positions 9 and 10 simply increases the tension on the governor spring, thereby causing the engine to turn faster.

19. CONTROLLING THE SPEED OF THE ENGINE: AS THE CONTROL LEVER IS ADVANCED, THE REVOLUTIONS PER MINUTE SHOULD BE COUNTED so that they do not exceed the rated speed of the engine. On some installations the revolutions will go far above the proper number if the lever is advanced to the last notch: EXAMPLE: A tow boat may have a propeller of a pitch and diameter that will permit the engine to turn 320 revolutions per minute, while moving very slowly through the water when towing a heavy barge. This same engine may turn 350 revolutions or more per minute, if opened up while the boat is running light, with no tow. ALWAYS KEEP YOUR ENGINE AT OR UNDER ITS RATED REVOLUTIONS.

20. STOPPING THE ENGINE: Lower the fuel regulator valve handle to the idling position. Move the control lever to the stop position. Refer to Figure 18-9. As the lever moves past position No. 7, the fuel cut-out starts to withdraw the fuel wedges. At No. 5 position, the wedges are out and no fuel is being supplied to the cylinders. At No. 1 position, the pilot valve controlling the flywheel brake opens and the brake is applied. NOTE: IF THE ENGINE IS TO BE IMMEDIATELY REVERSED, STAY IN THE STOP POSITION UNTIL THE ENGINE HAS STOPPED REVOLVING.

21. REVERSING THE ENGINE: All movements for reversing the engine are carried out in the same order for running astern as for running ahead, except that they are performed on the astern side of the control unit.

22. ADJUSTMENTS OF THE CONTROL MECHANISM: WARNING: DO NOT CHANGE THE ADJUSTMENTS IN THIS CONTROL UNIT UNTIL THE DEVICE UNDER CONTROL HAS BEEN THOROUGHLY CHECKED. Make sure the valves are not leaking; that no tubing or fittings are leaking; that the packing is not leaking or sticking, and that everything connected with the part to be adjusted is in working order. The various pilot valves in the control unit can be ground in the normal manner with fine grinding compound. GREAT CARE MUST BE TAKEN TO HAVE ALL PARTS THOROUGHLY CLEAN BEFORE ASSEMBLY, as much trouble can be caused by valves sticking or leaking.

If any new piping or tubing is installed in the air system, such pipes or tubing should be well blown out before the control unit is connected up.

23. ADJUSTMENT OF AHEAD AND ASTERN LATCH-RAM PILOT VALVES: The lever (C), Figure 18-11, is carried on a shaft which lies just above the shaft which carries the control handle. This latter shaft has cams which engage rollers that are held in the bottom part of lever (C), shown in Figure 18-12. This develops a reverse action which explains why valve (A), Figure 18-11, is opened when the lever is moved ahead and valve (B) is opened when the lever is moved astern. Lever (C) is held in a neutral position by the spring (D), Figure 18-11.

Reference to Figure 18-13 will show that the pilot valve is held on its seat by the spring

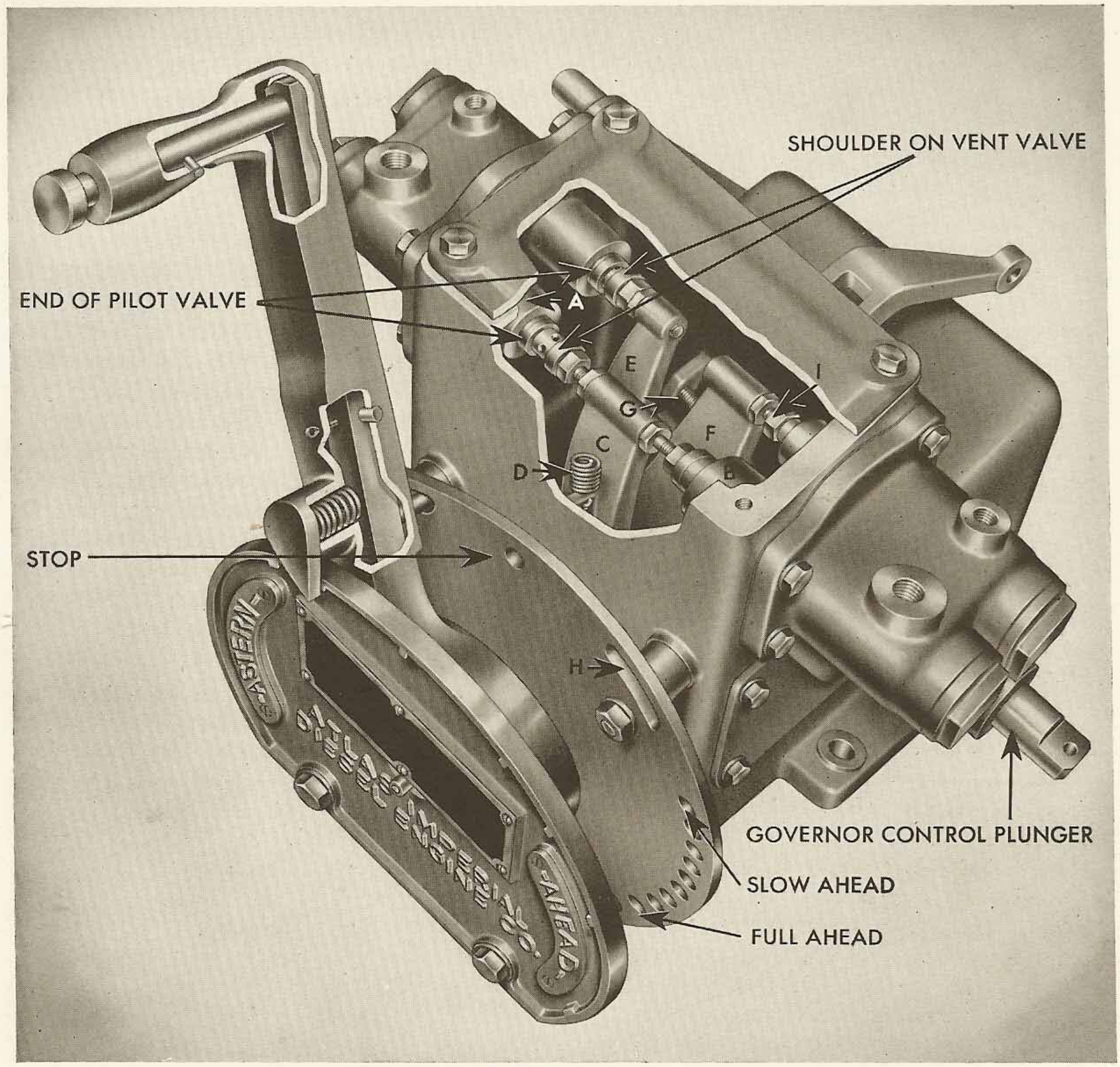


FIGURE 18-11

which fits over the head of the valve. The vent valve is held against the adjusting screw of lever (C), in Figure 18-11, by the vent valve spring. By turning the adjusting screws of lever (C), Figure 18-11, in or out, the vent valves will be moved in or out of the pilot valves. The operation of these valves is fully described in paragraph 32 of Section 5.

To adjust these screws, place the control lever in the stop position. Place the lever (C), Figure 18-12, in a vertical position by measuring the clearance between the rollers and their cam. The distance between each roller and the cam lobe must be equal. Set both adjusting screws of lever (C) so that the distance between the ends of the pilot valves (A) and (B) and the shoulders on the vent valves, which are shown in Figure 18-11, is exactly $\frac{7}{32}$ inch. The total movement of lever (C), each side of neutral, is $\frac{3}{8}$ inch. It requires $\frac{7}{32}$ inch travel to close the vent valve, which leaves $\frac{5}{32}$ inch of travel to open the pilot valve.

24. ADJUSTMENT OF THE BRAKE PILOT VALVE: The flywheel brake is actuated by a single-acting air piston and is released by a spring. Only one pilot valve, therefore, is necessary to admit and vent the air to the cylinder. Lever (E), Figure 18-11, con-

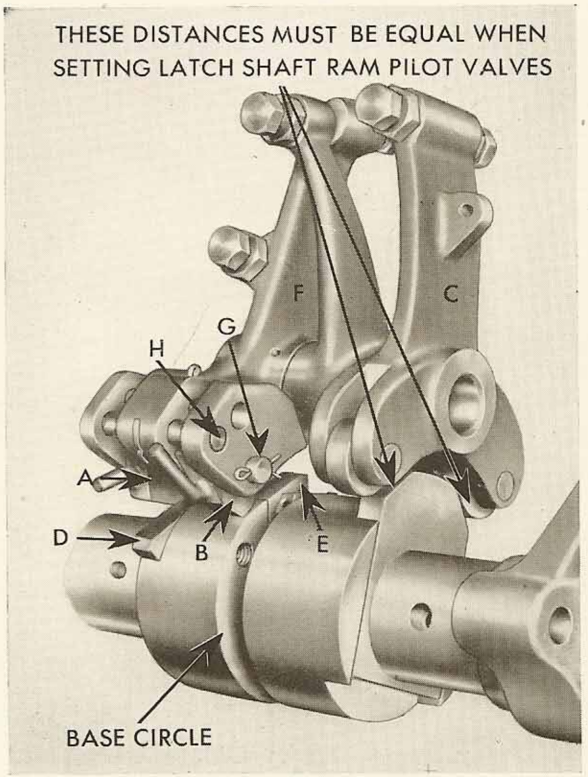


FIGURE 18-12

trols this valve, which is identical with the other pilot valves of the unit. Place the control lever in any of the running positions and set the adjusting screw in lever (E), Figure 18-11, so that the end of the pilot valve is 7/32 inch from the shoulder on the head of the vent valve.

25. ADJUSTMENT OF THE ROCKER-SHAFT AIR RAM PILOT VALVE: Lever (F), Figure 18-11, should first be located in a position half way between the cams which operate it for ahead and astern. There is an adjustment screw (G), Figure 18-11, on this lever which rests against a boss extending out from the side of the control housing. Move the control lever toward ahead starting position. At the exact point where lever (F) STARTS TO MOVE, scribe a line on the face plate of the control unit directly under the pointer on the handle.

Move the control lever toward the astern starting position and again scribe a line on the face

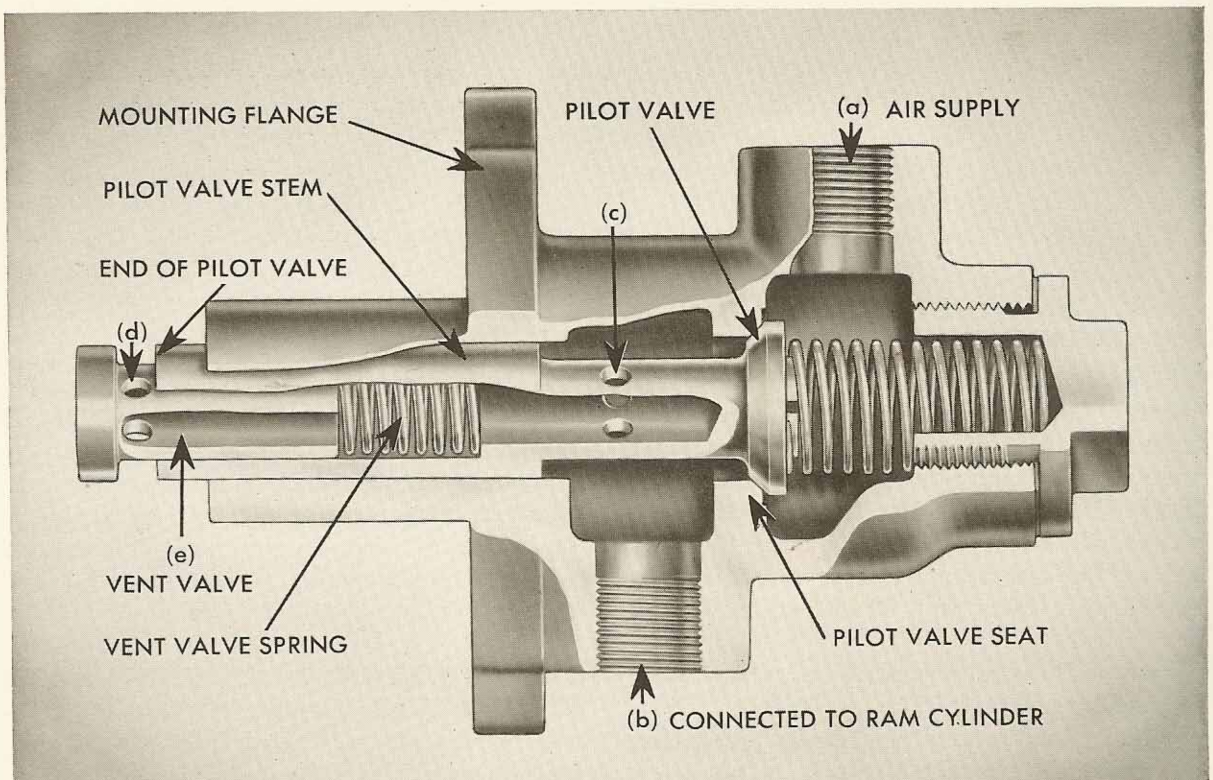


FIGURE 18-13

plate at the exact point where lever (F) starts to move. Measure the distance from the stop mark on the face plate to each one of the scribe marks. By adjusting the screw (G), Figure 18-11, the lever can be so positioned that these measurements will be alike. Be sure to tighten the lock nut when this adjustment is complete.

Place the control lever half way in the air starting slot (H), Figure 18-11. With the control lever held in this position, set the adjusting screw (I), Figure 18-11, so that the shoulder on the vent valve is just touching the end of the pilot valve.

Move the control lever half way down the astern starting slot and check to see if the vent valve is just touching the pilot valve. If the astern opening of the valve is slightly off, readjustment of the lever in its central position will average out any wear in the unit and start the valve opening in exactly the same place in either the ahead or astern starting slots.

Reference to Figure 18-12 will show two pawls (A) and (B) which engage the two cam lobes (D) and (E). The two pawls act as ratchets in the following manner: Pawl (B) is hinged on pin (G) and is stopped against pin (H). In this illustration the control lever is in the stop position. Assume that the control lever is moved to the left, toward the astern starting slot. At position (4), Figure 18-9, the pawl (B) will have climbed the lobe (E), thereby moving the lever (F) and opening the pilot valve which controls the rocker-shaft ram.

At position (6), Figure 18-9, the pawl will drop off the end of the lobe, closing the pilot valve. During any further movement of the control lever to the left, the pawl will ride on the base circle of the cam. When the control lever is moved back to the stop position from the run astern position, the pawl (B) comes against the steep side of the lobe (E). The short lever extending out from pawl (B) is attached to the housing by a light spring. This spring allows the pawl to flip over the cam lobe without moving the lever. This explains how the control lever can be brought from run position to the stop position without opening the rocker-shaft ram pilot valve.

The pawl (A) and the lobe (D) operate in just the opposite manner to open the pilot valve in the go ahead position. The two small springs can be inspected through the cover plate on the left side of the control unit.

26. LATCH-SHAFT INTERLOCK: The latch shaft must be in either the ahead or astern position before starting air is supplied to the engine. To safeguard this maneuver, an interlock is provided which makes a mistake impossible. This interlock also "freezes" the latch shaft in whichever position corresponds to the direction the engine is turning. It is controlled from the single lever control unit through the two gears shown in Figure 18-14. If these gears are removed they should be carefully marked so that they may be assembled in their correct position. Gear (A) is on the control lever shaft while gear (B) is on the cross shaft which operates the interlock.

