OPERATORS MANUAL

TC 1386

ATLAS IMPERIAL MARINE DIESEL ENGINE

MODEL 6HM464—120 HORSEPOWER

6 CYLINDER 7½ x 10½ 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

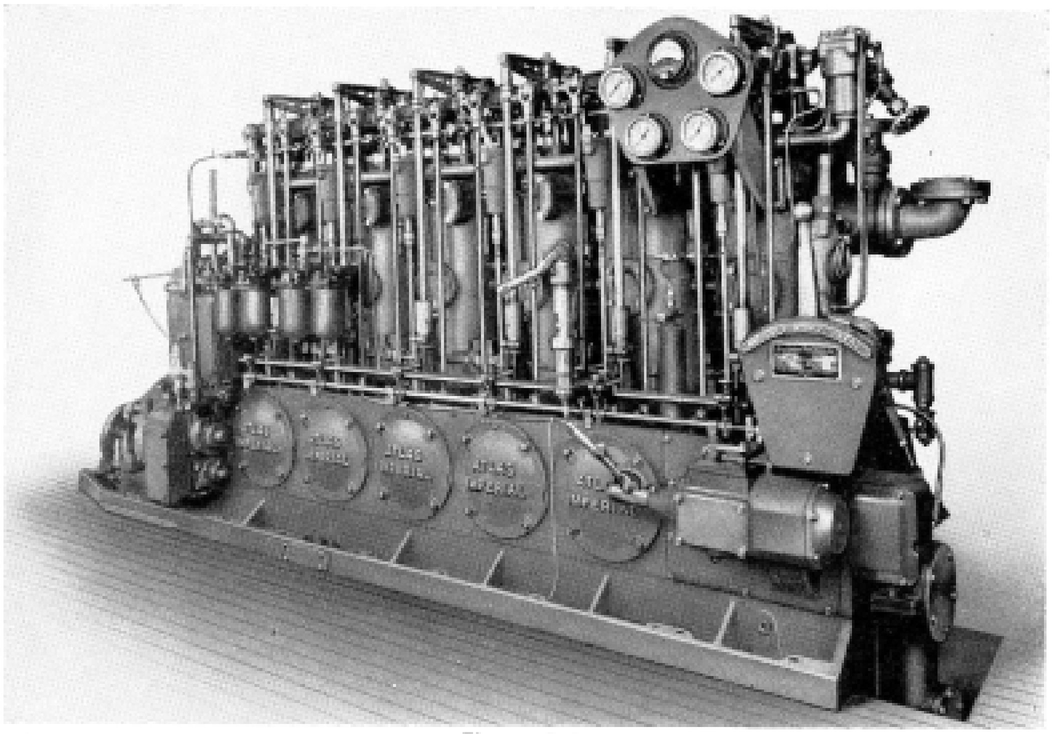


Figure 1-1

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.

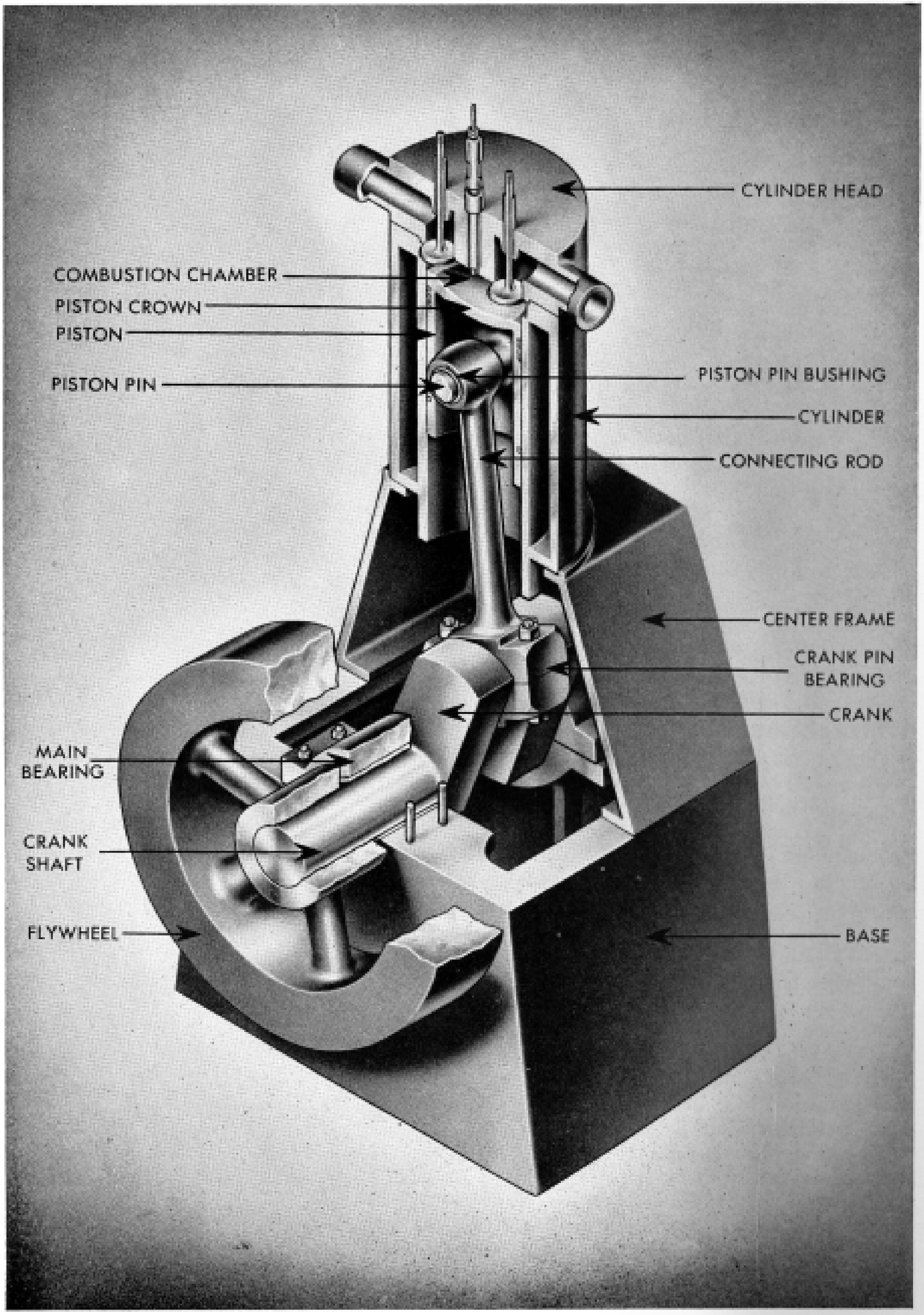

CYLINDER HEAD
COMBUSTION CHAMBER
PISTON CROWN
PISTON
PISTON PIN
PISTON PIN BUSHING
CYLINDER
CONNECTING ROD
CENTER FRAME
CRANK PIN BEARING
CRANK
MAIN BEARING
CRANK SHAFT
FLYWHEEL
BASE

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 7½ inches across (or has a piston 7½ inches in diameter, or has a bore of 7½ 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 44¼ square inches, or 26,550 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.

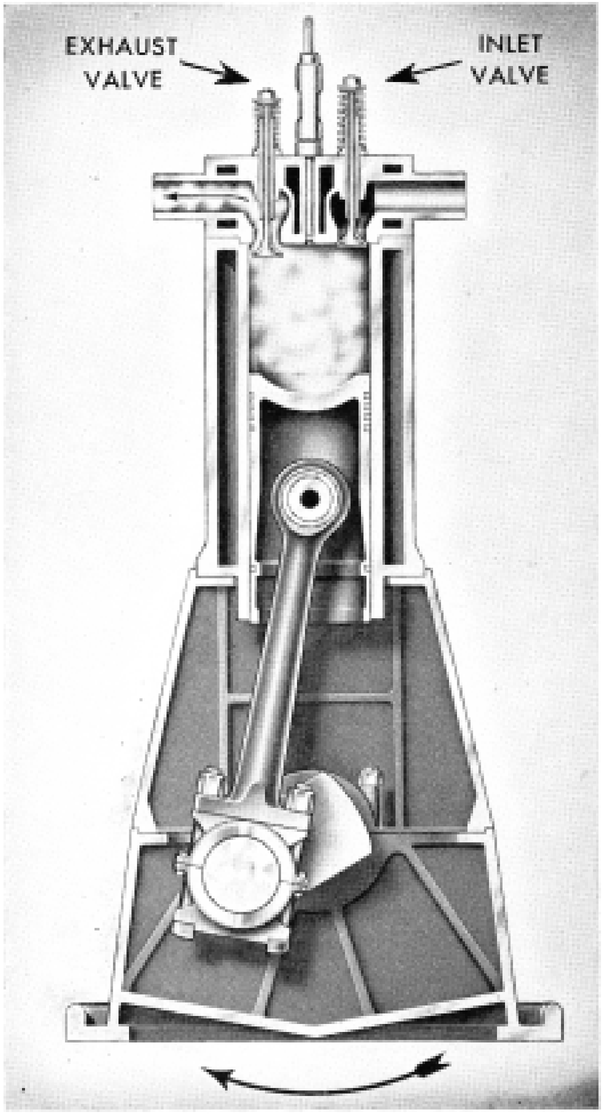


Figure 1-3

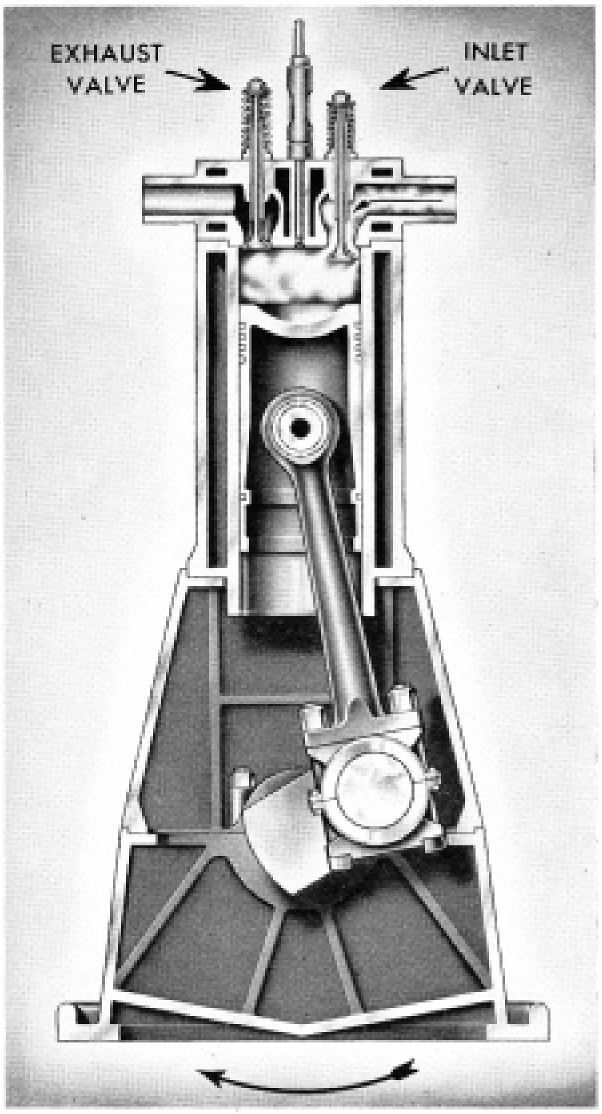


Figure 1-4

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.

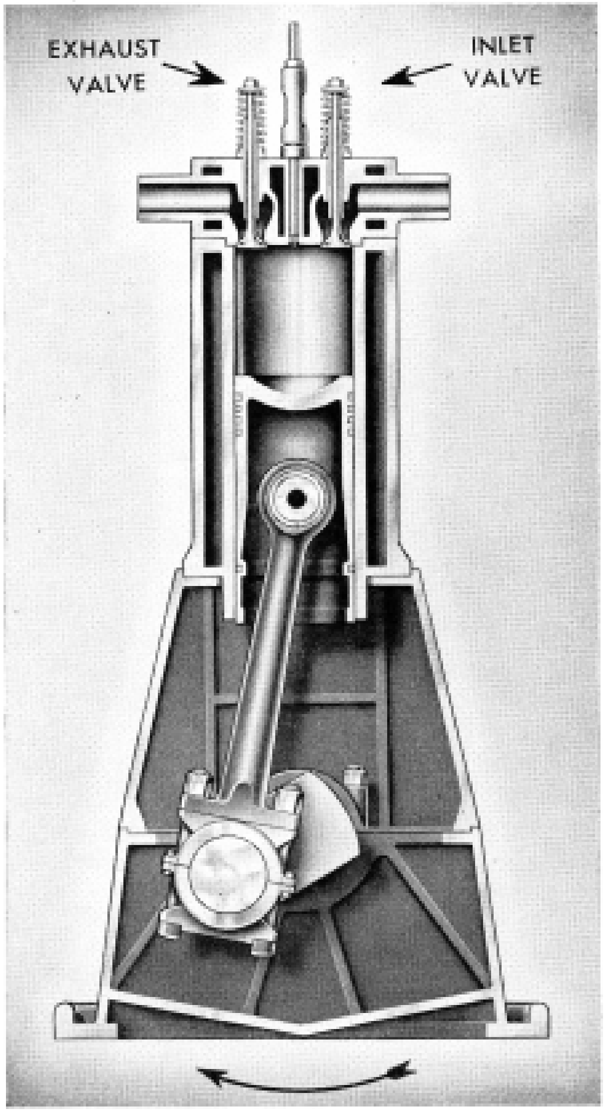


Figure 1-5

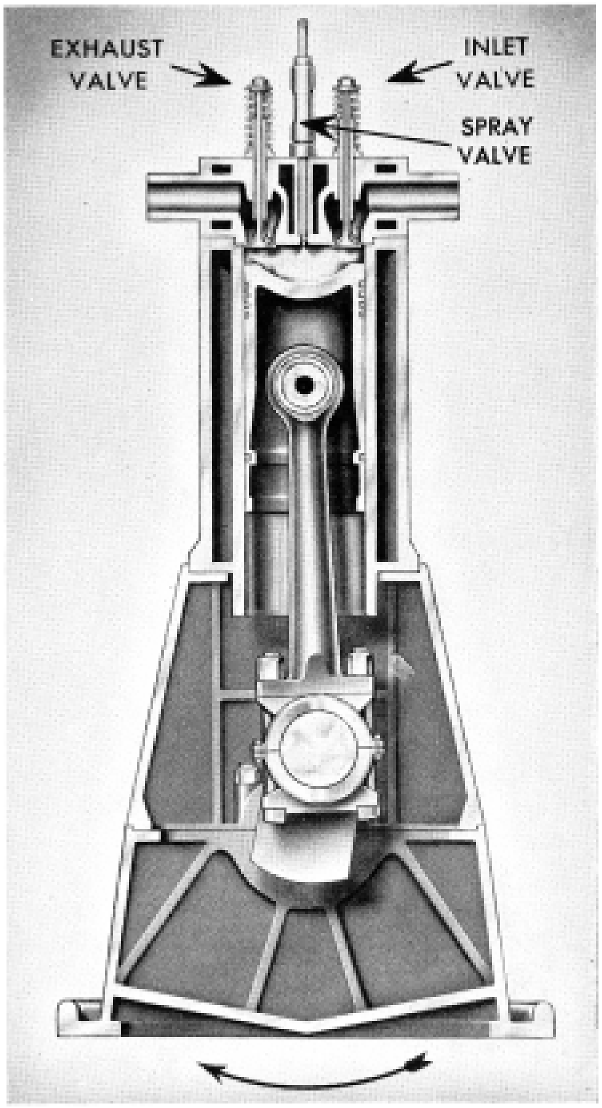


Figure 1-6

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.

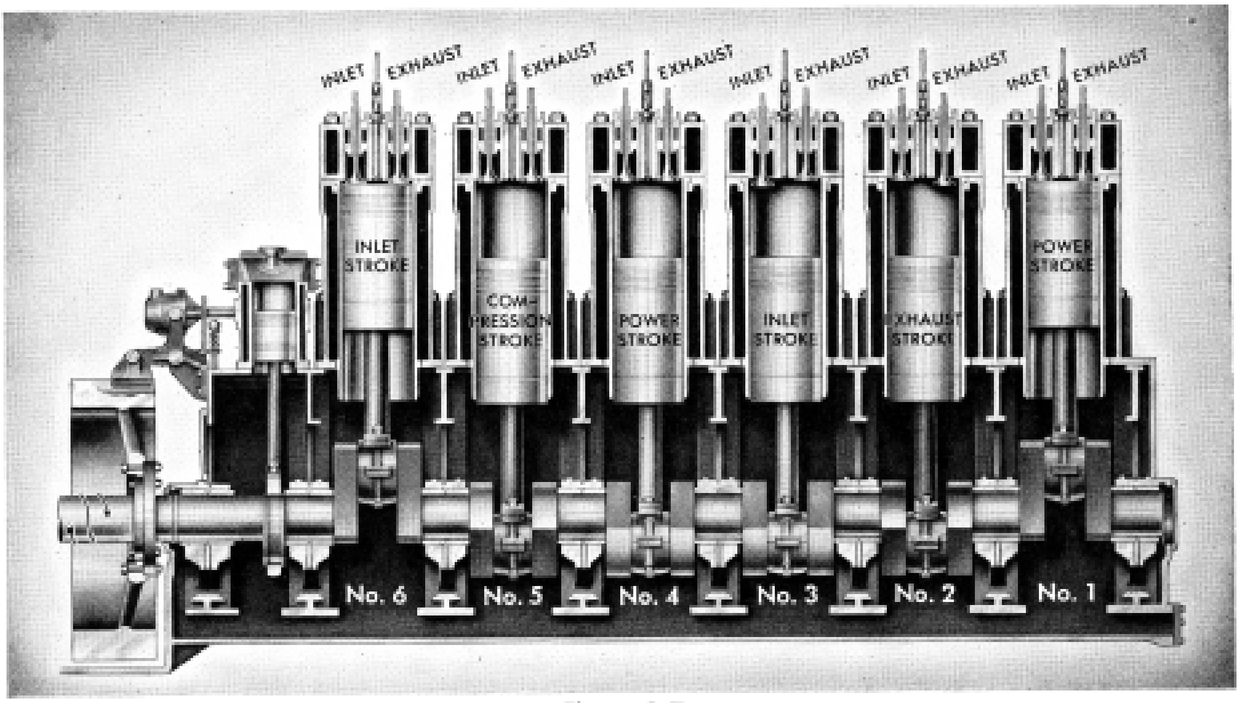


Figure 1-7

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

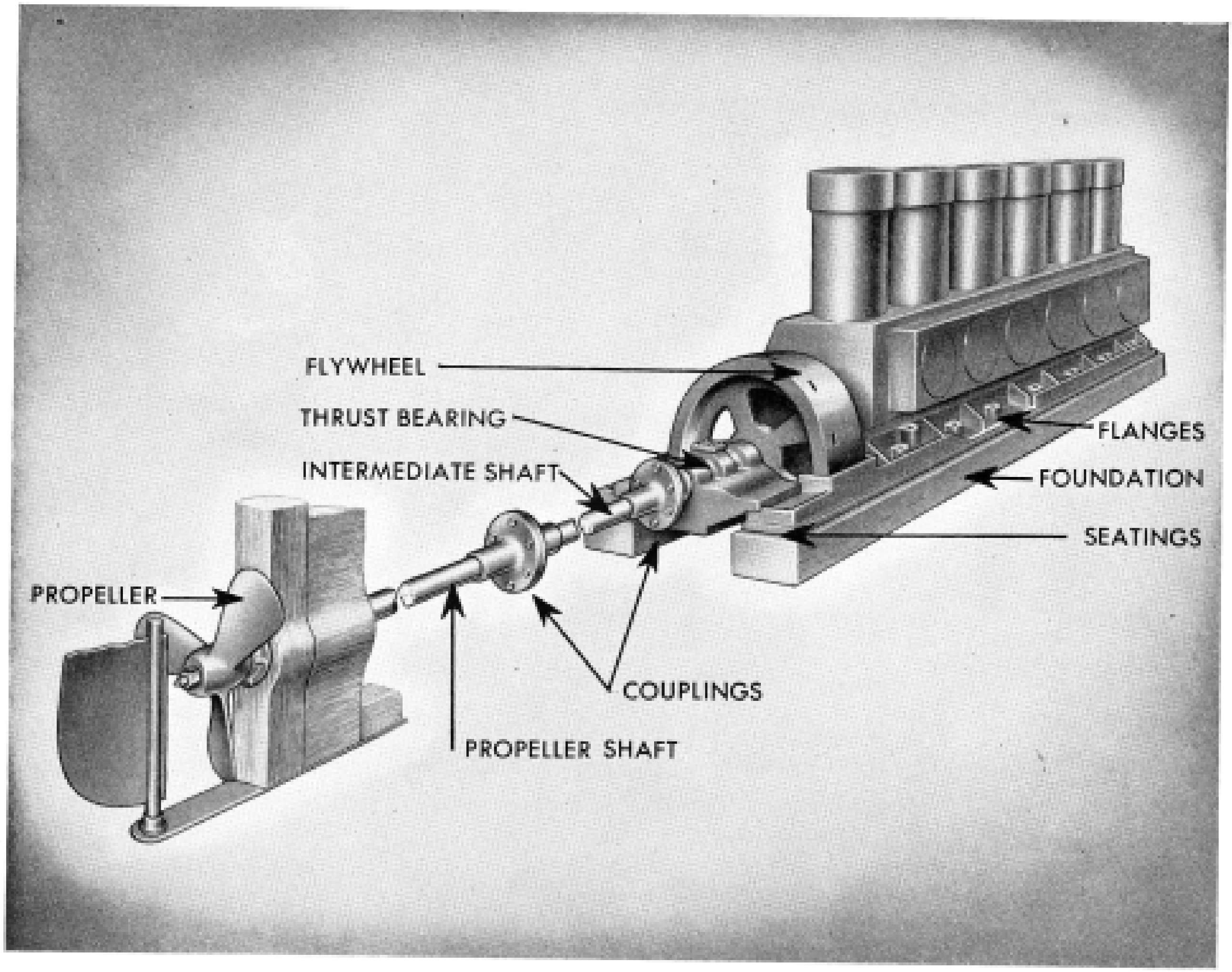


Figure 1-8

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 toward 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 the wear of 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 of 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 walls.

(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 subdivisions 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, usually called the lube service tank for short, furnishes storage capacity for the oil of the pressure system, shown in Figure 2-1.

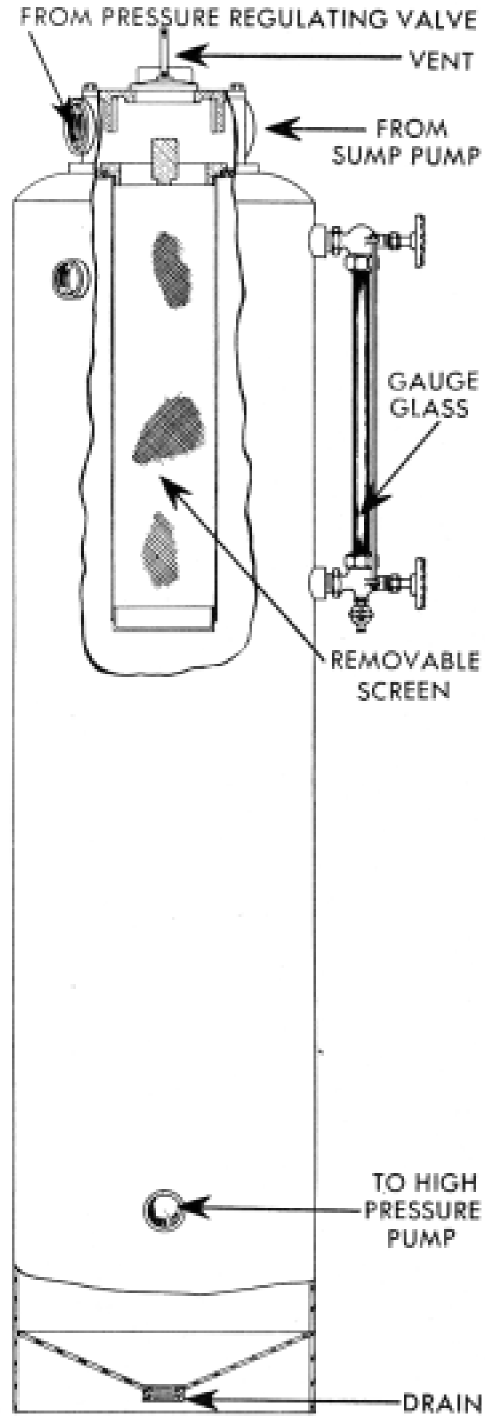


FIGURE 2-1

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 presure up to 35 or 40 pounds and send the oil on through the pressure system.

This pump has a hollow cylinder called a rotor, because it is rotated by gears driven from the engine camshaft. 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

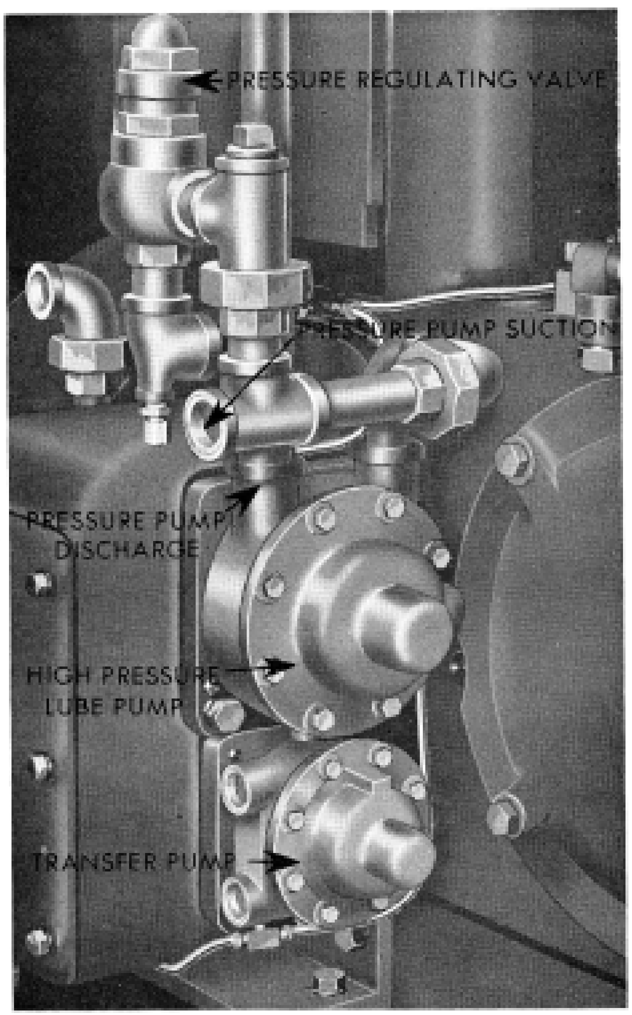


FIGURE 2-2

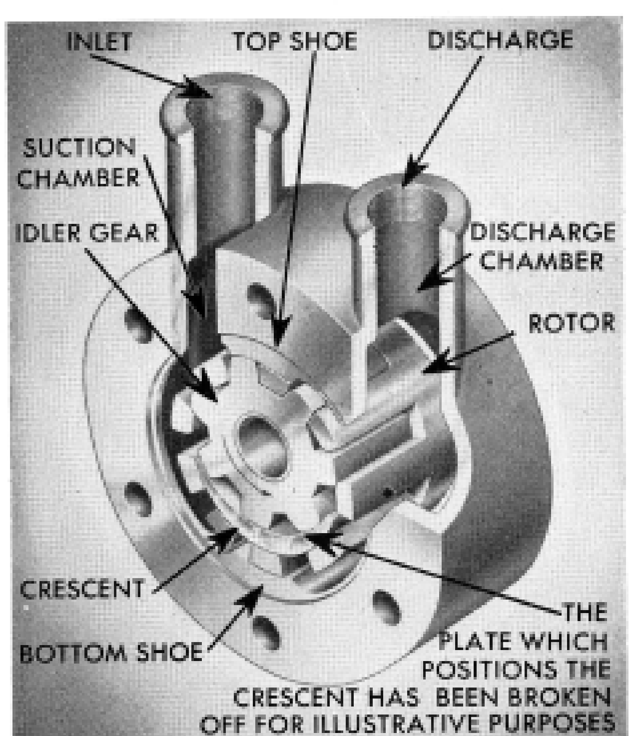


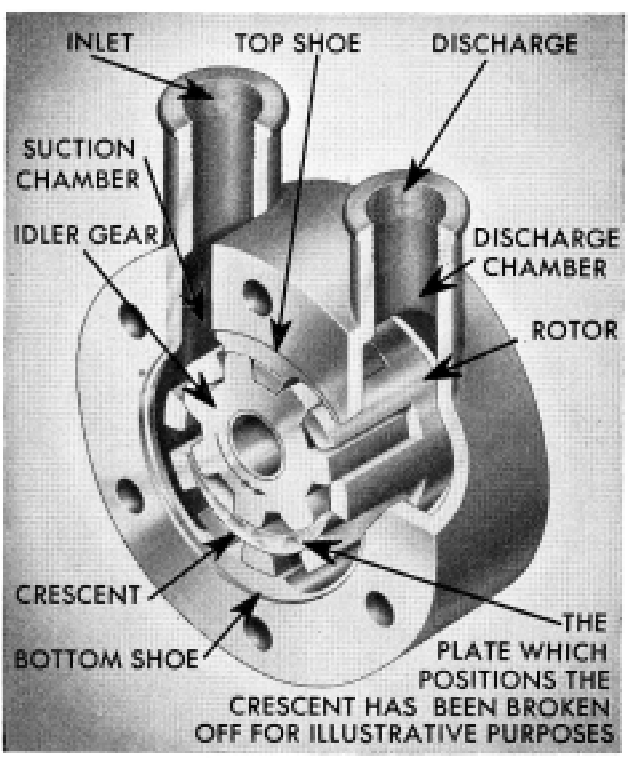
FIGURE 2-3

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.

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 the chamber.

As the main engine reverses its direction or rotation to propel the ship astern, and the pump is driven from the camshaft, 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 dis-



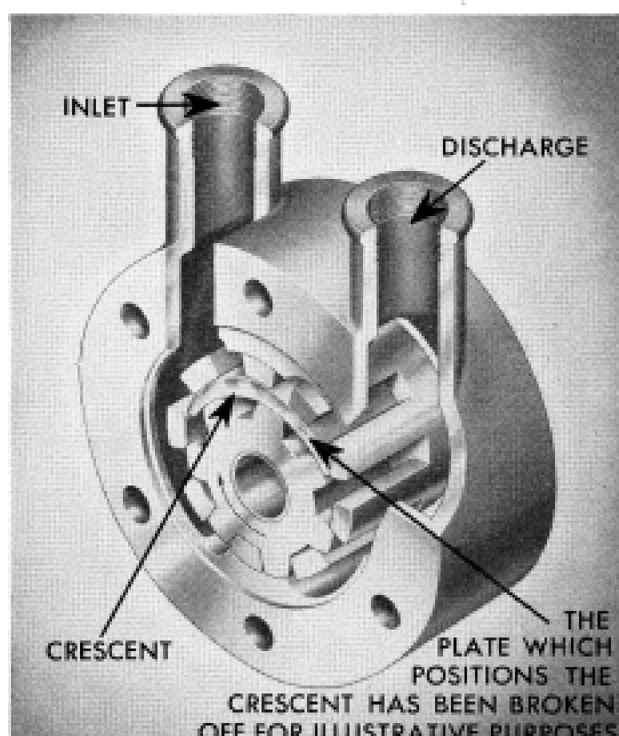


FIGURE 2-4

charge 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. This result is obtained by selecting a pressure pump, large enough so that it delivers more oil than is needed and at a pressure higher than is necessary. The supply and pressure are reduced to the desired amounts by the action of a pressure-regulating valve. A typical valve of this type is shown in Figure 2-5.

It is a valve so constructed that oil pressure tends to open it while a spring exerts pressure to hold it closed. It will open whenever the oil pressure overcomes the spring tension. When the valve opens it bleeds off some of the oil from the discharge line of the pump and by-passes it back to the suction side. 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. The adjustment should be such that the oil pressure reads from 35 to 40 pounds on the pressure gauge, when the engine is hot.

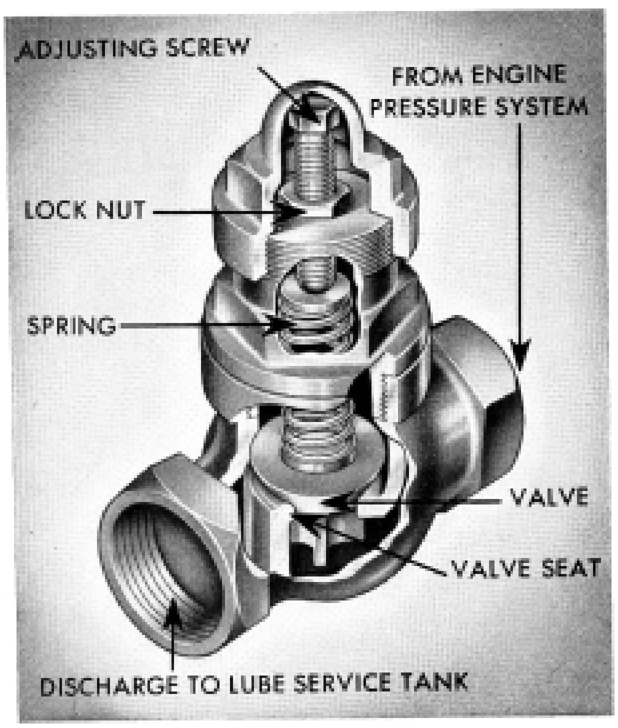


FIGURE 2-5

The piping layout for connecting up the pressure-regulating valve is shown in Figure 2-6. The discharge from the pressure pump to the filter is branched by a tee and the regulating valve is installed on this tee. The discharge from the valve is piped back to the suction of the pressure pump.

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. Next, examine all bearings and internal oil leads.

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 pressure pump 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. This filter is of a duplex type. In other words, it is really

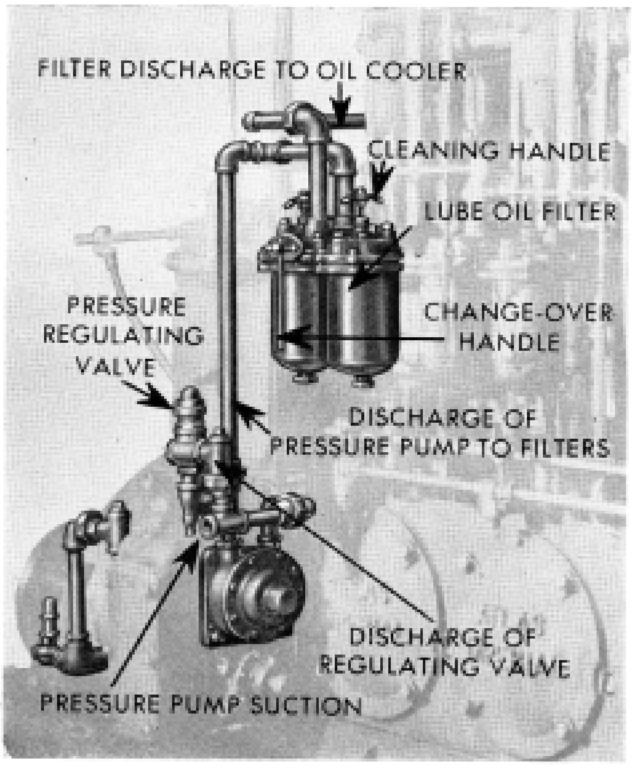


FIGURE 2-6

two filters, with piping and valves so arranged that one side or the other can be cut out so that the other half can be cleaned. The filter has a two-way valve, built into the head and operated by a handle, by which the oil can be directed into either half of the filter. When the lever is in the central position, both filter elements are in operation.

The filter is made up of a head to which are attached the two filter elements. These are encased in removable bowls. The element is made of brass in the shape of a cylinder and is perforated with openings 0.003 inch wide.

The oil is fed into the bowl, where it passes through the perforations into the core of the filter. From here it is led through the discharge opening and on to the engine. Most of the dirt particles strained out by the element will settle to the bottom of the bowl but some will adhere to the element. In order that such particles may be cleaned off periodically, there is a knife that bears against the element. A handle at the top of the filter turns the element cylinder and causes the knife to scrape off any dirt which may be clinging to it. This handle should be given a full turn each four hours of operation and at least once each week each filter 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 passage around some obstruction. As it is possible for the filter to become clogged to the point where oil could only pass through it with great difficulty, a 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 clogged, 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 shown in Figure 2-7.