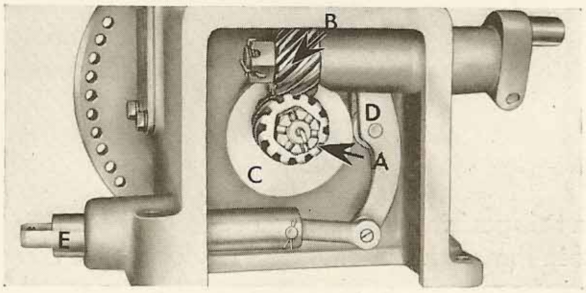


FIGURE 18-14

The two plungers, shown in Figure 18-15, are located one ahead of the other in a fore and aft direction. Each plunger is directly over adjacent flanges on the latch shaft. Plunger (A) and notch (C) mate for the ahead position while plunger (B) and the dotted notch (D), which is on the next latch-shaft flange, mate for the astern position.

27. OPERATION OF THE INTERLOCK: In Figure 18-15, the latch shaft is in the ahead position and the control lever in the stop position. Both plungers are withdrawn clear of their respective flanges. We will assume that the operator is starting the engine ahead. The control lever is moved ahead to (A), Figure 18-16. In this position the latch-shaft ram pilot valve is opened to shift the latch shaft to the forward position. The shaft is already

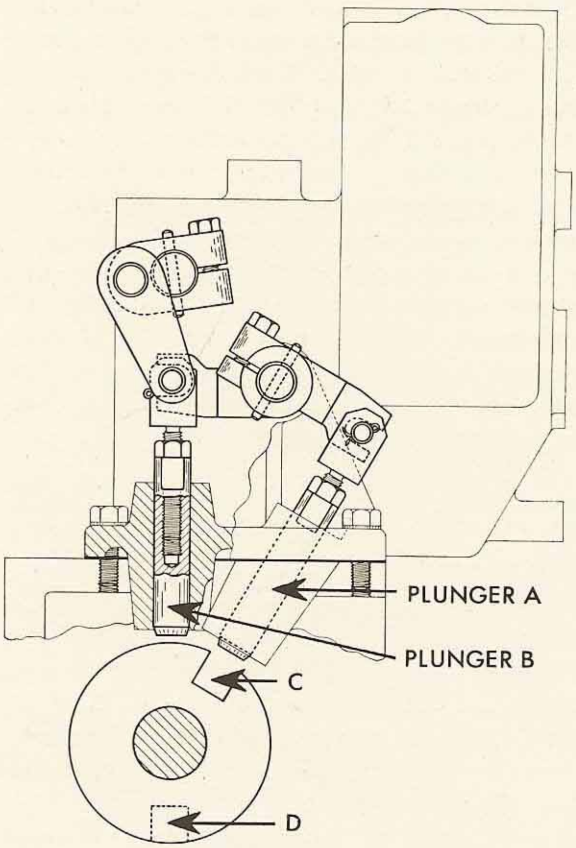


FIGURE 18-15

in this position so the notch (C), Figure 18-15, is in line with the plunger (A). The lever can now be moved to (B), Figure 18-16, where the starting air is supplied. After the engine has gained starting momentum on air, the lever is moved to (C) or other run ahead positions.

We now assume that the engine is to be reversed. The lever is shifted to the stop position, which withdraws the plunger (A) from the notch (C), Figure 18-15. After waiting in this position for the engine to stop turning, the lever is moved to (E), Figure 18-16. The latch-shaft ram pilot valve now opens to rotate the latch shaft to the astern position. Further movement of the control lever forces down plunger (B), Figure 18-15. It is apparent that this plunger cannot move down until the latch shaft has turned sufficiently to bring notch (D) directly under the plunger (B). In Figure 18-15, notch (D) is 180 degrees or one half turn out from mating with plunger B, and it is this half turn which is required to shift the latches from the ahead to the astern position. As soon as this latch shaft rotation is completed, the plunger (B) mates with the notch (D), and the control lever can be moved to (F), Figure 18-16, where starting air is supplied.

CAUTION: It should be understood that this interlock stop is primarily a safety device to prevent starting the engine before completion of the latch shaft shift, and it should not be abused by deliberately jamming the lever over against it, as this will result in excessive wear throughout the mechanism, if not, in damaged and broken parts. Normally the latch shaft will shift almost immediately upon opening the pilot valve, and it will be possible to move the control handle right along to the air start position, with only a slight pause at (A) or (E), Figure 18-16. During this pause, while the latch shaft is shifting, the control handle should not be moved past (A) or (E), or the plungers will be forced against the webs, causing wear and possible damage.

28. GOVERNOR CONTROL: As the control lever is moved toward either full speed ahead or astern, the cam (C), Figure 18-14, acts on the roller in lever (D). As this lever is pivoted

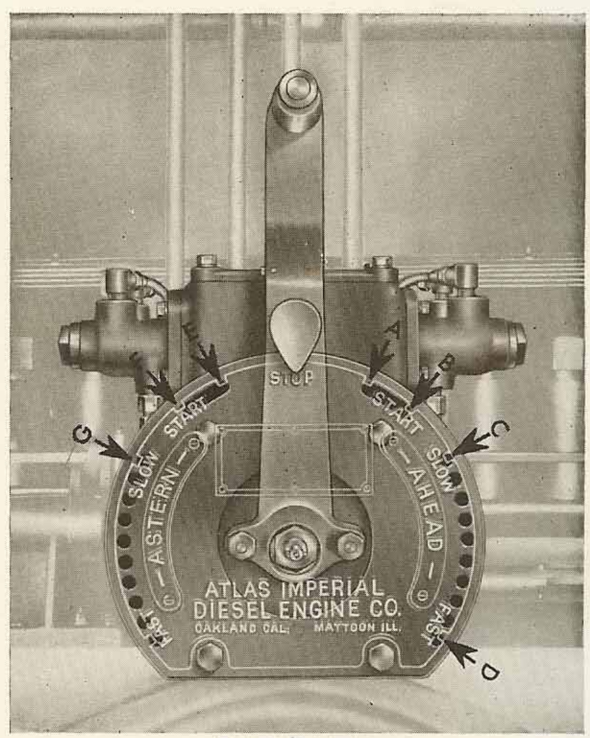


FIGURE 18-16

at the top end, the plunger (E) is pulled in each time the lever rides up on the lobe of the cam. This movement is transmitted through the linkage, shown in Figure 4-12, to the governor spring. In this illustration, the movement is supplied by the governor control handle, while on engines having single lever control, the rod is connected to the plunger (E), Figure 18-14.

29. SETTING SPEED RANGE: The speed range between fast and slow, on the control lever, can be altered by changing the amount of lever travel which is transmitted to the governor spring. On top of the vertical shaft (A), Figure 18-17, which applies governor spring pressure, there is a short horizontal lever (B), to which is attached the rod from plunger (E), Figure 18-14 or Figure 18-17.

In the end of this lever is a threaded sleeve (C). Screwing this sleeve in, increases the effect of the control lever movement on the governor spring. This means that there will be a greater number of revolutions difference between fast and slow.

Screwing the sleeve out, decreases the effect on the governor spring, which means that there will be a lesser number of revolutions difference between fast and slow.

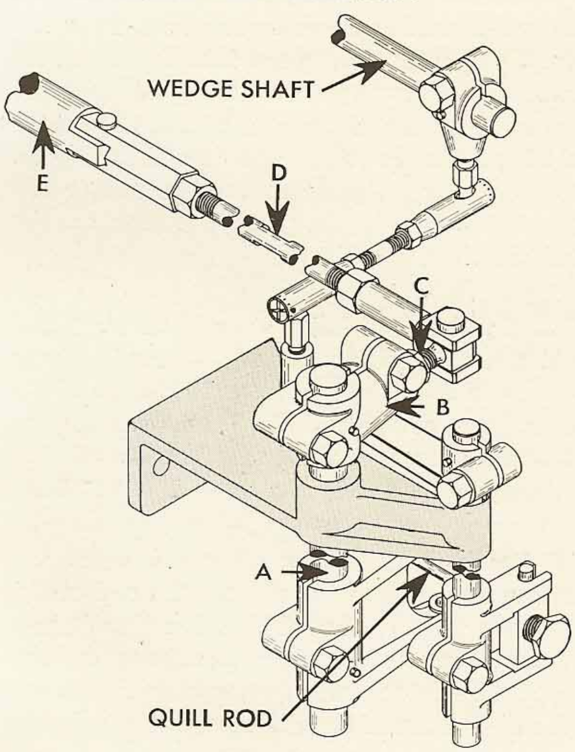


FIGURE 18-17

30. SETTING FULL SPEED ADJUSTMENT: The rod (D), which connects plunger (E), Figure 18-17, to the governor control linkage, has right and left hand threads and by turning, can be lengthened or shortened. Shortening the rod will apply more pressure to the governor spring for the same control lever position. This means that the engine will turn faster before the governor weights can move out, from centrifugal force, and act on the wedge shaft, through the quill rod and linkage.

Lengthening the rod will exert less pressure on the governor spring for the same control lever position. Therefore, less revolutions per minute will be required to move the governor weights out and withdraw the fuel wedges, through the quill rod, linkage and wedge shaft.

The wedge shaft spring (see Figure 18-8) is primarily for the purpose of taking up the lost motion in the linkage, but since it acts in the same direction as the governor spring, and is considerably lighter, it serves well as a governor spring during idling, and is so used. The idling speed may be varied by adjusting the clamp holding this spring to the wedge shaft, thus changing the tension on the spring. It should be set at from 100 to 120 revolutions per minute with the control lever at slow. This is usually obtained by tightening the clamp and spring about one half turn from its free position. This adjustment must be made in such a way that the effect of the wedge shaft spring will force the wedges to full speed position.

31. AUXILIARY SPRING: There is another spring acting on the wedge shaft. It is mounted on a stud on the centerframe and bears against a lever clamped on the wedge shaft. It serves as a buffer spring to prevent over-regulation by the governor when the propeller is thrown clear of the water in rough seas. It does not enter into the normal governoring of the engine. The adjusting nuts on the mounting stud should be set so that the upper spring washer just touches the lower nut when the engine is at slow.

32. FUEL CUT-OUT: The fuel wedges must be in the "out" position when the control lever is at stop. They must also be held out while the engine is revolving on air during the starting period. When the control lever is moved to either the ahead or astern running positions the wedges must be released to the control of the governor.

On the control lever shaft there is a cam (see Figure 18-18) so positioned that it lifts a plunger when the control lever is anywhere between the ahead or astern air-start positions. Lever (A) is pivoted on the fulcrum fixture (B) which is bolted to the top of the control housing. On the wedge shaft, lever (C) is clamped firmly while lever (D) is free to revolve.

In Figure 18-18, the cam has raised the plunger, and lever (D) has turned the wedge shaft by coming against the prong on lever (C). When the control lever is moved into either run position, the plunger will drop off the lobe of the cam and lever (D) will back away from the prong on lever (C), leaving the wedge shaft in control of the governor.

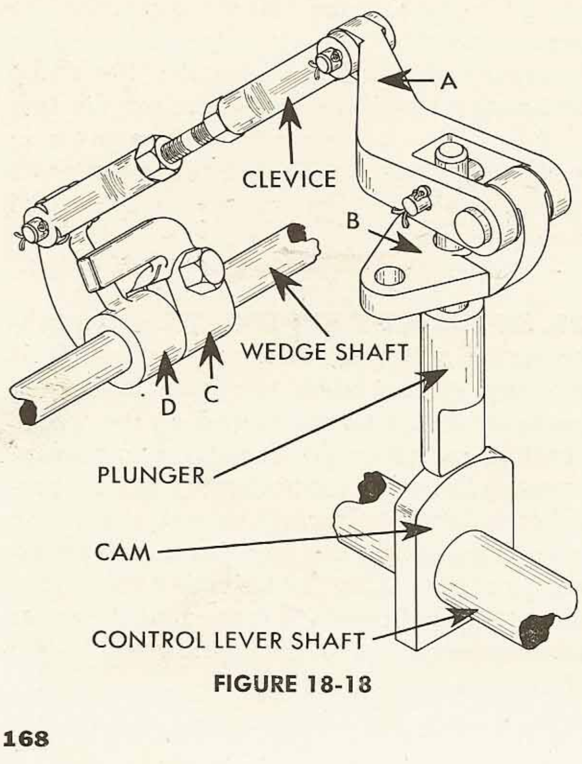


FIGURE 18-18

33. ADJUSTMENT OF FUEL CUT-OUT: With the engine operating in the slow or idling position, the clearance between lever (D), Figure 18-18, and the prong on lever (C) should be set at $\frac{1}{32}$ inch. This can be done by turning the clevice on or off the rod, which will lengthen or shorten the linkage.

34. OPERATION OF LATCH-SHAFT RAM: This ram, shown in Figure 18-19, is used to rotate the latch shaft and is operated by compressed air delivered by the single lever control unit. As explained in paragraph 32 of Section 5, the two pilot valves which control the ram are so arranged that when one valve is supplying air to one end of the cylinder, the other valve is venting the opposite end. The capacity of the vent valve is such that it allows the piston to travel rapidly from one end of the cylinder to the other.

However, some means of checking this rapid motion, at each end of travel, must be used. Figure 18-20 shows that the piston rod is enlarged each side of the piston leathers.

Inside of the cylinder head proper is a plate which almost closes off an area in the head of the cylinder. The air and vent tube, from the single lever control, opens into this area. As the piston is moving toward this plate, the displaced air passes through a hole in the center of the plate and out the vent line. Near the end of the stroke, the collar on the piston rod enters the hole in the plate and seals off the end area.

The air, ahead of the piston, is now trapped and can only escape through a small bleeder valve which is screwed into the plate and extends through the cylinder head. There is one of these valves at the end of each cylinder, although only one is shown in Figure 18-20.

35. CHECK VALVES: When it is necessary to move the piston to the opposite end of the cylinder, air must be admitted so that it acts on the full area of the piston. As the air supply, from the control unit, first enters the closed area at the end of the cylinder, it can only act on the end of the piston rod and collar. Check

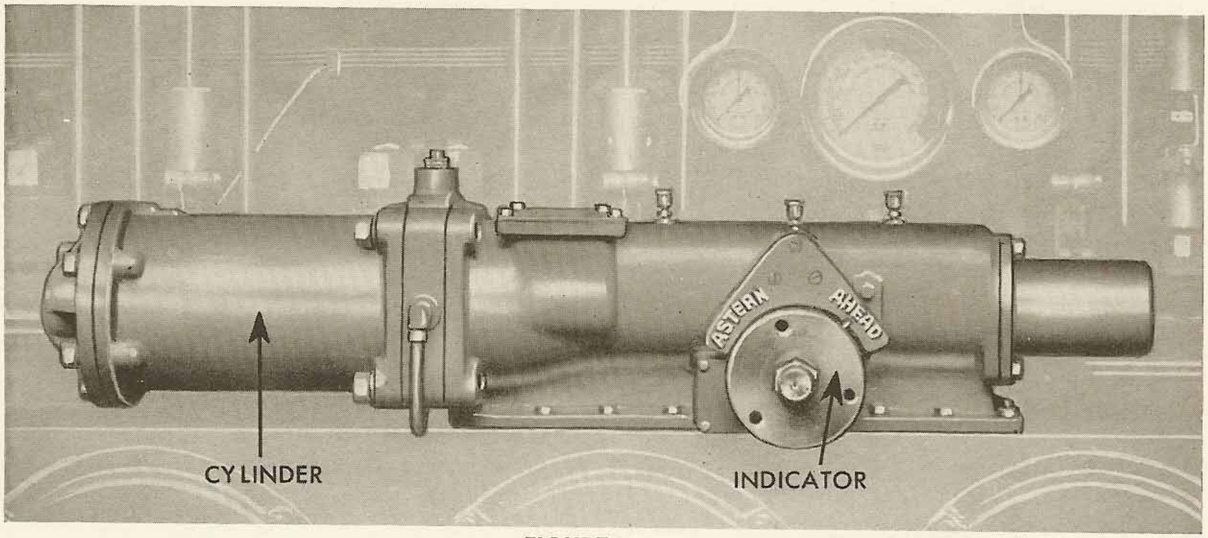


FIGURE 18-19

valves are installed in such a way that they pass air through the plate and into the cylinder proper, during the early portion of the stroke, while the passage between the closed area and the cylinder is sealed off by the collar on the piston rod.

36. ADJUSTMENT OF BLEEDER VALVES: Unscrew the plug in the cylinder head and the bleeder valve can be adjusted. It is simply a small needle valve which, when screwed in or out, controls the amount of air released. Screw it out or counter-clockwise to release air faster and in to retard the release of air. The setting of these valves should be such that there is no hard metallic knock in the cylinder head when the ram is operated.

37. PISTON LEATHERS: These can be removed by removing the cylinder head. Take off the big nut on the end of the piston rod and the leathers and the piston plate and followers will pull off. When installing the new leathers, be sure that they face each end of the cylinder. The piston rod is packed with four rings of well graphited $3/8$ inch square packing.

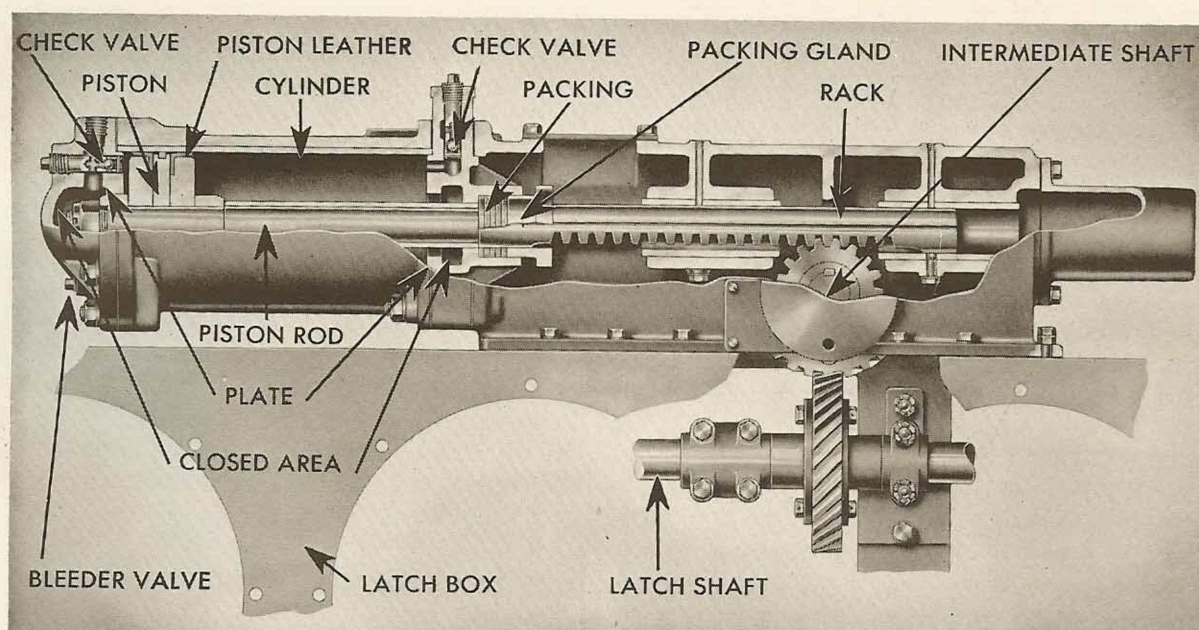


FIGURE 18-20

SECTION 19
LATCH SHAFT AND LATCHES
CAMSHAFT AND CAMS

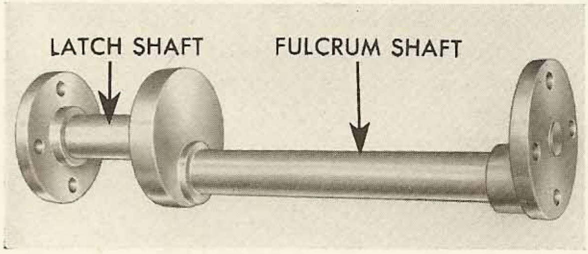


FIGURE 19-1

1. LATCH SHAFT — General: The latch shaft is made up of sections like the one shown in Figure 19-1. These are bolted together and supported on bearings, extending out from the centerframe. The latch shaft journals and the fulcrum journals are lubricated by oil sprayed from a small manifold that lies in the corner of the latch box. For this reason, it is important that the latches and bearings are thoroughly washed off each time the base is cleaned. The movement of the shaft and the latches is so slight that these parts seldom, if ever, require servicing. Keep all bolts and cap screws tight and properly secured.

2. LATCHES: The exhaust latch, shown in Figure 19-2, is identical with the inlet latch except that the position of the rollers is reversed. The fuel latch is lighter in weight and has the rollers placed in line, while the air-start latch has its rollers staggered. The complete latch assembly for one cylinder is shown in Figure 19-2. When removing the latches, care should be taken not to mix the caps or turn them on the latch when assembling.

3. RENEWAL OF LATCH ROLLERS AND PINS: Should any of the latch rollers become worn or the pins loose, they are easily replaced as follows: Remove the latch and center punch the exact center of the pin. Using a drill larger than the pin, drill in just far enough to remove the reriveted head of the pin. Select a piece of shim metal thick enough to take up the slack between the roller and the inner face of the latch. This is used to prevent the side of the latch being bent when the pin is driven out. When the new roller and pin are in place, insert the shim metal again and rerivet both ends of the pin. Remove the shim and make sure that the roller is free on the pin. Use new locking wire when installing the latch on the engine.

4. CAMSHAFT: The camshaft is made of two-inch ground steel shafting. The cams are so arranged that the firing order will be the same as stamped on the engine name plate. This firing sequence is always given for an engine in the ahead position and the cylinder at the forward end is always No. 1 cylinder. The high-pressure fuel pump crankshaft is an extension of the after end of the camshaft.

5. LUBRICATION: The forward and after bearings are oiled by the engine pressure system and drilled passages lead from the after bearing to the crankpin of the high-pressure fuel pump. All intermediate camshaft bearings are lubricated by splash and vapor in the crank case. For this reason, it is important that the camshaft and its bearings are THOROUGHLY CLEANED each time the base is washed out.

6. DISASSEMBLY: The removal of the camshaft and the renewal of cams or bearings is a major undertaking. Such work should be done only at a base or service depot, where skilled mechanics and proper equipment are available. The following instructions are given to assist anyone doing this job.

7. CAMSHAFT REMOVAL:

(a) Disconnect the linkage between the governor and the wedge shaft, and disconnect the lubricator strap and the pump connecting rods on the forward end of the camshaft.

(b) Remove the engine control parts, the latch-shaft interlock (on lever controlled engines), and the pilot valves from the top of the latch box.

(c) Remove the latch box.

(d) Remove the latch shaft and latches.

(e) Disconnect all the pushrods at their upper ends and remove them.

(f) Pull the lifters upward and away from the cams and secure them in this raised position with a hose clamp or some other suitable device.

(g) Remove the rotary pump housing together with the three pumps.

(h) Disconnect the fuel lines from the high-pressure fuel pump and remove the pump housing assembly.

(i) Remove the bearing caps of the high-pressure fuel pump connecting rods and remove the crosshead plugs, oil guards, sleeves and guides.

(j) Take out the cam bearing retaining capscrews.

(k) Loosen the cylinder nuts on the camshaft side of the engine.

(l) Remove the camshaft. Sledge each bearing block out of its seat a little at a time using a timber inserted through the openings on the exhaust manifold side. The end of the timber should be placed against the camshaft as close to the bearing as possible. When the

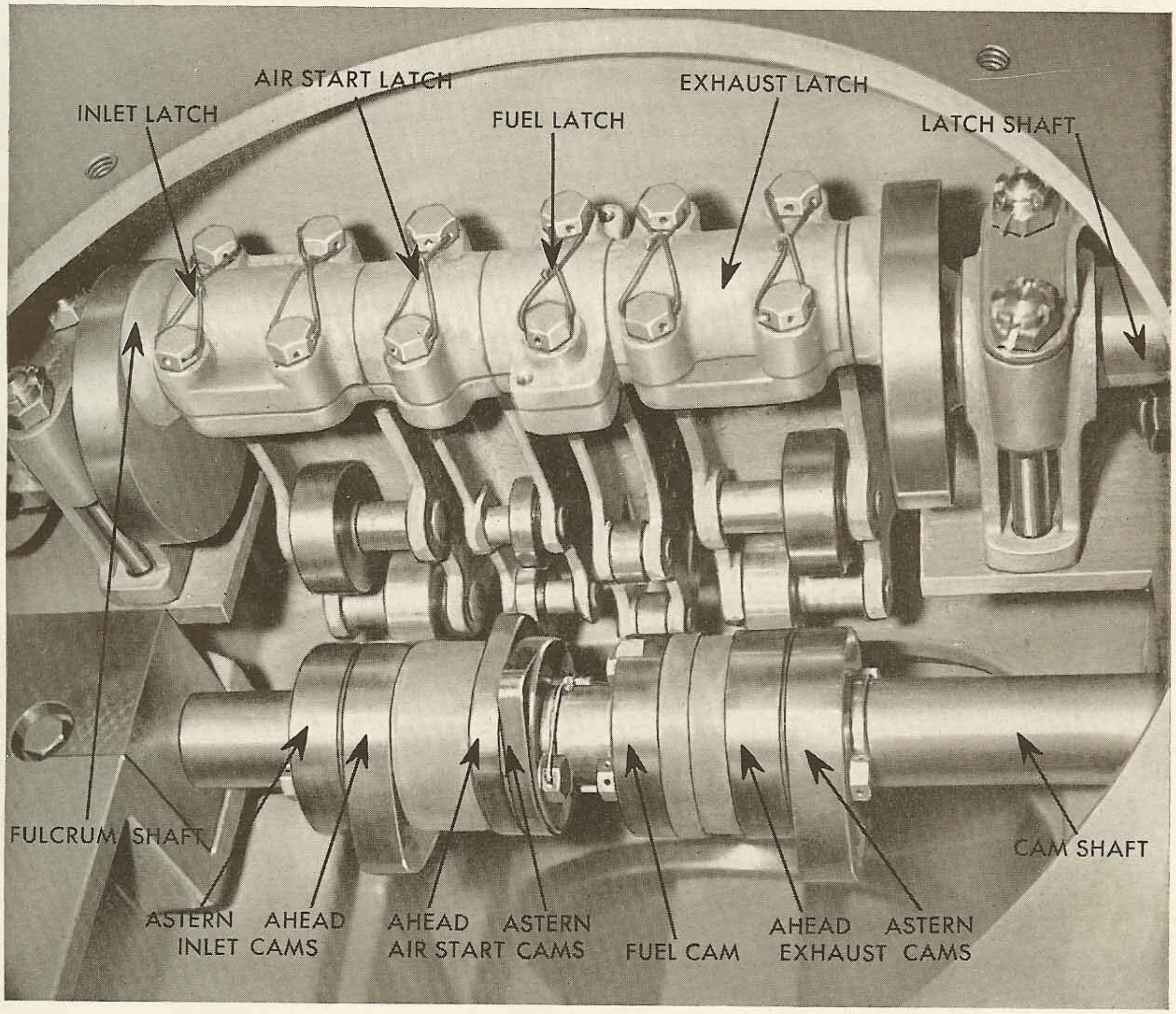


FIGURE 19-2

camshaft has been partially removed it will be possible to withdraw the connecting rods and crossheads of the fuel pump, downward.

8. CAMSHAFT DISASSEMBLY: After the camshaft has been removed from the engine, it should be disassembled as follows: The bilge-pump crank is removed either by a suitable puller or by driving with a babbitt hammer. Then, after removing the first cam bearing, the clamping bolts of the camshaft-gear hub are loosened and the whole assembly slid off. Bearings and cams are then removed successively from the forward end of the camshaft. The cam keys are loosened by driving FORWARD with a drift. The cams should slide on the shaft freely after the keys have been removed, but if it should be necessary to drive them off, only a babbitt hammer or brass drift should be used. Any burrs, particularly at keyways, must be dressed down with a file. If this precaution is not taken, the cams may seize as they are removed and forcing the cams, the remainder of the distance, will score the shaft.

9. CAMSHAFT ASSEMBLY AND INSTALLATION: When the camshaft is being reassembled, the same precautions with regard to burrs apply. Coating the bores of the cams with white lead will aid materially in sliding the cams into place without scratching the shaft. The bores of either new or old cams should be inspected carefully for any defects likely to scratch the shaft. Bearings and cams are installed successively from the forward end but are not keyed to the shaft until later. The hub and cam gear are assembled on the shaft and clamped tightly. The camshaft gear should be located with its forward face 6¼ inches from the end of the shaft.

The assembled camshaft is then installed in the engine. After starting each cam bearing in its seat, the bearings are driven into place a little at a time with a heavy brass bar. Each bearing should be driven a little and then left until all the others have been knocked in the same amount so that the camshaft will not be bent. The cam bearings will seat more easily if the cylinder nuts are loose.

The connecting rods and crossheads of the high-pressure fuel pump must be assembled as the camshaft is being driven into place. The crossheads should be inserted in the holes in the centerframe before the camshaft has been driven in any appreciable distance. When the camshaft has been partially installed, it will be possible to place the connecting rods on their respective cranks. After this last step, the connecting rods and crossheads need no further attention as the cam bearings are being seated.

After the cam bearings have been securely bolted, the latch shaft and latches should be installed. The cams are then ready for keying. Starting with No. 6 (flywheel end) cylinder, place each set of cams directly under the proper latch rollers and secure the cams to the shaft by inserting the taper keys. The keys should be driven toward the AFTER end of the engine to tighten. The large end of the key should be FORWARD of the cam.

The engine should next be timed, in accordance with the detailed instructions in paragraphs 13, 14, and 15, after which the latch box and control parts may be reassembled on the engine. For Fuel Spray Valve timing see Section 10.

10. VALVE TIMING: The correct valve timing for the engine is given in the following table.

Air-start valve opens five degrees before top center.

Air-start valve closes 45 degrees before bottom center.

Inlet valve opens ten degrees before top center.

Inlet valve closes 35 degrees after bottom center.

Exhaust valve opens 35 degrees before bottom center.

Exhaust valve closes five degrees after top center.

Fuel spray valve opens—See engine name plate.

Fuel spray valve closes—See engine name plate.

11. FLYWHEEL MARKINGS: The position of the piston may be determined from the flywheel pointer and the markings stamped on the flywheel rim. Top center of each piston is marked and stamped with the corresponding piston numbers, and degree marks are stamped for 25 degrees on each side of top center.These markings are sufficient for all valve timings. The intake valves normally open ten degrees before top center and the exhaust valves close five degrees after top center, and these points can, of course, be determined directly from the degree markings adjacent to the top center marking of the corresponding cylinder. The intake valves normally close 35 degrees after bottom center and the exhaust valves open 35 degrees before bottom center. These points may be obtained on the flywheel as follows:

Since the crankshaft has three throws, 120 degrees apart, the top centers of the three pairs of cylinders will be 120 degrees apart. Bottom center of any pair of cylinders is 180 degrees from top center. Therefore, the bottom center of any pair of cylinders is 60 degrees from the top centers of the other two pairs. As previously stated, each top center is marked for 25 degrees in either direction. Subtracting this 25 degrees from the above 60 degrees leaves 35 degrees. Hence, each 25 degrees after top center point is also 35 degrees before bottom center point for the preceding pair of cylinders and similarly, each 25 degrees before top center point is also the 35 degrees after bottom center point for the following pair of cylinders.