As the oil makes a complete circuit of the system in less than two minutes it absorbs considerable heat from the engine. This temperature will vary with the condition of the

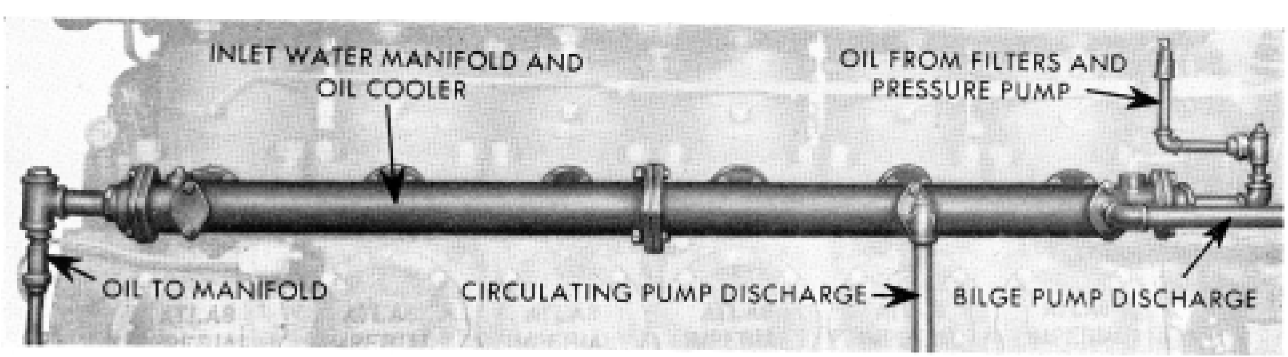


FIGURE 2-7

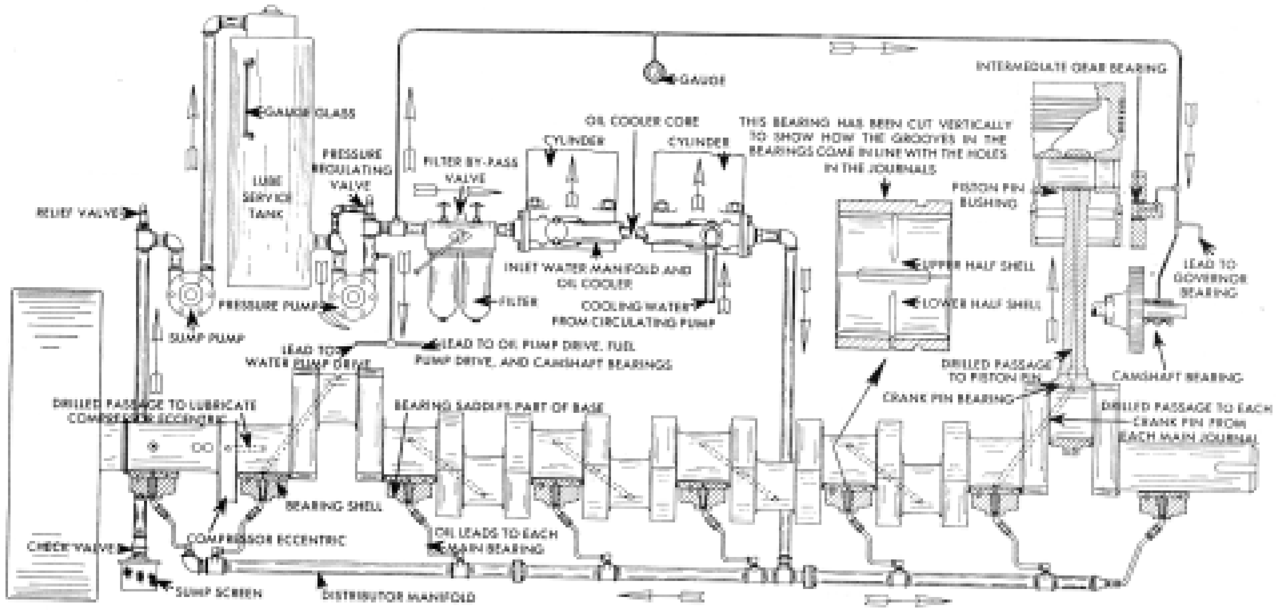


FIGURE 2-8

engine, the load it is carrying, and the climate the engine is operating in. As it is desirable to hold the operating temperature of the oil below 160 degrees Fahrenheit, the cooler is used to dissipate the excess heat. A cut-away illustration of the cooler is shown in Figure 3-7 and paragraph 12 of Section 3 explains its construction. Figure 2-7 shows how the oil, from the filter, enters the after end. When it leaves the cooler it is piped directly to the distributor manifold in the base.

The outside shell of the cooler is the water inlet manifold and it is apparent that if the boat is operating in water which carries considerable sediment the cooler assembly is the most likely place for deposits of silt to build up. The dismantling of the cooler for inspection is covered in Section 20.

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 the 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

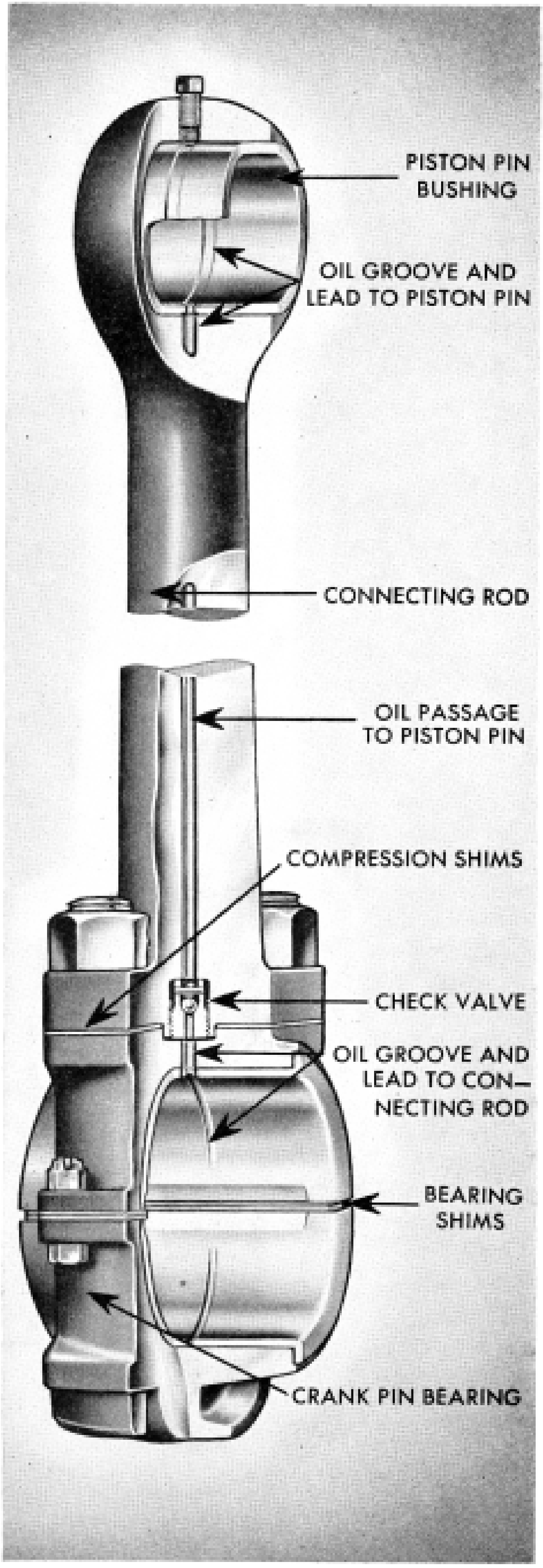


FIGURE 2-9

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 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: In marine installations, 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

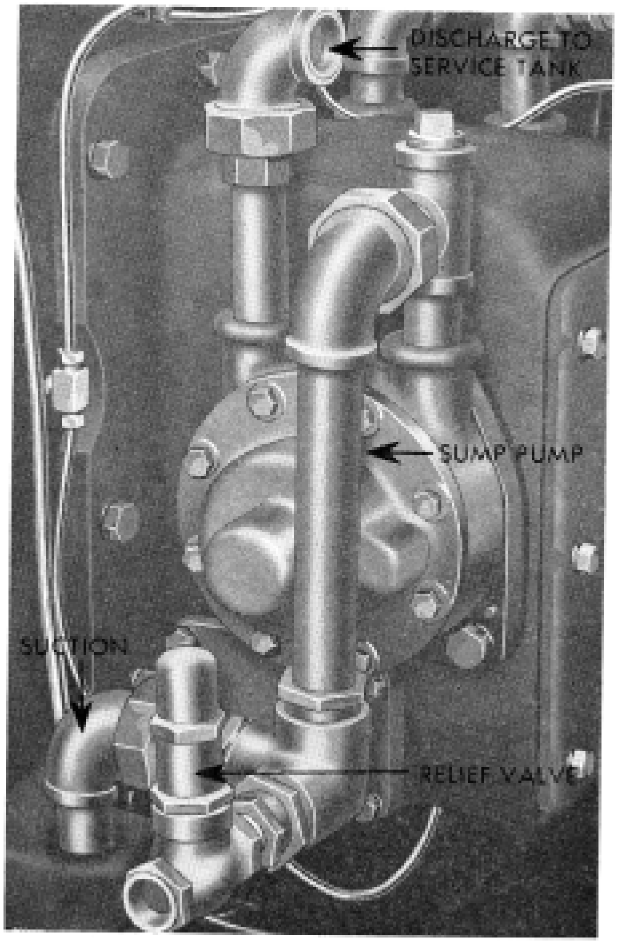


FIGURE 2-10

back to the sump, collects, and is picked up by a pump constructed exactly like the pressure pump but it is called the scavenging or sump pump. This pump, shown in Figure 2-10, delivers the oil back to the top of the lube service tank, where it is screened before passing into the body of the tank.

The sump pump suction line enters the engine base through a removable plate and is equipped with a screen and a foot valve on the lower end. 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. Its purpose is to keep the suction line of the pump full of oil while the engine is stopped. The screen should be removed and cleaned each time the base is washed out.

There is an adjustment to be made when replacing this suction assembly which is covered in Section 20.

As the sump pump reverses each time the engine does, pressure might be built up in the suction line against the foot valve during the short time required for the idler gear and crescent, in the sump pump, to turn into the reverse position. The relief valve, shown in Figure 2-10, is set to open and release any such excess pressure.

18. OIL LEVEL IN LUBE SERVICE TANK: Usually no shut-off valve is installed between the lube service tank and the 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 clearance 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 gauge, it is wise to take off the rear cover plate from the base and 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 or 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, 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 shaft with an eccentric for each set. The shaft is driven by the bilge pump eccentric on the end of the engine camshaft.

The first pump of each set draws oil from the lubricator reservoir, and forces it up through a small pipe from which it escapes by drops. These drops can be seen through the glass front of the lubricator. The drops drain into the cup-shaped end of a pipe, 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, shown in Figure 2-11, 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.

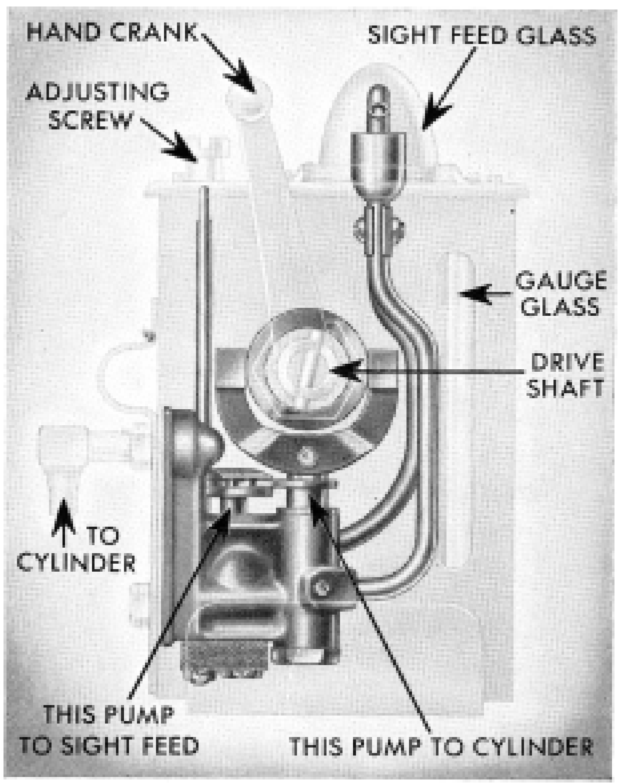


FIGURE 2-11

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 in copper tubing. It enters each side of the cylinder through oil pipes that are screwed into the cylinder proper and pass through the jacket in the packing glands as shown in Figure 2-12. These pipes are packed with rubber rings called grommets.

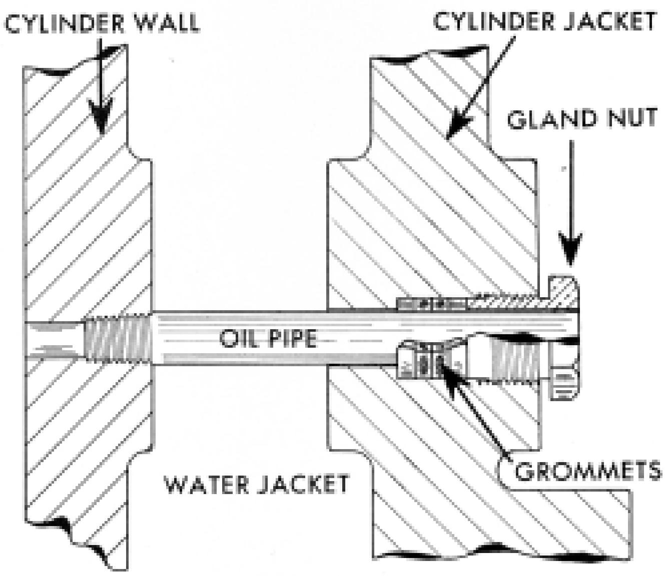


FIGURE 2-12

21. THRUST-BEARING LUBRICATION: Figure 2-13 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-bear-

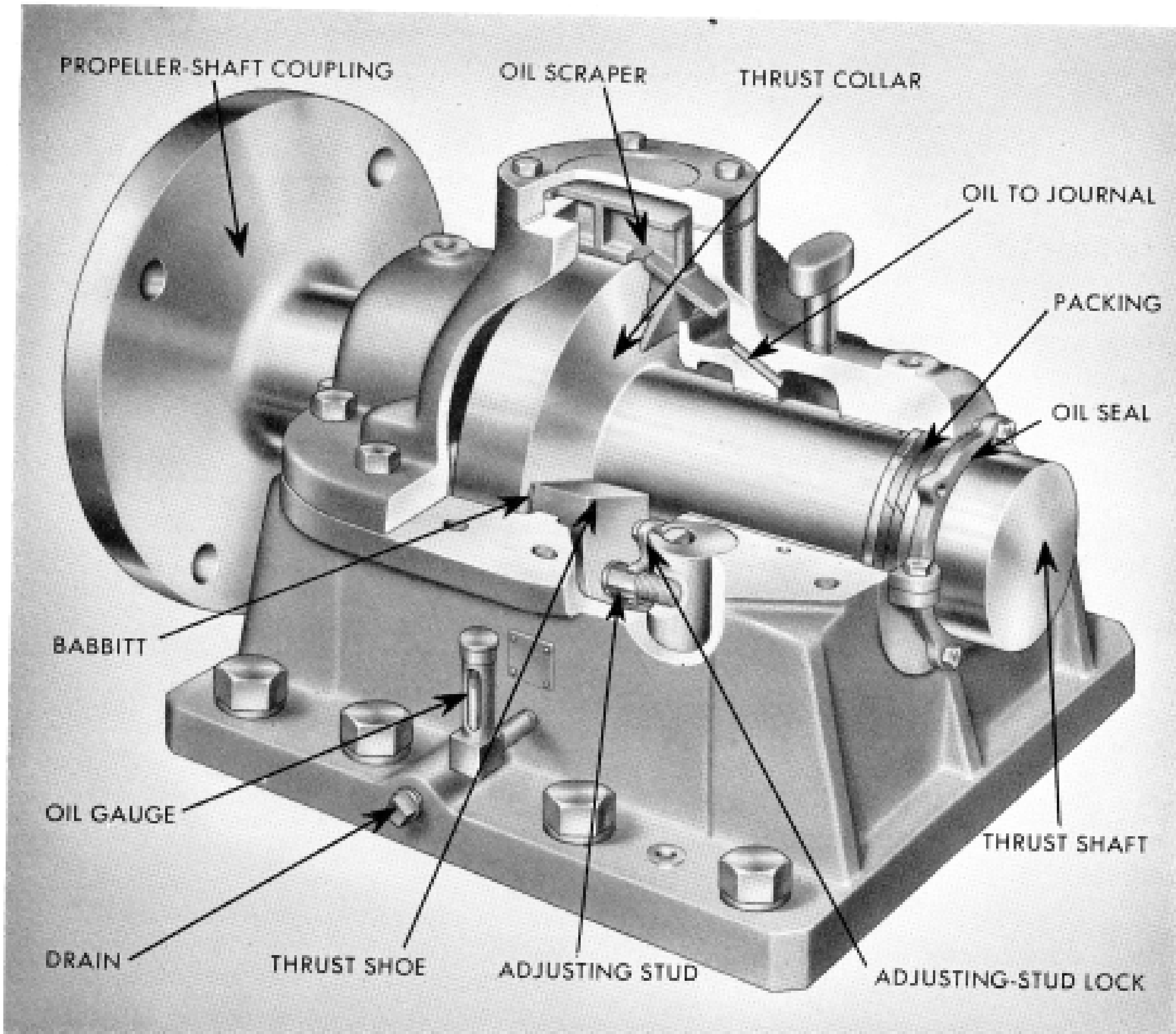


FIGURE 2-13

ing housing should be drained every 500 hours of engine operation. The time to drain is just after the engine has been running so that the oil is warm. The housing should then be refilled with new oil until the level shows in the gauge glass.

22. HAND OILING: Some places on the engine have open recesses which are connected to some part requiring oil. These recesses are packed with waste to avoid the oil splashing out. They should be oiled every four hours and the waste should be removed, the recess cleaned out and fresh waste put in at least once a month.

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. Some oil cups have lids and are filled with waste. These should be filled every four hours and, of course, the cover should be kept closed when not actually adding oil.

Another form of lubricator is the sight-feed oiler. This consists of a glass bowl reservoir, a small sight-feed glass and an adjustable stem. The stem is raised by a small lever and permits oil, by drops, to pass through the sight-feed glass. The number of drops per minute can be adjusted to meet the requirements of the part being lubricated. A sight-feed oiler and an oil cup are shown in Figure 2-14.

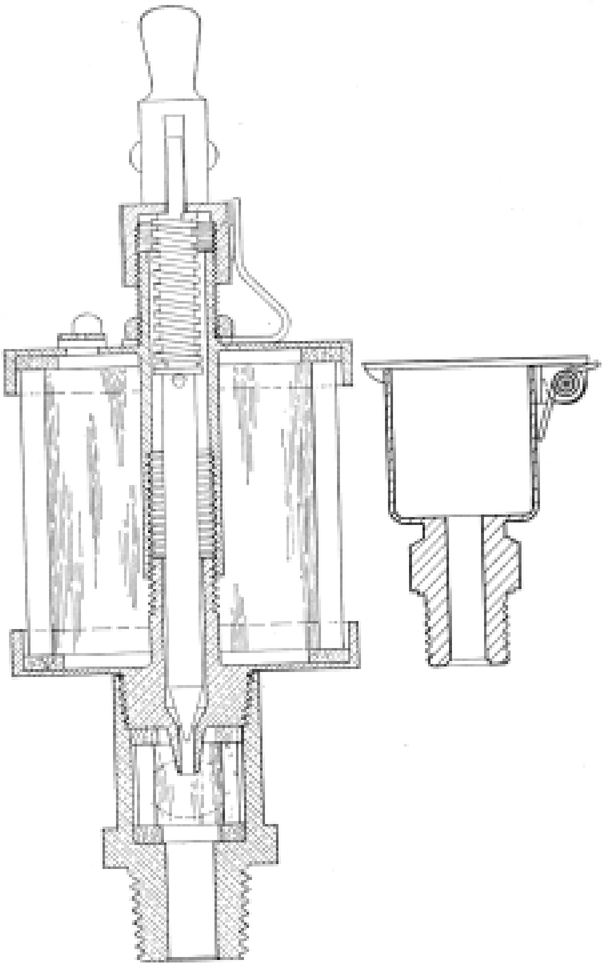


FIGURE 2-14

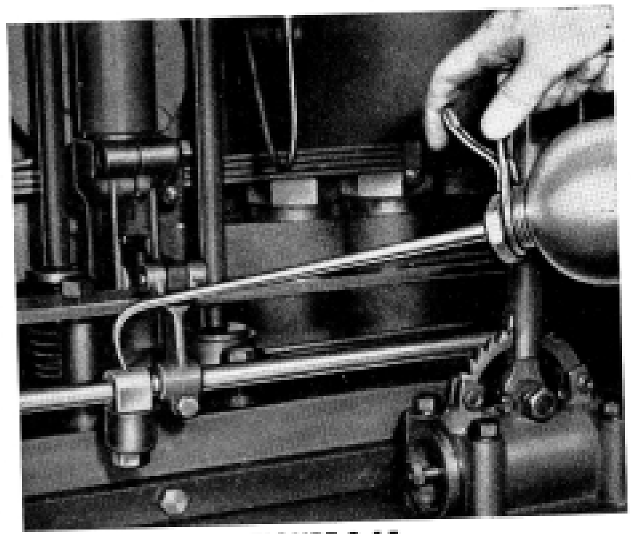


FIGURE 2-15

There are bearings that receive oil 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.

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 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.

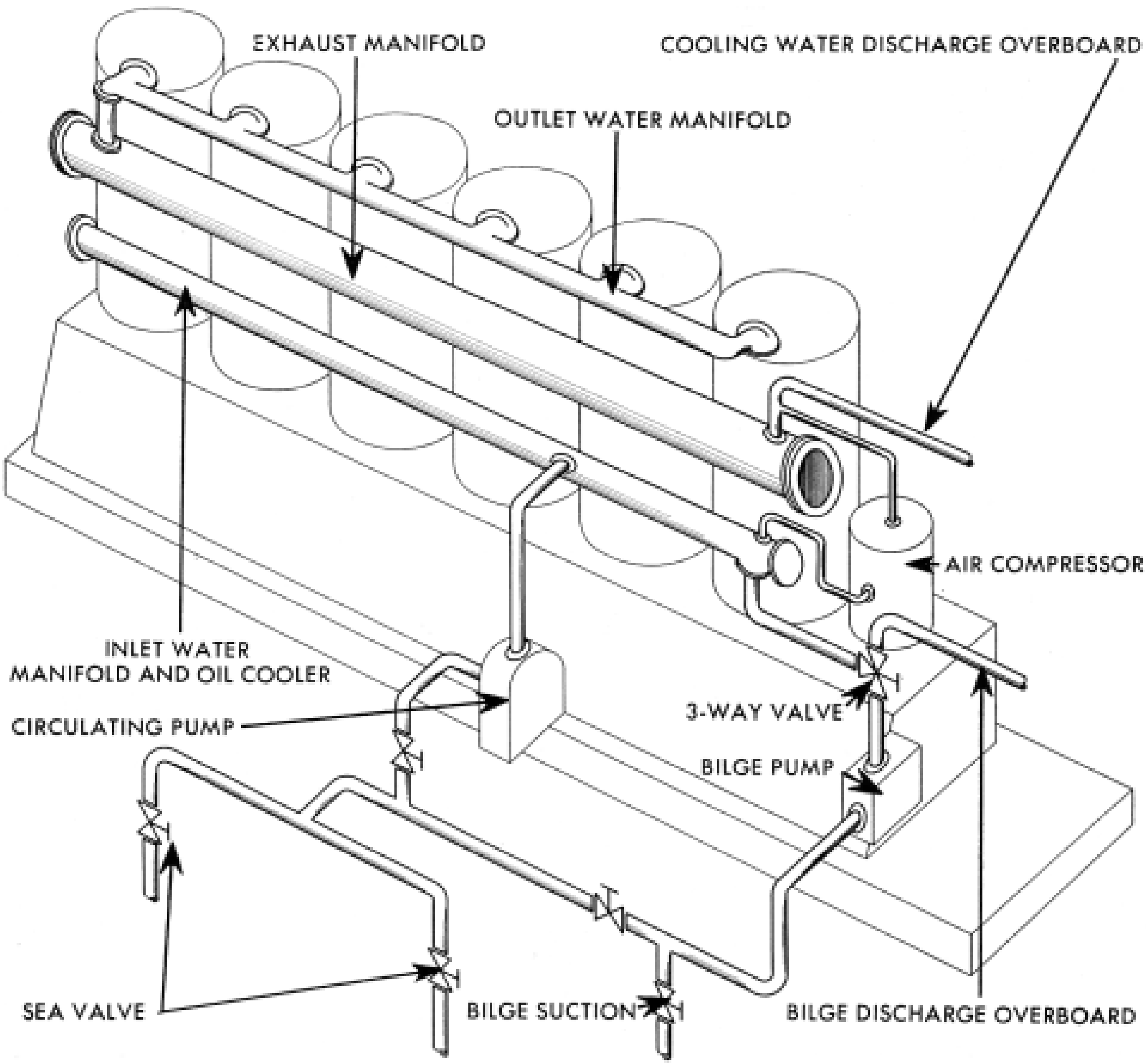


FIGURE 3-1

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 will 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.

3. RAW-WATER SYSTEM: A raw-water cooling system is the easiest to install, but 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.

4. VALVES: In any discussion of a system which carries gas, air, or liquids, frequent reference is made to valves. So that the various types and their operation may be understood, there follows a brief description of the more commonly used valves.

Globe Valves: Illustrated in Figure 31, Section 8, a valve having its seat on a horizontal plane and the valve attached to the stem which usually rises when opened. That is, the stem moves up as the valve is lifted from the seat. The seat may be formed in the body of the valve or it may be an insert of some non-corrosive metal. The valve proper is usually attached to the stem so that it "floats," making it possible for the valve to find its own center and plane on the valve seat. On gas or air lines the valve is often faced with a composition disc which permits a tight joint to be made, between the seat and the valve, with less pressure than would be required if both parts were metal. Globe valves are usually used on Diesel air lines and smaller oil and fuel lines. They are primarily high-pressure valves.

Gate Valves: Illustrated in Figure 31, Section 8, a valve having vertical seats and a wedge-shaped gate or disc which is either raised or lowered by a stem which may be either rising or non-rising. These valves offer little resistance to the flow of whatever they control as when the gate is lifted there is a straight-through passage from one side of the valve to the other. They are usually used on bilge or sea lines where the pressure is not great. They are better adapted to operating when partially open than globe valves. They are not practical for high-pressure air.

Two- and Three-Way Valves: Sometimes called stop cocks. Illustrated in Figure 31, Section 8, the two-way valve is generally used where a water line is either open or shut the majority of the time, and where the necessity of opening and closing the valve is not frequent. They are ideal for partially opened uses and offer little resistance to flow. They are not suitable for high-pressure use and tend to stick in any position they are left in for any length of time. The three-way valve is used where it is necessary to direct the flow of one line into either of two other lines. A good example of its use is found in Figure 3-1 which shows a three-way valve installed in the discharge line of the bilge pump. Let us assume that the pump is being used on bilge service. The line marked "bilge suction" would continue on to whichever places in the hull collect bilge water. The valve in the bilge suction line would be opened so that the line leading from the bilges would be open. The valve in the line leading from the sea valves would be closed, shutting off the sea water from the bilge pump. The three-way valve in the pump discharge would be so turned that the line leading to the inlet manifold would be shut off, leaving a clear passage for the bilge water, overboard through the bilge discharge pipe.

If it became necessary to use the bilge pump to circulate water through the engine the valve in the bilge suction line would be closed so the bilge suction was shut off and the valve in the sea line opened to the pump. The three-way valve in the discharge line would be turned so as to close the overboard pipe and open the short line into the inlet manifold. The bilge pump could now draw water from the sea valve and force it through the engine.

5. 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 bolted 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 the movement of the hands of a clock (counter-clockwise); to close it you turn it clockwise.

6. CENTRIFUGAL RAW-WATER CIRCULATING PUMP: The pump shown in Figure 3-3 is used on Atlas engines designed for raw-water cooling systems. It is of the reversible type as it must supply cooling water when the engine is operating either ahead or astern. It consists of a housing, an impeller,

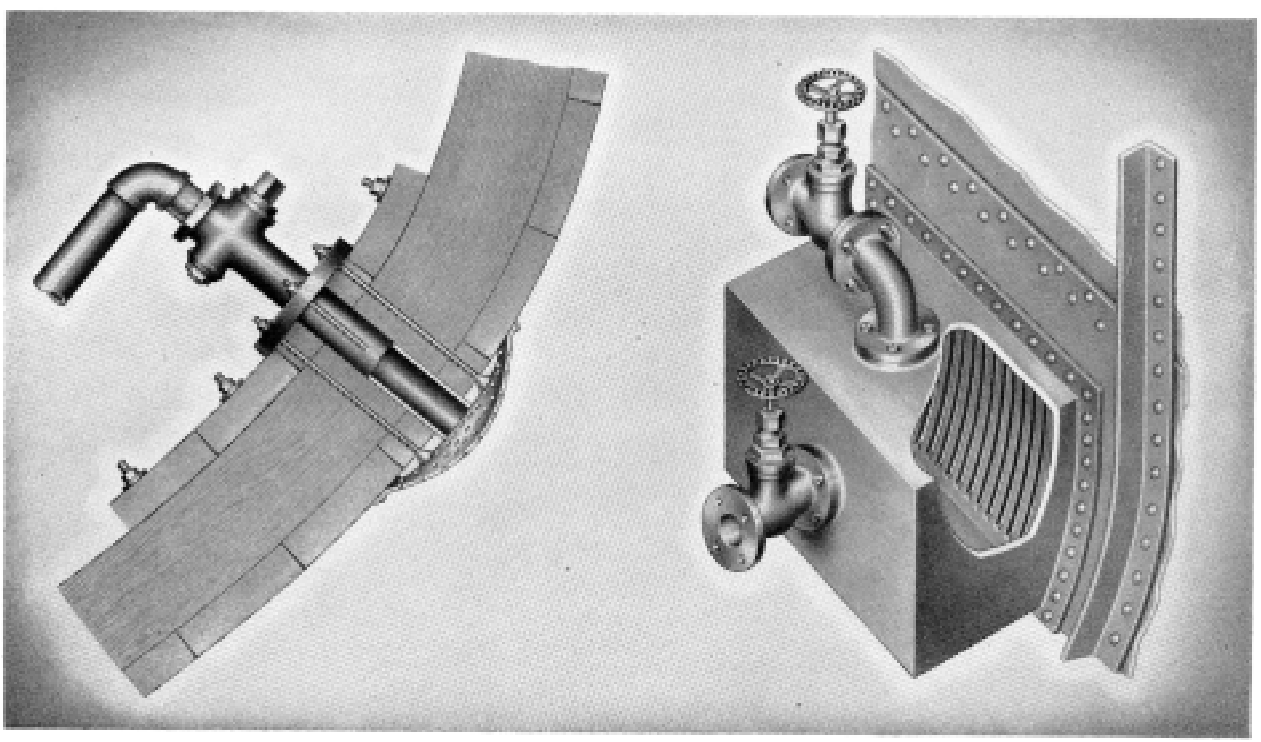


FIGURE 3-2

a shaft and packing gland and an outboard bearing. This bearing is used to locate the shaft and impeller in their correct fore and aft position and this adjustment is covered in Section 22.

The housing fits closely to each side of the impeller but is enlarged slightly around the circumference. At the top of the pump, this enlarged chamber is shaped into the discharge opening. The impeller is really two discs mounted on the shaft with blades or vanes arranged between the discs and extending from the circumference to the hub. The disc next to the suction opening is cut away in the center, so that an opening slightly larger than the suction pipe connects the slots between the vanes and the suction opening.

As the impeller is rotated rapidly, about 1700 revolutions per minute, water in the slots is thrown outward into the chamber. A pressure is built up in the chamber and water is forced out of the discharge opening. As the water is thrown out of the slots formed by the vanes,

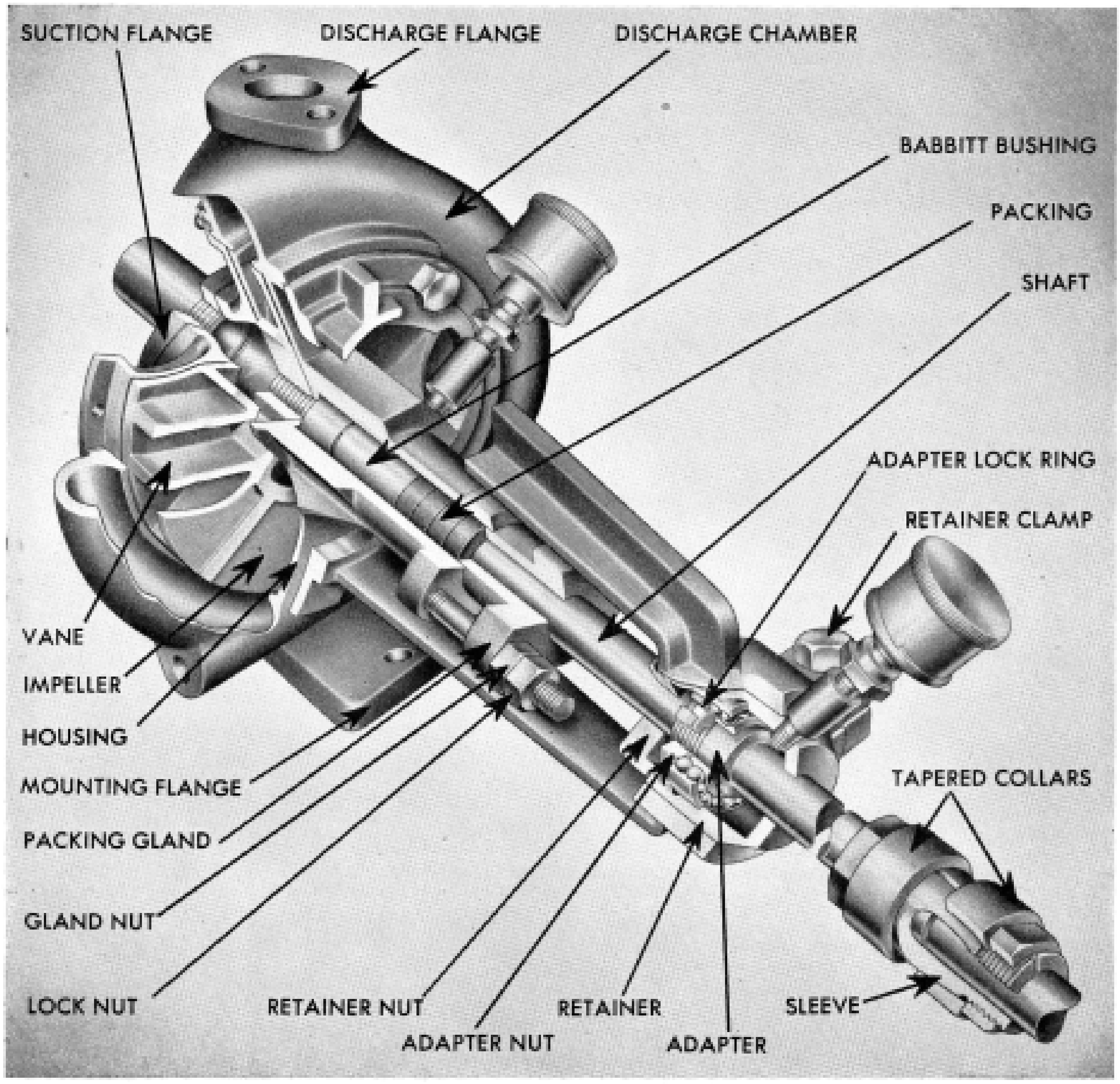


FIGURE 3-3

a slight suction is created which draws more water in through the suction opening. From the foregoing it will be seen that centrifugal pumps rely entirely on speed to operate and it must be remembered that there is a speed below which they will not function.

The speed at which these pumps operate requires that the impeller be in good balance. If through accident or rough handling the vanes of the impeller get chipped or broken, the shaft and impeller should be removed and checked for balance.