12. POINTER LOCATION: The location of the flywheel pointer should be checked occasionally by "splitting the center." With one of the cyinder heads removed, crank the engine to a point about 20 degrees off top center. Measure the exact distance from the top of the liner down to the piston and observe the pointer reading on the flywheel. Then set the piston to the same distance below the top of the liner on the other side of top center and observe the flywheel pointer reading. If the readings do not agree, adjust the pointer to give equal readings on each side. These readings should preferably be taken with an indicator and in each case the piston should be cranked upward into position.

13. CAMSHAFT TIMING: In order to time the engine it is necessary to determine the correct relation between the crankshaft and camshaft, which is done by positioning the camshaft gear on its hub, and then to adjust the pushrods to open and close the valves at the correct points. Unless the crankshaft gear, camshaft gear or camshaft gear hub have been replaced, the camshaft can be correctly timed after overhauling as follows:

Before breaking the gear train spot No. 1 piston exactly on firing top center. With a steel scale bearing firmly against the machined side of the centerframe, scribe a line across the side of the camshaft gear, parallel to the centerframe face. When reassembling, mesh the gears with the crankshaft and camshaft in the same relative positions, that is, with the No. 1 piston on firing top center and the line on the camshaft gear in line with the centerframe face.

If the crankshaft gear, camshaft gear or the camshaft gear hub is replaced, the camshaft may be timed as follows:

(a) Spot No. 1 piston 2½ degrees before top center in the AHEAD direction.

(b) Set the camshaft gear relative to its hub so that clamping bolts are approximately in the center of the slots. Position the camshaft gear so that the old dowel holes will not interfere with redoweling.

(c) Turn the latch shaft to the AHEAD position (latches out).

(d) Turn the camshaft (with the intermediate gear out of mesh) so that the inlet and exhaust lifters of the No. 1 cylinder are raised an equal distance. (NOTE: the piston was set at 2½ degrees before top center, as this is the mean position between the ten degrees before top center, opening of the inlet valve, and the five degrees after top center, closing of the exhaust valve, and at this position both valves should be open an equal distance.)

(e) Holding crankshaft and camshaft in above positions and allowing camshaft gear to slip on its hub as required, mesh the intermediate gear and tighten the clamp bolts between the camshaft gear and hub. After all valves have been timed and checked, drill $^{31}/_{64}$ inch holes through gear in line with dowel holes in hub and ream to .497 inch to .498 inch for dowels.

After determining the correct relation between the camshaft and crankshaft, the pushrods must be adjusted as follows: (See Section 10 for timing of the spray valve).

14. INLET AND EXHAUST VALVE TIMING:

(a) Spot the piston at ten degrees before top center at the end of the exhaust stroke.

(b) Adjust the inlet pushrod so that valve is just opening.

(c) Spot the piston at five degrees after top center on the inlet stroke.

(d) Adjust the exhaust pushrod so that the valve is just closing.

(e) Check the clearance between the valve stems and rocker rollers. The cams are designed for $^{1}/_{32}$ inch clearance with the valves set as above and with the engine cold, but this will vary somewhat due to manufacturing tolerances. When making the adjustments, aim at the opening and closing points but keep the clearances between 0.020 inch and 0.040 inch, varying the opening and closing points slightly, if necessary. Excessive clearances mean a noisy engine and increased wear on parts. Insufficient clearances prevent valves from seating properly, with consequent blowby and destruction of valves and seats.

(f) Check and record the closing point of the inlet valve and the opening point of the exhaust valve. These points should fall within five degrees of the position given in the timing table.

(g) Shift the latch shaft to ASTERN and check the opening and closing points of the inlet and exhaust valves when running ASTERN. Discrepancies from the AHEAD timing up to five degrees may occur due to manufacturing tolerances, but no attempt should be made to correct this condition, as any changes in the pushrod adjustments will upset the AHEAD timing.

(h) Adjust and record the valve timing for the other cylinders as above.

15. AIR-START VALVE TIMING:

(a) Turn the valve rocker shaft by hand to its starting position (up against the stop in the air cylinder).

(b) Spot the piston at five degrees before top center at the end of the compression stroke (in the AHEAD direction and with latch shaft AHEAD) and adjust the pushrod so that the valve is just opening. Check the closing point, which should fall within five degrees of the position given in the table. (See paragraph 10.)

(c) Shift the latch shaft to ASTERN and spot the piston at five degrees before top center ASTERN.

(d) Adjust the astern air-starting cam, relative to its hub, so that the starting air valve is just opening, and clamp the cam to the hub. Check the closing point.

(e) Adjust and record the starting air valves for other cylinders as above.

SECTION 20

LUBRICATING OIL AND TRANSFER PUMPS

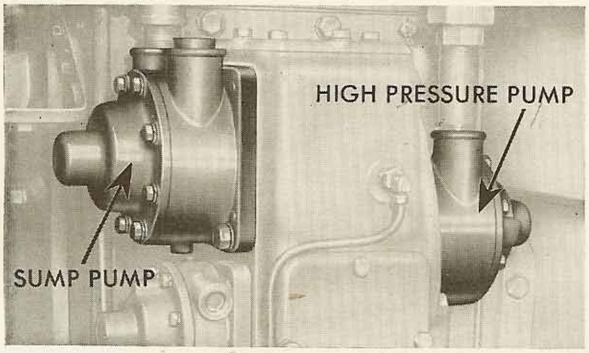


FIGURE 20-1

1. DESCRIPTION OF PUMPS: Figure 20-1 shows the pressure lube oil pump, and the sump lube oil pump. The two oil pumps are alike except for the length of the shafts and the position of the keyways. They are of the gear reversible type pump using a gear, an idler and a crescent-shaped baffle to maintain the direction of flow through the pump regardless of rotation. Figures 20-2 and 20-3 show how this crescent shifts when the rotation is changed, by following the rotation of the idler.

2. DISASSEMBLY: These pumps will need little attention, but if they are taken apart great care should be taken that all parts are marked so they will be assembled in the proper order. The pumps are attached to the engine by adapters which permit their removal in one piece for inspection of the bushings. As these bearings do not wear out all at once, we suggest that if they are worn, the pump be reinstalled on the engine and repairs made at a base where the necessary equipment is available. Figure 20-4 shows the adapter plates which hold the bushings of the pump shafts.

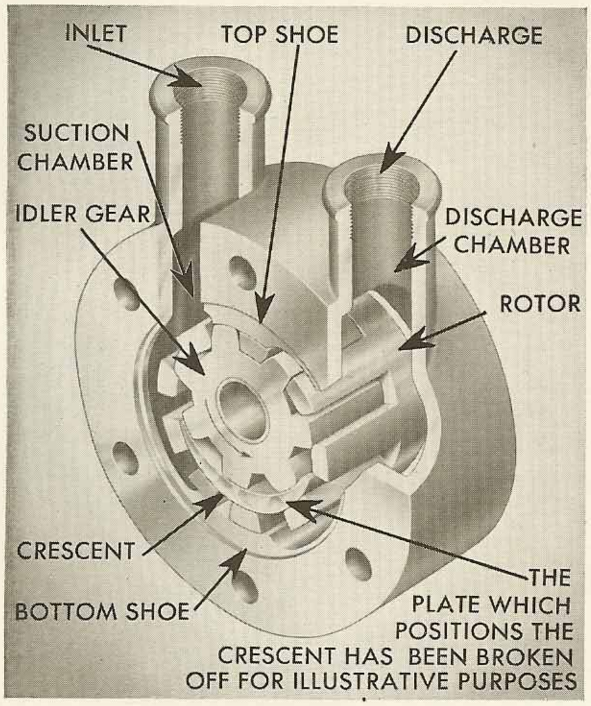


FIGURE 20-2

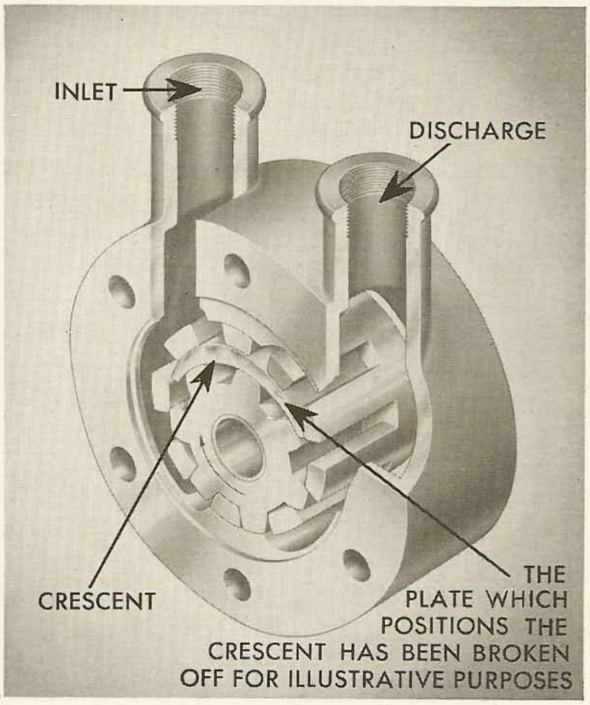


FIGURE 20-3

3. ASSEMBLY: The moving parts of these pumps operate between the end cover of the pumps and the adapter plate. The assembly of the pump to the adapter plate should be made on the bench where the clearance between the end plate and the adapter can be checked by revolving the pump by hand. While this clearance is only from 0.001 to 0.003 inch (a very small lengthwise movement of the shaft) it is important that the crescent-shaped baffle can move freely, otherwise the pump would not deliver oil when the engine rotation is changed.

4. ASSEMBLY: The correct assembly may be determined by remembering that the crescent always moves in the suction zone when the pump changes direction. There is a projection on the inside of the pump cover which acts as a stop for the crescent and the cover should be attached with this projection toward the suction port of the pump. Follow these directions for determining the rotation rather than rely on the direction arrows on the pump body.

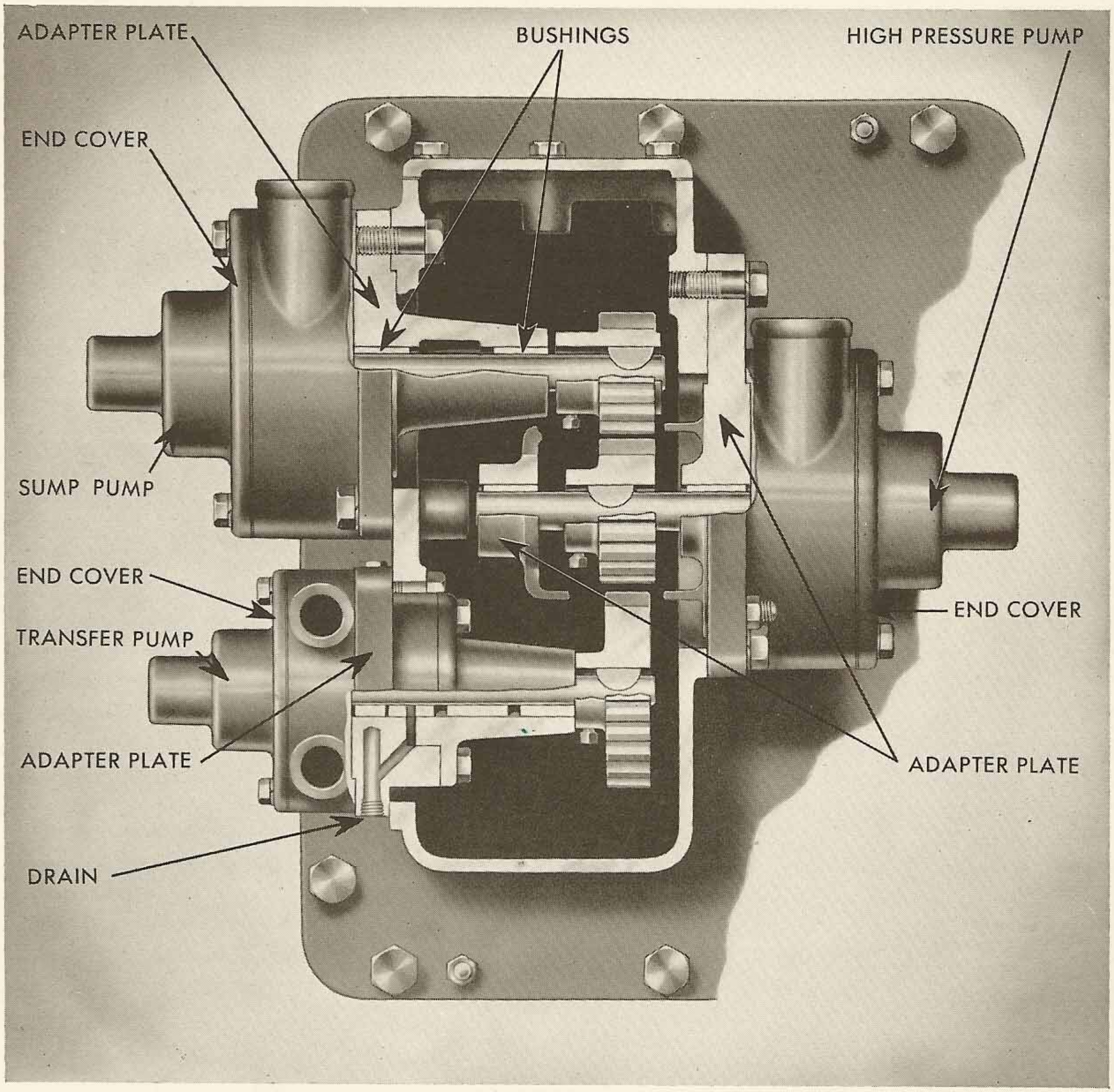


FIGURE 20-4

5. FUEL-TRANSFER PUMP: Figure 20-4. This pump is exactly the same in principle and operation as the two lube pumps except that there is a drain arranged so that fuel leakage can not find its way into the crankcase. This drain is shown in Figure 20-4 and SHOULD NEVER BE PLUGGED.

6. PUMP LUBRICATION: The outer bushings of these pumps, that is, the bushings next to the pump proper, are lubricated by leakage along the shaft from the pump chamber. The inner bushings as well as the gears that drive the pumps are constantly sprayed with oil led in from the high-pressure system.

7. LUBE OIL STRAINERS: The oil from the pressure pump next passes through the strainers shown in Figure 20-5. These strainers are so arranged that oil can be directed through one while the other is being cleaned. This change over is made by moving the lever from one extreme position to the other. The strainer consists of a metal element having openings about 0.003 inch. The dirt and solid matter is caught on the outside of this element where it can be scraped off by a knife blade that is held against the side of the element. The element is revolved by a hand wheel on top of the strainer. It is good practice to scrape these strainers just after shutting the engine down as this removes the dirt and allows it to settle to the bottom of the bowl where it can be drained off by removing the plug in the bottom. The knife scraper should be turned several times every 4 hours of running. This strainer has a built-in by-pass valve which opens at about 18 pound pressure if the screen of the strainer clogs up. However, this is only a safety device and the strainer should be cleaned regularly.