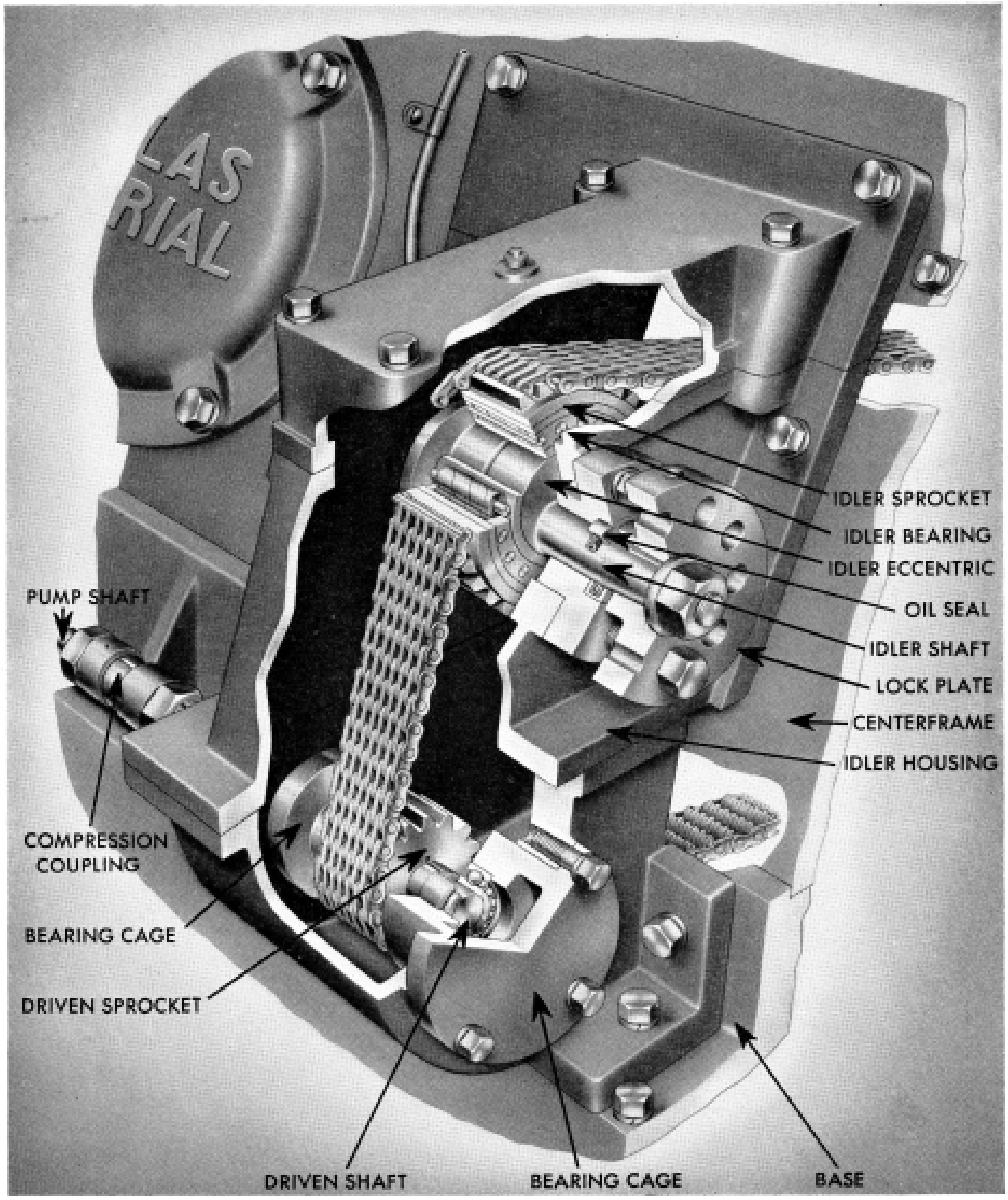


FIGURE 3-4

7. PUMP BEARINGS: As these pumps are designed to operate in salt water the housing and impeller are made of bronze, a metal which is impervious to salt water corrosion. The shaft is made of either bronze, monel, or stainless steel and is carried on a babbitt bushing which is pressed into the housing. This bearing is lubricated by a grease cup which is screwed into the housing at a point which lines up with a circular groove on the outside of the bushing. Holes in the bottom of this groove lead the grease through the bushing into the bearing area. As this bearing lies between the pump proper and the packing gland a waterproof grease should be used.

The outboard bearing is carried on an extension frame which bolts onto the pump housing. The retainer which houses the bearing is equipped with a grease cup that should be filled with a good grade of ball bearing grease.

8. PUMP COUPLING: This pump is connected to the drive shaft by a compression coupling. There is a sleeve with a bore slightly larger than the size of the shafts and split on one side. Each end of this sleeve is threaded and the part of the sleeve adjacent to each threaded area is tapered. There are collars, with corresponding tapers, which are forced onto the sleeve by nuts, on each end. The coupling is slipped over the ends of both shafts and when the nuts are tightened the tapered collars squeeze the sleeve tightly to the shafts. The alignment of these shafts before attaching the coupling is described in Section 22.

9. PUMP DRIVE: The pump drive, shown in Figure 3-4, consists of sprockets, silent chain, a tightening idler and a housing to carry the driven shaft and the idler. There is a sprocket on the crankshaft at the after end of the engine. A silent chain is driven by this drive sprocket and passes around the sprocket on the driven shaft and over a tightening idler. The driven shaft is supported on ball bearings that are fitted to the cages which attach to the drive housing. The tightening idler is carried on a roller bearing which is mounted on the eccentric hub of the idler shaft, which, when revolved, moves the idler closer or further away from the driven shaft sprocket.This is an adjustment which takes up any slack in the chain. This adjustment is described in Section 22.

Figure 3-4 shows that the teeth of the sprockets do not come through this type of chain as they do in the ordinary roller chain. It is apparent that if the chain is run slack, it will tend to climb the teeth of the sprockets which will cause excessive wear. It is very important that the adjustment of this chain is checked frequently.

10. PUMP SHAFT PACKING: The pump shaft must be packed, to prevent excessive leaking, where it enters the pump. Figure 3-3 shows the design of the packing gland. Square packing of the correct size, which has been well impregnated with tallow or graphite, should be used. Packing of this kind usually comes in long coils and should be cut into lengths which are just short of meeting when placed around the shaft. This slight gap allows for expansion when the packing is compressed by the gland.

These cuts should be made on an angle as shown in Figure 3-5 and the joint of each ring should be positioned so that it does not line up with the joint of the preceding ring. An easy way to accomplish this is to imagine the opening of the packing recess as the face of a clock. Place the first joint at 12 o'clock, the next at three, and so on.

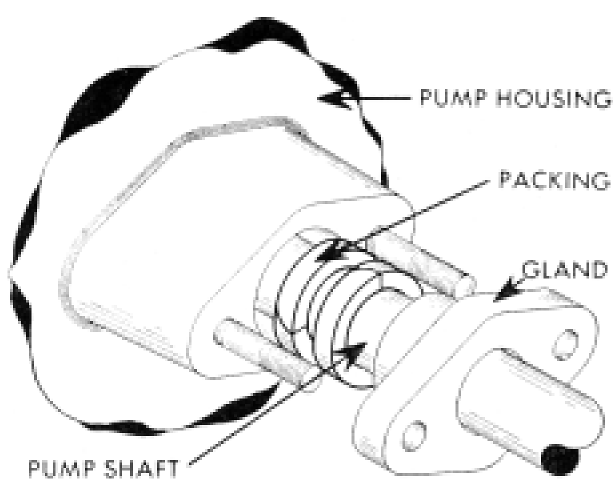


FIGURE 3-5

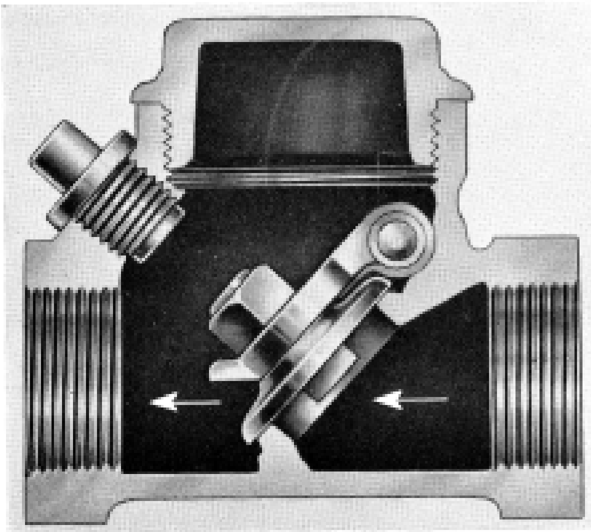


FIGURE 3-6

When removing the old packing with a hook, care should be taken not to score the shaft; dry flax or hard metallic packing should not be used as scoring of the shaft may result. Continuous tightening of the gland will eventually "kill" the life of the packing and further tightening will result in a scored shaft. The packing should be renewed at not too long intervals.

The packing is forced into the recess by the packing gland. The flange of this gland fits over two studs and the gland is "taken up" by tightening a nut on each stud. These nuts should be tightened evenly so that the gland is not twisted and after the adjustment is made the lock nuts should be well tightened.

The gland should never be tightened more than enough to stop leakage. Both the shaft and the packing will last longer if a few drops of water are allowed to escape.

11. PUMP CHECK VALVE: The location of the circulating pump, on the engine, assures its being well below the water line, therefore it should not require priming as the sea water will naturally flood the pump as soon as the suction line to the sea valves is opened. However, a check valve as shown in Figure 3-6 is fitted in the suction line. This valve will stop water from flowing back out of the engine when the pump is stopped, thus avoiding the chance of the engine operating with empty water jackets, until the pump has had time to fill them up.

12. WATER INLET MANIFOLD AND OIL COOLER: The water leaving the pump is piped directly to the inlet water manifold, shown in Figure 3-7, which extends the length of the engine. This is a large pipe-shaped casing having flanges on each end and six flanged openings, along one side, which match the openings on the bottom of the cylinder water jackets. On the opposite side of the manifold are two openings, one to receive water from the circulating pump while the other is connected to the discharge of the bilge pump. This connection is made so that the bilge pump may be used to cool the engine in case of accident to the circulating pump. The method of positioning the three-way valve in this emergency is described in paragraph 4 of this section.

The cooling water from the pump is distributed evenly to all six cylinders by this manifold, and a small pipe from the after end supplies cooling water for the air compressor.

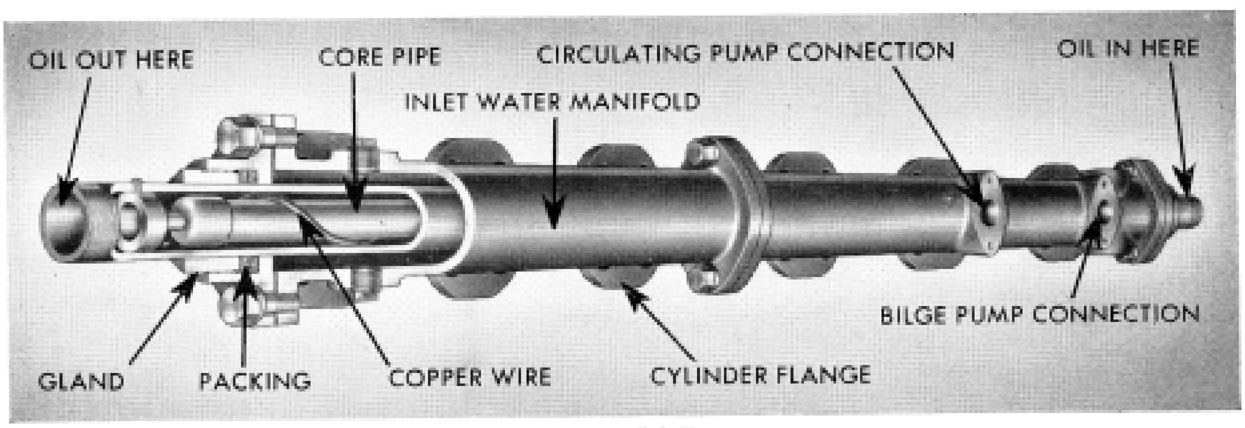


FIGURE 3-7

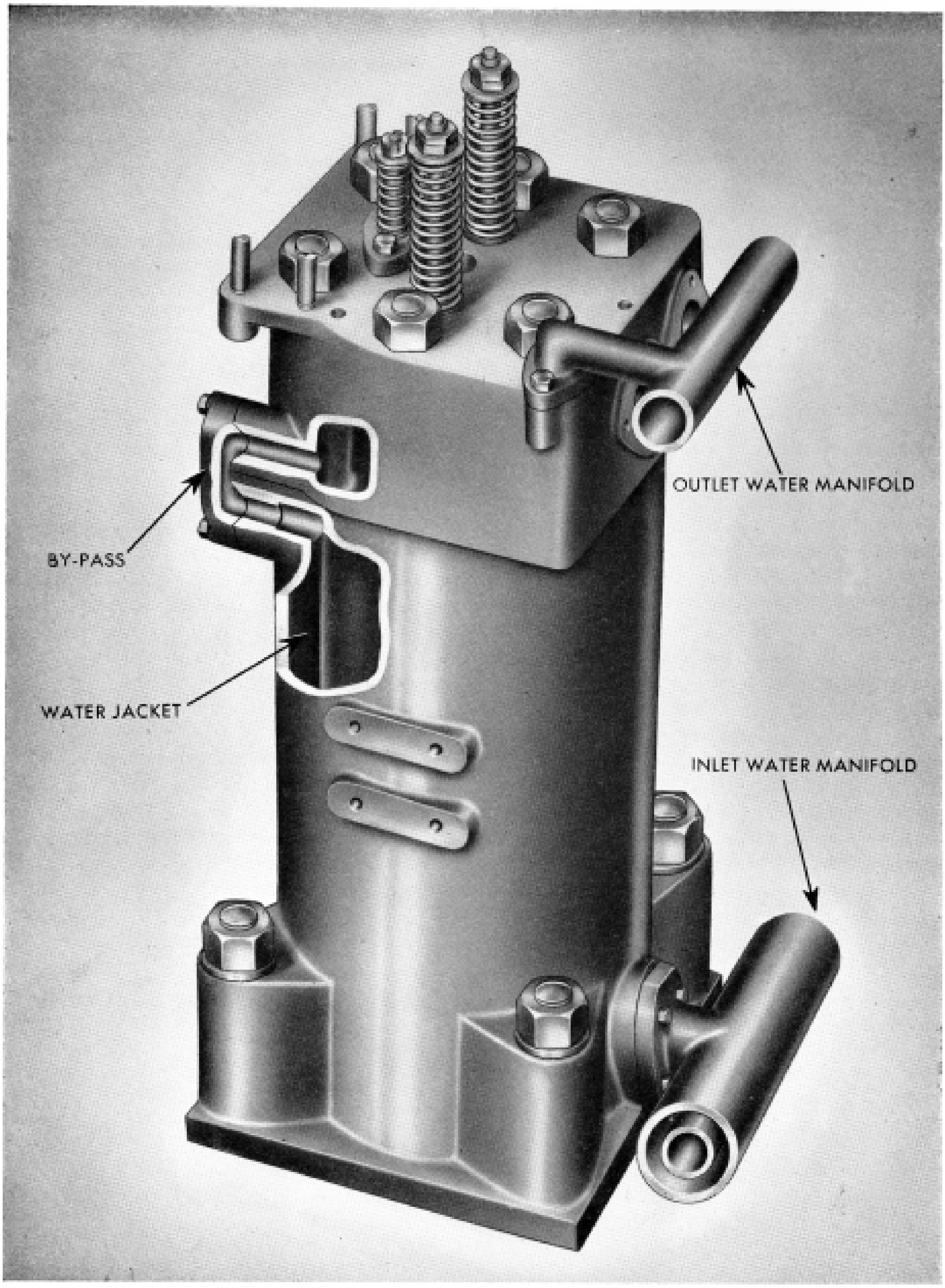

OUTLET WATER MANIFOLD
BY-PASS
WATER JACKET
INLET WATER MANIFOLD

FIGURE 3-8

Running through the center of the inlet water manifold is a 1½-inch copper pipe. The oil from the pressure lube pump is piped into one end of this pipe and led from the other end to the oil distributor manifold in the base. As this copper pipe is always surrounded with the cold sea water from the circulating pump, much of the heat is taken out of the oil during its passage through this cooler.

So that the majority of the oil will come in contact with the inside of the copper pipe, a second ¾-inch core pipe is suspended inside the larger one. One-fourth inch copper wire is soldered to the smaller pipe in the form of a spiral. This gives the oil a slow swirling motion as it passes through the cooler and assures a more efficient contact with the cooling surface of the 1½-inch copper pipe.

13. CYLINDER WATER JACKET: Figure 3-8 shows how the cylinder water jacket is formed by the outside wall of the cylinder proper and the jacket. The water enters this space at the bottom from the inlet-water manifold and flows up and around the entire cylinder wall. The jacket is equipped with clean-out covers which should be removed at least once a year to determine the amount of scale and sediment that has collected in the jacket.

14. WATER BY-PASS: As the water reaches the top of the cylinder water jacket it is led into the cylinder head by a by-pass shown in Figure 3-8. This by-pass is attached by two cap screws, one into the head and the other into the cylinder. This joint is made with rubber gaskets which should not be coated with white lead or any gasket compound.

15. OUTLET-WATER MANIFOLD: While in the head, the water cools the valve ports, guides and seats, as well as the spray valve opening and the top of the combustion space. It then leaves and is collected in the outlet-water manifold which also extends the length of the engine.

16. EXHAUST MANIFOLD COOLING: The exhaust manifold which collects the exhaust gases from the cylinders is water jacketed in the same manner as the cylinders are and the water leaving the outlet-water manifold is piped directly to the exhaust manifold. After the water traverses this manifold the cooling in a raw-water system is completed so the water is now 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 pipe so that the flow of water is visible.

17. 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.

18. 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 3-9.

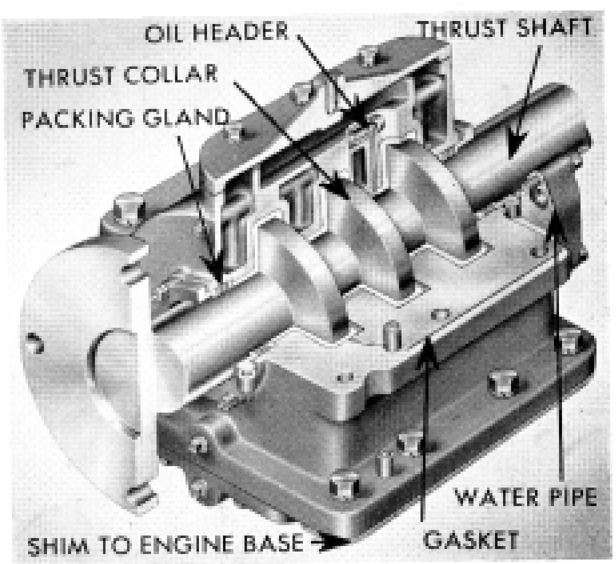


FIGURE 3-9

19. TEMPERATURE RISE: Atlas engines equipped with centrifugal 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.

20. 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.

21. 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 overboard discharge line to the suction pipe of the circulating 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 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. This by-pass line and valves convert a raw-water system into a raw-water recirculating system.

22. 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.

23. FRESH-WATER COOLING: A way of preventing salt or mud deposits in the engine cooling 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.

Some fresh-water cooling systems are installed on engines during manufacture while many are assembled in the boat at the time of engine installation. The many types of heat exchangers, twin pumps and piping layouts that can be used in a fresh-water cooling system make it impossible for us to explain in detail the particular system you may have on your engine. However, we will describe a typical layout commonly used on Atlas engines.

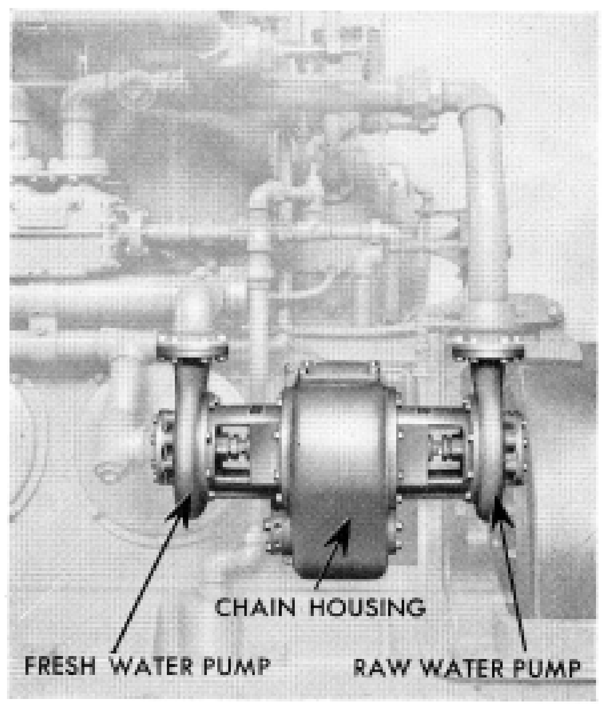


FIGURE 3-10

24. ENGINE COOLING SYSTEM FOR FRESH-WATER COOLING: A fresh-water cooling system requires two pumps, one to circulate sea water through a heat exchanger and the other to circulate the jacket water through the engine and the heat exchanger. Twin pumps, like the ones shown in Figure 3-10, are often used although some installations utilize the regular circulating pump which is on the engine for the jacket water system, and add a belt or chain driven pump for the raw-water circuit. An oil cooler, a heat exchanger, an expansion tank, and the necessary valves and piping make up the balance of the system.

25. HEAT EXCHANGER: A device similar to a small steam boiler consists of a shell, two headers, two bonnets, tubes and baffle plates and various pipe connections. The tube bundle is made up of a series of copper tubes which are attached to a header at each end. These headers are copper or brass plates, drilled so that the tubes are separated and held in the desired pattern as shown in Figure 3-11.

The tube bundle is encased in a shell which has covers or bonnets bolted to each end. These bonnets form chambers which distribute the liquid over the entire header. The jacket water is piped into one of these bonnets, passes through the tubes and out the opposite bonnet.

The shell has a pipe connection at each end. The raw water is piped into one of these openings where it is forced to flow around all parts of the tube bundle by baffle plates. When the raw water leaves the opposite end of the shell its work is finished so it is piped overboard.

26. OIL COOLER: On smaller Atlas engines, such as covered by this manual, the oil cooler is combined with the inlet-water manifold. As the jacket water in a fresh-water cooling system is carried at too high a temperature to efficiently cool the oil, it is necessary to install an independent oil cooler when converting the engine to fresh-water cooling. This cooler is usually identical with the heat exchanger, only much smaller. It is so connected that the raw water from the pump passes through it before going to the heat exchanger. In an oil cooler the raw water passes through the tubes while the oil flows around the tube bundle.

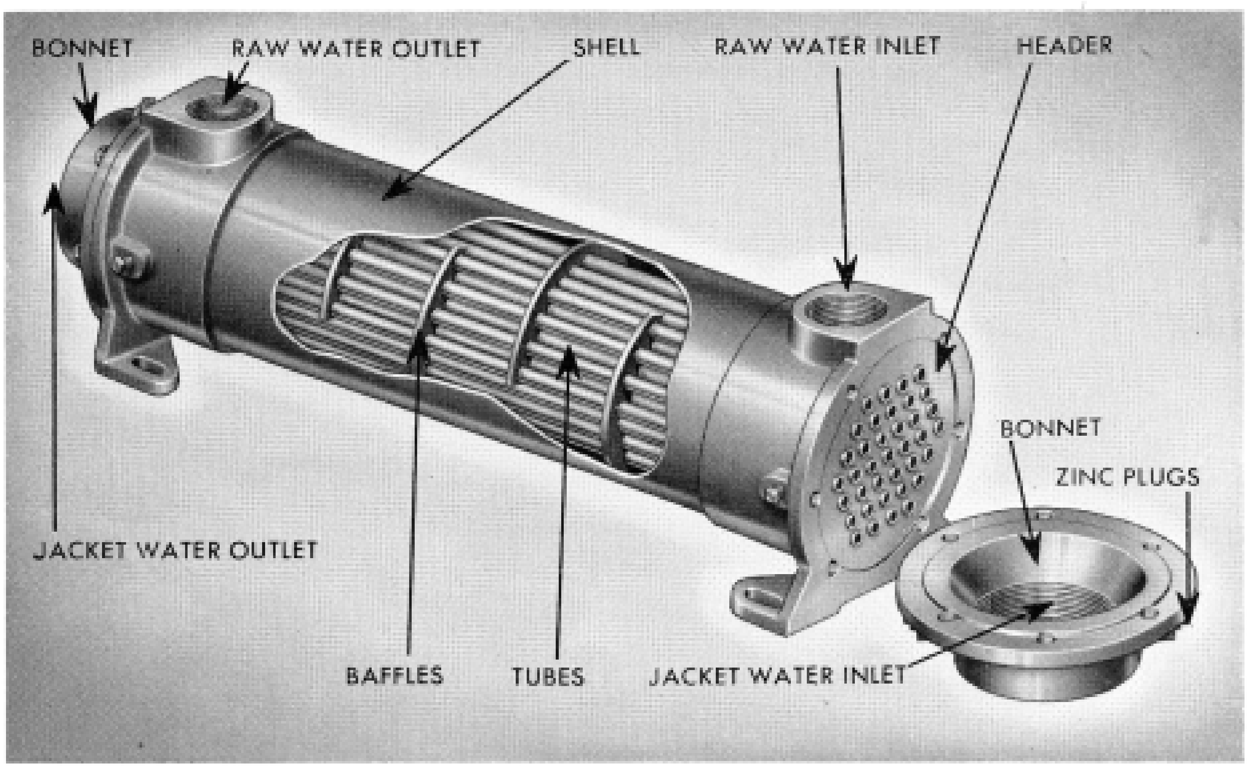


FIGURE 3-11

27. 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 during 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 leading to the deck and if so, fresh water is added to the system at that point.

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 will permit throttling of the flow (throttling the discharge of a centrifugal pump reduces the output). More raw-water flow causes the fresh-water temperature to drop; less raw-water flow causes the fresh-water temperature to rise.

In the layout shown in Figure 3-12, the temperature is controlled by a thermostat and blender. You will notice that a pipe leads from one side of the blender to the heat exchanger. Another pipe goes from the opposite side of the blender directly to the suction side of the fresh-water pump. The single pipe into the top of the blender is the fresh-water discharge from the engine.

In this discharge pipe is a thermostat which is simply a long metal bellows. It is fixed at the top end while a valve is attached to the lower end, in the blender. When the engine is started up and the cooling water is cold the thermostat bellows is contracted and closes the opening to the heat exchanger. The engine cooling water goes directly from the discharge to the suction of the fresh-water pump. It is then forced into the inlet manifold and back through the engine. As the cooling water is now by-passing the heat exchanger, it soon warms up and this expands the bellows of the thermostat. The valve from the blender to the heat exchanger gradually opens permitting some of the water to pass through the exchanger. As the temperature of the discharge water increases, more and more of it is direct-

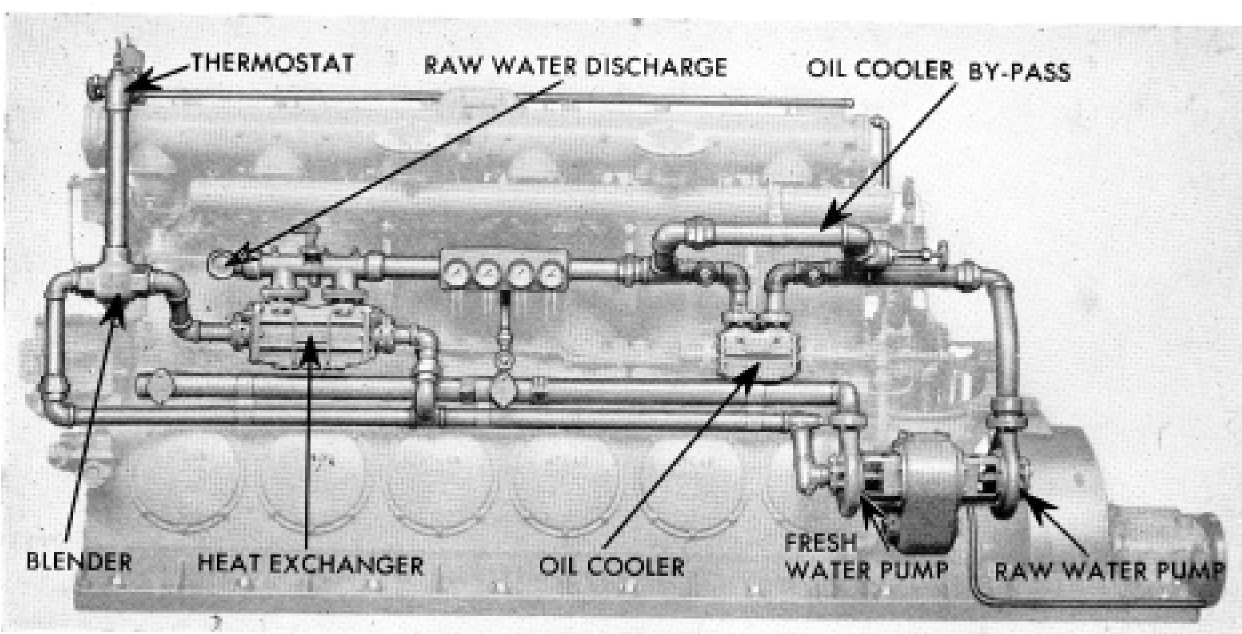


FIGURE 3-12

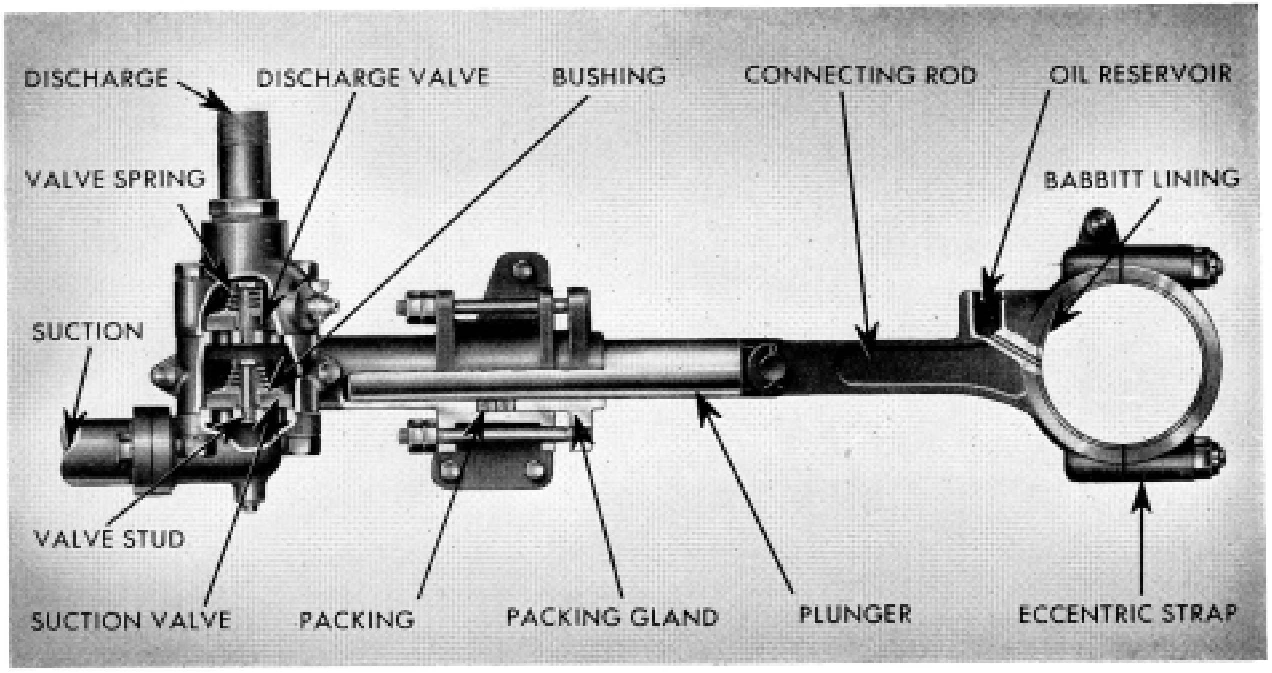


FIGURE 3-13

ed through the heat exchanger. Thus cooling water is maintained at whatever temperature the thermostat is set for.

29. BILGE PUMP: The pump shown in Figure 3-13 is a single acting reciprocating pump driven by an extension of the after end of the camshaft. 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 is usually a large auxiliary pump driven by the auxiliary engine. How the bilge pump can be used as an auxiliary to the cooling system was told in paragraph 12.

30. RECIPROCATING PUMP PRINCIPLE: Reciprocating pumps are known as positive displacement pumps and operate as follows: Refer to Figure 3-13 and it will be seen that the pump consists of an eccentric drive, a connecting rod, a piston, a cylinder, and a valve chamber.

As the piston leaves the end of the cylinder, nearest the valve chamber, a suction is created. The discharge valve is held to its seat both by the spring and suction, while the suction valve is opened and water is drawn into the cylinder. At the outer end of the stroke the cylinder is nearly full of water and the piston reverses its motion and starts back toward the valve end. The suction valve is now forced onto its seat by water pressure and the discharge valve is opened. The water, displaced by the piston, is forced out of the discharge valve and pipe. This cycle is repeated each stroke or every second revolution of the engine, as the pump is driven by the camshaft.

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 camshaft. 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 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.

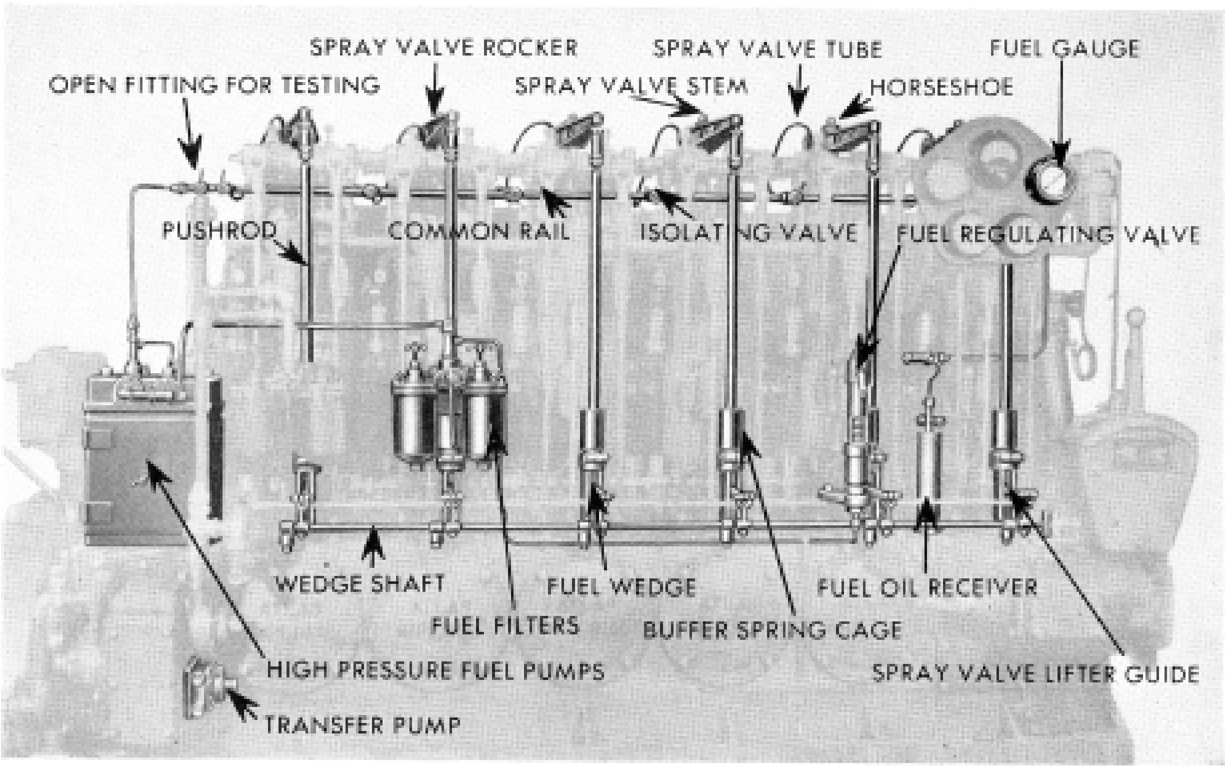


FIGURE 4-1

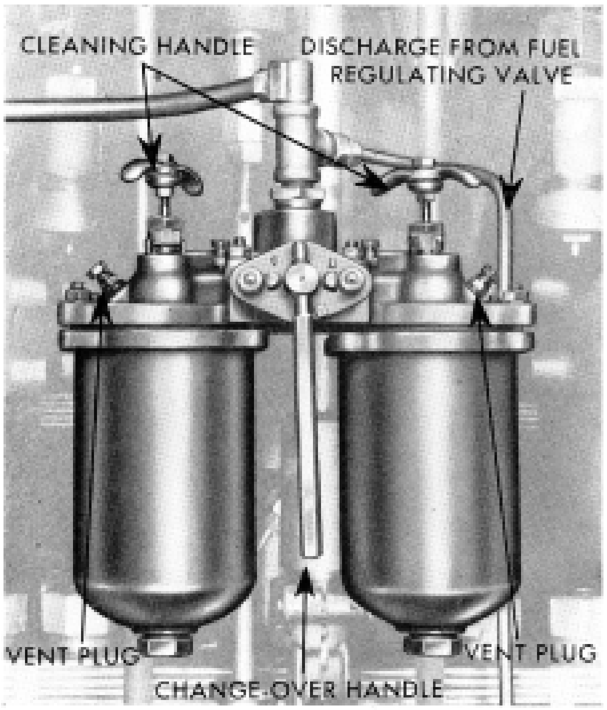


FIGURE 4-2

4. FUEL FILTER: The fuel filter is a metal element, duplex type filter, similar to the lubricating oil filter described in Section 2 and a detailed description will not be repeated here. There are two elements, so arranged that the changing of the lever, shown in Figure 4-2, from one extreme position to the other, cuts out either filter for cleaning. When the lever is in the central position as shown, both filters are in operation. The element has openings 0.0015 inch so that any dirt particles larger than this measurement will be caught before entering the core of the filter.

While most of this dirt will fall to the bottom of the bowl, a knife is provided which bears against the outside of the element so that any dirt adhering to the filtering surfaces will be removed when the element is turned by the handle which extends out the top of the head. This cleaning process should be carried out every four hours of engine operation and the filter should be temporarily cut out so that the dirt will have a chance to settle freely to the bottom of the bowl. The bowls should be removed and cleaned before the sediment builds up to the bottom of the element.

After draining, refill the filter through the priming plug in the top, and leave the vents slightly open when starting the engine to allow the trapped air to bleed out. The elements may be renewed by removing the handles and bowls and unscrewing the elements from the head. CAUTION: The elements are attached to the head with a left-hand thread.

5. HIGH-PRESSURE FUEL PUMP: The after end of the camshaft has two cams, shown in Figure 4-3, which drive the two plungers of the high-pressure fuel pump. These two drives are lubricated by a passage drilled from one of the camshaft bearings. The fuel supply line from the filter is connected to the suction opening of each pump. The fuel day tank should be located so that fuel will flow, by gravity, from the tank through the filter and flood the fuel pumps.

The valves for each pump are arranged in a cage which screws into the pump block. A discharge fitting attaches to the top of the valve cage and makes the connection between the pump and the tube going to the common rail.

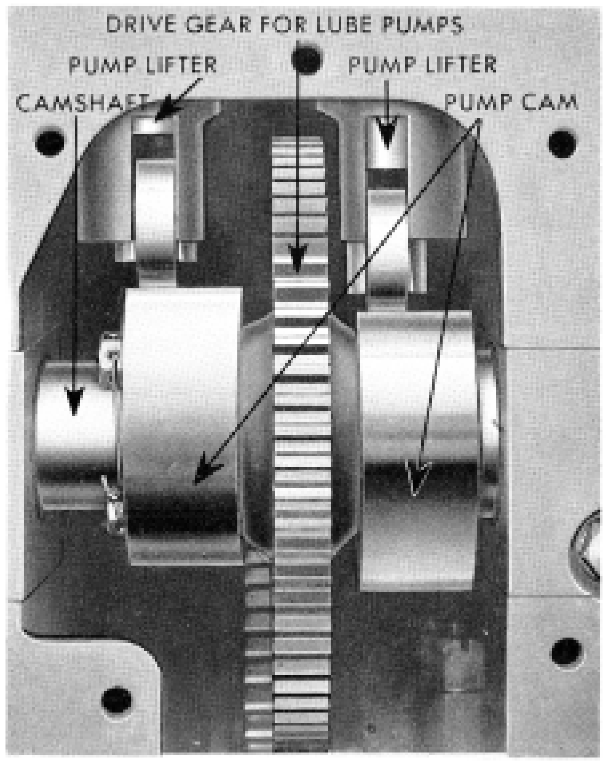


FIGURE 4-3

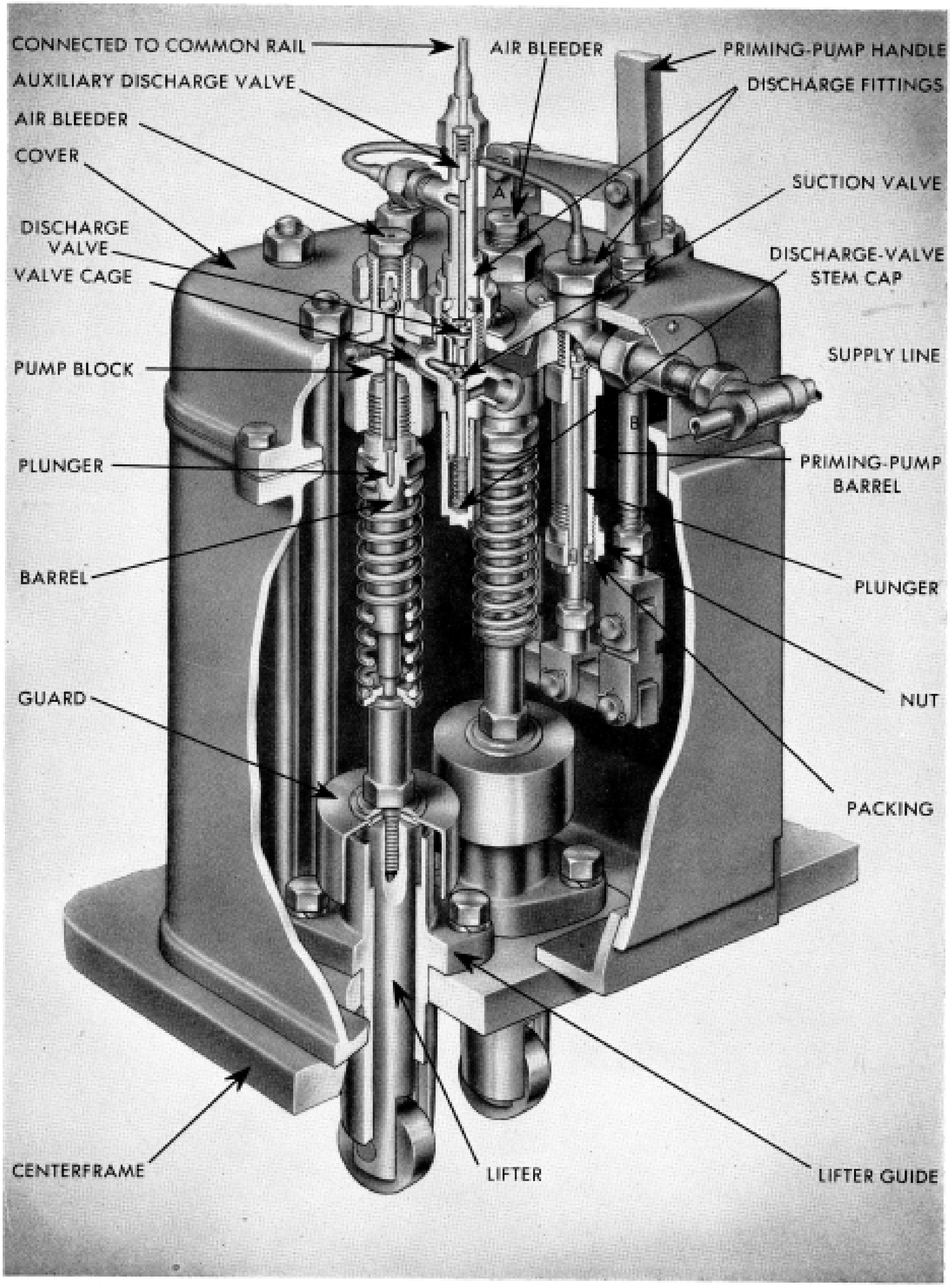

CONNECTED TO COMMON RAIL
AIR BLEEDER
PRIMING-PUMP HANDLE
AUXILIARY DISCHARGE VALVE
DISCHARGE FITTINGS
AIR BLEEDER
COVER
SUCTION VALVE
DISCHARGE VALVE
DISCHARGE-VALVE STEM CAP
VALVE CAGE
PUMP BLOCK
SUPPLY LINE
PLUNGER
PRIMING-PUMP BARREL
BARREL
PLUNGER
NUT
GUARD
PACKING
CENTERFRAME
LIFTER
LIFTER GUIDE

FIGURE 4-4

The suction valve is located directly beneath the discharge valve which acts as a stop to limit the lift of the suction valve. The discharge fitting extends down into the valve cage and controls the lift of the discharge valve. There is an auxiliary discharge valve in the discharge fitting of the pump which is connected to the fuel rail. The other pump discharges, through a short pipe, into the discharge fitting between the main and auxiliary discharge valves of the first pump.

A down stroke of either plunger creates suction which draws fuel into the pump in which the stroke was made. The suction valve is held closed by a spring, but the spring tension is not sufficient to hold the valve shut against the suction of a down stroke of the plunger. An upstroke of the plunger displaces the fuel which was drawn into the pump cylinder by the down stroke and creates a pressure which forces the suction valve closed and opens the discharge valve, releasing the fuel, under pressure, to the discharge line.

The discharge valve is hardened and seats on a hard seat insert which is pressed into the valve cage. The suction valve is held on its seat by a small spring which fits over the stem. The discharge valve has no spring but the auxiliary discharge valve in the discharge fitting has a spring which lies on top of the head of the valve.

Bleeder valves, for venting trapped air, are installed in the pump block directly over the end of each barrel.

6. PLUNGER AND BARREL: The pump plunger moves in a pump body or barrel as shown in Figure 4-4. 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 matched sets. In ordering new parts, therefore, always order a plunger and a barrel together.

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. The unit of the pump (the half shown in Figure 4-4) has a hand-priming pump 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 4-5, while the assembled valve is shown in Figure 4-6.

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 fuel filters.

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

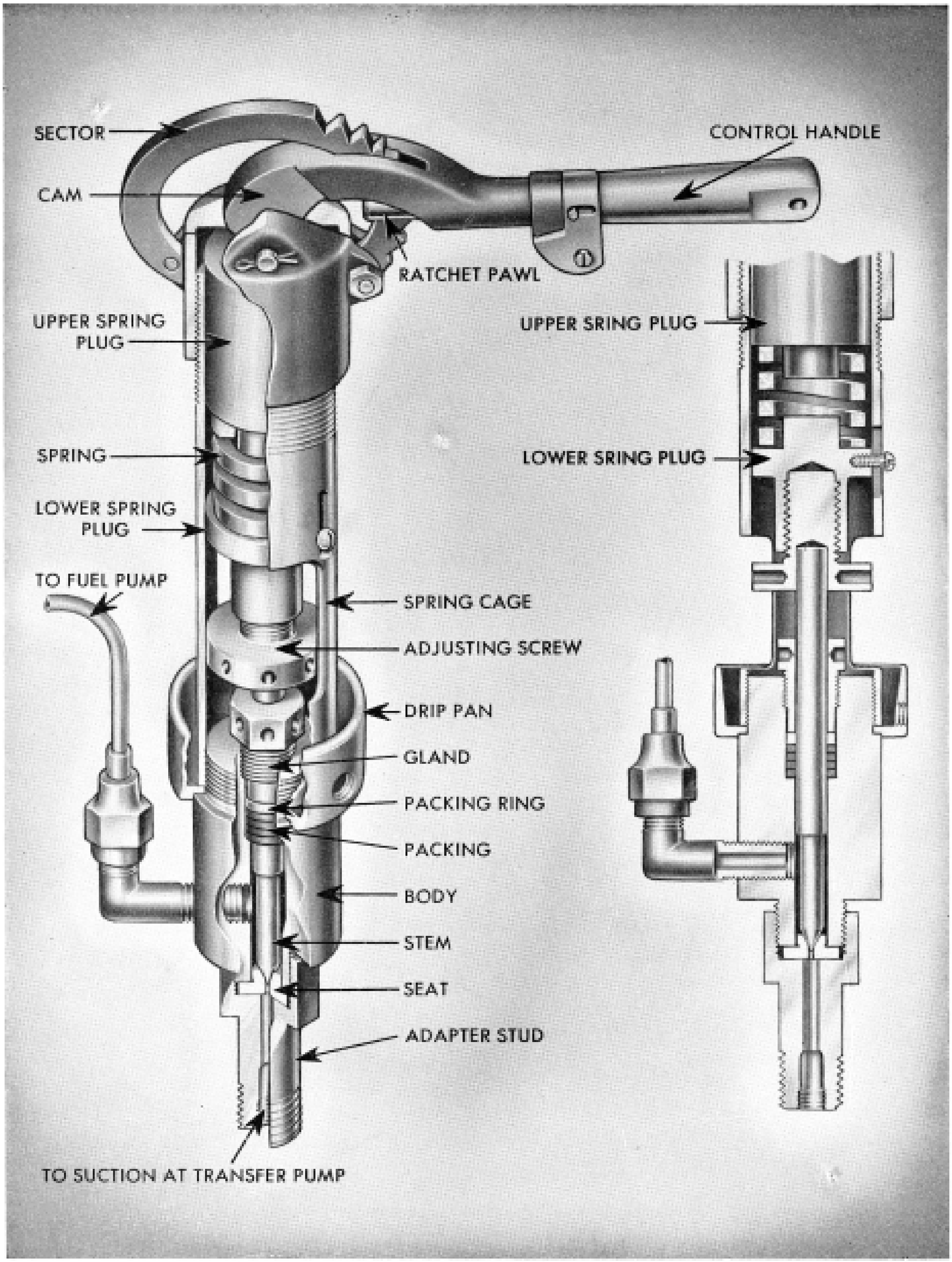

SECTOR
CAM
CONTROL HANDLE
RATCHET PAWL
UPPER SPRING PLUG
UPPER SRING PLUG
SPRING
LOWER SRING PLUG
LOWER SPRING PLUG
TO FUEL PUMP
SPRING CAGE
ADJUSTING SCREW
DRIP PAN
GLAND
PACKING RING
PACKING
BODY
STEM
SEAT
ADAPTER STUD
TO SUCTION AT TRANSFER PUMP

FIGURE 4-5

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 to any one spray valve. At times it is necessary to crank the engine over without any fuel being injected, and these isolating valves are installed for that purpose.

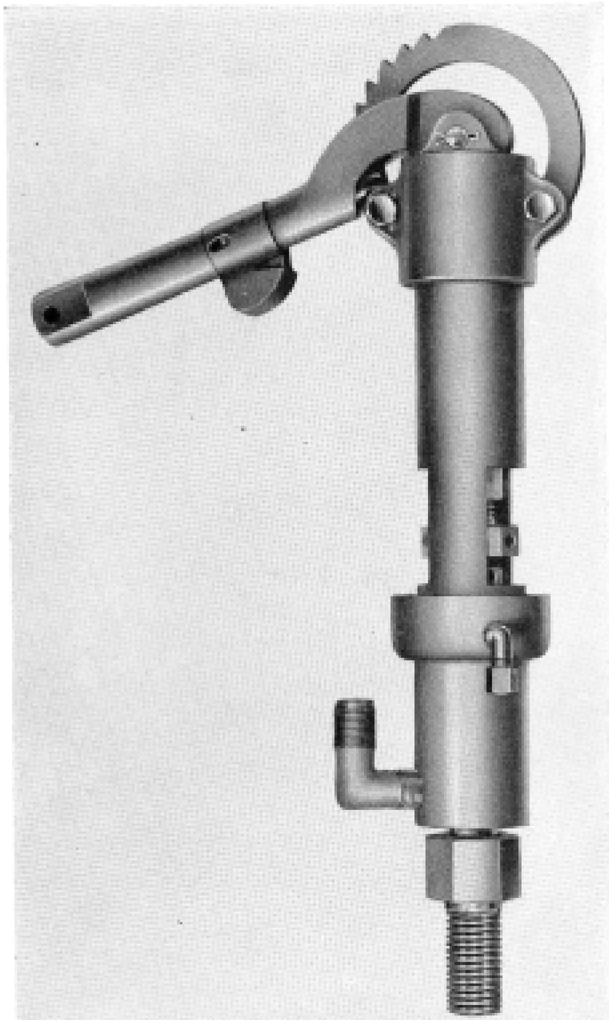


FIGURE 4-6

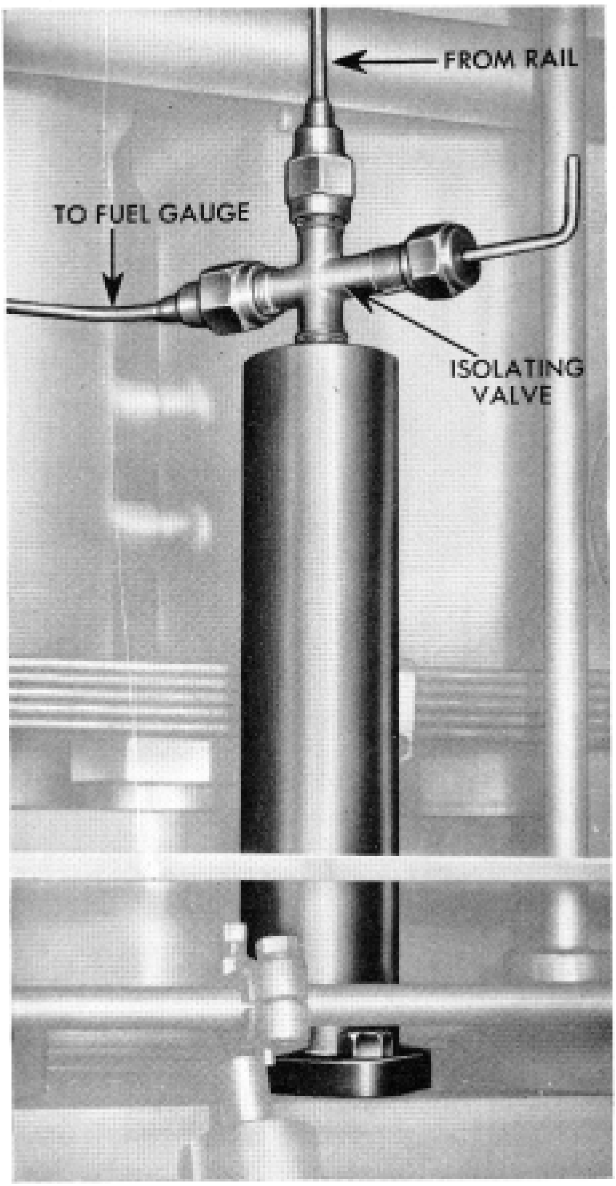


FIGURE 4-7

13. FUEL OIL RECEIVER: The forward end of the common rail connects to a fuel-oil receiver shown in Figure 4-7. 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 which are caused by the pump strokes and by the spray valves opening and closing. 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 4-8 and the assembled valve in Figure 4-9. 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 4-10. The number and sizes of these orifices varies with each engine size:

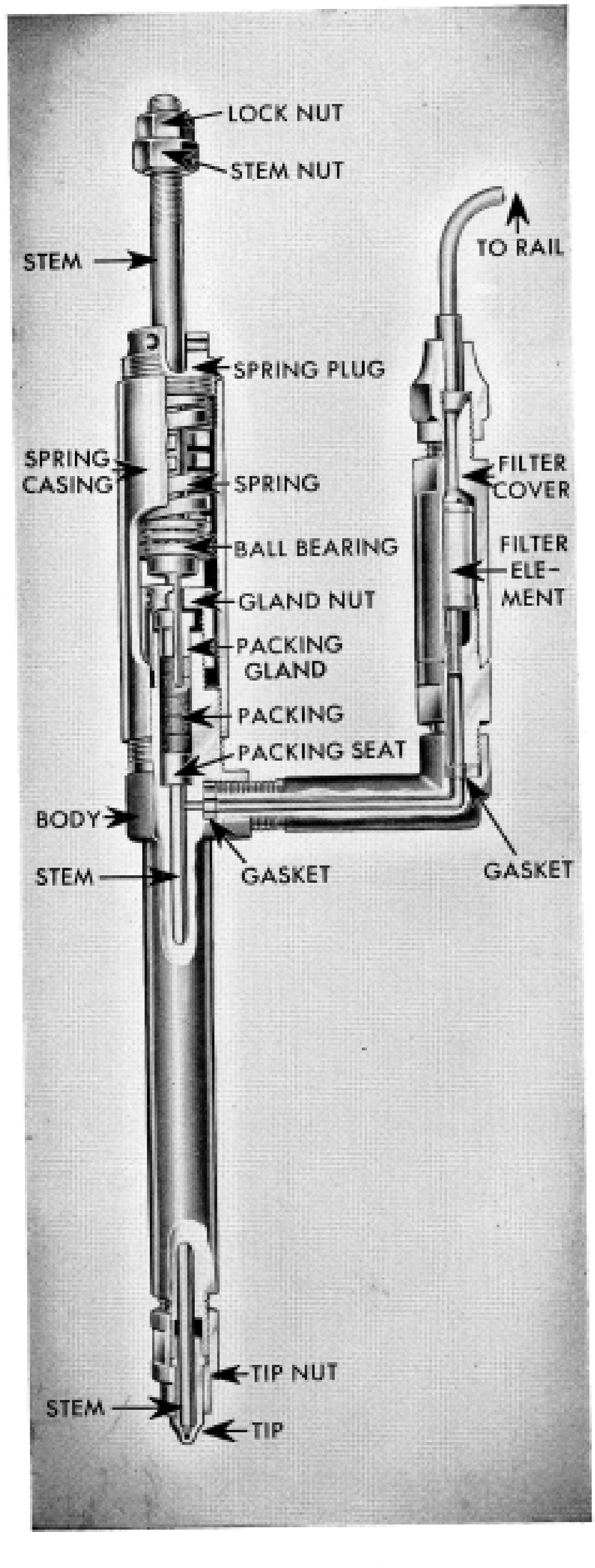


FIGURE 4-8

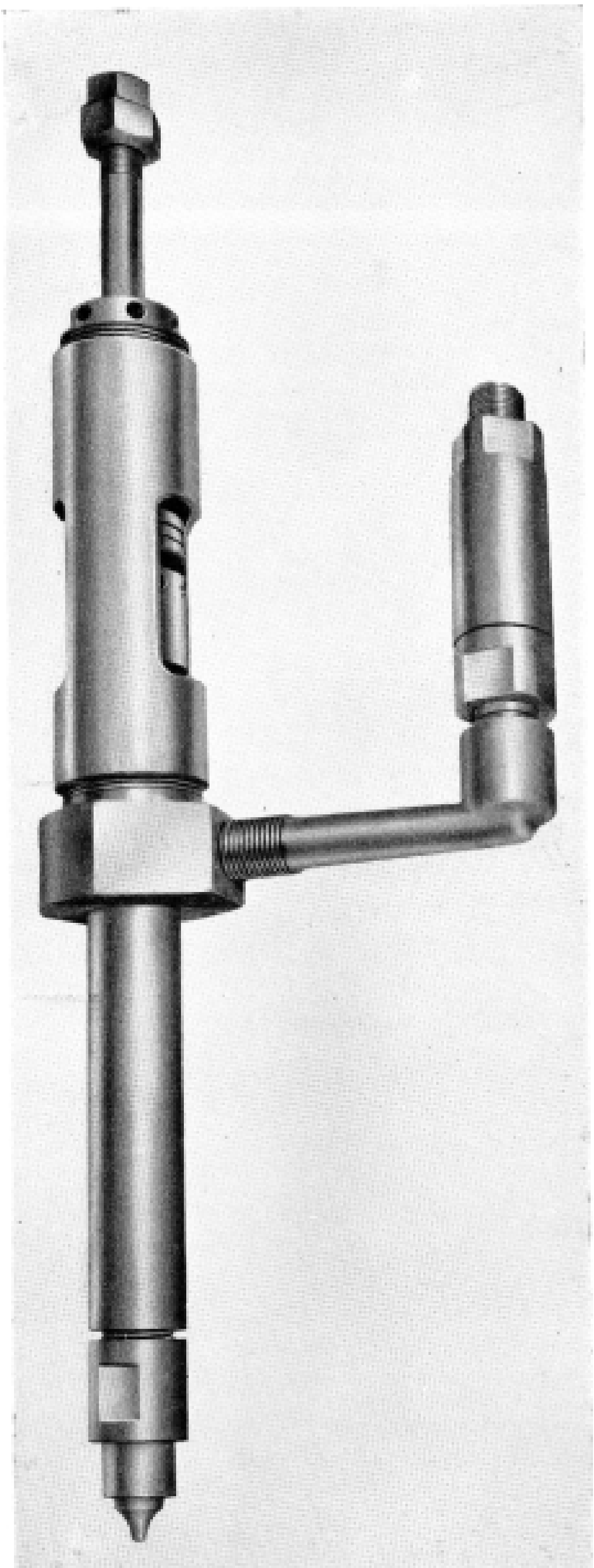


FIGURE 4-9

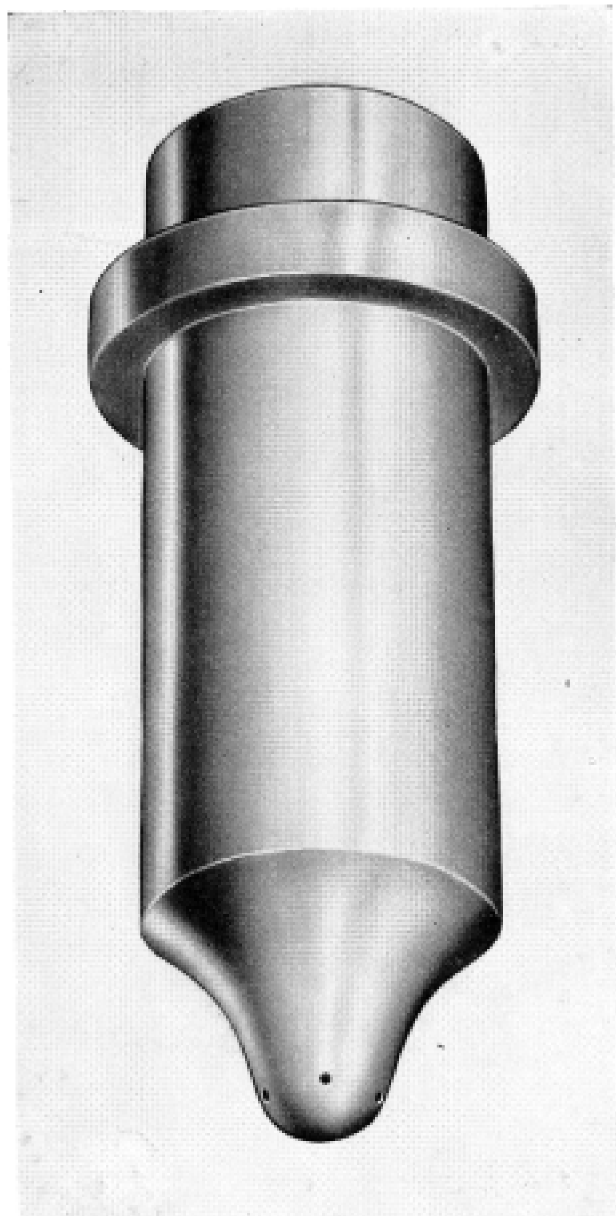


FIGURE 4-10

Each tip on the 7½ x 10½ engine has five orifices, each 0.008 inch in diameter.

Each tip on the 11½ x 15 engine has seven orifices, each 0.012 inch in diameter.

Each tip on the 13 x 16 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.

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

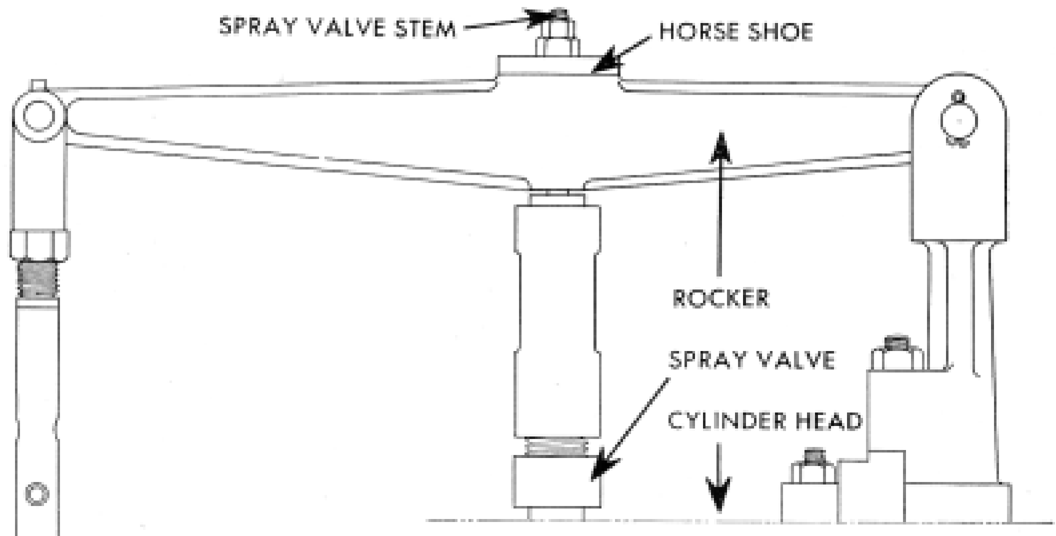
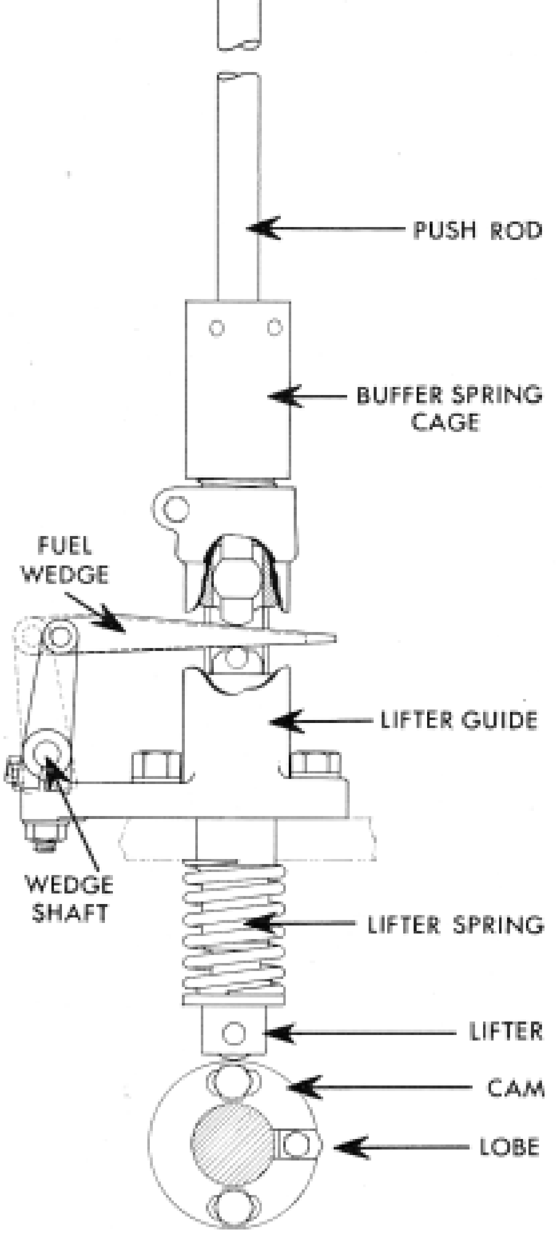



FIGURE 4-11

(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 having a nose or lobe built up on a portion of the circumference. The cams are mounted on a 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 which has a roller riding on the cam. This lifter operates in a guide which bolts to the centerframe and is lubricated by oil thrown from the camshaft. The roller is held to the cam by the lifter spring, shown in Figure 4-11.

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 usually referred to by Atlas as the spray-valve rocker.)

19. SPRAY-VALVE STEM: The spray-valve stem extends up through a hole in the rocker and ends in a nut with a lock nut. 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 4-12. 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

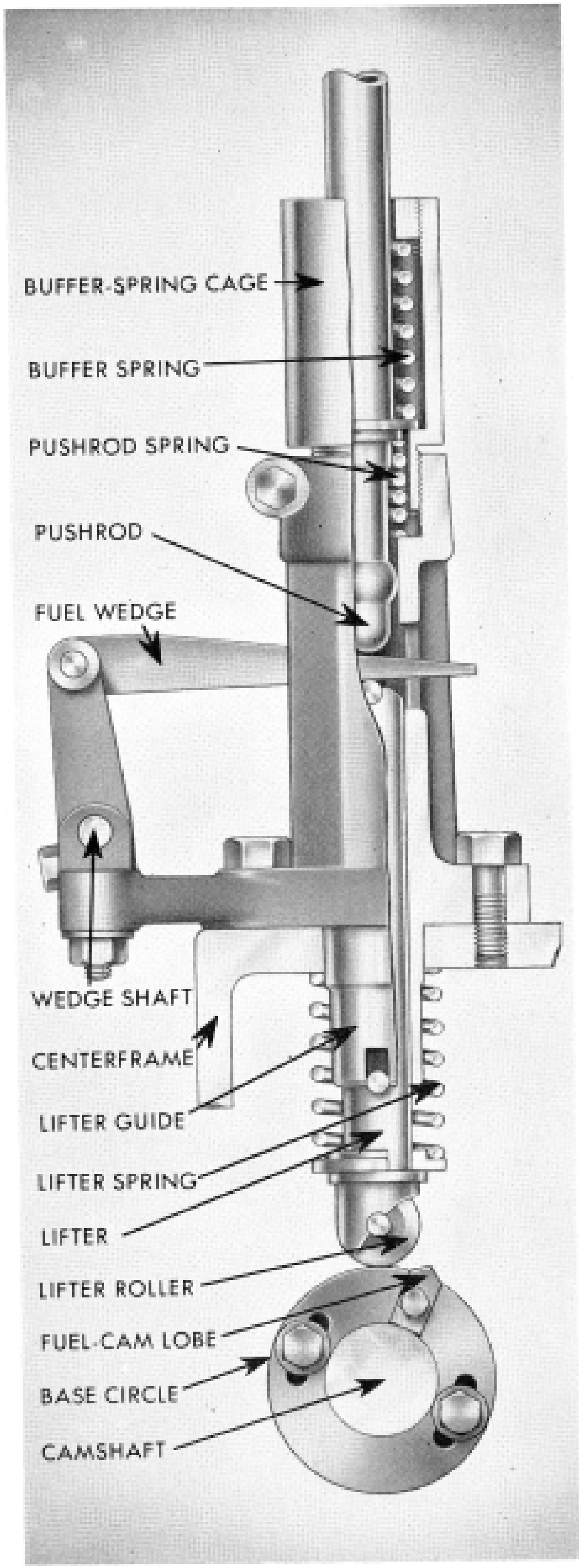


FIGURE 4-12

the camshaft so that the cam comes around sooner or later, in relation to the crank, the start of injection will be advanced or delayed. This is covered in Section 10. Section 5 explains how there are actually two fuel cams, so positioned that fuel injection timing remains the same regardless of the direction of engine rotation. These different cams are brought in contact with the lifter roller by sliding the camshaft.

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 4-13.

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 from 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 weights will open farther, 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

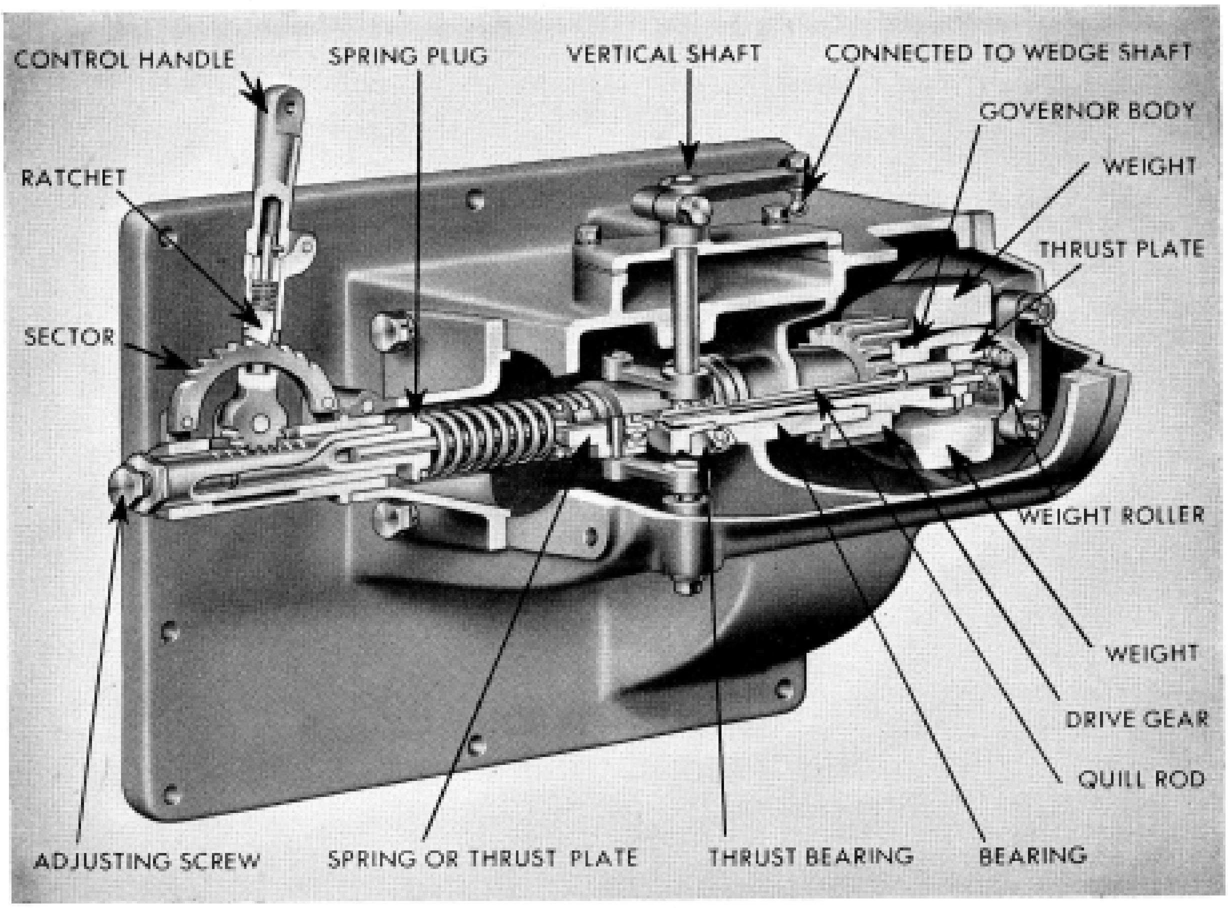


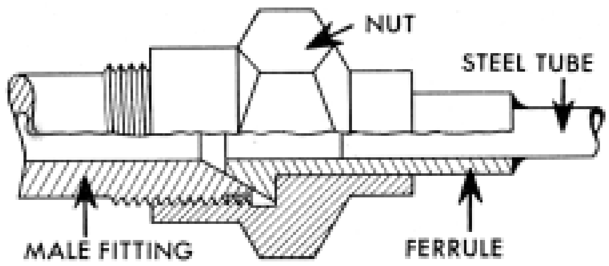
FIGURE 4-13

to come together, and the thrust block follows them because of the governor spring, making the wedges enter farther between lifters and 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 thrust block and the spring block, 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



HIGH PRESSURE FITTING
FIGURE 4-14

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 pounds of fuel pressure without leakage occurring, and ordinary pipe fittings would be entirely inadequate.Special fittings, called compression fittings, shown in Figure 4-14, are used and are made 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.