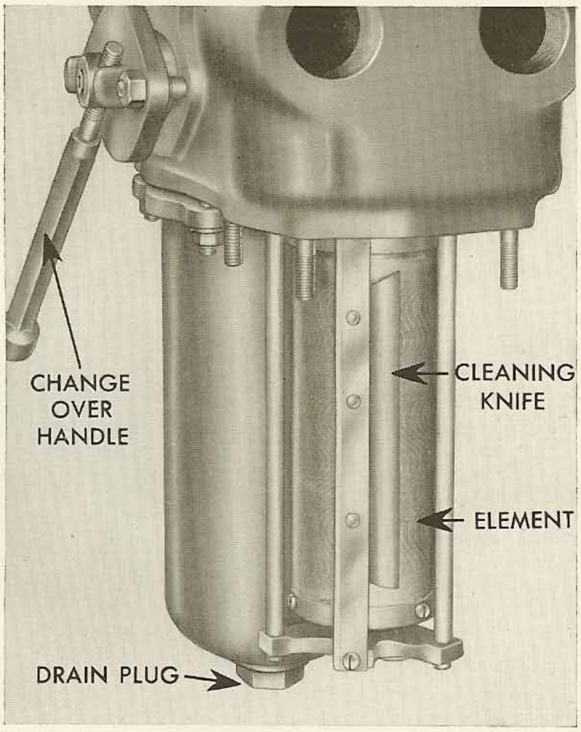


FIGURE 20-5

8. OIL COOLER: The oil passes from the strainers to the oil cooler shown in Figure 20-6. The cooling water goes in one end, through the tubes and out the other end of the cooler. The oil is delivered to the shell of the cooler where it is directed around the tubes. After being cooled, the oil goes directly to the base manifold.

At the after end of the cooler where the oil goes in there is a valve by which the oil can be sent through the engine without being cooled. This is used only in case of the cooler being damaged. Normally the valve is so turned that the oil is passed through the cooler. If this valve is changed while the engine is operating, it should be moved quickly from one position to the other as there is a point where the oil is completely shut off. As a safeguard a relief valve is installed in the line. This relief valve will open only if the four-way valve on the cooler is left in a neutral position.

There are zinc plugs in the bonnets at each end which protect the cooler against electrolytic action. These plugs should be inspected every 30 days and if found corroded should be replaced. ALWAYS BE SURE ZINC PLUGS ARE USED FOR REPLACEMENT.

9. CLEANING THE COOLER: Depending upon the type of water used, the cooler should be cleaned occasionally. Remove the cooler from the engine and take off the two bonnets. Clean out the tubes with a small tube

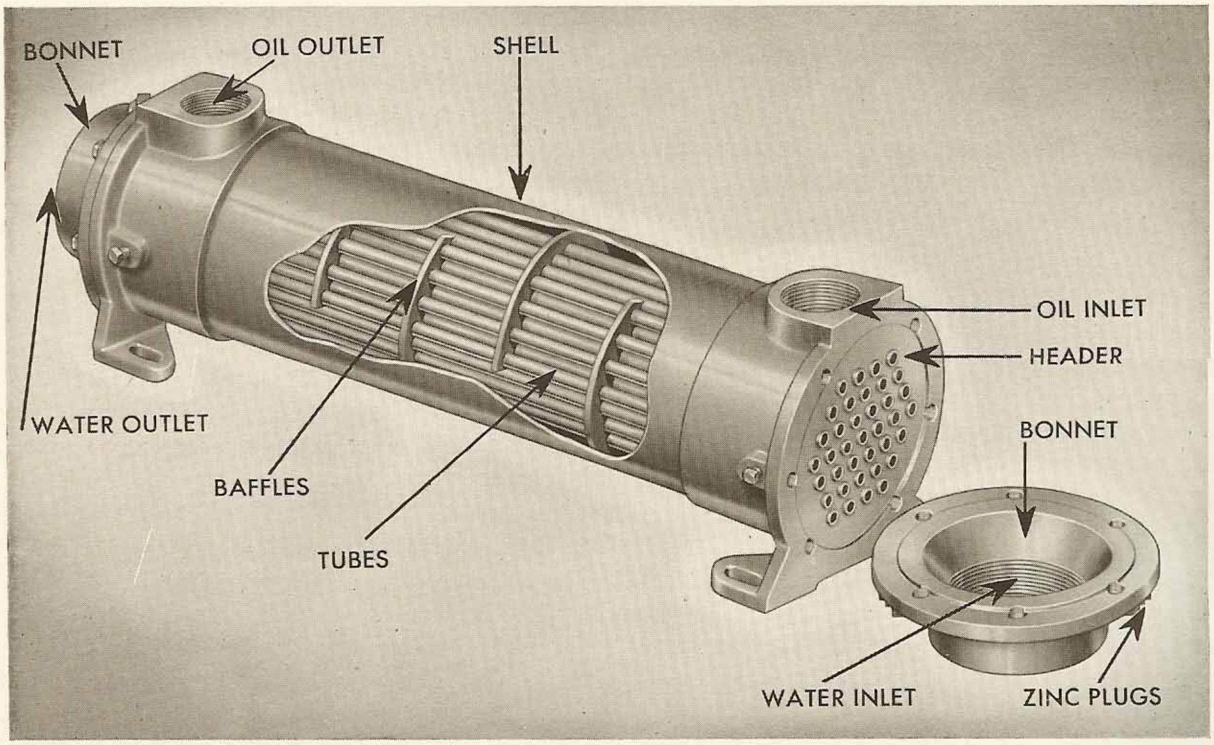


FIGURE 20-6

brush. Fill the casing around the tubes with a suitable cleaning fluid. DO NOT USE ANY COMPOUND THAT IS CORROSIVE TO BRONZE OR COPPER. We suggest carbon tetrachloride as a safe solvent.

Before assembling on the engine remove the drain plugs and blow the casing out well with compressed air to remove all water. WARNING: Be sure and open the drain plugs in the bonnets if the engine is being laid up where there is any danger of freezing.

10. LUBE OIL RELIEF VALVE: This valve allows the excess oil delivered by the pressure pump to pass back into the lube oil service tank. Figure 20-7 shows that it is an adjustable spring loaded check valve. By screwing down on the adjusting stud the tension of the spring is increased, thereby holding the valve down on its seat. Do not adjust this valve until the engine and the oil in the system are thoroughly warm. Be sure and tighten the lock nut when the adjustment is complete.

If there is a sudden drop in oil pressure, do not correct by adjusting this valve without first checking the following:

(A) Low lubricating oil level in the lube oil service tank.
(B) Restriction in suction pipe of either lubricating oil pump.
(C) Broken pipe or fitting.

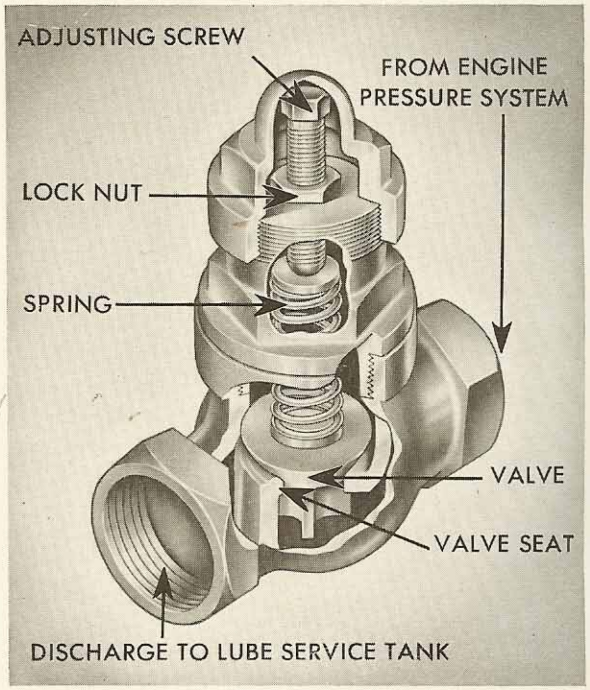


FIGURE 20-7

(D) Faulty crankshaft bearing.
(E) Worn pump parts.
(F) Oil too thin.

11. THE SUMP PUMP: This pump is so connected as to draw the oil, which collects in the base after being thrown out by the bearings, and deliver it to the lube oil service tank.

The suction assembly is shown in Figure 20-8 and consists of a screen, a check valve, and a relief valve.

12. REMOVAL OF SCREEN: Disconnect the two unions in the line just above the base cover and lay aside the short piece of pipe. Take out the cap screws holding the cover to the base. The suction assembly will now lift out. Examine the ball check valve and the relief valve. Wash the screen off thoroughly.

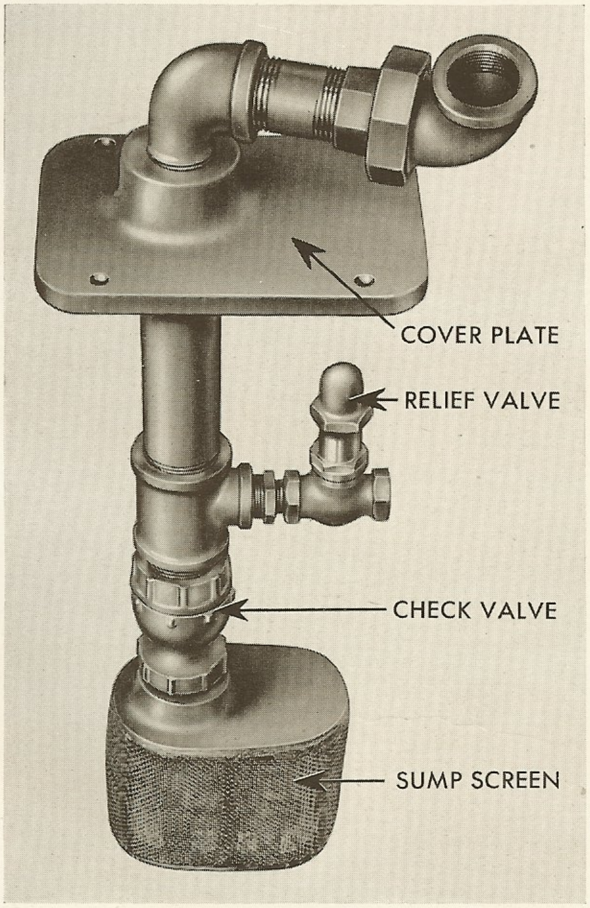


FIGURE 20-8

If this assembly is taken apart be sure and use the same pipe nipples when assembling. A CHANGE IN LENGTH OF THIS ASSEMBLY MAY CAUSE SERIOUS DAMAGE as the suction of the pump is located by the total assembled length of these various pipes and fittings.

13. ASSEMBLY OF SCREEN: Be sure the ball check is installed right side up. That is, the ball must have its seat underneath. Renew the plate gasket unless the old one is in good condition. Tighten both unions well.

14. CLEANING THE BASE: While the sump pump screen is out for inspection the engine base should be thoroughly washed out. Remove all the pit doors. Wash off the crankshaft, bearing caps, connecting rods, crankpin bearings and pits with fuel oil and rags. Clean in and around the cam and latch shaft and latches, as many parts in these assemblies rely on splash lubrication. When everything is clean BE SURE ALL FUEL OIL IS REMOVED FROM THE BASE AND THAT NO RAGS ARE LEFT IN.

15. CLEANING OF THE LUBE OIL SERVICE TANK: When the base is cleaned out the lube oil service tank should be drained from the valve in the bottom of the tank. Remove the screen and wash it in fuel oil. Wash out the tank with fuel oil and drain again. Fill up the tank with new clean oil.

16. MECHANICAL LUBRICATOR: This lubricator is mounted on the forward cylinder and is driven by an eccentric on the end of the camshaft. It supplies oil to the cylinder liner walls and to the thrust bearing (multi-cooler type only). Figure 20-9 shows the adjusting screw on top of the box.

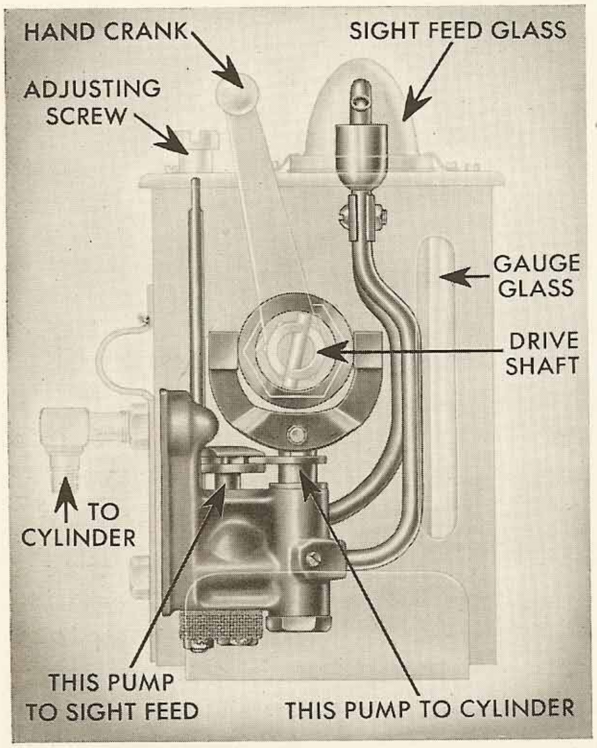


FIGURE 20-9

Each feed is set for 20–25 drops per minute for new engines. After the rings and liners are well worn in this can be decreased to about 15–20 drops per minute. KEEP THE LUBRICATOR WELL FILLED WITH THE SAME OIL AS IS USED IN THE ENGINE. ALWAYS USE NEW CLEAN OIL. The filling of this lubricator should be made a part of the engine room routine, as serious damage will occur to the pistons and cylinder liners if it is allowed to run dry.

SECTION 21

AIR COMPRESSOR AND UNLOADER

1. DISASSEMBLY OF CYLINDER HEAD: Disconnect the tube leading to the unloader. Remove the cylinder head nuts and the cap screws that attach the water by-pass. Remove the cap screws that attach the discharge pipe. Lift off the head.

2. OPERATION OF UNLOADER: Figure 21-1 shows the compressor head and the position of the unloader as related to the suction valve.