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 interrelated 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 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 bronze bushed bearings which are secured in the centerframe. A gear mounted on the crankshaft drives a gear on the camshaft through an 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

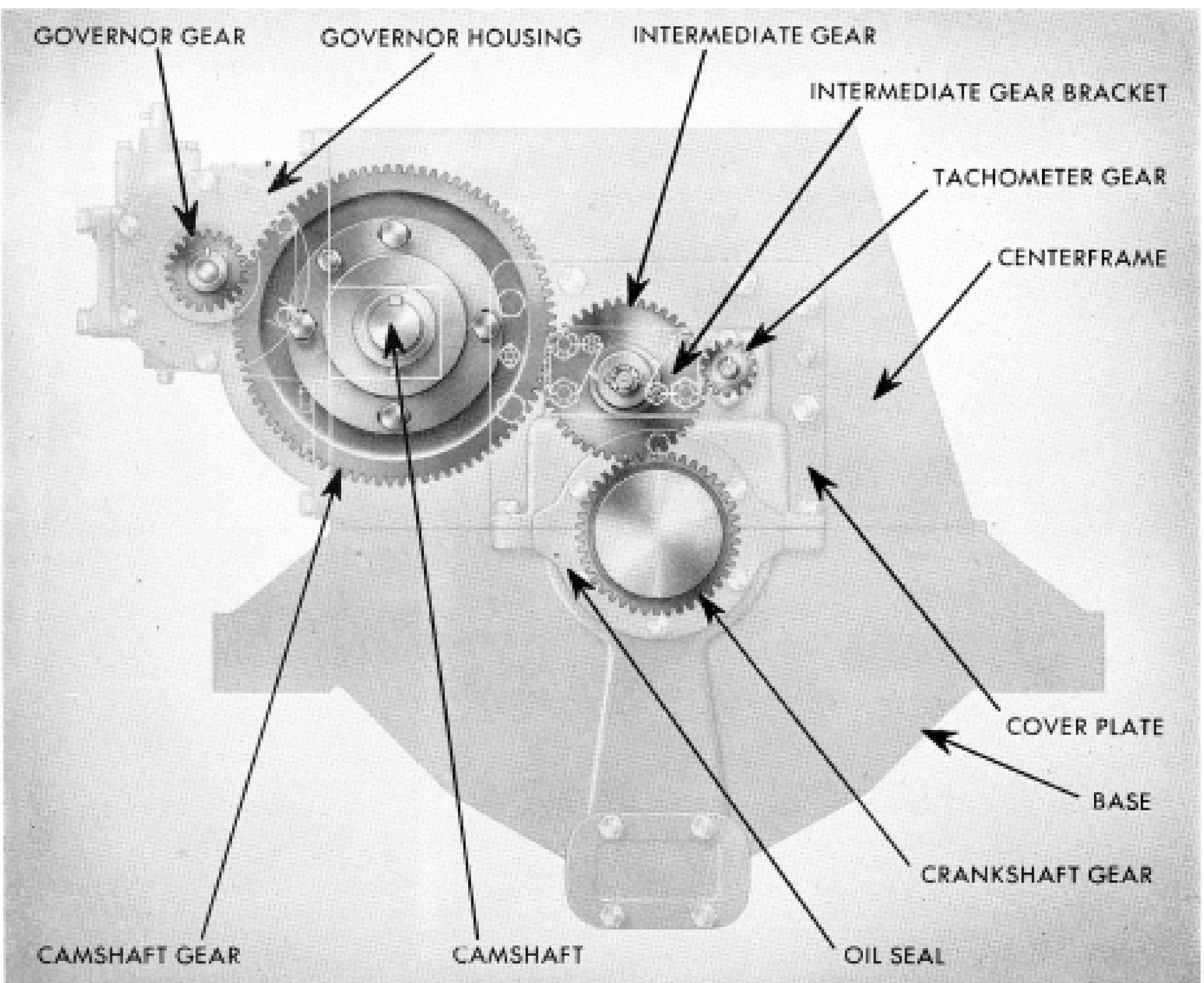


FIGURE 5-1

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 intermediate gear.

3. CAMS: On the camshaft are various cams, or round discs, each with a nose or lobe. These cams operate valves through mechanism 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.

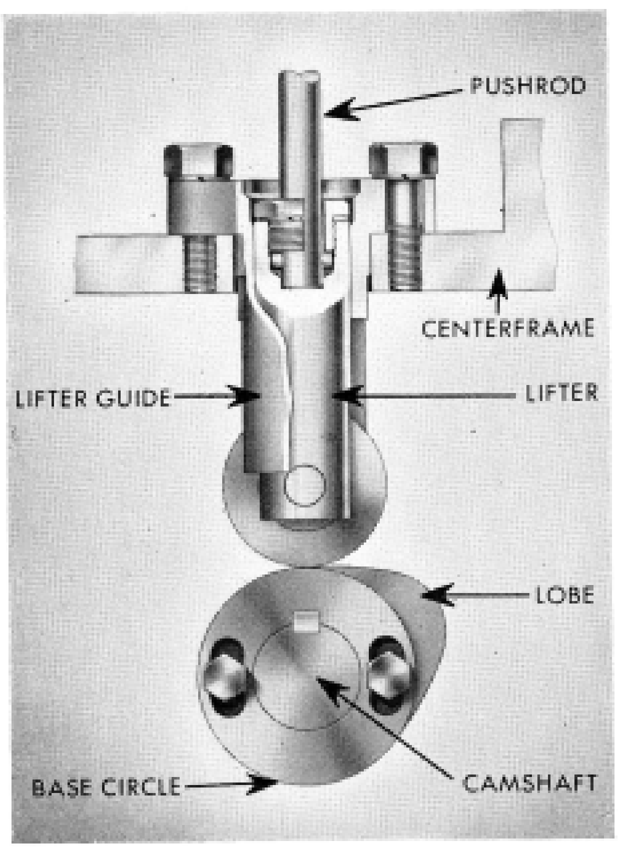


FIGURE 5-2

5. VALVE LIFTER: The valve lifter moves up and down, as it follows the shape of the cam, in a guide which is bolted to the centerframe as shown in Figure 5-2. The lower end of the lifter is equipped with a hardened roller and the upper end attaches to the pushrod.

6. PUSHRODS: The pushrods carry the action of the lifter up to the valve rockers. They are attached to the rockers by a fork and pin. The pushrod forks are numbered to correspond to the valves they operate and they should not be mixed during overhaul.

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

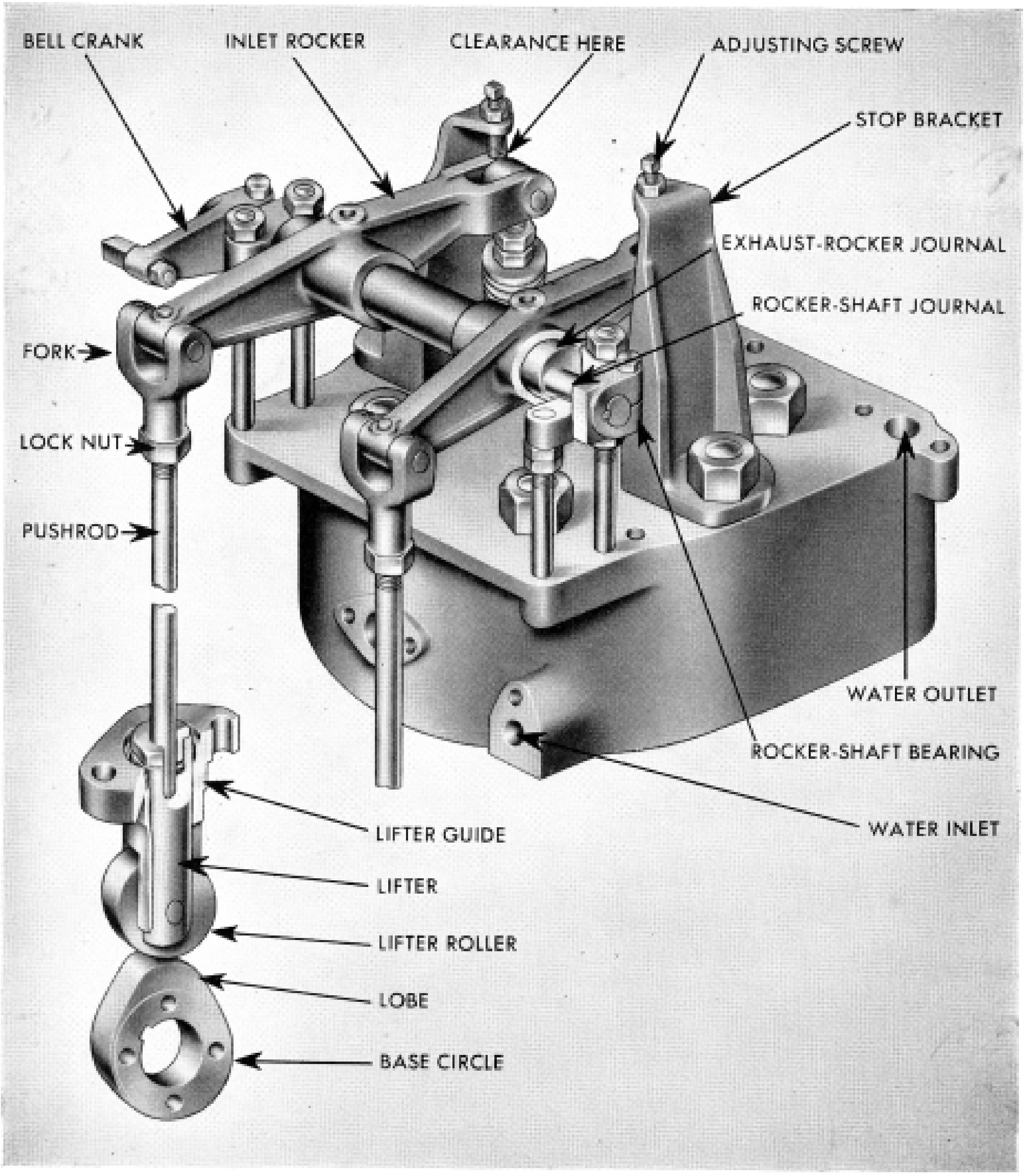


FIGURE 5-3

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).

13. INLET- AND EXHAUST-VALVE TIMING: On Atlas engines, the inlet valve opens five 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.

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: Correct 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 astern rotation. In order to bring the proper cams under the lifter rollers, for each rotation, the entire camshaft is moved fore or aft. This total movement is ⅞ inch which is the distance apart the respective cams are located on the camshaft for ahead and astern.

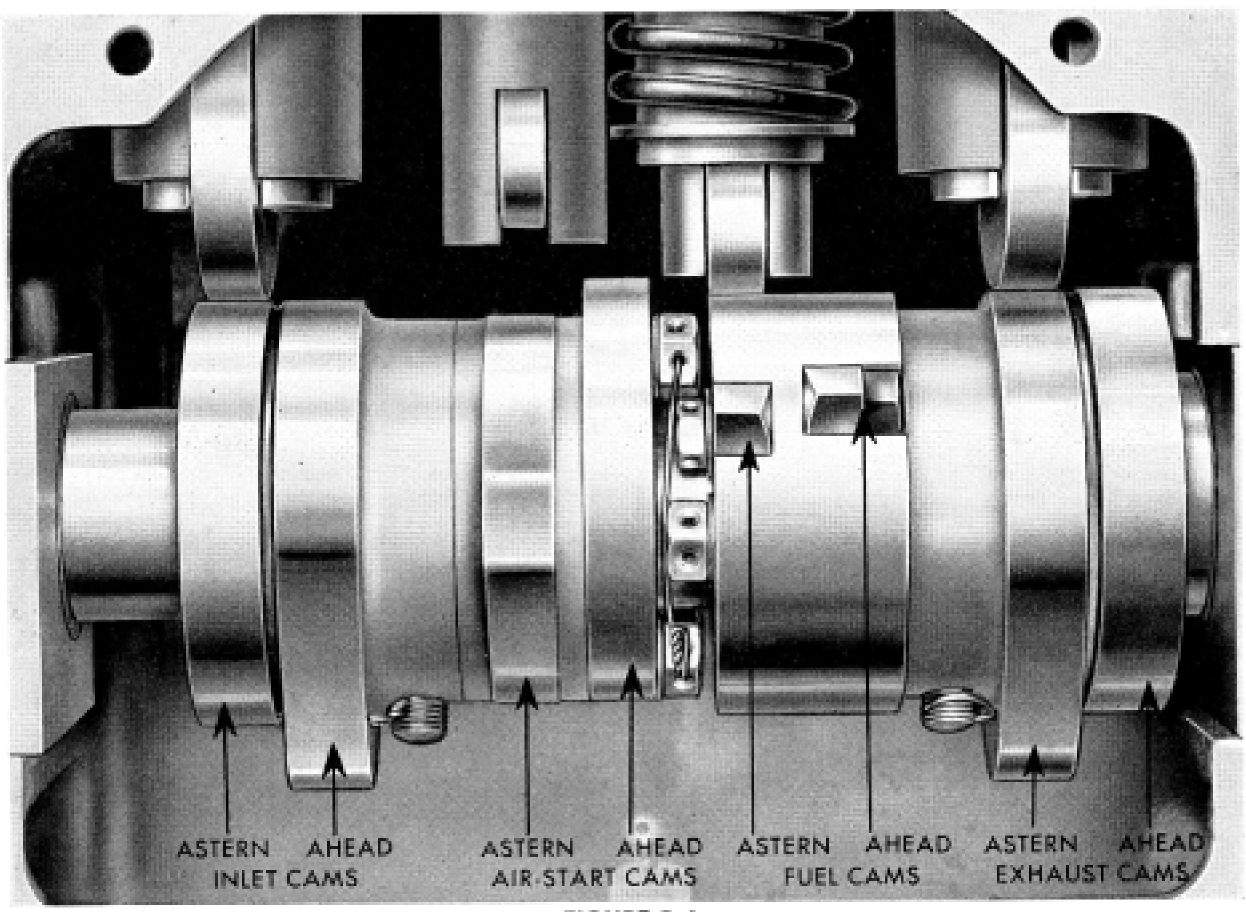


FIGURE 5-4

Figure 5-4 shows the section of cams for one cylinder. When the camshaft is aft, the ahead cams are under the rollers. When the camshaft is ahead, the cams for astern operation are under the lifter rollers.

16. SHIFTING CAMSHAFT: Figure 5-5 shows that the camshaft gear is very wide, which allows it to move fore and aft, the required ⅞ inch, without coming out of mesh with the idler gear. The fuel pump cams are also wide enough to allow fore and aft movement. The bilge pump drive eccentric cannot move fore and aft, so the hub is mounted on a floating sleeve which has two keyways cut for its entire length. The camshaft has two corresponding keys which act as splines and drive the eccentric but still permit the camshaft to be moved fore and aft.

It is apparent from Figure 5-4 that it would be impossible to move the camshaft with the exhaust and inlet lifter rollers resting on the cams, as some one or more cams would be in a position to catch on side of a roller were the camshaft moved endwise. To overcome this difficulty, a method is provided for lifting all the inlet and exhaust rollers clear of the cams, each time the camshaft is shifted.

17. ECCENTRIC ROCKER SHAFT: The rocker shaft for each cylinder head is carried on two bearings which are supported on long studs that screw into the cylinder head. As shown in Figure 5-3, the two bearing journals are eccentric to the inlet and exhaust rocker journals. As the rocker shaft is turned a part of a revolution the rockers will be raised or lowered by the eccentric action of the shaft. Figure 5-3 also shows a bracket with an adjusting screw which lies over the valve end of the rocker. It is apparent that when the shaft is turned to lift the rockers the valve end of the rocker will be stopped by this bracket. The fork end of the rocker will be lifted approximately twice the amount of eccentricity of the shaft.

As the lifter is attached to the lower end of the pushrod as shown in Figure 5-2, the lifter roller will be raised clear of the cams. Figure 5-3 shows the bell cranks by which all six rocker shafts are connected, causing them to move as one shaft.

18. ROCKER SHAFT RAM: This raising of the lifter is the first part of any maneuver which calls for a change of rotation. Move-

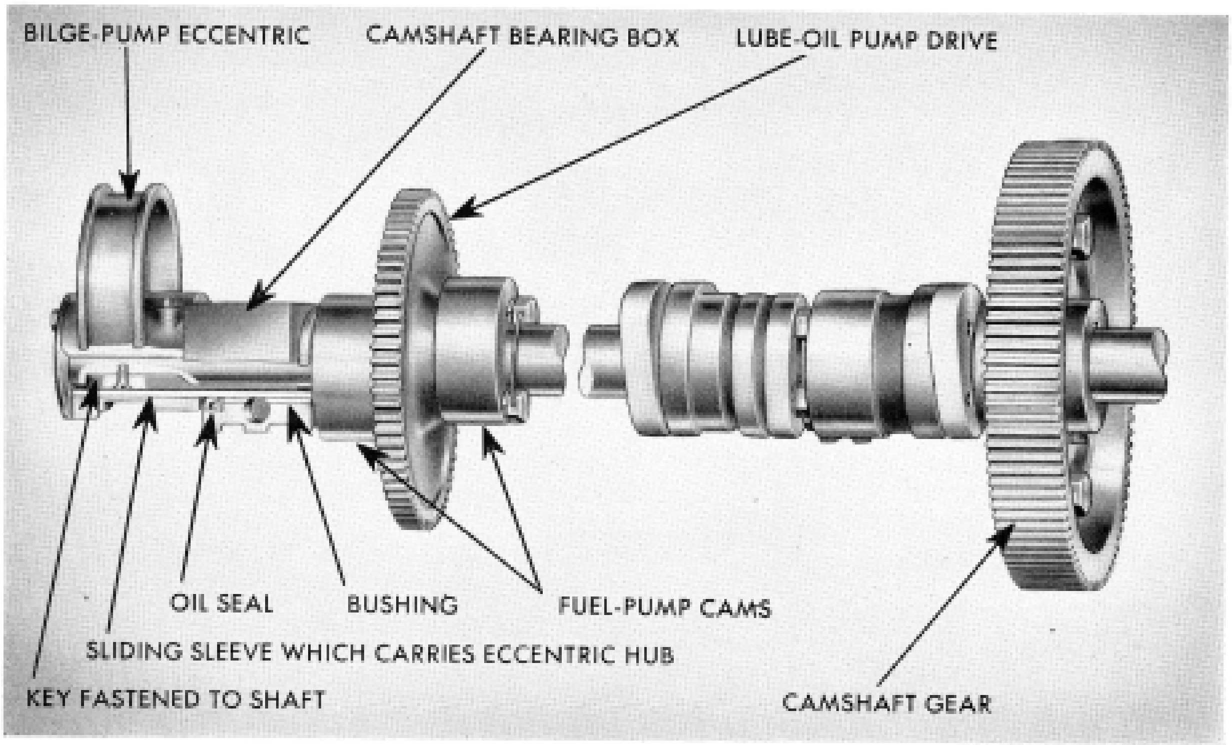


FIGURE 5-5

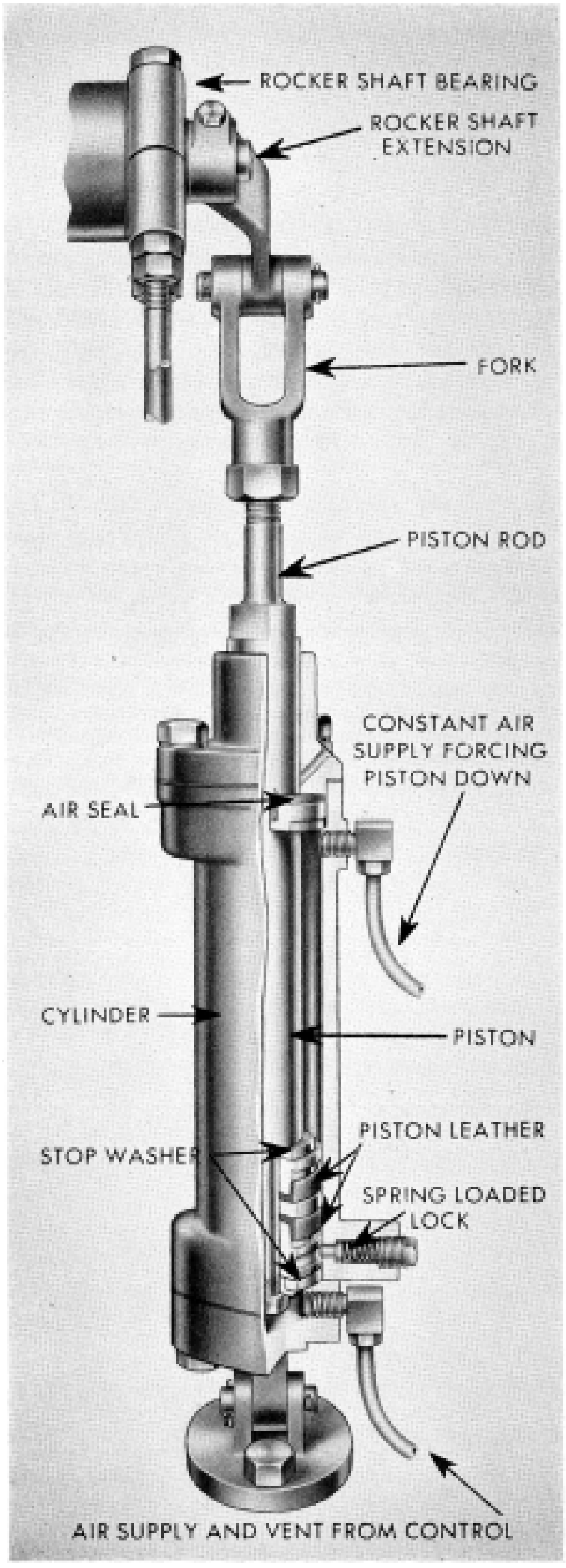


FIGURE 5-6

ment of the rocker shaft is accomplished by the rocker shaft ram shown in Figure 5-6. The rocker shaft of No. 1 cylinder has a forward extension to which is attached a lever and this lever is moved through a 90 degree arc to rotate the rocker shaft. The rocker shaft ram is simply a cylinder, a piston and a piston rod which is connected to the rocker shaft lever. This piston is moved up or down by air pressure, turned on or off by the control handle, as we shall describe later.

Reference to Figure 5-6 shows that the piston diameter is almost as large as the cylinder bore. At the lower end of the piston there are two leathers faced in opposite directions. The upper end of the cylinder is closed off by a special synthetic air seal which acts as a packing gland. This seal and the upper piston leather form a space to which air is constantly admitted under pressure. This forces the piston down at all times. This air, however, 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 supply of air to the lower end of the cylinder is shut off. As the piston moves down, the displaced air in the lower chamber is bled off by the same valve that originally admitted the air.

19. ROCKER SHAFT BELL CRANK: The various rocker shafts are interconnected 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 lock nut and turning the piston rod out or in the fork, which connects to the rocker shaft lever.

20. SPRAY VALVE CAMS: Figure 5-4 shows that the spray-valve cam lobes have ramps cut in the side to assist the spray-valve lifter roller in climbing up to the peak of the lobe when the camshaft is shifted.

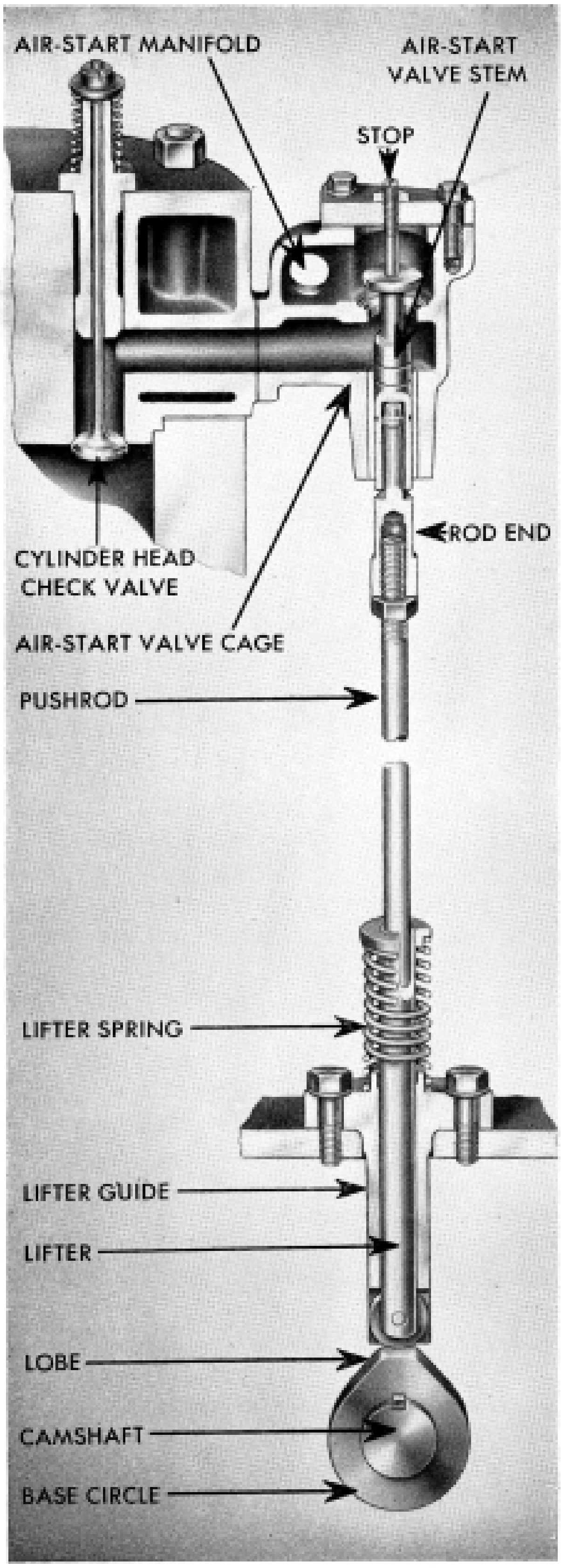


FIGURE 5-7

21. AIR-START VALVE CAMS: The air-start valve and lifter are held up and out of action by springs that will be described later in this section. They offer no difficulty to a fore or aft movement of the camshaft.

22. 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 the fuel wedges are withdrawn until no fuel is delivered to the spray valves. This is done by revolving the wedge shaft through linkage connected to the control unit and 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 heavy Diesel would require too large a motor and battery. Compressed air is used instead, to get the engine revolving, much in the way steam is used in a steam engine.

23. AIR-START VALVE OPERATING MECHANISM: As stated before, the air-start lifter rollers are held up and clear of the camshaft all the time the engine is operating. Figure 5-7 shows how the spring which lies between the shoulder on the lifter and the lifter guide keeps the roller clear of the cam.

The cage of the air-start valve is divided into two chambers. One, above the head of the air-start valve, is connected to the air-start manifold. The other, below the head of the air-start valve, leads directly into the check valve in the cylinder head. In Figure 5-8 the air-start valve is open. Assume that air pressure is delivered to the air-start manifold by the master valve, which will be described later. Some of the air will pass through the open air-start valve but not enough to open the cylinder head check valve. There will be enough pressure, however, to force the enlarged stem of the air-start valve down until the valve seats. Now the full pressure of the manifold air is on the head of the valve, holding it closed and forcing the lifter roller onto the cam.

In Figure 5-7 the air-start valve could not close, as the lobe of the cam is under the roller.

Therefore, the full manifold pressure would pass into the cylinder as this full pressure is sufficient to open the cylinder head check valve. If the cam were in the position shown in Figure 5-7, the piston would be at the top of the cylinder. The air pressure would start the piston down, and continue to force it down until the engine had turned enough to roll the cam lobe from under the air-start lifter, which would close the air-start valve. By this time the next cylinder in the firing order would duplicate this air stroke. This is the way engine speed is built up for starting and when sufficient momentum has been stored in the flywheel, the air is turned off and fuel fed to the cylinders.

24. MASTER VALVE AND STARTING MANIFOLD: The air-start valves are supplied with compressed air from the ship's air tanks which is piped to the starting manifold. This manifold connects all the air-start valve cages. As air pressure is required in the manifold only during starting or maneuvering, a master valve is installed on the forward end of the manifold. This valve, shown in Figure 5-8, is operated by the control unit.

The head of the valve is shaped to form a piston much larger than the valve proper. The sectional illustration shows a small equalizing hole which permits the air to pass into the chamber above the piston. This leaves the air pressure exerting force on the head of the master valve only, to hold it closed. The spring adds additional force in this direction.

The area above the piston is connected, by tubing, to a vent valve on the control unit. When this vent valve is opened the air pressure above the piston is quickly released, and as it can only build up again through the equalizing hole, there is a much greater force of air pressure under the piston to lift it than the spring and head of the master valve exert, to close it. Therefore, as long as the control unit vent valve is held open the master valve is also open, and the main air pressure can pass through the valve and on into the starting manifold.

25. BLEEDING THE MANIFOLD: After the maneuver has been completed and the master valve closed it is necessary to bleed off any pressure remaining in the manifold. Fig-

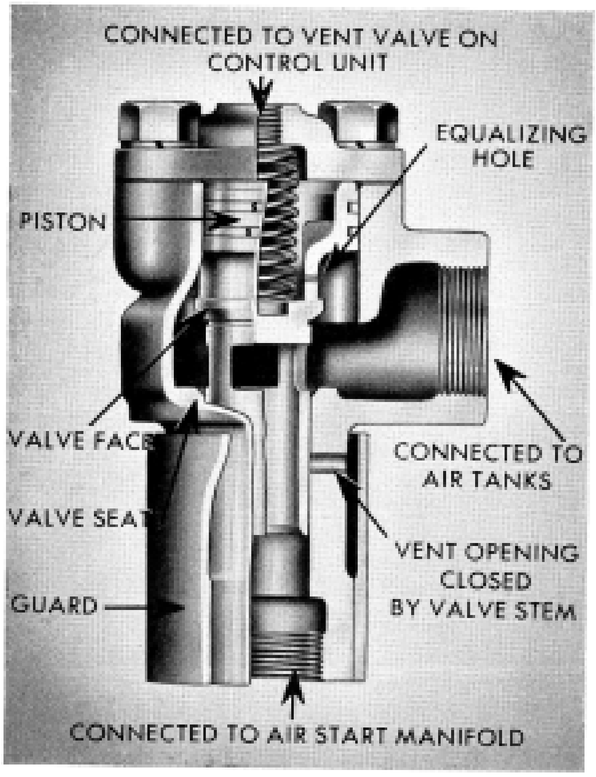


FIGURE 5-8

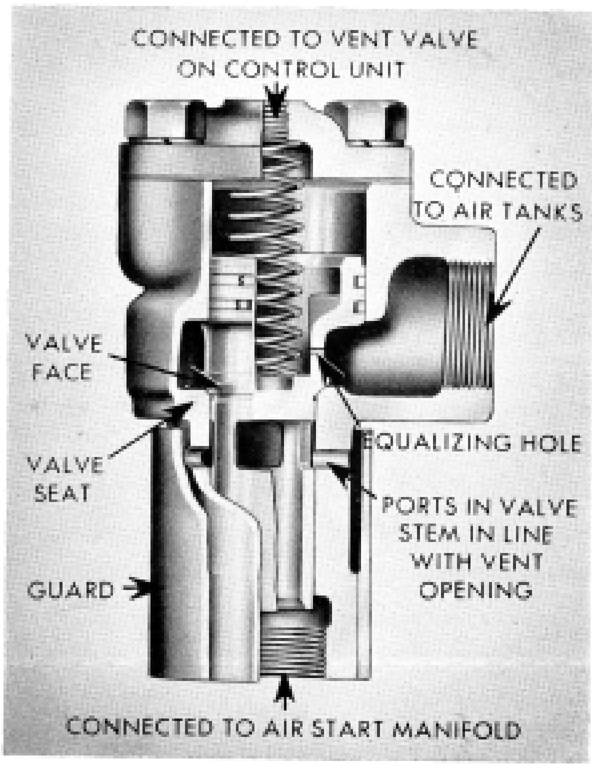
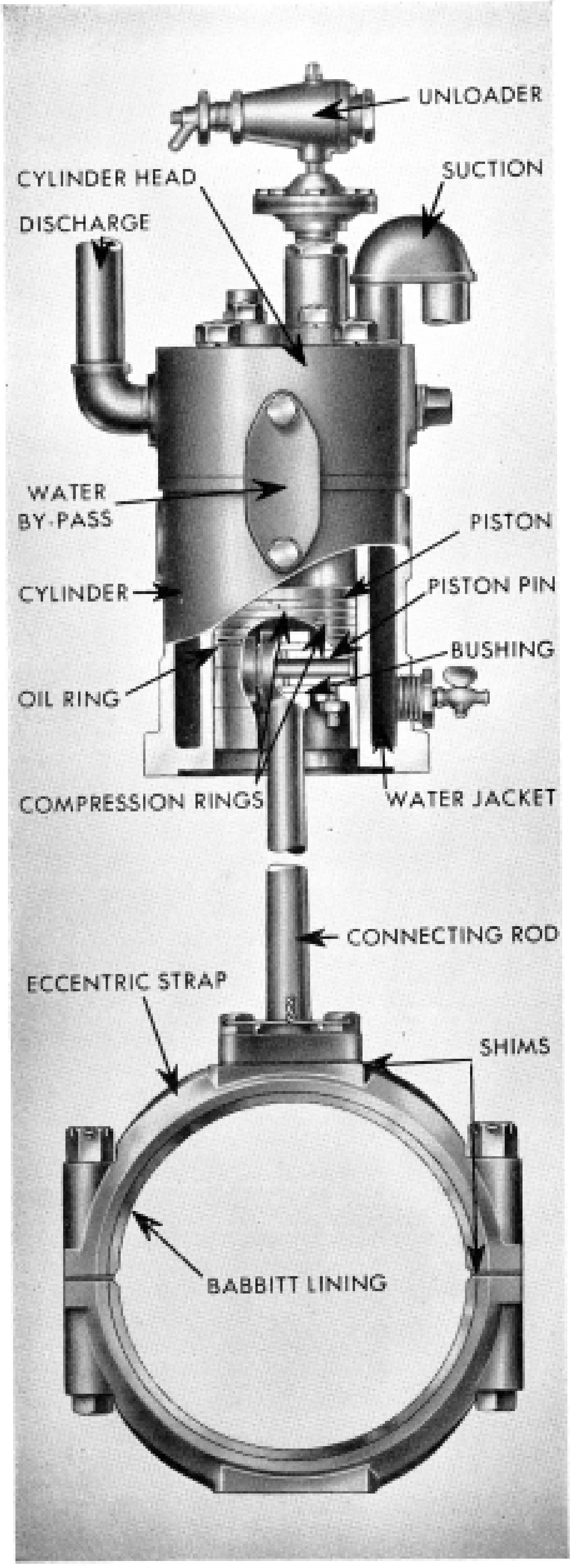


FIGURE 5-9



FGURE 5-10

ure 5-9 shows the master valve closed. It also shows that the ports in the hollow stem, which pass the air through the valve when it is open, are now lined up with holes that pass through the body of the valve and connect the manifold to the atmosphere. As these holes radiate around the entire valve body, the guard sleeve shown is put on to avoid air being blown into the operator's face.

26. 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. The eccentric strap has been turned ¼ turn for illustrative purposes.

27. 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 from its seat, thereby allowing air to pass to the top of a diaphragm. The diaphragm, being flexible, expands downward when the air pressure is applied. To this diaphragm is attached a short plunger which is located directly above the stem of the suction valve. As the diaphragm and plunger move downward the suction valve is held off its seat. When the air pressure in the tank drops below or lower than the spring tension, the piston is forced back onto its seat, cutting off the air supply to the diaphragm. The plunger 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 20

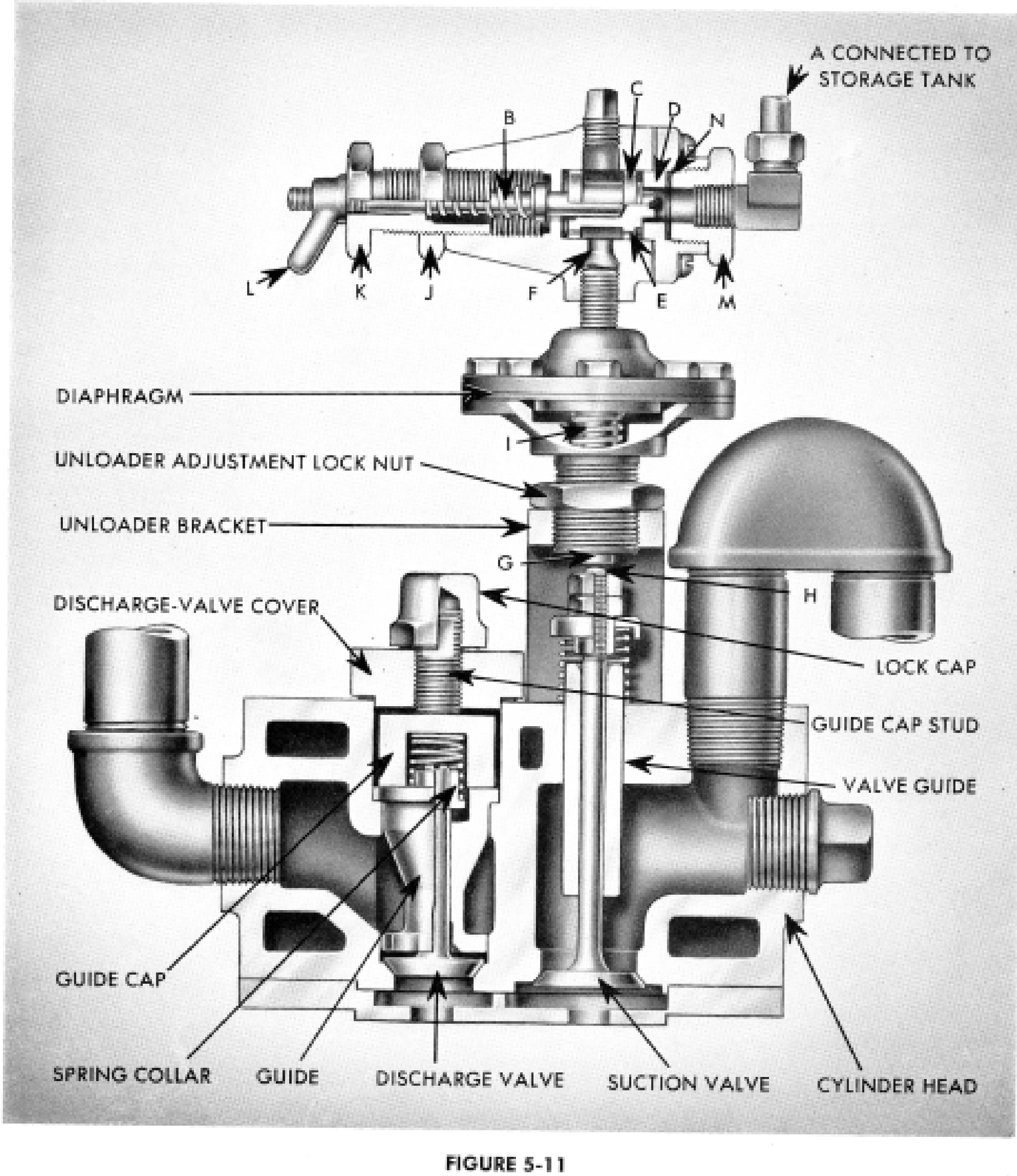


FIGURE 5-11

pounds under the limit pressure of the air tank safety valves. This is done to avoid the safety valves blowing continuously. 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.

28. 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 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.

29. 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.

30. FLYWHEEL BRAKE: When reversing from ahead to astern, or vice versa, you MUST

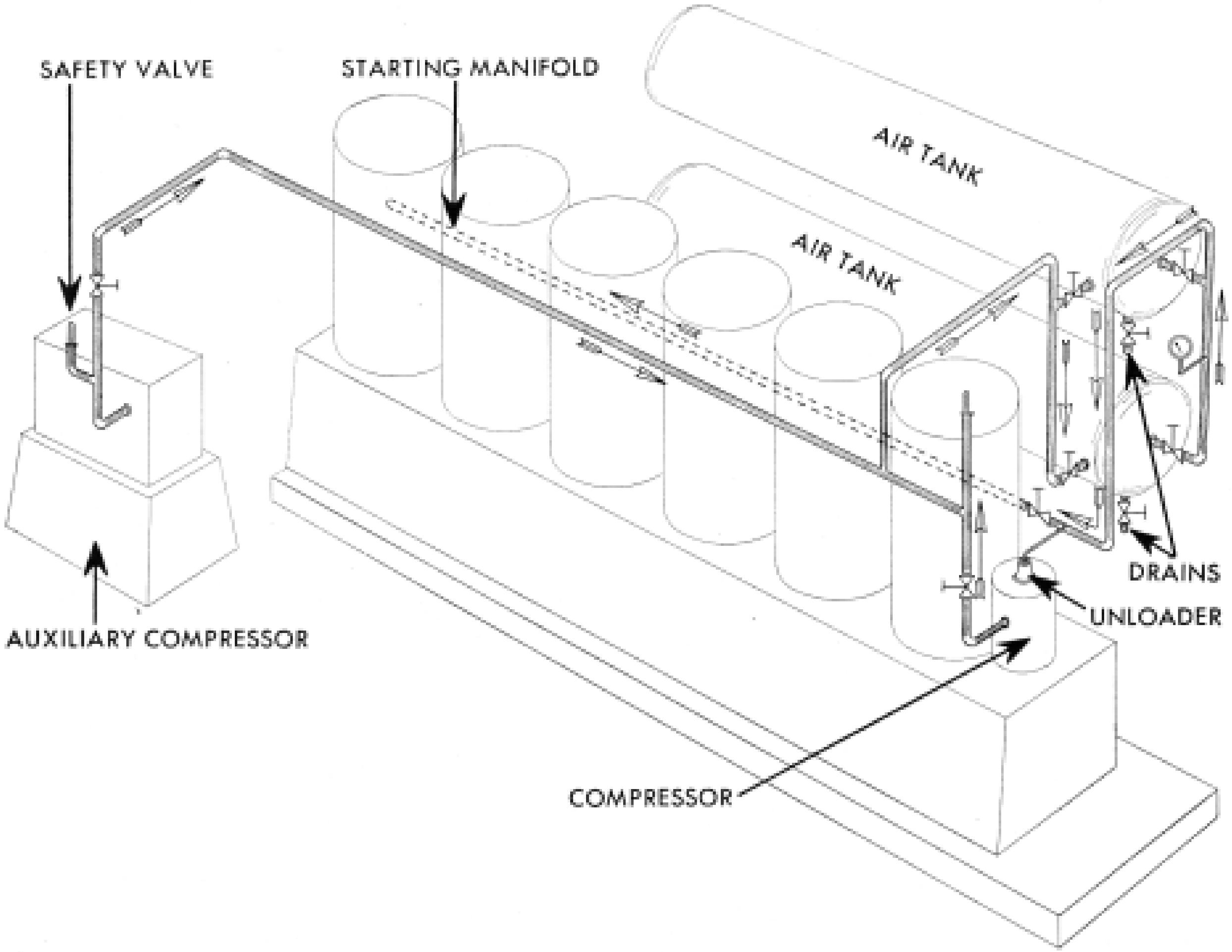


FIGURE 5-12

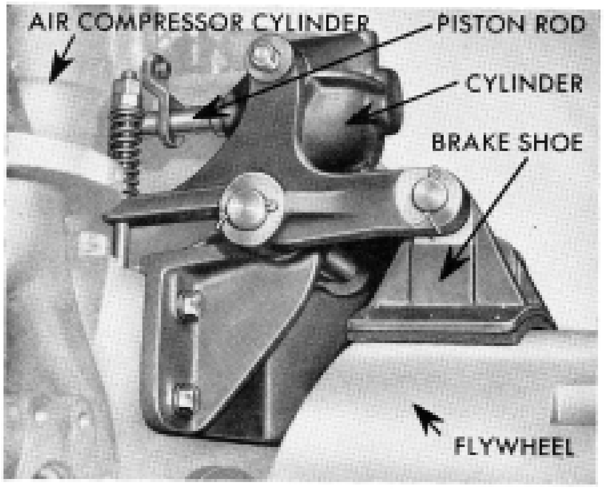


FIGURE 5-13

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 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 control lever, which we shall describe next.

31. CONTROL UNIT: The fuel cutout, the rocker shaft ram, the flywheel brake, the master valve, and shifting the camshaft are all accomplished by the one lever of the control unit. This lever is mounted so that it may be moved fore and aft, from one side of the control unit to the other, and also it can be moved in or out, or thwartship. The fore and aft movement shifts the camshaft from ahead to astern, operates the pilot valve controlling the rocker shaft ram and flywheel brake as well as the fuel cutout mechanism. During this motion the lever is confined to a slot in the control housing. At either end of its stroke, however, notches in the slot permit the lever to be pushed in, toward the engine. This movement operates the vent valves which control the master air-start valve. Notches directly opposite these first mentioned two, allow the lever to move out away from the engine, where it is held by a light spring which locks the unit in either ahead or astern position. The movement from the inner notch to the outer one releases the fuel cutout mechanism. There is another "out" notch in the center of the slot which locks the lever in the stop position. The various positions are illustrated in Figure 5-14.

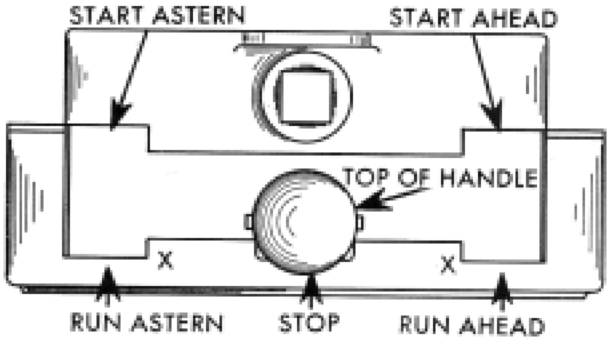


FIGURE 5-14

32. CAMSHAFT SHIFTING MECHANISM: As the control lever is moved fore or aft the camshaft is shifted to the ahead or astern running positions through the linkage shown in Figure 5-15. In this illustration the lever is aft and the camshaft has been slid forward, which brings the astern cams under the lifter rollers. The drag link that connects the control lever to the shifter lever is slotted. This slot will permit the control lever to be moved to the central or stop position, without shifting the camshaft.

When the control lever is moved forward, from stop, the end of the slot in the drag link will engage the pin in the shifter lever and pull the camshaft aft, which brings the ahead cams under the lifter rollers. The total movement of the camshaft from ahead to astern is ⅞ inch.

33. PILOT VALVE, ROCKER SHAFT RAM, AND FLYWHEEL BRAKE: Paragraph 18 explained how the rocker shaft ram lifted the inlet and exhaust lifter rollers up and clear of the camshaft before it is shifted to either ahead or astern. This ram, as well as

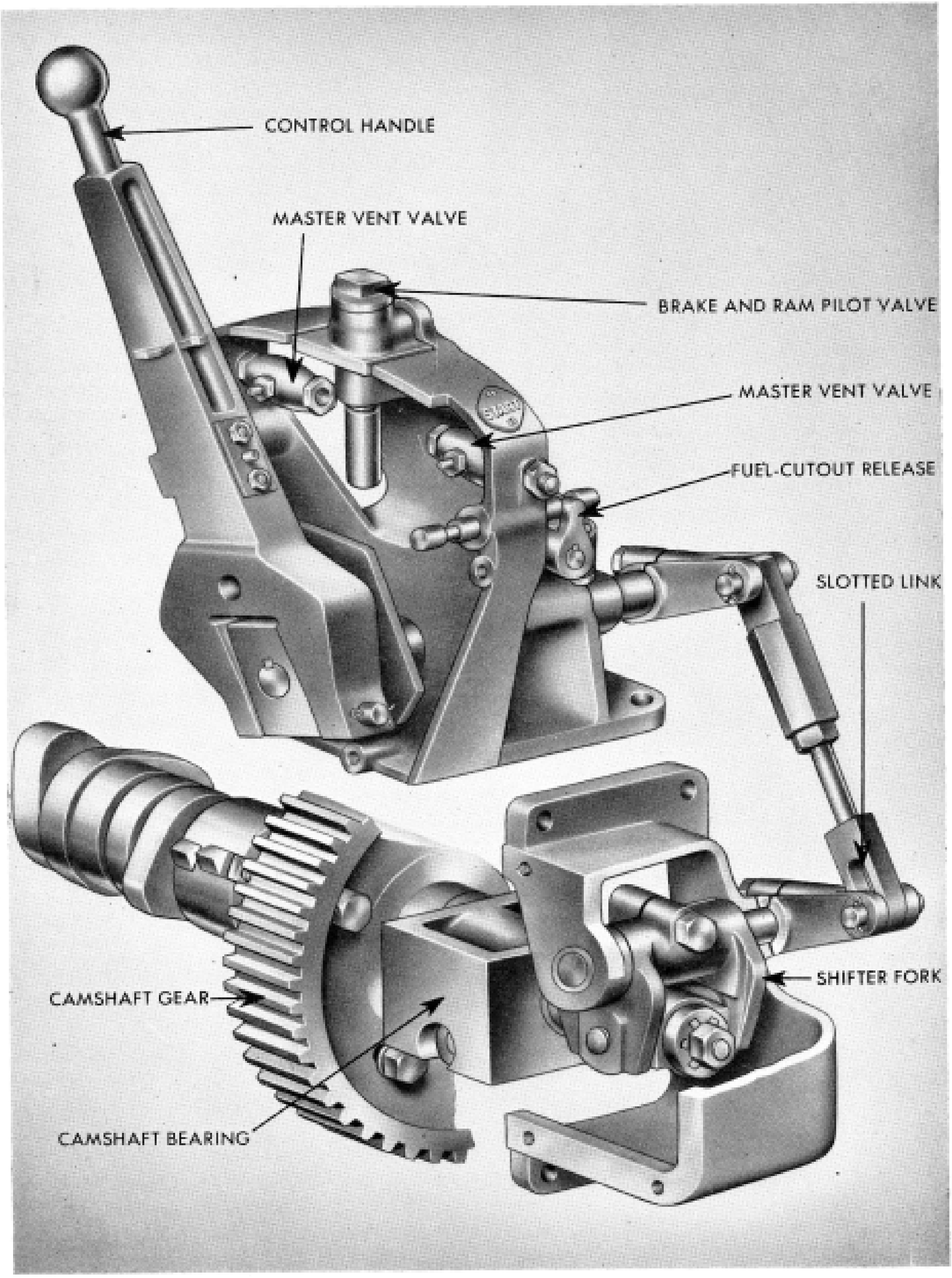

CONTROL HANDLE
MASTER VENT VALVE
BRAKE AND RAM PILOT VALVE
MASTER VENT VALVE
FUEL-CUTOUT RELEASE
SLOTTED LINK
SHIFTER FORK
CAMSHAFT GEAR
CAMSHAFT BEARING

FIGURE 5-15

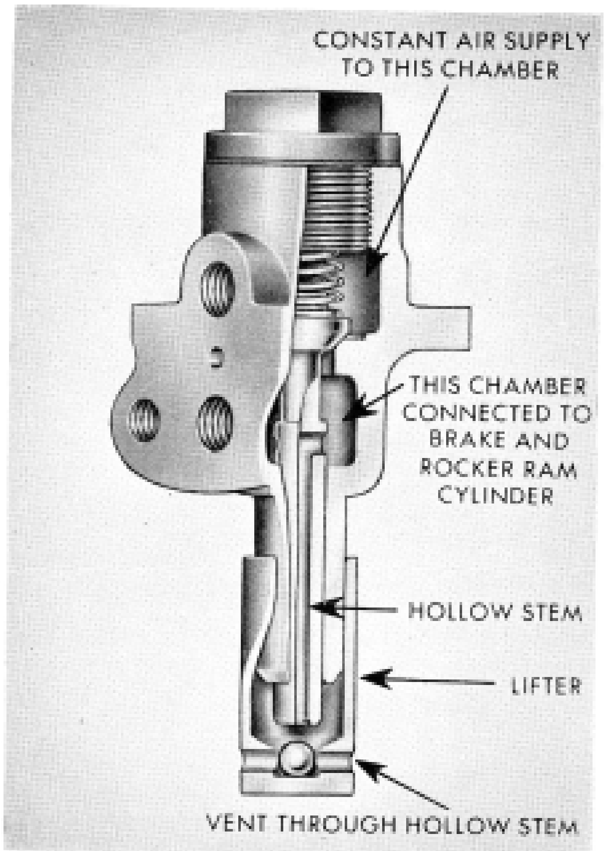


FIGURE 5-16

the flywheel brake, is controlled by the pilot valve shown in Figure 5-16. This valve is mounted in a housing that bolts to the control unit and is operated, through a lever, by a cam which is rotated by the control lever shaft. Air pressure is constantly on the head of the valve, and the spring shown assists to hold the valve closed. From the chamber under the head of the valve, one tube leads to the bottom of the rocker shaft ram cylinder while another tube leads to the cylinder of the flywheel brake.

The stem of the pilot valve is hollow up to the holes shown, which are bored in from the sides of the stem. The lifter which slides over the lower portion of the valve body has a ball so positioned that it closes up the hole in the valve stem before the valve is lifted off its seat. When the pilot valve is closed, this lifter is down far enough to permit the ball to vent the hole in the stem, which in turn vents both the rocker ram and the flywheel brake cylinders. This valve is open whenever the control lever is between the (X) marks, Figure 5-14.

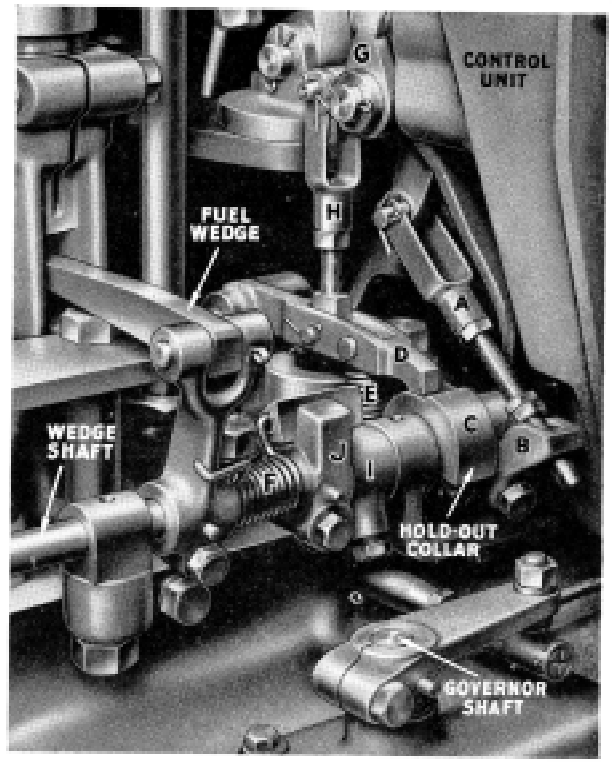


FIGURE 5-17

34. FUEL CUT-OUT MECHANISM: When the engine is stopped and during the time it is turning over on starting air it is necessary that the fuel supply be cut off from the spray valves. This is accomplished by withdrawing the fuel wedges as explained in Paragraph 20 of Section 4. So that this operation is automatic, the device shown in Figure 5-17 is arranged to function through the movement of the control lever. All references to lettered parts in Paragraphs 34, 35, and 36 will be found in Figure 5-17 unless otherwise noted.

There is a cam attached to the control lever shaft which causes the adjustable link (A) to press down on the short lever (B) whenever the control lever is between the (X) marks, Figure 5-14. Lever (B), Figure 5-17, is attached solidly to the wedge shaft as is the hold out collar (C). In this illustration the control lever is at (STOP) and the wedge shaft has been turned so that the fuel wedges are withdrawn, cutting off the fuel supply to the spray valves.

If the control lever is moved into either start position the link (A) will slide freely in the slot in lever (B) without moving it. The latch

(D) is held down by spring (E) and it is apparent that when the link (A) is withdrawn, by movement of the control lever, the latch will engage the notch in the holdout collar. As this collar is fixed to the wedge shaft, it will be seen that the wedges will be held in the (out) position until the latch is released.

35. FUEL RELEASE MECHANISM: After the engine is revolving on starting air and starting speed has been attained, the control lever is moved from the starting to the run position. This movement operates the lever (G) and the adjustable link (H) which raises the latch (D), releasing the holdout collar (C). The wedge shaft now turns to the (in) position by the tension of spring (F) which is constantly exerting force to turn the wedge shaft to the (in) position.

As long as the control lever is in the (run) position the latch (D) will be held up clear of the holdout collar. Movement out of the run position releases latch (D), and spring (E) draws it down on the face of the holdout collar where the latch is in position to drop into the notch in the holdout collar as soon as the shaft is turned by the fuel cut out mechanism.

36. GOVERNOR CONNECTION TO THE WEDGE SHAFT: The spring (F) is constantly exerting force to hold the wedges at the (in) position while the governor, described in Paragraph 22 of Section 4, withdraws the wedges to a greater or lesser degree, depending on the speed of the engine and the governor control handle setting. The connection between the governor and the wedge shaft is made through the linkage shown in Figure 5-17.

Lever (I), which is connected to the governor shaft, has a prong which extends behind lever (J). Lever (J) is fixed to the wedge shaft, therefore it has the same tendency to turn to the (in) position as the wedge shaft due to the effect of spring (F).

Lever (I) floats on the wedge shaft but it is able to withdraw the wedges by the extension prong which comes against lever (J). This type of connection permits the fuel cutout mechanism to withdraw the wedge shaft any time the control lever is moved to (stop), regardless of governor action or setting.

A full description of the operation and adjustment of these various control components is given in Section 18.

37. CONTROLLING ENGINE SPEED: The regulation of the governor control handle, and the pressure regulating valve relative to the engine speed, is explained in Section 6.

38. 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 cylinder, filled with baffles to break up the pulsations of the exhaust from the six cylinders. When the gases escape to the atmosphere in a steady stream, less noise will be produced.

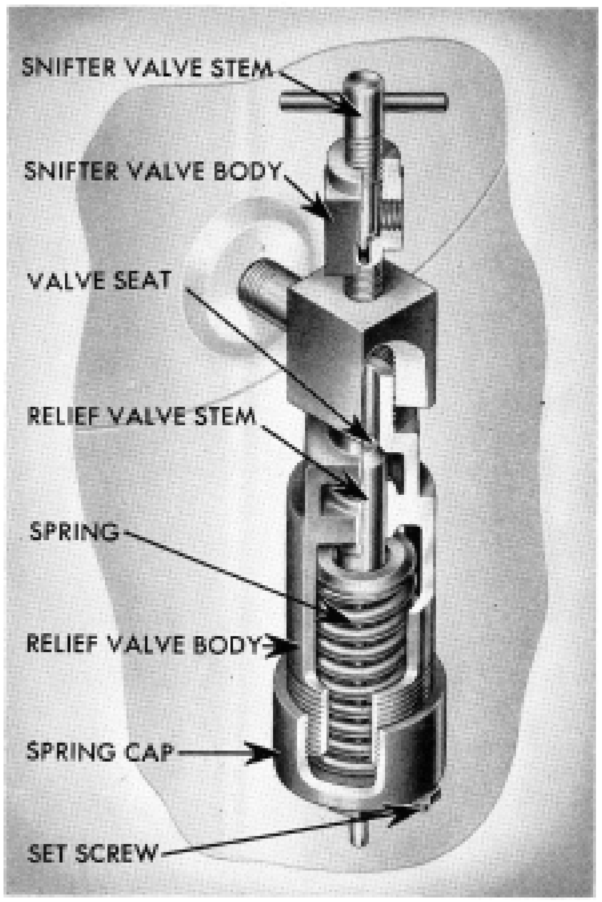


FIGURE 5-18

39. 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.

40. 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.

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 time. 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, 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 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

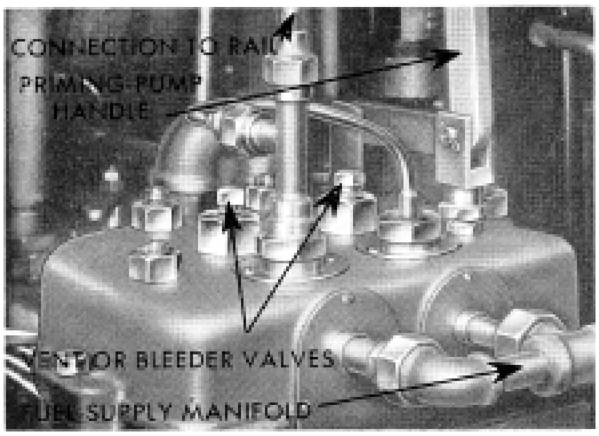


FIGURE 6-1

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 TO 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.

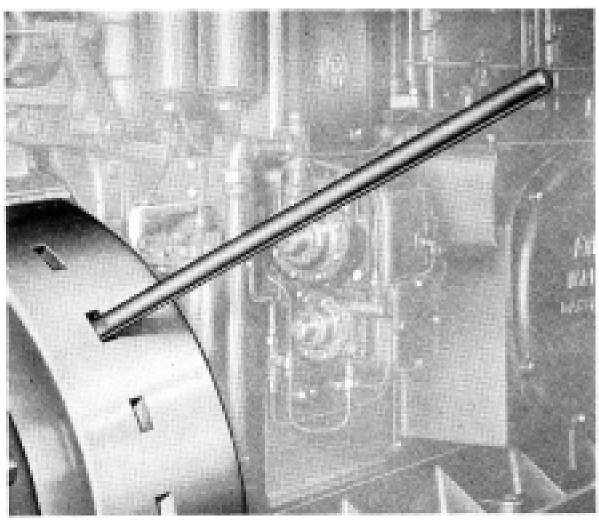


FIGURE 6-2

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. CONTROL MECHANISM: Before the operator attempts to run the engine, he should carefully study the chapters dealing with the mechanical details, especially those of the control system. A thorough understanding of each function of the control system will assist the operator to understand the significance of each movement of the control lever.

We will now briefly outline these control movements in sequence for each maneuver.

10. TO START THE ENGINE AHEAD FROM STOP:

(a) Set the governor control lever at approximately the center of its sector.

(b) Set the fuel pressure regulating valve lever at about 1500 pounds. Determine the correct position for this pressure by use of the priming pump.

(c) Move the control lever to AHEAD. (When the control lever is at STOP the camshaft may be in either the ahead or astern positions. If it is astern, it will be shifted to ahead when the lever is moved to AHEAD. If it is already ahead, the lever will move freely with no resistance.)

(d) Push the control lever in toward the engine to admit starting air. Hold until the engine is rolling.

(e) Pull lever out to RUN.

(f) Control engine speed as desired by the governor control lever and by the fuel pressure regulating valve.

11. TO REVERSE THE ENGINE FROM AHEAD:

(a) Push the control lever in toward the engine sufficiently to clear the retaining notch in the control panel. DO NOT PUSH IT IN FAR ENOUGH TO OPEN THE STARTING AIR PILOT VALVE.

(b) Move the lever to STOP and HOLD IT IN THIS POSITION UNTIL THE ENGINE STOPS ROTATING.
(c) Move the lever to ASTERN. The camshaft will be shifted to its astern position.
(d) Push the control lever in toward the engine to admit starting air. Hold until engine is rolling.
(e) Pull lever out to RUN.
(f) Control engine speed as desired by the governor control lever and by the fuel pressure regulating valve.

12. TO STOP THE ENGINE:

(a) Push the control lever in toward the engine sufficiently to clear the retaining notch in the control panel. DO NOT PUSH IT IN FAR ENOUGH TO OPEN THE STARTING AIR PILOT VALVE.
(b) Move the lever to STOP and HOLD IT IN THIS POSITION UNTIL THE ENGINE STOPS ROTATING.

13. PRELIMINARY CRANKING: If the engine has been worked on and especially if the spray valves have been timed there is always the possibility of excess fuel being in the cylinders. To avoid blowing the cylinder relief valves, and to prevent engine racing, it is advisable to turn the engine over a few times on air alone to clear the combustion chambers. Proceed as follows:

Close all isolating valves, open the cylinder snifter valves. Move the control lever to (A), Figure 6-3. Press the lever into (D), which applies starting air. After the engine has revolved two or three revolutions move the lever to STOP. Any excess fuel will now be out of the cylinders and the engine is ready for operation after the snifter valves are closed and the isolating valves are opened.

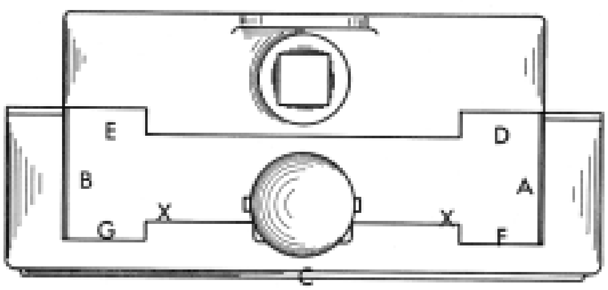


FIGURE 6-3

14. EXPLANATION OF THE CONTROL MOVEMENTS: From stop to run ahead. When the control lever is at STOP (C), Figure 6-3, the pilot valve is open, which applies the flywheel brake and lifts the piston of the rocker shaft ram. The valve lifters are up and clear of the cams.

Movement of the control lever from (C) STOP to (A) run ahead, moves the camshaft so that the ahead cams are under the lifters. As the lever passes (X), the pilot valve controlling the brake and rocker shaft ram closes, thereby releasing the brake and returning the ram to its running position, which lowers the lifters onto the cams.

Movement of the lever into the slot (D) opens the vent valve which controls the master air valve. When the master valve is open starting air is delivered to the various cylinders in proper sequence by the air-starting valves. The lever is held in this position until the engine has gained momentum. When the engine is warm this usually means only part of a revolution.

As the lever is moved from (D) to (F) the master valve vent is closed, which cuts off the starting air supply to the manifold. The same movement operates the wedge-shaft release mechanism, returning the fuel wedges to the control of the governor. The notches (F) and (G) are simply locks to hold the control lever in either the run ahead or run astern position.

15. FROM RUN AHEAD TO STOP: The control lever is moved out of the notch (F) and directly to (C). Care must be taken that the lever does not enter (D) during the stop maneuver, as starting air would be applied. As the lever passes (X) the pilot valve is opened, which applies the flywheel brake. The same pilot valve operates the rocker-shaft ram, thereby raising the valve lifters clear of the camshaft.

The fuel cutout also operates as the control lever passes (X) on the way to (C) STOP. This mechanism revolves the wedge shaft a part of a turn, which withdraws the fuel wedges, cutting off the fuel supply to the spray valves. The fuel wedges are held out whenever the control lever is between the two (X) marks. Between these two points the flywheel brake is on and the valve lifters are up and clear of the camshaft

16. FROM AHEAD OR STOP INTO ASTERN: If a maneuver is being made from either ahead to astern or from astern to ahead be sure to HOLD THE CONTROL LEVER AT (C) UNTIL THE ENGINE HAS STOPPED REVOLVING. The events occur in the same sequence in an astern maneuver as they do when starting ahead except that they are carried out in the astern part of the control unit.

17. RUNNING CHECKUP: Immediately after the engine starts running on fuel at slow speed, 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.

18. INCREASING ENGINE SPEED: If the engine has been started up from cold it is advisable to increase the speed gradually so that the engine can warm up evenly. After each increase the operator should go through the running check-up outlined in paragraph 17. As the governor control handle is advanced the fuel pressure should be increased proportionately by the fuel regulating handle 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 between 1000 and 1500 pounds and the exhaust may be hazy.

19. FULL SPEED REGULATION: Do not operate your engine over its rated full speed revolutions. If the engine is equipped with a tachometer it is an easy matter to watch the speed. If it is not, learn to count the revolutions by hand. As the valves open only once each two revolutions, the number of openings in a minute can be counted by holding onto one of the pushrods. You can count the strokes for ½ minute and multiply by four or count the strokes for a full minute and multiply by two. Either way will give you the revolutions per minute.

Remember that an engine in a tow boat, which has a propeller designed to pull heavy barges, will turn far in excess of its rated revolutions, if opened up when the boat is not towing. On the other hand, an engine in a boat with a propeller designed for free and away running can not be expected to turn up to its rated revolu-

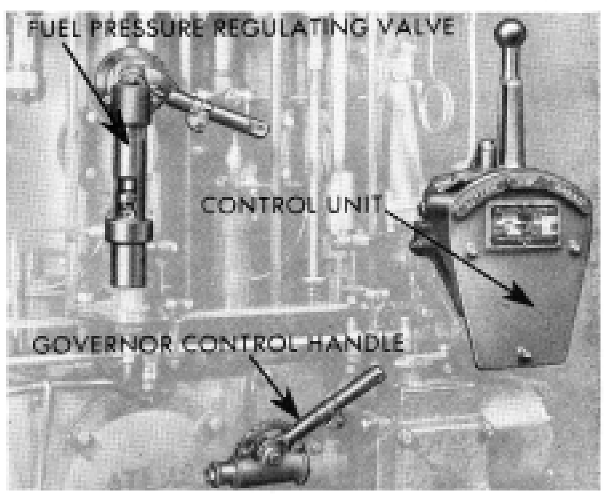


FIGURE 6-4

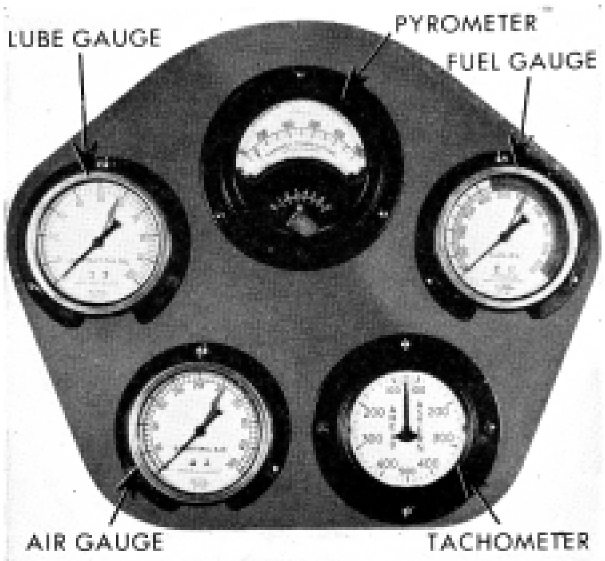


FIGURE 6-5

tions if it is towing another vessel or if the propeller has been damaged in such a way that it is out of pitch or balance.

20. GAUGE BOARD: For convenience the various gauges which record pressures, temperature, and engine speed are grouped on one panel located just above the control position. These gauges are delicate instruments and should be returned to the nearest service depot for repairs if needed.

The lubricating-oil gauge is connected to the discharge line of the pressure lube pump and records the pressure of the oil between that pump and the bearings. On starting up when the oil is cold, the pressure may go up to 60 pounds or more, but after the engine is warm the oil pressure should hold between 35 and 40 pounds.

The air gauge is usually connected to the air-storage tanks but sometimes a tubing line is led from the pipe line which supplies the master valve. This gauge should always read between 225 and 250 pounds, as many more maneuvers are possible if the tanks are kept up to capacity.

The high-pressure fuel gauge is supplied by a line taken off the top of the fuel-oil receiver. This line is controlled by an isolating valve which should be so nearly closed that the fluctuations of the fuel pressure do not cause the gauge needle to vibrate. The high-pressure fuel gauge should be checked against a master gauge occasionally so that the operator is sure the correct fuel pressure is being recorded.

The tachometer is used to record the speed of the engine both ahead and astern. There is a small electrical generator driven by a flexible shaft from the timing gears. As the output of this generator varies with the speed of the engine, the tachometer records the speed changes in terms of revolutions per minute. If this unit is in need of repairs it should be sent to the nearest service depot.

The use of the pyrometer is described in Section 10, Paragraph 20. In each exhaust elbow there is a thermocouple which consists of a tube that encases two wires of dissimilar metals. These wires, when heated by the exhaust gases, produce a minute electrical energy which varies in direct proportion to the temperature increase. This energy is recorded on the dial of the pyrometer in terms of degrees Fahrenheit when the selector switch is turned to whichever exhaust elbow the reading is to be taken in.

21. REGULAR RUNNING INSPECTION: 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.

(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 drops 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.

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

A. Using engine oil, oil the following:
   - (a) rockers at rocker shaft
   - (b) rockers at pushrod forks
   - (c) fuel wedges
   - (d) fuel buffer springs
   - (e) wedge-shaft bearings
   - (f) tachometer drive
   - (g) governor bearing and governor linkage, bilge-pump connecting rod, both ends of the eccentric strap of the mechanical-lubricator drive.
   - (h) oil holes on control box
   - (i) sight feed to pump
   - (j) horseshoes on spray valves
   - (k) rocker-shaft bearings
   - (l) 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. Turn grease cups on circulating pump.

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

A. Hand oil:
   - (a) flywheel brake (oil holes)
   - (b) rocker-shaft ram (oil holes)
   - (c) control mechanism (oil holes)
   - (d) fuel cutout and release mechanism

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 standing 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.