The unloader holds the suction valve open

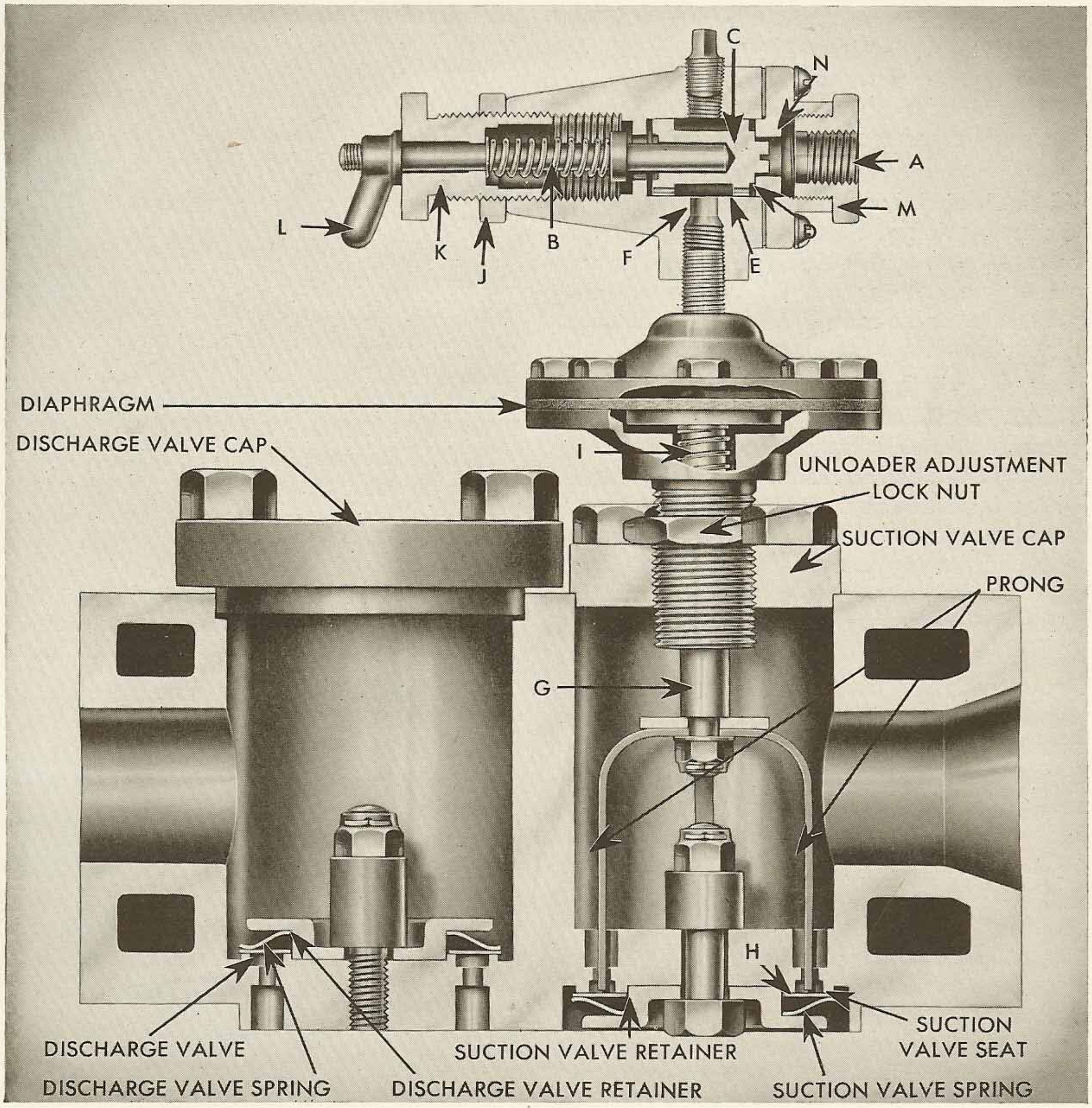


FIGURE 21-1

when the air pressure in the storage tank reaches the desired pressure. When this pressure drops below a certain point, the unloader releases the suction valve, allowing the compressor to replenish the storage tanks. The opening (A), Figure 21-1, is connected to the air storage tank.

The spring (B) holds the piston (C) against the seat (D). When the air pressure in the storage tank exceeds the spring tension, the piston is backed away, allowing the air to pass through the hole (E) and out the opening (F) onto the diaphragm. The air pressure bends the diaphragm down which moves the rod (G) and the prong down on to the suction valve (H), holding it off its seat, thereby stopping the compressor from delivering air.

When the air pressure in the tank drops below the set tension of the spring, the piston (C) returns to its seat, cutting off the air to the diaphragm. The spring (I), under the diaphragm, lifts the rod (G) and prong, allowing the suction valve of the compressor to operate.

3. ADJUSTMENT OF UNLOADER: The pressure at which this unloader cuts in or out can be varied by increasing or decreasing the spring tension. Unscrew the lock nut (J) and screw the sleeve (K) in to increase the pressure and out to decrease the pressure. After the proper adjustment is obtained, tighten the lock nut.

By screwing the wing nut (L) in a clockwise direction, the spring pressure on the piston will be released and the compressor will not function as long as there is enough air pressure in the tank to overcome the tension of the spring. For normal operation, this nut should be unscrewed far enough so that it will not touch the sleeve (K).

The unloader will need little attention, but if the seat (D) is leaking, it can be ground as follows: Remove the sleeve (K). Withdraw the rod and spring. Remove the nut (M) and take out the screen (N). Apply fine grinding compound on the head of the piston. Replace the piston, rod and spring. Screw in the sleeve so that slight pressure is exerted against the piston. With a small screwdriver turn the head of the piston back and forth until a good seat is ground in. Wash all parts thoroughly before assembling.

4. DISASSEMBLY OF THE SUCTION VALVE: Figure 21-1. Remove the cap screws which hold down the suction valve cap. Lift out the unloader assembly. Remove the cotter pin and nut from the bolt which holds the valve retainer. If the flat disc valve is badly pitted, rusted or cracked, it should be renewed. The curved valve spring should be renewed if it is badly corroded.

5. ASSEMBLY OF THE SUCTION VALVE: Be sure the retainer bolt is tight and the cotter pin is installed. When attaching the unloader, be sure the prongs enter the holes in the head. If the unloader prongs are too long or too short, they can be adjusted by loosening the lock nut which tightens against the suction valve cap. Screw the unloader in or out to make the proper adjustments and tighten lock nut.

6. DISASSEMBLY OF THE DISCHARGE VALVE: Remove the valve cap. Remove the cotter pin and nut from the retainer stud. Lift out the retainer, spring and valve. Examine and assemble as in assembly of the suction valve, paragraphs 4 and 5.

7. DISASSEMBLY OF ECCENTRIC STRAP, CONNECTING ROD AND PISTON: Remove the eccentric pit door on the manifold side of the engine. Cut the lock wire in the two cap screws which attach the connecting rod to the eccentric strap. Unscrew the cap screws and the rod and piston can be removed through the top of the cylinder. DO NOT LOSE THE COMPRESSION SHIMS that lie between the foot of the connecting rod and the eccentric strap. Figure 21-2 shows the various parts of this assembly. The eccentric strap has been turned ¼ turn for illustrative purposes.

8. REMOVAL OF THE PISTON PIN: Figure 21-2 shows that this pin is step cut. That is, the end which has the set screw in the

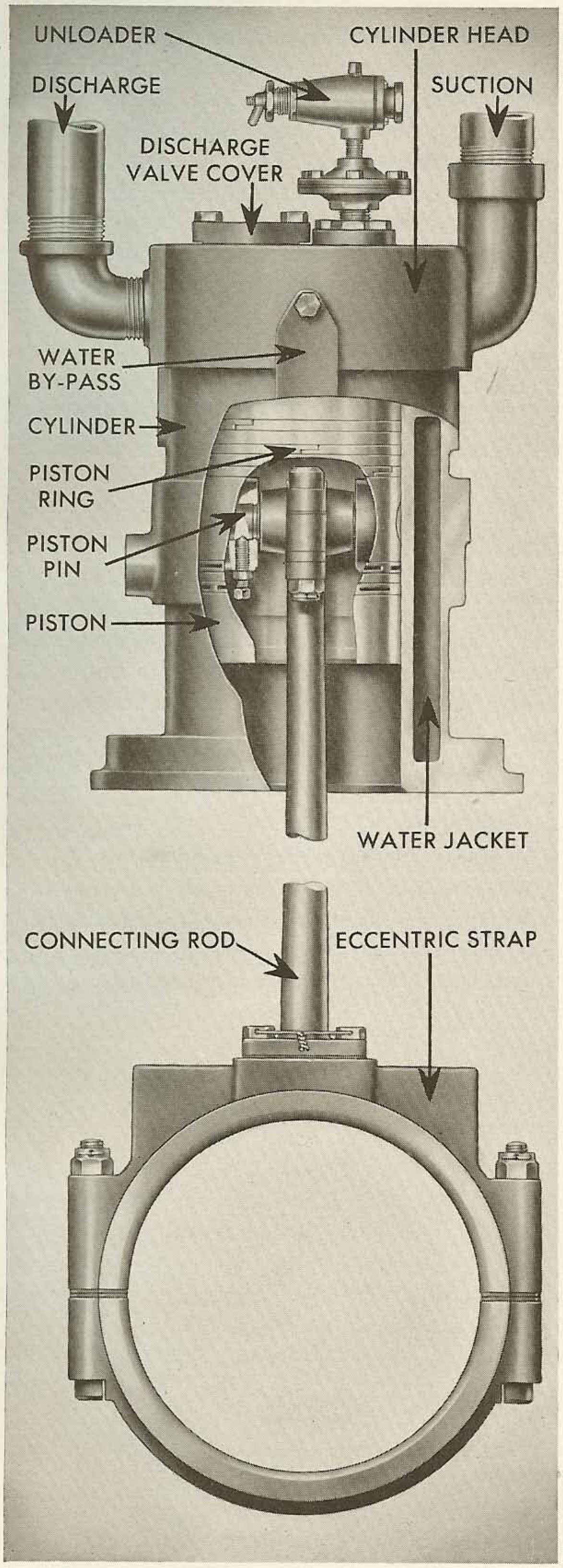


FIGURE 21-2

piston-pin boss is smaller. THE PIN MUST ALWAYS BE DRIVEN OUT FROM THE SMALL END. Use a brass drift and a three or four pound hammer. The pin has several holes drilled from the bearing area through to the hollow center. See that these holes are clean as the oily vapor finds its way through these holes to supply lubrication. When removing the two halves of the piston pin bearing, do not lose the adjusting shims.

9. REMOVAL OF THE PISTON RINGS: These rings are removed in the manner described in Section 12, paragraph 2. Check the gap clearance of each ring by placing it in the cylinder and measuring the clearance as described in Section 12, paragraph 5. The gap clearance of the two top rings should not be less than 0.012 inch and 0.009 inch for the other three rings. The clearance between the top of the ring and the ring groove should be from 0.002 to 0.005 inch for all rings. If the gap clearance of any ring exceeds 0.030 inch, it should be renewed. The two lower rings are designed for oil control and are known as ventilated rings. The piston grooves of these rings have small holes drilled into the center of the piston to carry off excess oil. These holes should be thoroughly cleaned.

10. ASSEMBLY OF THE PISTON AND ROD: The piston pin bearing is shimmed to 0.002 inch clearance. This measurement can be taken by a feeler gauge after the pin is inserted in the bolted-up bearing. After this adjustment has been made, replace the cotter pins. Position the connecting rod in the piston so the piston pin can be slipped through and driven home. Before the set screw is installed, be sure the spotted hole in the pin is directly under the hole in the piston-pin boss. Tighten the set screw lock nut.

11. ECCENTRIC STRAP: This strap is babbitt lined and shimmed the same as a crankpin bearing for running clearance. See paragraphs 4, 5, 6, and 7, Section 13. This clearance should be from 0.006 to 0.010 inch and the side clearance between the eccentric strap and the flanges of the hub, 0.003 to 0.005 inch. If the eccentric strap is taken apart ALWAYS REPLACE THE TWO HALVES WITH THE

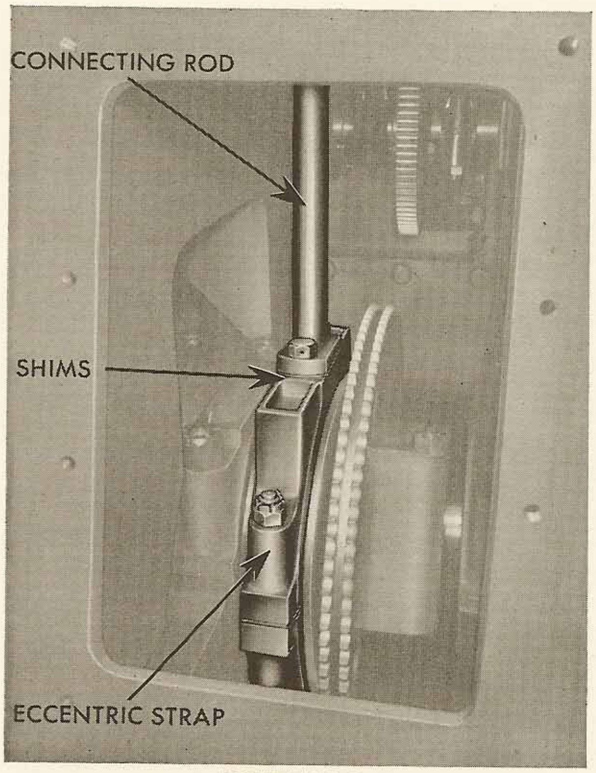


FIGURE 21-3

SAME FACES TOGETHER. The strap is lubricated by a hole drilled from the running surface of the hub into the oil passage in the center of the crankshaft. The strap and rod are shown in Figure 21-3.

12. ASSEMBLY: After the eccentric strap has been fitted for clearance, bolt the two halves tightly together on the eccentric hub and replace the cotter pins. There should be a slight fore and aft movement to the strap. Insert the assembled connecting rod and piston through the top of the cylinder. Lay in the compression shims between the foot of the connecting rod and the strap. Draw up the two cap screws tight. Try the assembly for a slight fore and aft movement. If this movement has been lost since tightening up the cap screws in the foot of the rod, check under each end of the connecting rod for dirt which might be cocking the assembly.

THIS FORE AND AFT MOVEMENT OF THE ECCENTRIC STRAP, HOWEVER SLIGHT, MUST BE ATTAINED BEFORE THE ASSEMBLY IS COMPLETE.

Turn the engine over until the eccentric is on top center. The top of the piston should now be EXACTLY EVEN with the top of the cylinder. This adjustment can be made by adding or subtracting compression shims under the foot of the connecting rod. After this adjustment has been made, go over all nuts to see that they are tight and cotter pins and locking wire installed.

13. INSTALLING THE HEAD: The cylinder head gasket should be made out of graphite packing $1/64$ inch thick and should be put on dry. Pull the cylinder head nuts down evenly. Use a new rubber gasket under the water bypass. Before starting the engine, bar it over at least one full turn to make sure everything is clear.

SECTION 22

CIRCULATING PUMP AND BILGE PUMP

1. RECIPROCATING PUMP: This type of pump is shown in Figure 22-1. Most of the servicing of this pump can be done without its removal from the engine.

2. DISASSEMBLY OF VALVES: Remove the two valve cover plates. The two discharge valves and cages will lift out. Unscrew the valve stud from the seat which releases the fiber or rubber valve and spring. Examine the stud and the bronze bushing, which fits into the valve, for wear. If these parts are $\frac{1}{32}$ inch loose, they should be renewed.

The valve studs of the suction valves are screwed directly into the body of the pump and have to be unscrewed to release the valve and spring. Examine both the stud and the bushing, for wear. The grid-like seat upon which the valve rests should be smooth and free from ridges or grooves. If the springs are corroded, they should be renewed.