SECTION 7

ENGINE SPECIFICATIONS AND CLEARANCES

FUEL AND LUBRICATING OIL

Number of cylinders	6
Bore	7½ inches
Stroke	10½ inches
Maximum rated speed	400 revolutions per minute
Horsepower at maximum rated speed	120 horsepower
Firing order	1-5-3-6-2-4
Weight of engine including flywheel	13,600 pounds approximately
Weight of one cylinder head assembly	120 pounds approximately
Weight of one piston and connecting rod	116 pounds approximately
Lubricating-oil pressure, minimum	30 pounds per square inch at rated engine revolutions per minute
Lubricating-oil pressure, maximum	30 to 45 pounds per square inch when oil is hot
Lubricating oil, grade—summer	SAE Heavy 30 or Light 40
Lubricating oil, grade—winter	SAE Light 30 (NOTE: subject to consideration for extreme cold)
Lubricating oil, capacity of engine	17 gallons
Lubricating oil for thrust bearing, grade	Heavy SAE 30
Lubricating-oil feed for mechanical lubricator, number of drops per minute	15 to 20 drops per minute
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	4 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	0.029 cubic feet at rated engine revolutions per minute
Raw-water cooling: capacity of circulating pump at full speed	37 gallons per minute
Bilge pump speed	½ engine speed
Bilge pump bore	2 inches

Bilge pump stroke	3¼ inches
Bilge pump capacity at full engine speed	7 gallons per minute
High-pressure fuel pump type	Single stage—2 cylinder
High-pressure fuel pump stroke	1 inch
High-pressure fuel pump bore	½ inch
High-pressure fuel pump speed	½ engine speed
Transfer pump make	Tuthill Pump Company
Transfer pump speed	300 revolutions per minute
Transfer pump capacity at full speed	1.25 gallons per minute
High-pressure lubricating oil pump make	Tuthill Pump Company (Internal Gear)
High-pressure lubricating oil pump speed	655 revolutions per minute
High-pressure lubricating oil pump capacity at full speed	5.2 gallons per minute at 50 lbs. pressure per square inch
Sump lubricating oil pump make	Tuthill Pump Company (Internal Gear)
Sump lubricating oil pump speed	900 revolutions per minute
Sump lubricating oil pump capacity, full speed	8.1 gallons per minute
Lubricating oil cooler make	Atlas Imperial Diesel Engine Co.

2. BEARING CLEARANCES:

Main bearings	0.0045 to 0.008
Crankpin bearings	0.0045 to 0.006
Piston-pin bushings	0.0035 to 0.005
Camshaft bearings	0.005 to 0.007
Rocker-shaft bearings	0.001 to 0.003
Intermediate cam train bearings	0.002 to 0.005
Air compressor eccentric strap	0.006 to 0.009
Bilge pump eccentric strap	0.004 to 0.006

3. MISCELLANEOUS CLEARANCES:

Piston to cylinders (top)	0.040 to 0.045
Piston to cylinders (bottom)	0.006 to 0.007
Piston rings clearances in groove	0.003 to 0.005
Piston rings gap clearance (two top rings)	0.038 to 0.060
Piston rings gap clearance (all other rings)	0.023 to 0.060
Piston to top cylinder	31/32 inch
Inlet and exhaust valves stem to bushing clearance (Exhaust)	0.004 to 0.005
Inlet and exhaust valves stem to bushing clearance (Inlet)	0.003 to 0.004
High-pressure fuel pump plunger to barrel	Lap fit

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. D189)	Maximum 1.0%
Ignition quality	40 to 60 cetane number or equivalent in other ignition index.

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 are 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. Cleanliness in handling the fuel is also important.

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 periods 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 compounded 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. For good grades of oil, the deposits are not excessive or 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, of course, not be worn out after 200 hours of service if it is of a good grade. It will, however, be dirty and will contain insolubles which should be removed from the lubricating oil before it is reused.

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 only new oil be used.

SECTION 8

STANDARD TERMS, FITTINGS, AND TOOLS

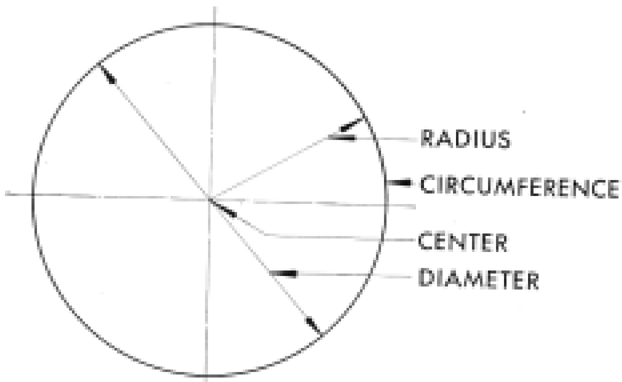


FIGURE 8-1

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.

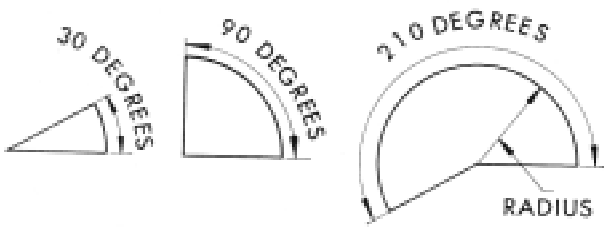


FIGURE 8-2

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.

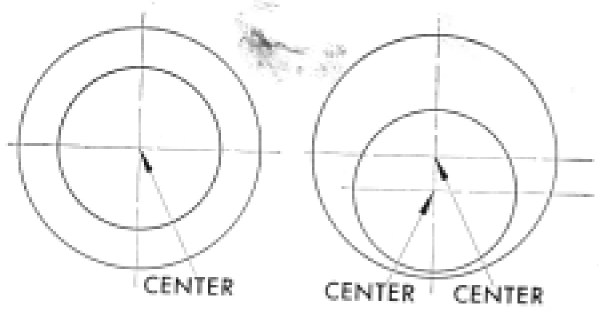


FIGURE 8-3

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.

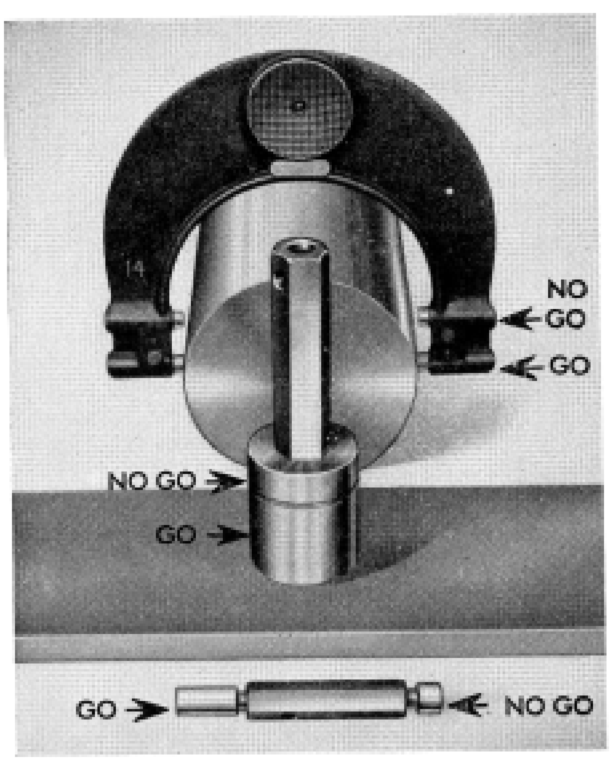


FIGURE 8-4

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

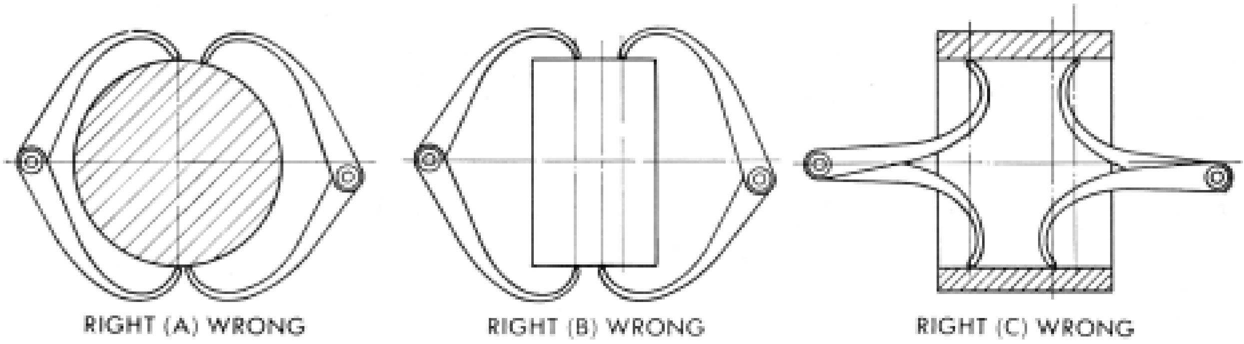


FIGURE 8-5

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.

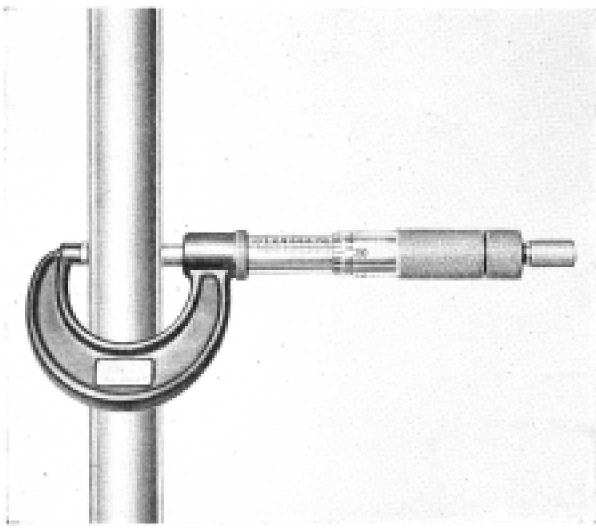


FIGURE 8-6

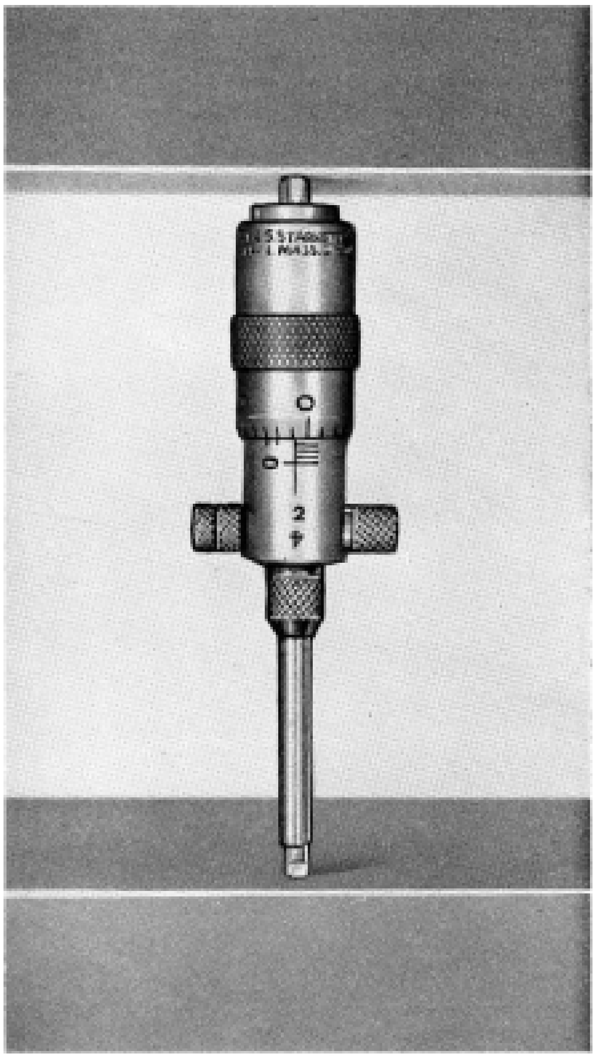


FIGURE 8-7

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.

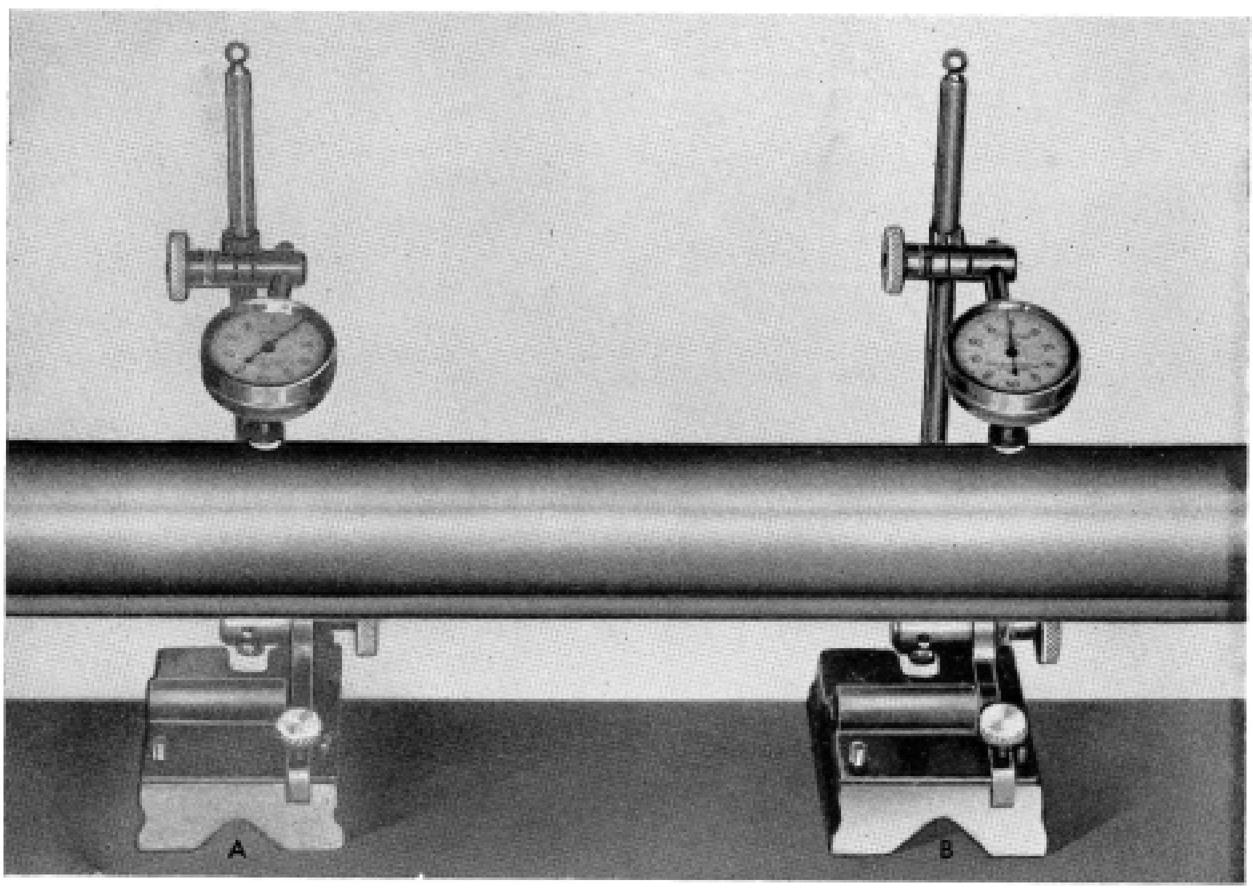


FIGURE 8-8

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.

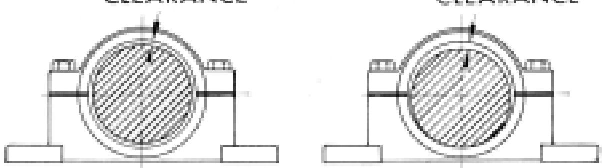


FIGURE 8-9

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.

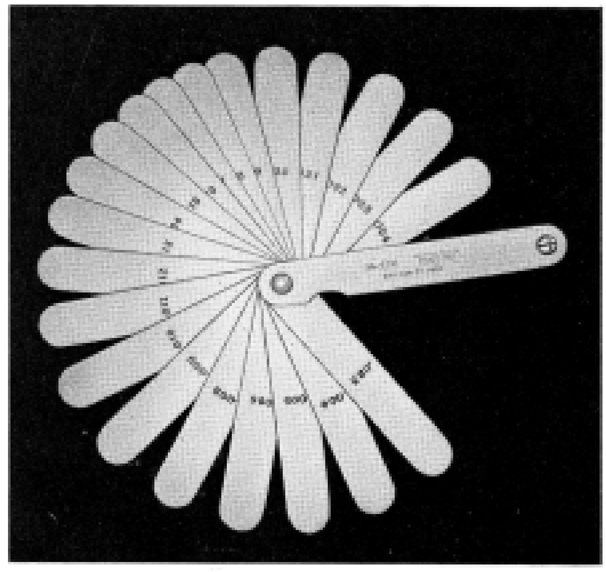


FIGURE 8-10

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

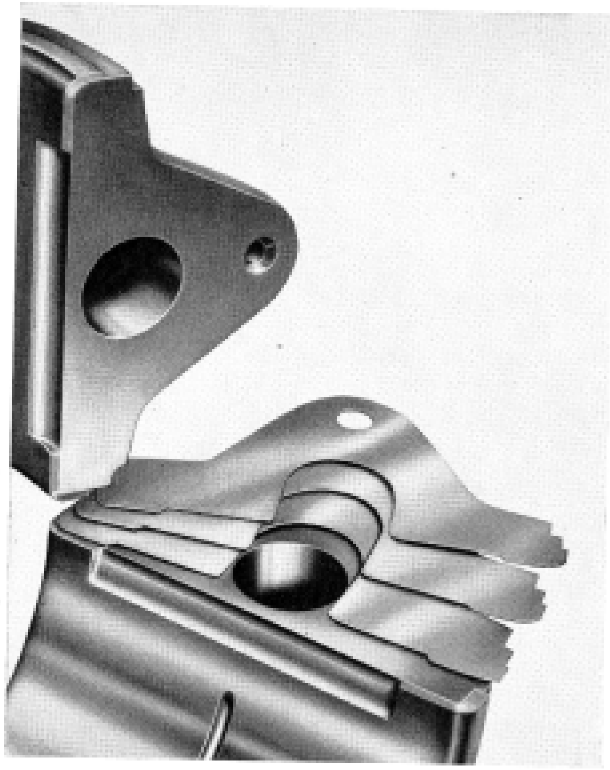


FIGURE 8-11

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.

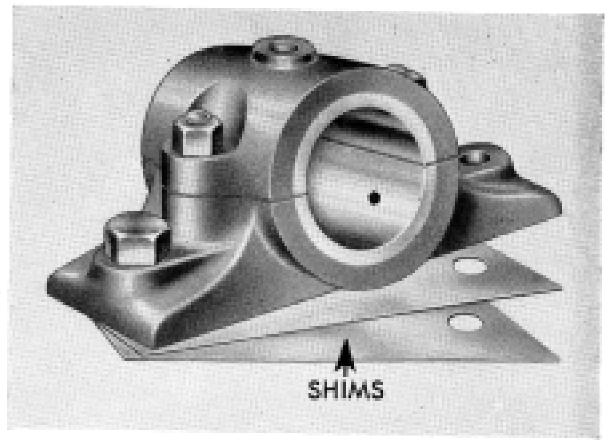


FIGURE 8-12

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

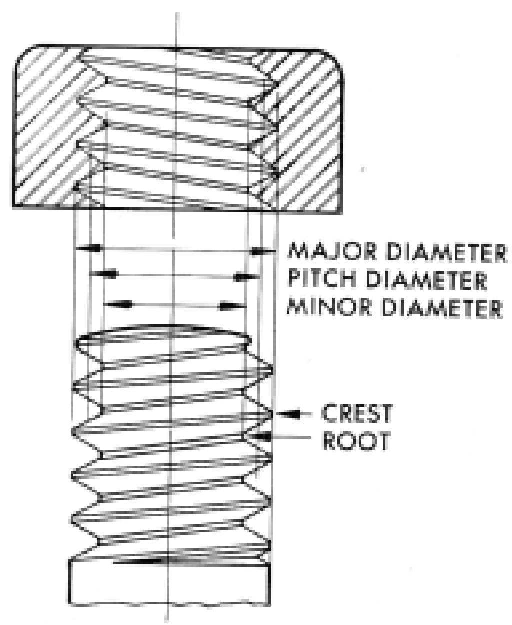


FIGURE 8-13

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.

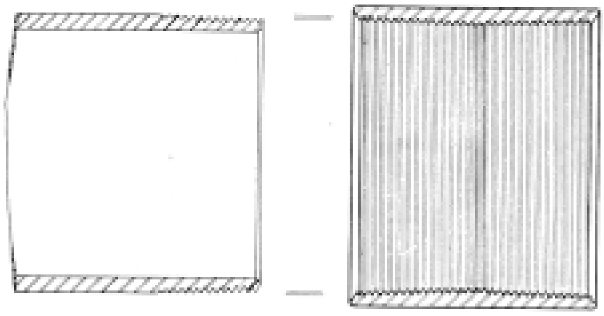


FIGURE 8-14

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

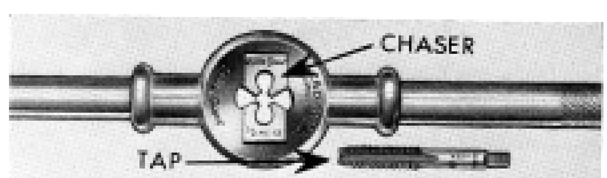


FIGURE 8-15

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.

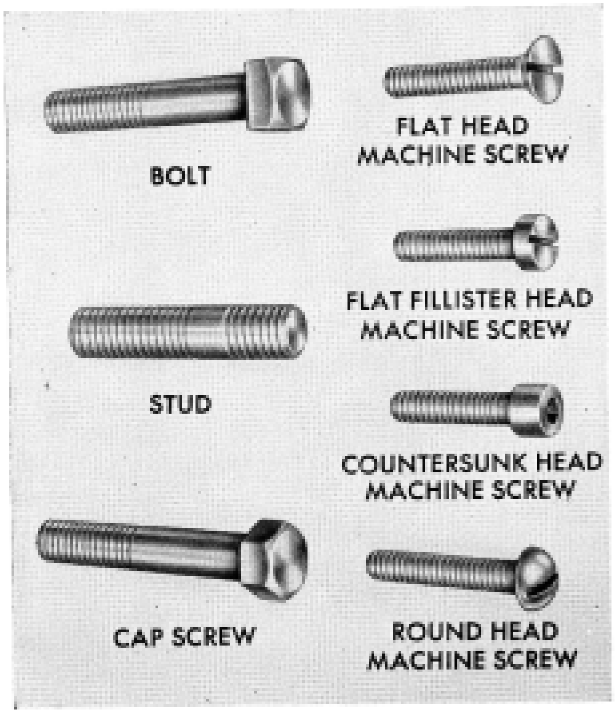


FIGURE 8-16

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.

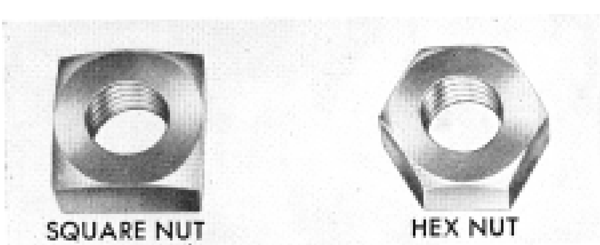


FIGURE 8-17

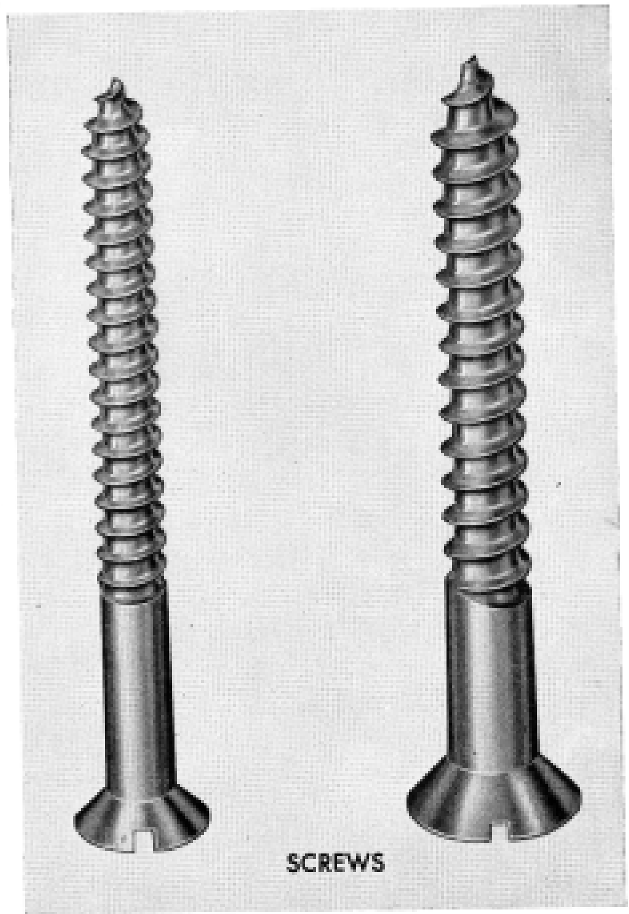


FIGURE 8-18

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.

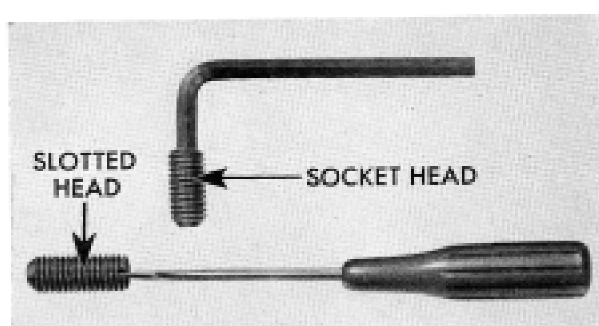


FIGURE 8-19

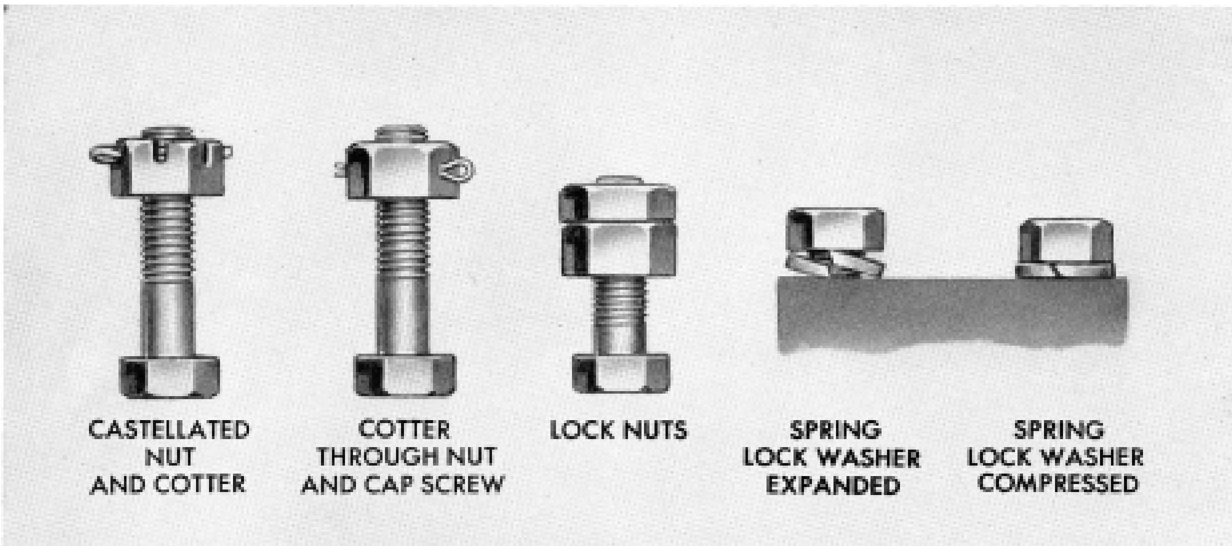


FIGURE 8-20

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

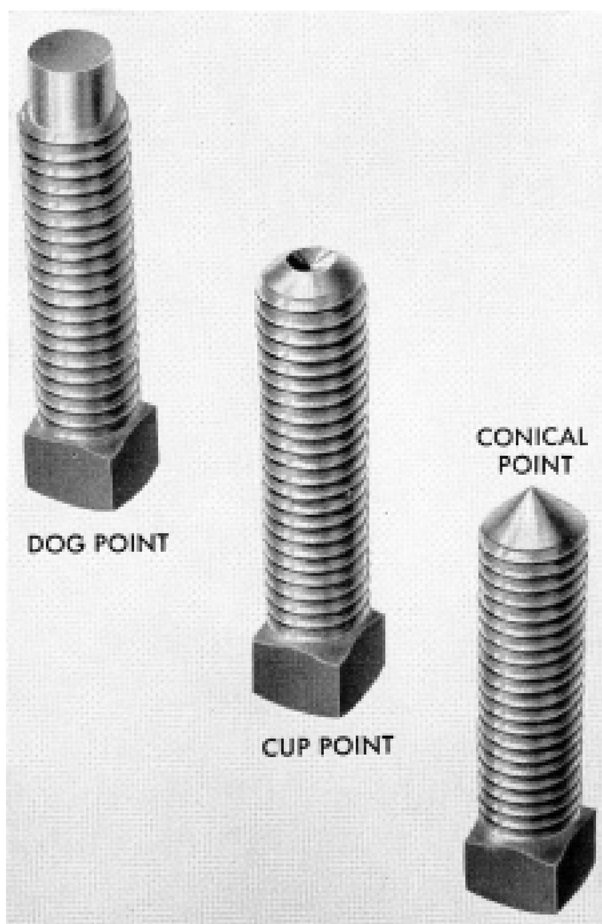


FIGURE 8-21

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.

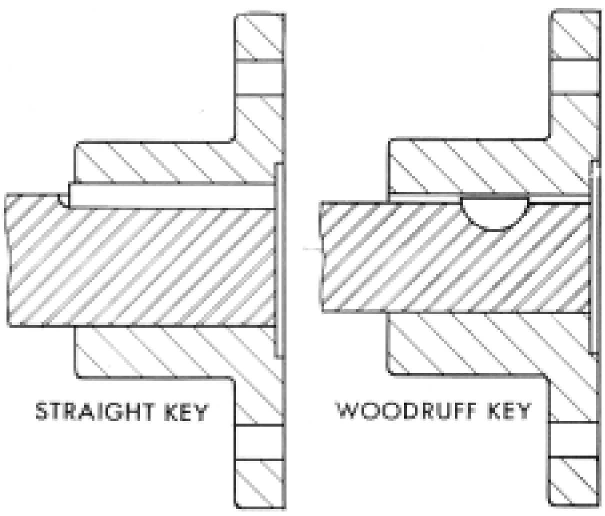


FIGURE 8-22

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.

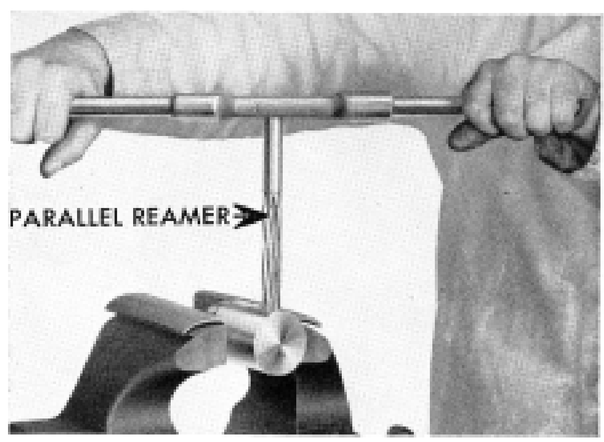


FIGURE 8-23

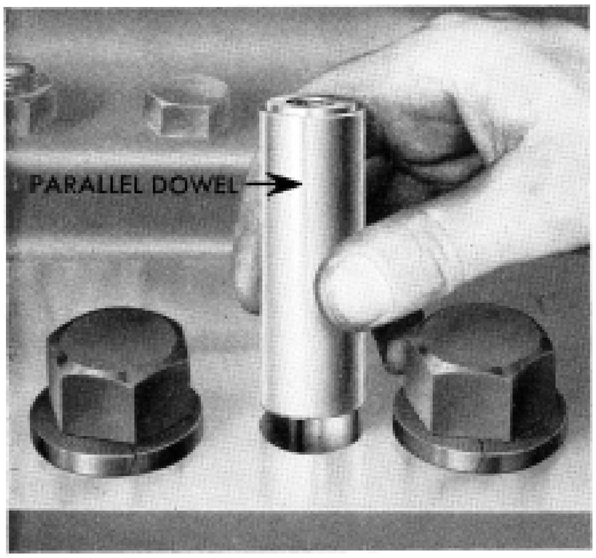


FIGURE 8-24

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

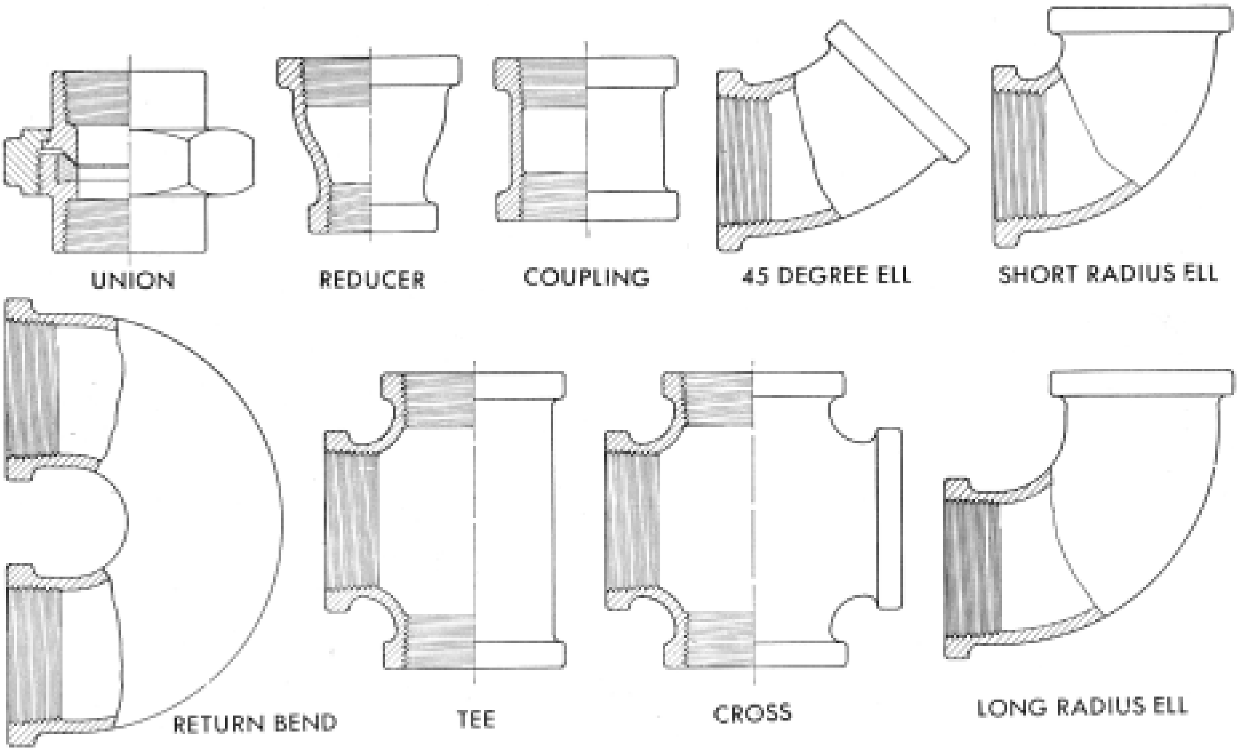


FIGURE 8-25

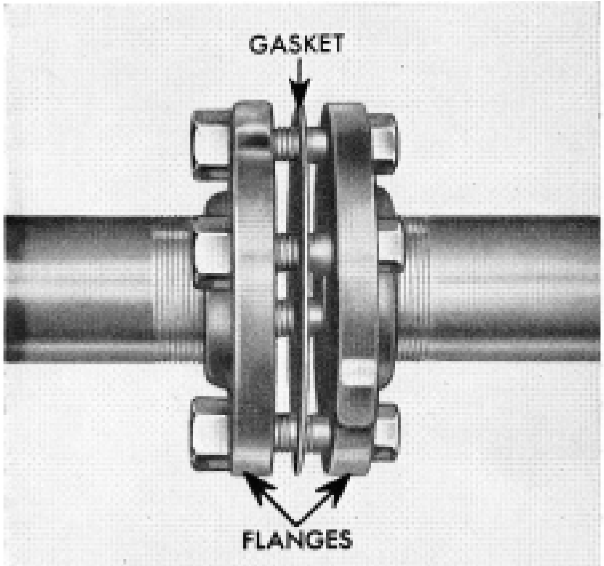


FIGURE 8-26

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

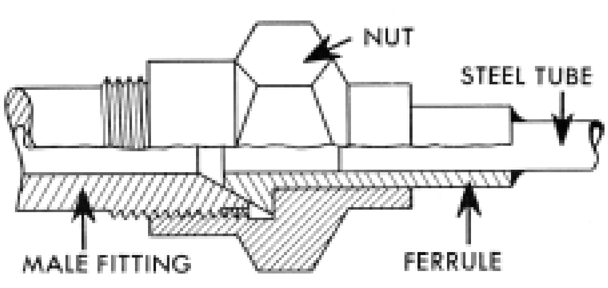


FIGURE 8-27

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.