3. ASSEMBLY OF VALVES: When installing the suction valves be sure the valve studs are screwed in tightly and that the bushing works freely on the stud. After the dis-

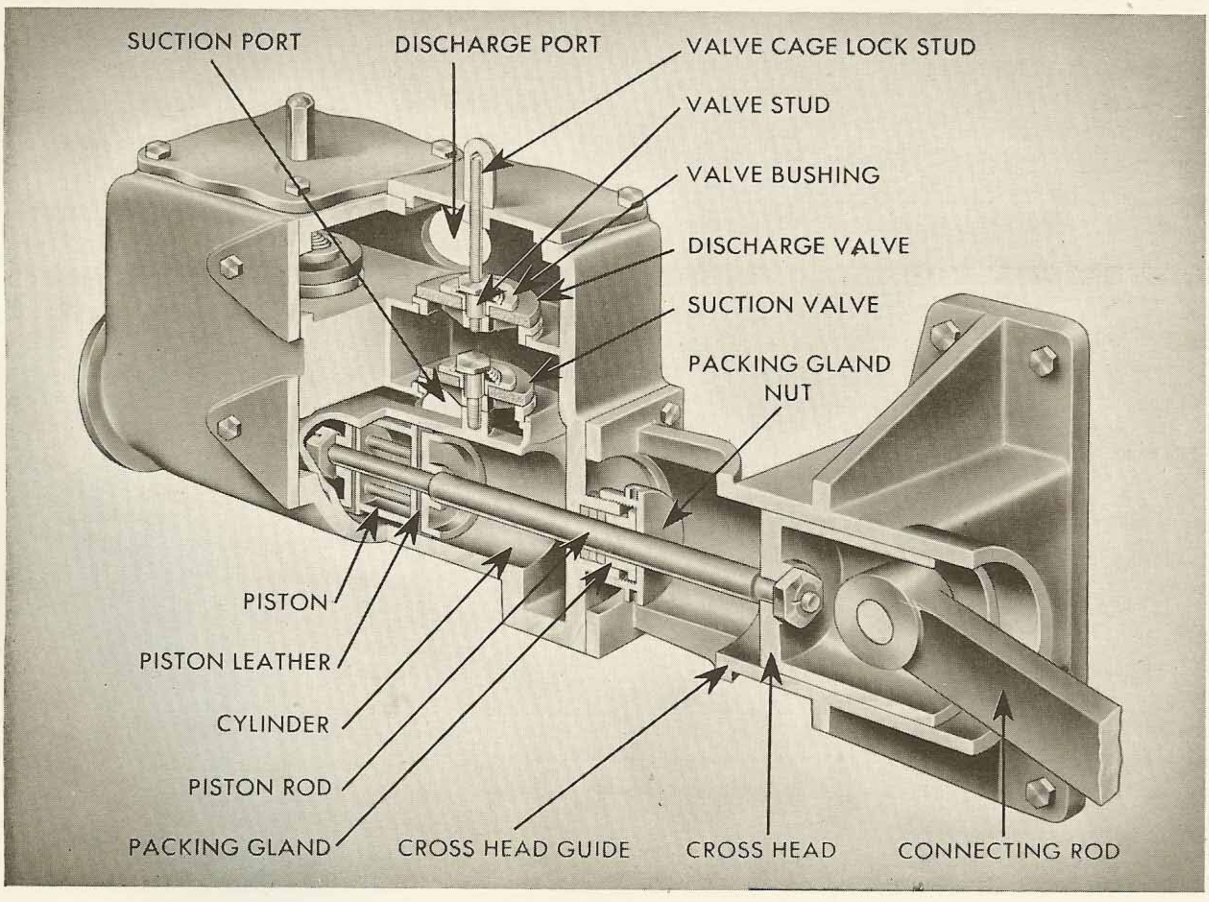


FIGURE 22-1

charge valve assemblies have been laid in, remove the hexagon cap from the valve covers and screw out the valve cage stud. Put on the valve covers and tighten the cap screws. Now screw down the lock stud so that the end presses firmly on the heads of the discharge valve studs. This is the adjustment which holds the discharge valve assembly in place. Screw on the hexagon cap nuts which lock the adjustment.

4. REMOVAL OF THE PISTON: Remove the locking wire and the two cap screws (E), Figure 22-2, and DO NOT LOSE THE SHIMS. Remove the packing gland nut (D) and dig out all the old packing. Remove the pump cylinder head and the rod, piston and crosshead can be pushed through far enough to remove the large nut on the end of the rod. The piston and leathers can now be removed. Take out the four cap screws (A), Figure 22-2, and the pump body can be set aside.

Examine the leathers and if new ones are required be sure they are installed with the cups pointing toward each end of the cylinder. Examine the piston rod (B) in the packing way, for scoring. If this rod is very rough, it will be impossible to keep the packing gland tight.

5. DISASSEMBLY OF THE CROSSHEAD GUIDE: Withdraw the crosshead, piston rod, and connecting rod from the crosshead guide. Loosen the lock nut and set screw (F) and drive out the crosshead pin (G). If this bushing and pin have more than 0.010 inch clearance, they should be renewed.

6. ASSEMBLY OF THE CROSSHEAD AND CONNECTING ROD: Clean out the oil reservoir in the connecting rod and pack it with clean waste. Be sure the oil passage to the bearing area is clear. Fit the bearing to about 0.002 inch clearance by adding or subtracting shims.

After the crosshead pin has been driven in, be sure the spotted hole in the pin is directly under the hole in the crosshead pin boss before screwing in the set screw. Tighten the lock nut. Attach this assembly to the engine and repack the piston rod with a good grade graphite flax packing $3/8$ inch square. Cut the packing into rings that will just go around the rod once. Angle cut the ends.

DO NOT TIGHTEN THE GLAND NUT UNTIL AFTER THE ENGINE IS RUNNING and then only tight enough to stop leaking.

7. ASSEMBLY OF THE BODY: Assemble the body and the piping in the order removed. Go over the entire assembly to make sure all cap screws and nuts are tight and all cotter pins replaced.

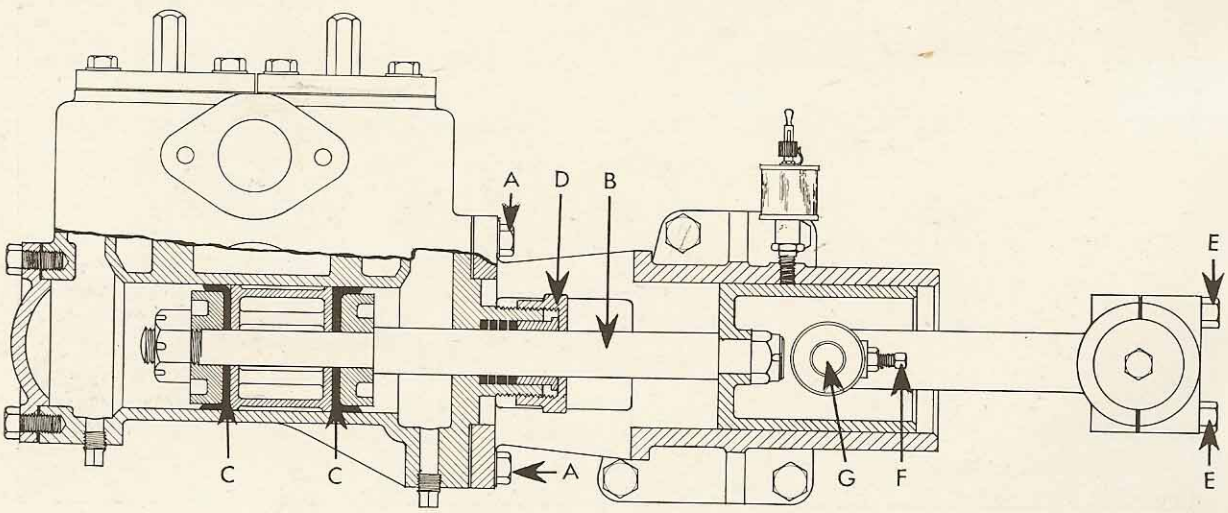


FIGURE 22-2

8. BILGE PUMP: This pump, which lies across the forward end of the engine, is driven by an extension of the camshaft. Figure 22-3 shows the connecting rod, the pump body and the plunger. Figure 22-4 is a view of the end of the pump cut away to show the valves.

9. REMOVAL OF THE PLUNGER: Take off the cap screw and washer (A), Figure 22-3. Remove the two cotter pins and the cross-head pin (B). Remove the packing gland (C) and withdraw plunger.

10. EXAMINATION FOR WEAR: Examine the crosshead pin, plunger eye and connecting rod fork for wear. If the total looseness in these three parts exceeds $\frac{1}{32}$ inch, the plunger eye and the connecting rod fork should be reamed out and an oversize pin fitted.

Measure the clearance in the bushing end of the connecting rod by placing the rod on the crank pin on the end of the camshaft and insert the leaves of a feeler gauge. If this clearance is greater than 0.010 inch, a new bushing should be installed.

The amount of roughness and scoring that the plunger will stand will have to be determined by the amount of trouble experienced in keeping the packing tight. If this gland is continually leaking after new packing has been put in, a new plunger should be installed.

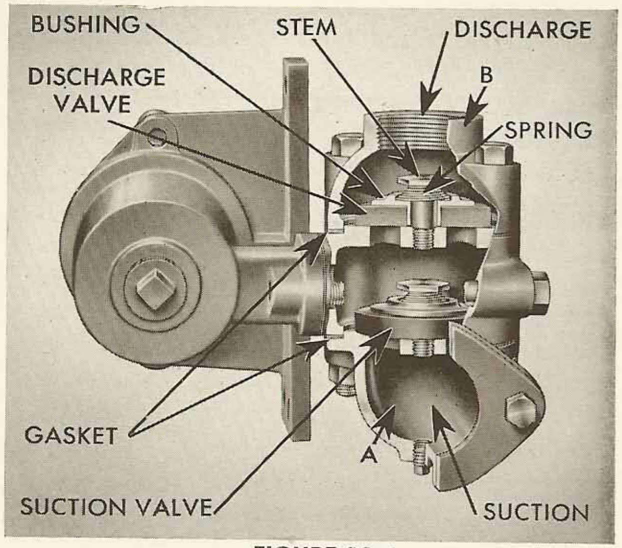


FIGURE 22-4

11. PACKING THE PUMP: A good grade of greased flax ½ inch square, should be used. This packing should be cut in lengths just long enough to go around the plunger once. The ends should be cut on an angle. The packing gland should not be tightened until the engine is running and then only enough to stop leaking.

12. DISASSEMBLY OF THE VALVE CHAMBER: Figure 22-4 shows this assembly. Disconnect the pipes leading to the suction bonnet (A) and the discharge bonnet (B). Remove the nuts from the two bolts clamping these two bonnets to the valve body. The suc-

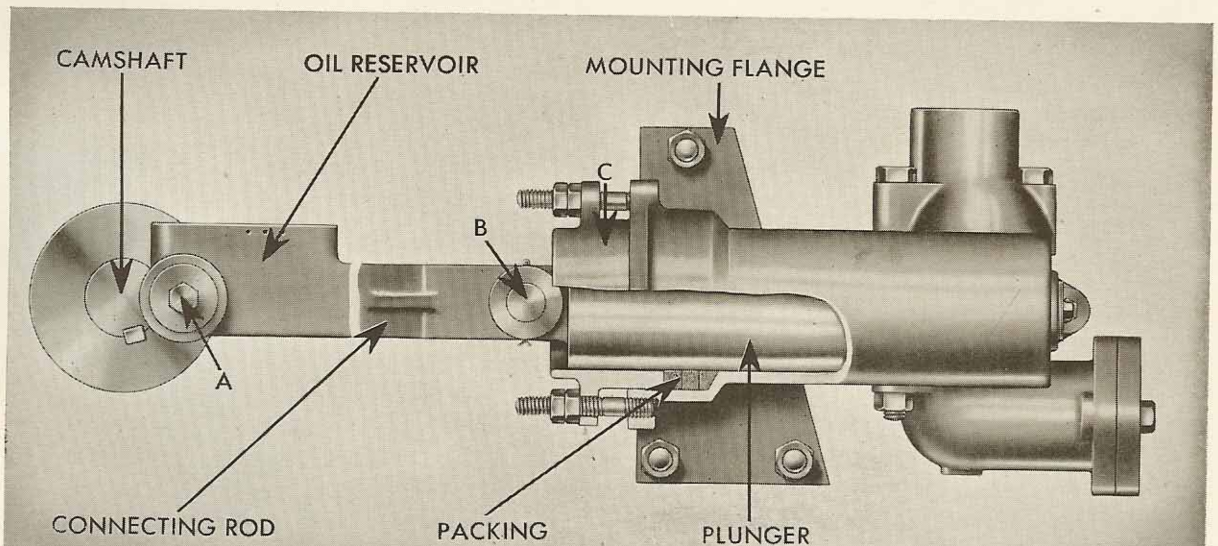


FIGURE 22-3

tion valve seat is part of the suction bonnet. The removal of the discharge bonnet exposes the discharge valve. Both valves and their parts are interchangeable with the valves and parts in the circulating pump and are serviced in the same manner.

13. ASSEMBLY: When assembling the suction and discharge bonnets, new copper asbestos gaskets should be used. Great care should be taken that the spigots of each bonnet enter properly. If the two clamping bolts are drawn up without these spigots entering, the bonnet will be warped, making it impossible to attain a tight joint.

14. CENTRIFUGAL PUMPS: Certain engines, when equipped with fresh-water cooling and a heat exchanger, use this type of pump. Figure 22-5 shows how these pumps are installed on the engine. One pump circulates the jacket cooling water and the other passes sea water through the heat exchanger.

These pumps are driven by a double roller chain which passes over a sprocket on the crankshaft and around a ball-bearing idler as well as the pump drive sprocket.

15. ADJUSTING THE CHAIN: This chain should never be allowed to run slack, as this tends to wear the sprockets excessively.

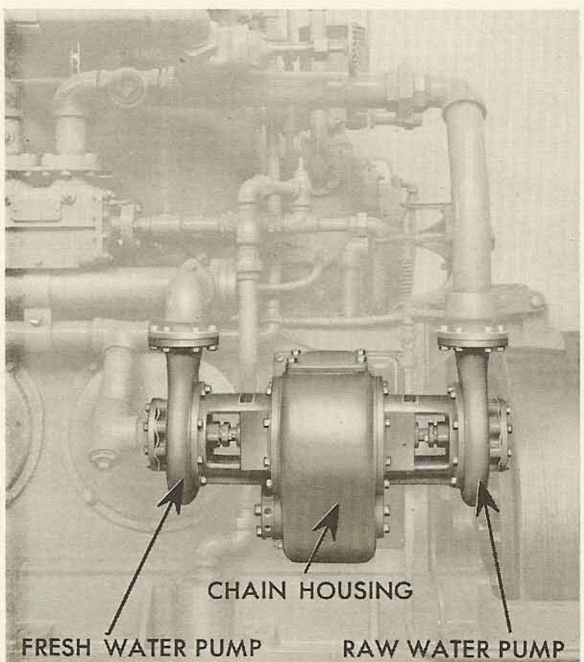


FIGURE 22-5

Remove the cover on the top of the drive housing. By forcing the chain up and down by hand, at right angles to the lay of the chain, the slackness can be tested. This movement should not exceed one inch.

Remove the four cap screws shown in Figure 22-6 and with a bar turn the plate. As this idler shaft is mounted eccentrically on its bearings, it will be found that revolving the plate will tighten or loosen the chain. When the engine leaves the factory, this idler is adjusted to its shortest position, so by the time all the adjustment is used up, it is probable that the chain is worn out and should be renewed. If this is done, examine the sprockets for wear, as they will, most likely, need replacement also. After the proper adjustment is made, replace the four cap screws.

16. LUBRICATION: This pump drive assembly is lubricated by a spray of oil led in from the main engine pressure system.

17. PACKING THE PUMPS: These pumps should be packed with rings of a good grade greased flax packing, 1/4 inch square. The ends of each ring should be cut on an angle. The packing gland should not be tightened more than enough to stop leaking.

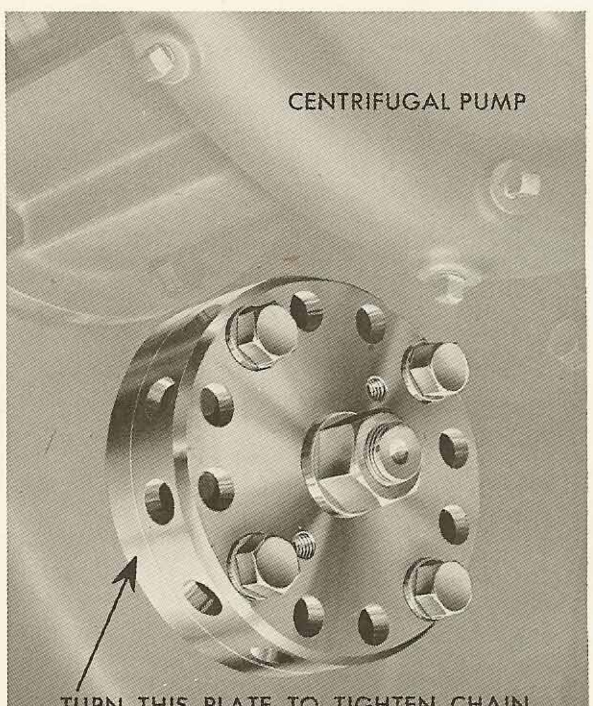


FIGURE 22-6

SECTION 23

RECONDITIONING AN ENGINE THAT HAS BEEN SUBMERGED IN SALT WATER

1. DECIDING WHAT CAN BE DONE: The amount of work that can be done to prevent serious damage to an engine that has been submerged depends entirely upon how soon this work can be started after the engine has been raised and, of course, on the length of time the engine was submerged.

2. LENGTHY SUBMERSION: If the engine has been under water a matter of many days or weeks it will require a complete overhaul and this should be undertaken only at a base or service depot where suitable labor and equipment are available. Take as many of the preventive measures as possible, which are listed in the paragraphs on Short Submersion as anything done which will prevent corrosion by salt water will save much time and replacement during the overhaul.

3. SHORT SUBMERSION AND IMMEDIATE CARE: Assuming that the engine has been under water only a day or so and that protective work can be commenced as soon as the water is out of the engine room, proceed as follows:

4. SPRAY VALVES, CYLINDER AND HIGH-PRESSURE FUEL PUMP: Remove all spray valves and leave them in a container full of fuel oil until they can be taken apart and cleaned. Unscrew the relief valve assembly from each cylinder head. Turn each piston to top center and blow the water out of the combustion chamber by inserting an air hose in the spray valve opening in the head. The majority of the water should pass out of the relief valve openings. Put one-half gallon of lubricating oil in each cylinder through the spray valve openings and turn the engine over by hand several revolutions so that the oil is spread over the cylinder liner walls. Remove the complete high-pressure fuel pump assembly and fuel-regulating valve. Leave it covered with fuel oil until cleaning is possible.

5. CONTROL LEVER BOX AND LATCH SHAFT RAM: Remove the single lever control unit and leave in fuel oil until cleaning is possible. Thoroughly oil or grease all gears and steel or iron parts of the latch shaft ram.

6. CRANKSHAFT AND PISTON PINS: Remove all base doors and bail out water. If it is possible to obtain fresh water under pressure, disconnect the discharge pipe of the high-pressure lube pump and connect the fresh-water hose to this line, which supplies the engine with oil under pressure. Turn on the full force of the fresh water and allow it to pass through the crankshaft and bearings for hours. As the water leaks out around the bearing and piston pin clearances it will gradually fill up the base of the engine. Allow it to overflow into the bilges where it can be pumped out. This circulating of fresh water will, in time, kill the corrosive action of the salt water on the journals, crank pins and piston pins. If fresh water under pressure is not available the same effect can be obtained by filling the base with fresh water and circulating it by any hand or power pump that can be had.

7. THRUST BEARING AND AIR COMPRESSOR: Remove the thrust bearing cap and drain off water. Dry off the thrust shaft and spread heavy oil or grease over any part of the shaft or collar which is not covered after the thrust bearing housing has been filled with fresh oil. Remove the air compressor cylinder head and submerge it in fuel oil. Spread heavy oil on the walls of the cylinder.

8. MECHANICAL LUBRICATOR, GAUGES, GOVERNOR, AND SERVICE TANKS: Drain the mechanical lubricator and flush out several times with fuel oil. Fill with fresh oil and crank one hundred or more revolutions to force all water from the check valves and out of the tubes. Remove all gauges and soak them in fuel oil. Remove the governor assembly and thoroughly dry and clean all iron and steel parts. Drain both the fuel and lube service tanks. Flush them out well.

9. BALL BEARINGS, ENGINE EXTERIOR AND CENTER FRAME ASSEMBLIES: Remove and thoroughly clean all ball bearings, as hardened steel is more liable to corrode than almost any other metal. Dry off all bright exposed parts of the engine and smear them with grease. If an air hose is available blow all the salt water from around the latch shaft, camshaft, idler gear, air compressor eccentric and main bearing caps.

10. INSPECTION: Look the engine over carefully for any pockets that would hold salt water which might not drain out. Remove one main-bearing cap and top half shell. Remove one crank pin bearing and one piston pin. Examine the crankshaft for traces of salt water. If there are stains on the journals or crank pins or piston pins they should be removed with fine emery paper and all other bearings opened up and inspected. If any emery paper or other abrasive is used to remove stains from the crankshaft great care should be taken that none of the dust gets into the oil passages in the crankshaft or bearing saddles. ALL PARTS SHOULD BE THOROUGHLY WASHED BEFORE ASSEMBLY.

11. FINAL CARE AND STARTING: If a hand or auxiliary pump is available connect it up in such a way that several gallons of lubricating oil can be forced through the high-pressure oil system. This treatment should carry off the last traces of water from the bearings and piston pins. After this oil has collected in the base it should be pumped out and discarded. WARNING: BEFORE ATTEMPTING TO START THE ENGINE REMOVE THE LUBRICATING OIL THAT WAS PUT INTO THE CYLINDERS. This can be done by either blowing it out with air or by a hand pump equipped with a long slender suction extension. Fill the engine system with fresh oil and run for about two hours. Again drain all the oil and fill with fresh. Run for eight to ten hours and drain oil again. Inspect one or two crank pin and main bearings, and the engine in general. Fill with fresh oil and commence normal operation.

12. CARE DURING OPERATION: An engine that has been submerged may develop trouble many days after it has started operating again. There are many parts that can be affected by the action of salt water over a period of time. A ball bearing, for instance, may have just one pit in the ball that would not show up in the most careful examination. As this bearing continues operation the pit will become enlarged until the bearing fails. Such a failure may lead to further trouble unless caught in time. Therefore, it is advisable to keep a close check on all parts that could be affected by salt corrosion even though the engine seems to be running well.

SECTION 24
TROUBLE SHOOTING

SMOKY EXHAUST

PROBABLE CAUSE	REMEDY
1. LEAKY SPRAY VALVE	If the smoke is intermittent find out which cylinder is at fault by closing off one isolating valve at a time. The smoke puffs will stop when the leaking spray valve is cut off. As a further check, stop the engine and close all the isolating valves. Spot the flywheel at least 30 degrees from any top center. Open the isolating valve to the doubtful spray valve. Pump up fuel pressure with the priming pump. If the pressure will not hold up, the spray valve is leaking (see Section 17) or the fuel-regulating valve is leaking. See "Leaky Regulating Valve" under "No Fuel Pressure" this section.
2. OVERLOAD	This will be indicated by exhaust temperatures in excess of 750 degrees, also by engine not turning full speed with fuel pressure at 4200 pounds and fuel wedges full in.
3. WIRE, ROPE OR OTHER OBJECT CAUGHT IN PROPELLER	Two or three short reverses of the engine will often free the propeller of the obstruction causing the overload.
4. OVERHEATED BEARINGS	Stop the engine. Remove base doors. Feel all bearings and piston pins for heat. Feel thrust bearing, intermediate bearings, and stuffing box. See Sections 13 and 14 on Bearings.
5. OVERHEATED ENGINE	Check the flow of cooling water. If raw-water cooled, temperature at the engine outlet should not exceed 120 degrees. If fresh-water cooled, temperature should not exceed 160 degrees. See "Overheated Engine" this section.
6. LOW OIL PRESSURE	This should not be below 35 pounds when the oil in the system is hot. See "No Oil Pressure" this section.

PROBABLE CAUSE	REMEDY
7. LEAKY EXHAUST OR INLET VALVES	Stop the engine. Open all snifter valves except the one for any one cylinder that is just starting a compression stroke. With a cranking bar turn the flywheel as far as possible against the compression. With force still applied to the cranking bar, listen at the inlet pipe opening. Escaping air will be heard if the inlet valve is leaking. Listen at top of the exhaust pipe. Compression leak will be heard if the exhaust valve is faulty. Repeat this check on all cylinders one at a time. For valve troubles and corrections for them see Section 11.
8. POOR COMPRESSION	This may be the result of a scored liner or stuck piston rings. Proceed as for leaky exhaust valves, but take off all base doors on the manifold side of the engine and listen for compression escaping past the rings into the base. See Section 12 for ring clearance. By turning each piston to top center the walls of the liner can be examined for scoring or scuffing.
9. IMPROPER VALVE TIMING	See Section 10 for proper setting.
10. OBSTRUCTION IN INLET MANIFOLD	Rags or other objects may be lodged in the inlet manifold.

NO FUEL PRESSURE

PROBABLE CAUSE	REMEDY
1. NO FUEL IN DAY TANK	This may be the result of valves to the storage tank being closed, transfer pump not operating, pipe lines may be broken, fuel filter may be clogged.
2. AIR IN HIGH-PRESSURE FUEL PUMPS	See Section 16 for Air Bleeding.
3. LEAKY SPRAY VALVE	See "Leaky Spray Valve" this section.
4. LEAKY REGULATING VALVE	Shut off all isolating valves. Pump fuel pressure up. Disconnect discharge line of regulator. If fuel drips out, regulator is leaking. See Section 16 for regulator maintenance.
5. LEAKY DISCHARGE VALVES IN HIGH-PRESSURE PUMP	Proceed the same as for leaky regulator valve. If fuel does not drip out of regulating-valve discharge line and pressure will not hold up, discharge valves in high-pressure fuel pump are leaking. See Section 16 for repairs.

NO OIL PRESSURE OR LOW OIL PRESSURE

Should not be below 35 pounds when oil in system is hot

PROBABLE CAUSE	REMEDY
1. LOOSE OR BURNED-OUT BEARINGS	See Sections 13 and 14 for Bearing Adjustment.
2. NO OIL IN LUBE-SERVICE TANK	This may be the result of a broken pipe line, or the sump pump not working. Sump pump suction screen may be clogged. Such conditions will be indicated by oil in the crankpits.
3. FAULTY HIGH-PRESSURE LUBE PUMP	This may be the result of worn pump parts. See Section 20 on lube pump maintenance.
4. OIL TOO THIN	Oil may be diluted with fuel oil or water. Oil temperature may be too high. It should not exceed 160 degrees before entering the oil cooler.
5. FAILURE OF OIL COOLER	This will be indicated by oil in cooling water discharge.
6. DEFECTIVE PRESSURE REGULATING VALVE	Valve spring may be weak or broken. Valve seat may be dirty. See Section 20.
7. BROKEN OIL LINE	Check all oil piping.

OVERHEATED ENGINE

The water temperature of the engine should not exceed 120 degrees for raw-water or 160 degrees for fresh-water cooling

PROBABLE CAUSE	REMEDY
1. SEA VALVE CLOSED OR OBSTRUCTED	Disconnect line ABOVE sea valve and see if water flows freely.
2. CIRCULATING PUMP NOT WORKING	See Section 22.
3. OVERLOADED ENGINE	See paragraph 2 (Smoky Exhaust).
4. IMPROPER VALVE TIMING	See Section 10 for proper settings.
5. COOLING WATER DISCHARGE OBSTRUCTED	Check all valves.
6. SCALE IN WATER JACKETS	Remove the cylinder clean-out covers and inspect.
7. AIR VENT OBSTRUCTED	Where fresh-water cooling system is used the vent in the expansion tank must be open.

ENGINE DOES NOT START OR MANEUVER ON FUEL

PROBABLE CAUSE	REMEDY
1. LOW STARTING AIR PRESSURE	Use auxiliary air compressor to charge air tanks. Low air pressure may roll the engine over, but not quite fast enough to start it firing. During cold weather, especially, full air pressure should be used for starting.
2. NO FUEL PRESSURE	See "No Fuel Pressure" this section.
3. IMPROPER TIMING	See Section 10 for proper settings.
4. STARTING CONTROL OUT OF ADJUSTMENT	See Section 18 for adjustment.

ENGINE DOES NOT TURN OVER WHEN STARTING AIR IS APPLIED

PROBABLE CAUSE	REMEDY
1. STUCK AIR-STARTING VALVE	Check as follows: Open all snifter valves. Locate the starting lever or hand wheel, in stop position. Open air starting tank and disconnect link that connects the master air valve on the starting manifold to the rocker shaft. Press down on the master air valve to open the line. If air blows out snifter valves the air-start valve is stuck open. See Section 11 for repairs.
2. INLET OR EXHAUST VALVE STUCK OPEN	With the engine in the stalled position apply the starting air and listen at inlet-manifold opening and at the end of the exhaust pipe. The sound of air escaping at one of these places will indicate a leaky inlet or exhaust valve, respectively, see Section 11 for repairs.
3. IMPROPER TIMING	See Section 10 for proper settings.
4. STARTING CONTROL OUT OF ADJUSTMENT	See Section 18 for adjustment.

ENGINE WILL NOT TURN UP TO FULL REVOLUTIONS

WARNING: Remember that the engine in a boat such as a tender or freight-and-passenger boat will not turn up to full revolutions if towing another vessel or barge. A towing propeller is designed to allow an engine to turn up full revolutions when the boat is moving slowly through the water while a propeller on a vessel running free and away is designed for maximum speed and cannot be expected to tow efficiently.

If after checking all the items under "Smoky Exhaust" the engine does not turn up to full revolutions, proceed as follows: Set the fuel pressure at 4200 pounds and the governor lever (in case of hand-wheel control) or the single-lever control, in full-speed position. Count the number of revolutions per minute. Press the fuel wedges full in by hand and count the revolutions per minute again. If this action produces the rated speed of the engine, or over, adjust the governor as described in Section 18.

ENGINE REQUIRES EXCESSIVE BALANCING TO EVEN UP CYLINDER LOAD AFTER TIMING

REMEDY	PROBABLE CAUSE
1. SPRAY VALVE TIP OPENINGS TOO LARGE	Check hole sizes. See Section 17 for spray valve maintenance.
2. WORN FUEL CAM LOBES	Check for wear, see Section 17 for cam lobe maintenance.

ENGINE KNOCKS

PROBABLE CAUSE	REMEDY
1. SPRAY VALVE STUCK OPEN	Shut off each isolating valve one at a time. When leaking valve is located, check as described in "Leaky Spray Valve" this section. A blowing cylinder-relief valve often goes with a stuck spray valve.
2. LOOSE BEARINGS	See Sections 13 and 14 for bearing adjustment.
3. LOOSE FLYWHEEL OR COUPLING BOLTS	Check all bolts for tightness.
4. LOOSE PROPELLER	This can usually be detected as an engine is just stopping by listening close to the propeller shaft. The sound of a loose propeller will travel along the shaft as a dull thud just as the engine rocks to a stop.
5. LOOSE PISTON PIN	Spot the piston on top center. Clamp a dial indicator to the crank web, and position it so a reading can be taken on the vertical movement of the piston skirt. Install a jack between the other web and the piston skirt. Jack up the piston and measure the total lift on the dial indicator. Subtract the clearance in the crank pin bearing. The difference is the piston pin clearance. See Section 12 for piston pin clearance.