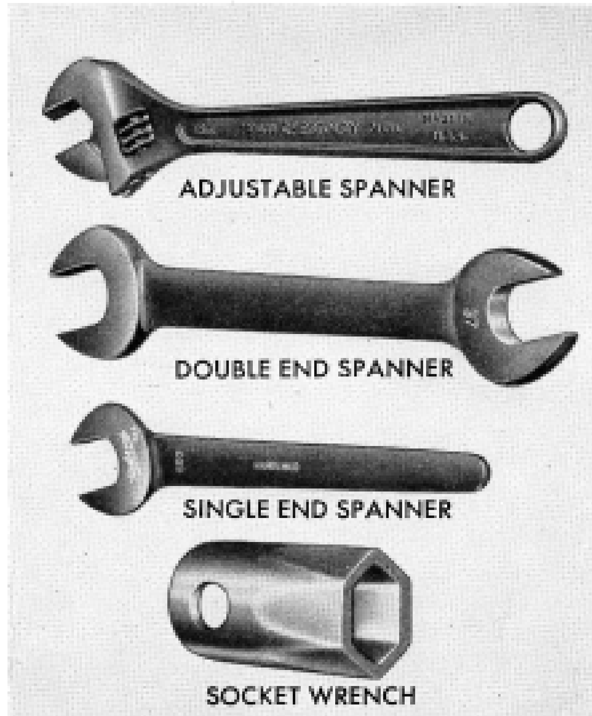


FIGURE 8-28

44. CORRECT APPLICATION OF A WRENCH: Figure 8-29 shows the correct way to tighten a nut with an adjustable wrench.

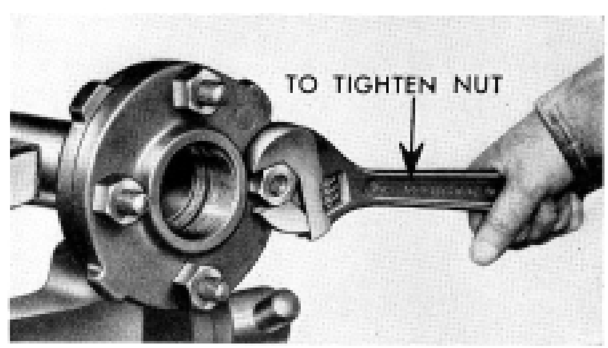


FIGURE 8-29

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.

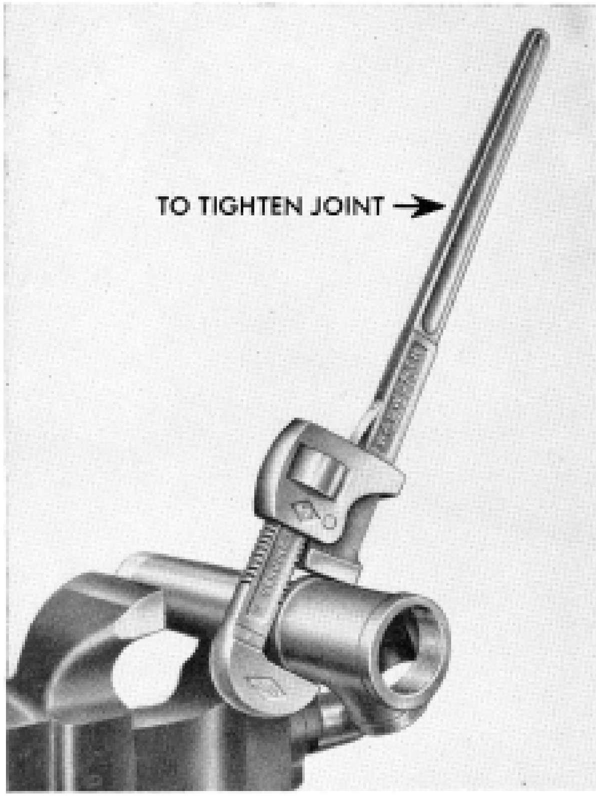


FIGURE 8-30

46. PIPE WRENCHES: Wrenches for turning pipe (also called Stillson wrenches) have roughened jaws and a movable 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.

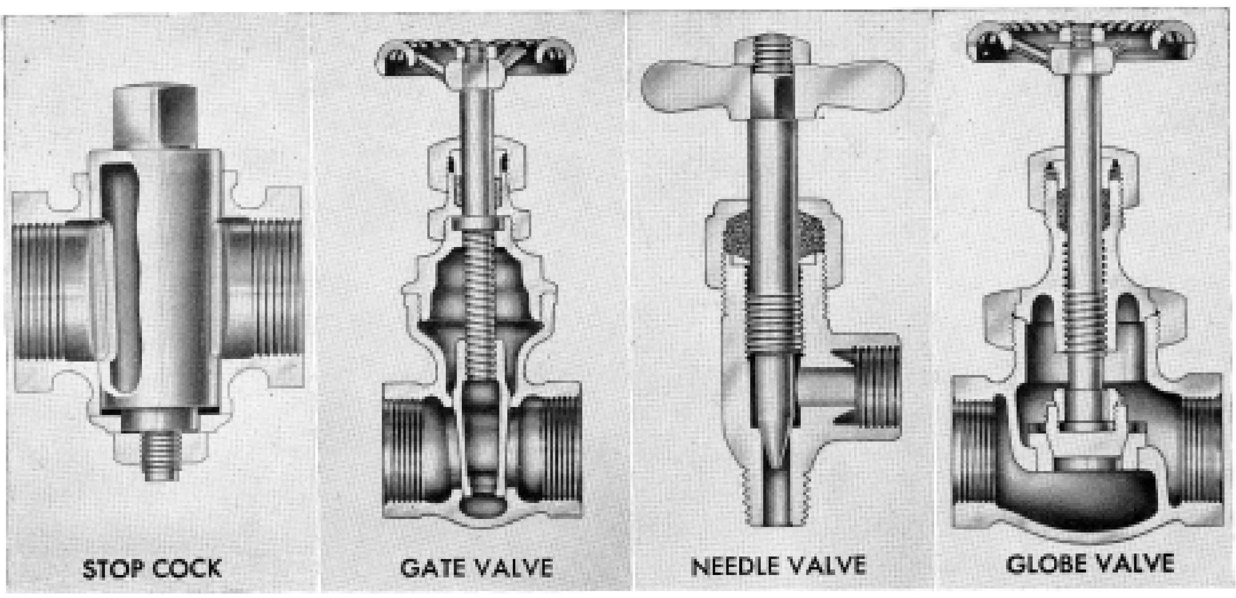


FIGURE 8-31

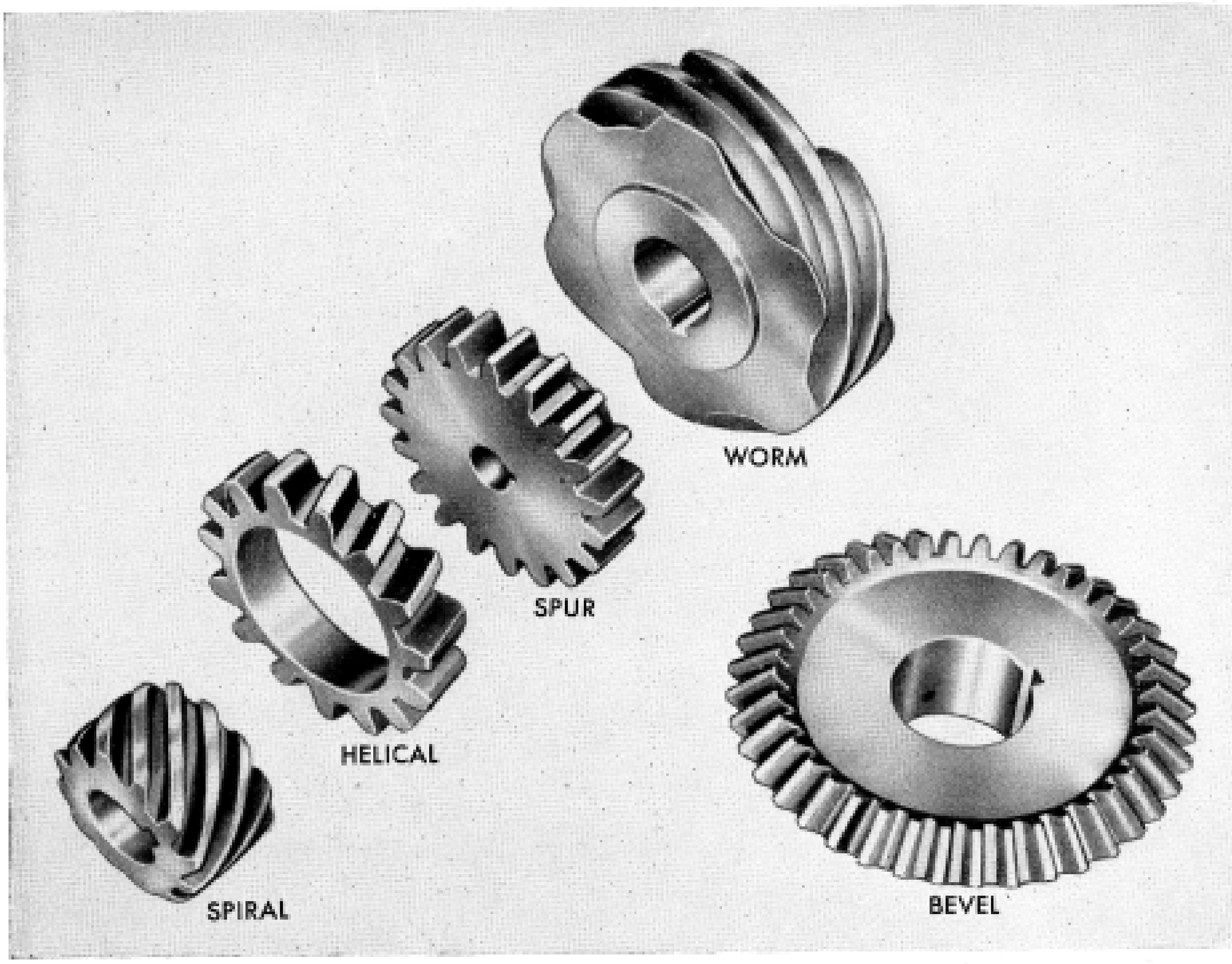


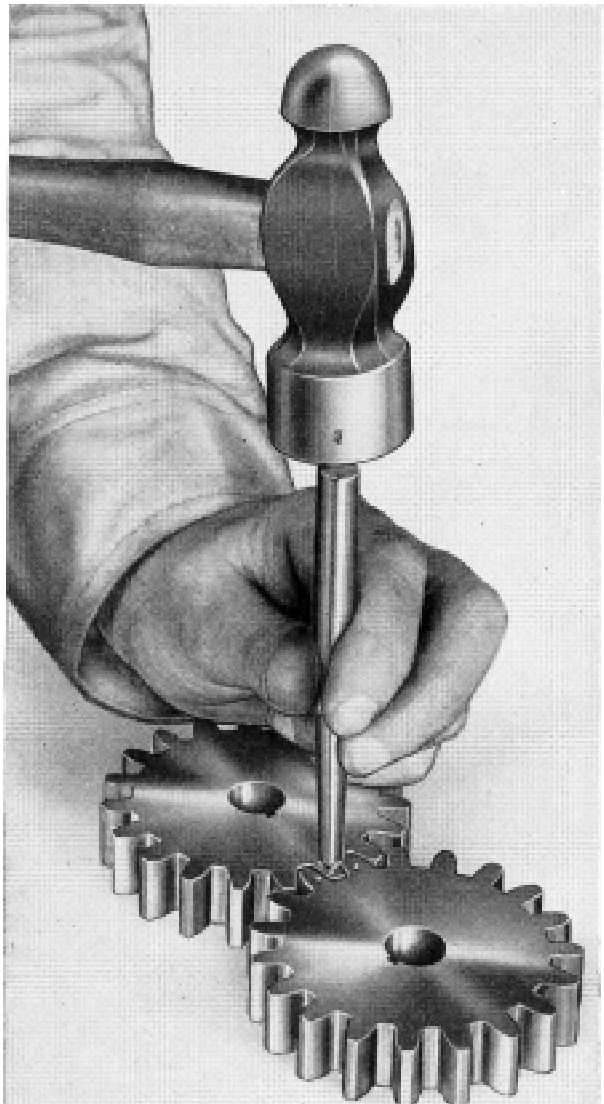
FIGURE 8-32

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 damaged 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

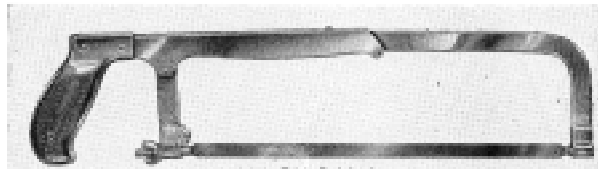


CENTER PUNCHING GEARS

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.

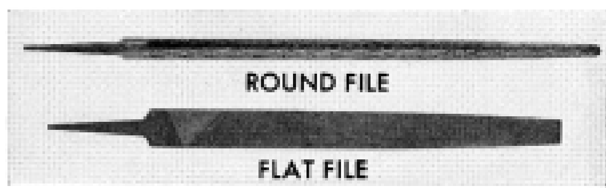
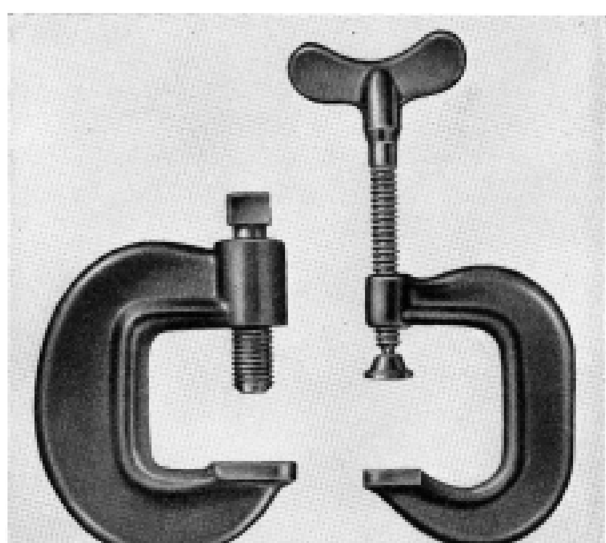


FIGURE 8-36

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 is forming and 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 ¾ 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.

(e) Turn down grease cups on centrifugal pump.

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 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 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. 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 chain tension.

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

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

(k) 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. 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 cylinders. 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.)

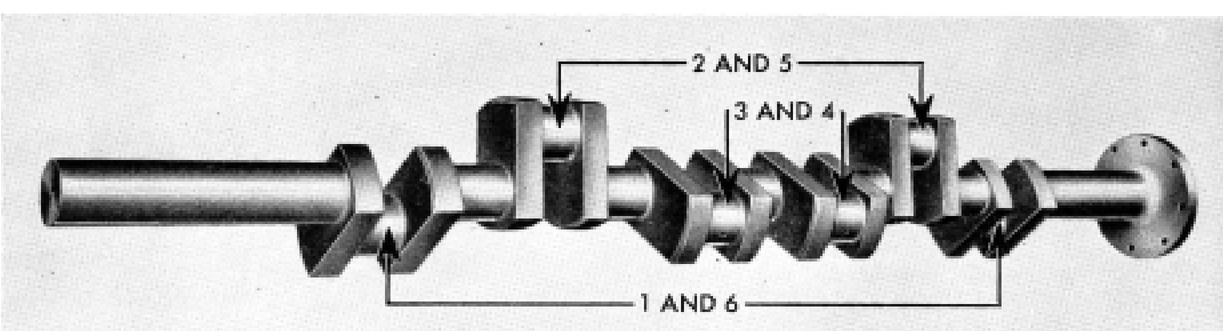


FIGURE 10-1

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. STANDARD AND OPPOSITE ROTATION: Standard six-cylinder Atlas Imperial Diesel engines have the firing order 1-5-3-6-2-4. 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 this 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.

6. NO. 1 TIMING GROUP: Move the control lever to the run ahead position. If this can not be done, owing to a lifter roller striking the side of a cam, turn the starting air on long

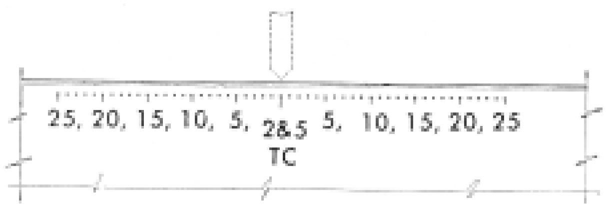


FIGURE 10-2

enough to get the camshaft into the ahead position and then shut off the air. Make sure that the rocker shaft ram is right down at the bottom of its stroke.

Turn the engine to eight 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.

The outer rim of the flywheel is laid out with three groupings of centers spaced 120 degrees apart. See Figure 10-2. 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.

7. NO. 1 TIMING GROUP (continued): NO. 1 SPRAY VALVE. Open the isolating valve to No. 1 spray valve, one half turn. Pump up about 1500 pounds fuel pressure with the hand priming pump.

The lock nut under the ball socket on the upper end of the pushrod should be loose and the pushrod screwed into the ball socket (to shorten the pushrod) so that the rod can be moved up and down slightly by hand. Adjust No. 1 pushrod by screwing it out of the rocker until the spray valve is just opened. This opening is indicated by the needle on the fuel gauge dropping, showing that the pressure in the system is being reduced by the open valve.

As soon as the gauge needle starts to drop, close the isolating valve to avoid excess fuel passing into the cylinder. Hold the socket with one wrench while the lock nut is tightened with the other wrench as shown in Figure 10-3. The socket must not turn on the pushrod or the adjustment is lost.

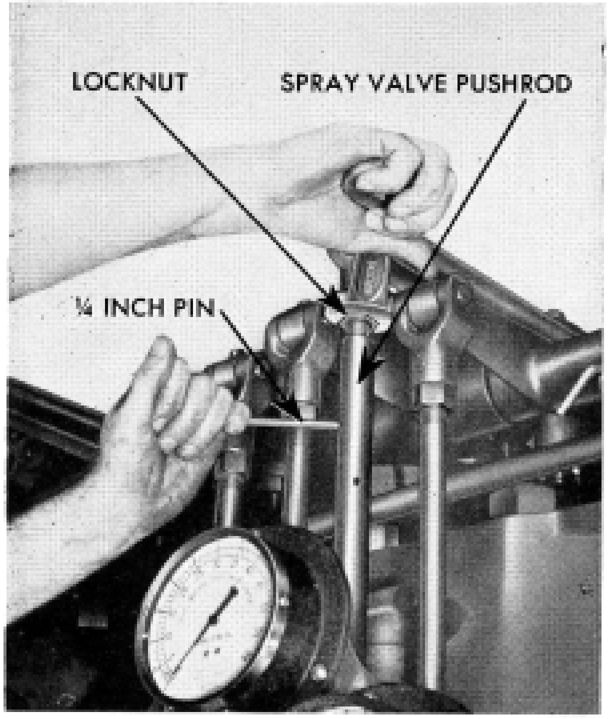


FIGURE 10-3

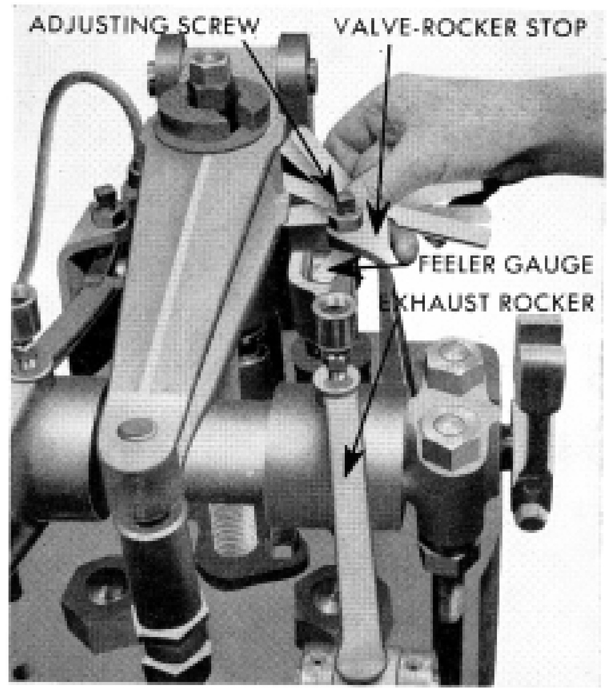


FIGURE 10-4

To check this setting, back the flywheel up to about 15 degrees before top center. Pump up 1500 pounds fuel pressure. Open the isolating valve and pull the flywheel 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 adjustment and check again.

8. NO. 1 TIMING GROUP (continued): NO. 6 CYLINDER INLET: Turn the flywheel to five degrees before top center. 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 and all of the up and down movement in the pushrod is taken out. Tighten the lock nut. This means that 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.

Refer to Figure 10-4 and it will be seen that there is an adjusting screw in the valve rocker stop. These stops hold down the roller ends of the inlet and exhaust rockers when the eccentric rocker shafts are turned in order to raise the lifters clear of the cams.

With a feeler gauge used as shown set the clearance, between the top of the rocker and the adjusting screw, at 0.030 inch. While this adjustment is being made, hold the pushrod down so that the lifter roller is on the cam. This adjustment must be made whenever the inlet or exhaust valves are timed.

9. NO. 1 TIMING GROUP (continued): NO. 1 AIR-START VALVE: Turn the flywheel to four degrees before top center. As the air-start valves are in operation only during the starting period, the method of keeping the lifters up and clear of the camshaft, described in Paragraph 23 of Section 5, is used. But before they can be correctly timed they must be put in the operating position, which means that the air-start valve must be seated and the lifter roller must be resting against the cam.

Remove the three cap screws and the cover from the top of each air-start valve. The air-start valve can now be held down on its seat. After loosening the lock nut under the rod end, screw the air-start pushrod out of the rod end (to lengthen the rod) until all of the up and down movement of the rod is taken up. Do not lift the air-start valve off its seat. Be sure that the lifter is forced down on the cam, against the lifter spring. Tighten the lock nut, being careful not to turn the rod end on the pushrod.

As the camshaft turns ahead the air-start lifter roller will start to climb the lobe of the cam, opening the valve at four degrees before top center, which is the desired opening.

10. NO. 1 TIMING GROUP (continued): NO. 6 EXHAUST: Turn the flywheel to five degrees after top center. Screw No. 6 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 and all the up and down movement in the pushrod is taken out. Tighten the lock nut. 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. Adjust rocker stop as in Paragraph 8.

11. NO. 1 TIMING GROUP (continued): CHECKING NO. 1 SPRAY-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 21 of 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.

12. NO. 5 TIMING GROUP: If you continue turning the engine forward the next cylinder to come into firing position will be No. 5. Proceed to time No. 5 and No. 2 in the same way as No. 1 and No. 6.

Stop at eight degrees before top center.
Time and check No. 5 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 2 inlet-valve opening.
Adjust rocker stop No. 2 inlet valve.
Turn the flywheel to four 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.
Adjust rocker stop No. 2 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 5 spray-valve closing.

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

Stop at eight degrees before top center.
Time and check No. 3 spray-valve opening.
Turn flywheel to five degrees before top center.
Time No. 4 inlet-valve opening.
Adjust rocker stop No. 4 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 3 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 4 exhaust-valve closing.
Adjust rocker stop No. 4 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 3 spray-valve closing.

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

Stop at eight degrees before top center.
Time and check No. 6 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 1 inlet-valve opening.
Adjust rocker stop No. 1 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 6 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 1 exhaust-valve closing.
Adjust rocker stop No. 1 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 6 spray-valve closing.

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

Stop at eight degrees before top center.

Time and check No. 2 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 5 inlet-valve opening.
Adjust rocker stop No. 5 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 2 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 5 exhaust-valve closing.
Adjust rocker stop No. 5 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 2 spray-valve closing.

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

Stop at eight degrees before top center.
Time and check No. 4 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 3 inlet-valve opening.
Adjust rocker stop No. 3 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 4 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 3 exhaust-valve closing.
Adjust rocker stop No. 3 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 4 spray-valve closing.

17. 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 10-5 is followed in rotation. This timing circle represents two crankshaft revolutions.

18. 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 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:

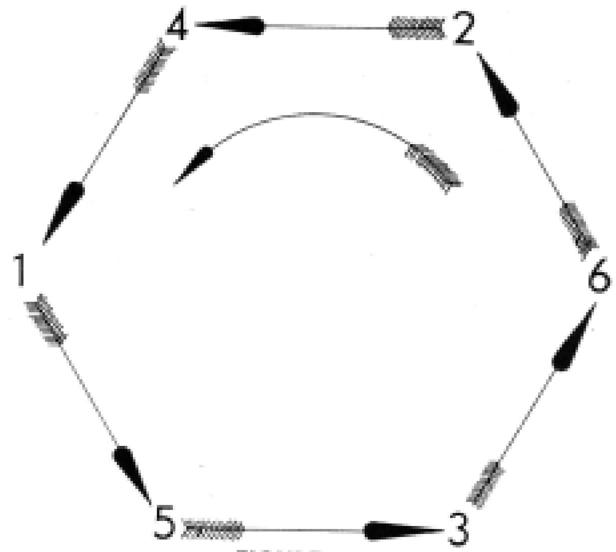


FIGURE 10-5

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 IS CHANGED.

19. 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 0.030 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 0.030 inch do not alter, but if it is less, adjust the valve pushrod until the 0.030 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

20. BALANCING THE ENGINE WITH THE PYROMETER: The timing of the spray valves 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 10-6.

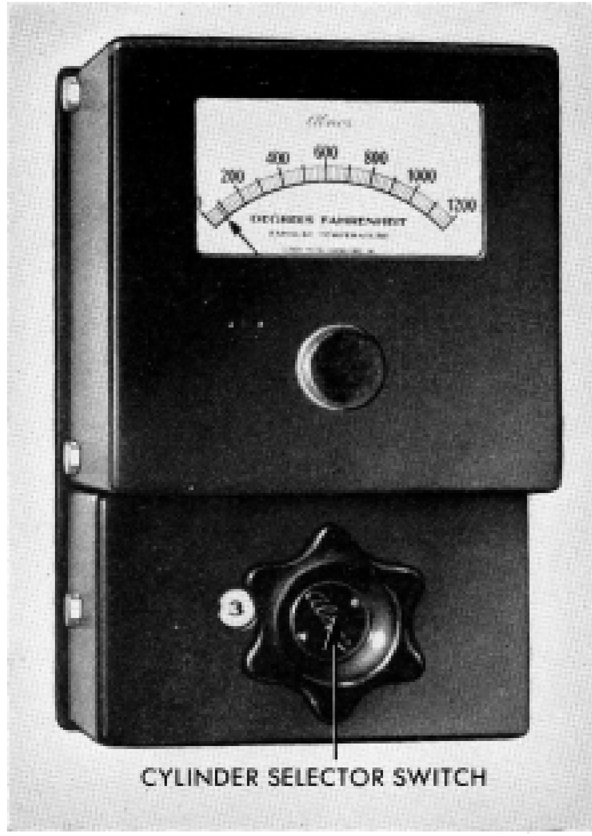


FIGURE 10-6

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 particular elbow. These readings should never vary over 50 degrees between the highest and the 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 PUSHROD 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.

21. ADJUSTMENT OF FUEL CAM IF CLOSING OF SPRAY VALVE IS LATE: The fuel cam lobes for both ahead and astern are held in one cam disc which is adjustable. Therefore, the ahead lobe is the only one that can be correctly positioned for opening and closing. Do not attempt to time the spray-valve opening or closing or alter fuel-cam lobe setting in the astern running position. Adjustment for late closing is made as follows:

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.

A. Remove the crankpit cover and cut the lock wire on the fuel cam. See Figure 10-7.

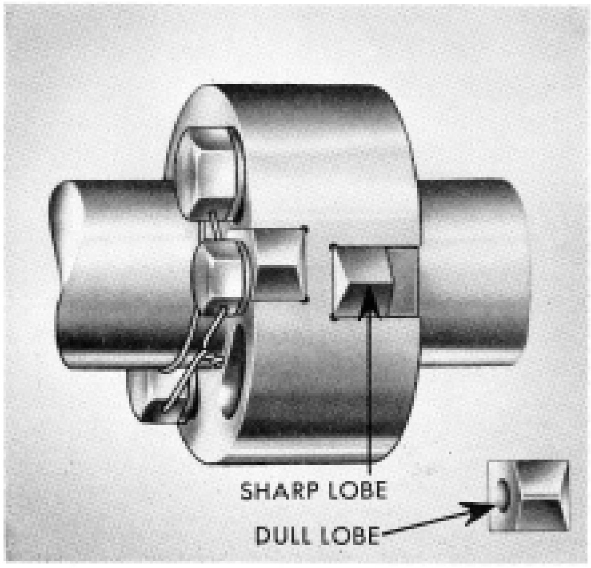


FIGURE 10-7

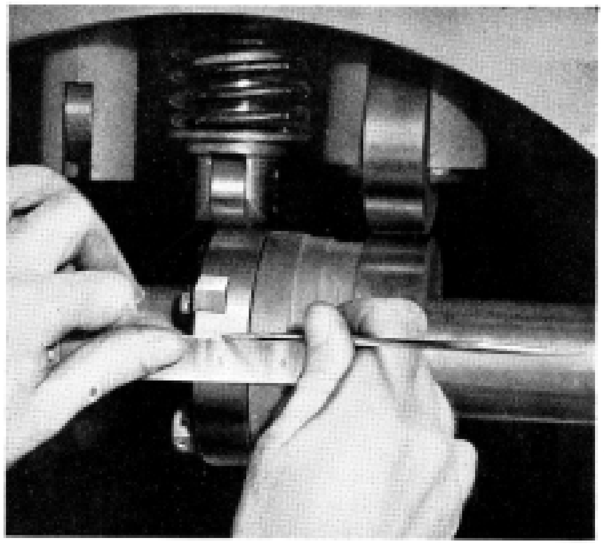


FIGURE 10-8

B. With a scale or scriber draw a line across the face of the cam as shown in Figure 10-8. 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 the 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 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 this section, Paragraphs 6 to 10. Check the closing in the normal manner as described in Paragraph 11. If the new closing point is within one degree of 18 degrees after top center no further adjustment is necessary. Replace the lock wire.

22. 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 crankpit cover and cut the lock wire on the fuel cam. See Figure 10-7.

B. With a scale or scriber draw a line across the face of the cam as shown in Figure 10-8. Loosen the two ½-inch cap screws. Do not loosen the ⅜-inch cap screw in the cam lobe. As 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, 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 10. Check the closing in the normal manner as described in Paragraph 11. If the new closing is within one degree of 18 degrees after top center no further adjustment is necessary. Replace the lock wire.

23. 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:

24. NO. 1 TIMING GROUP: Turn the flywheel to eight degrees before No. 1 firing top center.

Time and check No. 1 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 6 inlet-valve opening.
Adjust rocker stop No. 6 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 1 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 6 exhaust-valve closing.
Adjust rocker stop No. 6 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 1 spray-valve closing.

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

Time and check No. 4 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 3 inlet-valve opening.
Adjust rocker stop No. 3 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 4 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 3 exhaust-valve closing.
Adjust rocker stop No. 3 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 4 spray-valve closing.

26. NO. 2 TIMING GROUP: Turn the flywheel to eight degrees before No. 2 firing top center.
Time and check No. 2 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 5 inlet-valve opening.
Adjust rocker stop No. 5 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 2 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 5 exhaust-valve closing.
Adjust rocker stop No. 5 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 2 spray-valve closing.

27. NO. 6 TIMING GROUP: Turn the flywheel to eight degrees before No. 6 firing top center.
Time and check No. 6 spray-valve opening.
Turn the flywheel to five degrees before top center.

Time No. 1 inlet-valve opening.
Adjust rocker stop No. 1 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 6 air-start valve opening.
Turn flywheel to five degrees after top center.
Time No. 1 exhaust-valve closing.
Adjust rocker stop No. 1 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 6 spray-valve closing.

28. NO. 3 TIMING GROUP: Turn the flywheel to eight degrees before No. 3 firing top center.
Time and check No. 3 spray valve.
Turn the flywheel to five degrees before top center.
Time No. 4 inlet-valve opening.
Adjust rocker stop No. 4 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 3 air-start valve.
Turn flywheel to five degrees after top center.
Time No. 4 exhaust-valve closing.
Adjust rocker stop No. 4 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 3 spray-valve closing.

29. NO. 5 TIMING GROUP: Turn the flywheel to eight degrees before No. 5 firing top center.
Time and check No. 5 spray-valve opening.
Turn the flywheel to five degrees before top center.
Time No. 2 inlet-valve opening.
Adjust rocker stop No. 2 inlet valve.
Turn the flywheel to four degrees before top center.
Time No. 5 air-start valve.
Turn flywheel to five degrees after top center.
Time No. 2 exhaust-valve closing.
Adjust rocker stop No. 2 exhaust valve.
Turn flywheel to 25 degrees after top center.
Back up and check No. 5 spray-valve closing.

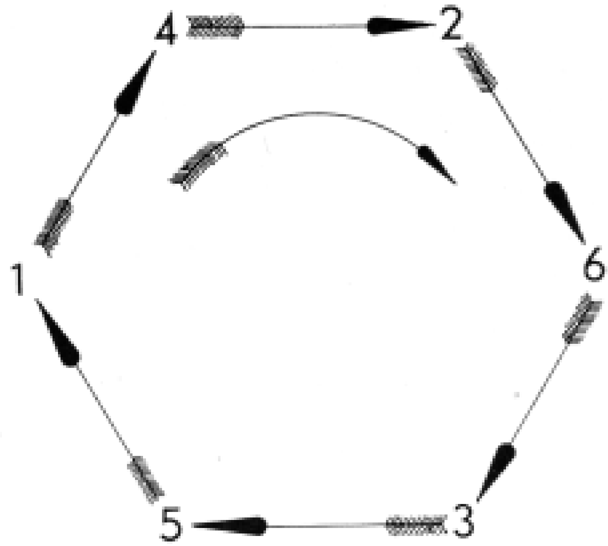


FIGURE 10-9

30. 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 10-9 is followed in rotation. This timing circle represents two crankshaft revolutions.

31. BUFFER-SPRING ADJUSTMENTS: Read Paragraph 18.

32. CHECKING FOR VALVE CLEARANCE: Read Paragraph 19 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 20 to 22 for further adjustments.

SECTION 11
CYLINDER HEAD AND VALVES

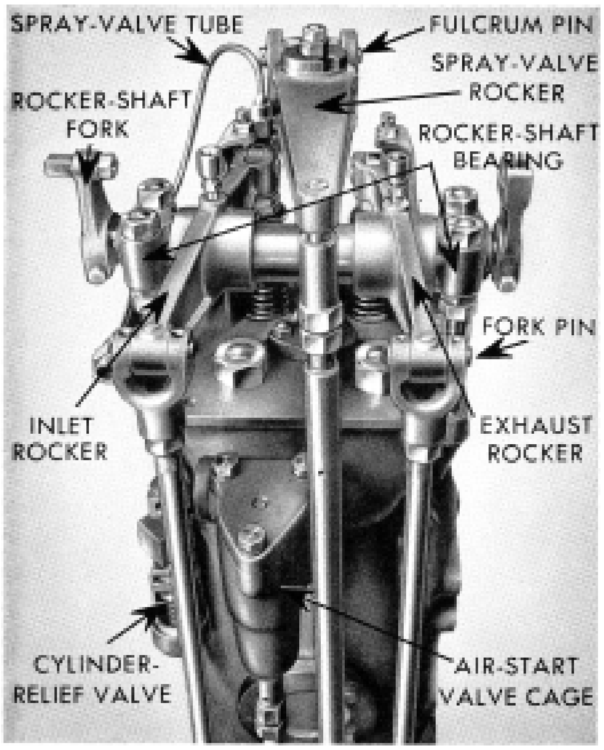


FIGURE 11-1

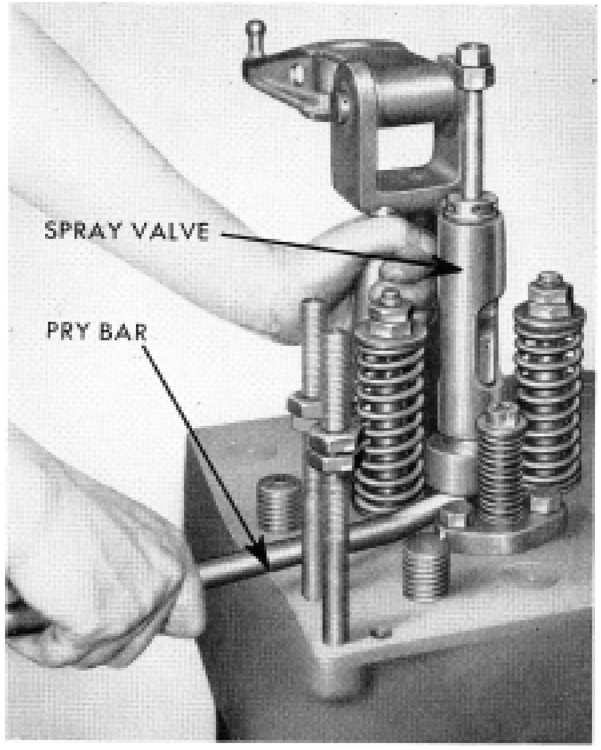


FIGURE 11-2

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 and lift off the rocker. Drive out the fork pins in the inlet and exhaust 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 rocker shaft, it will be necessary to remove these pins before lifting off the rocker assembly.

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 are easily damaged.

3. 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 and valve. Remove all the cylinder head stud nuts. Attach a lifting 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 11-3. 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 11-1 to avoid damage while the head is being handled on the floor.

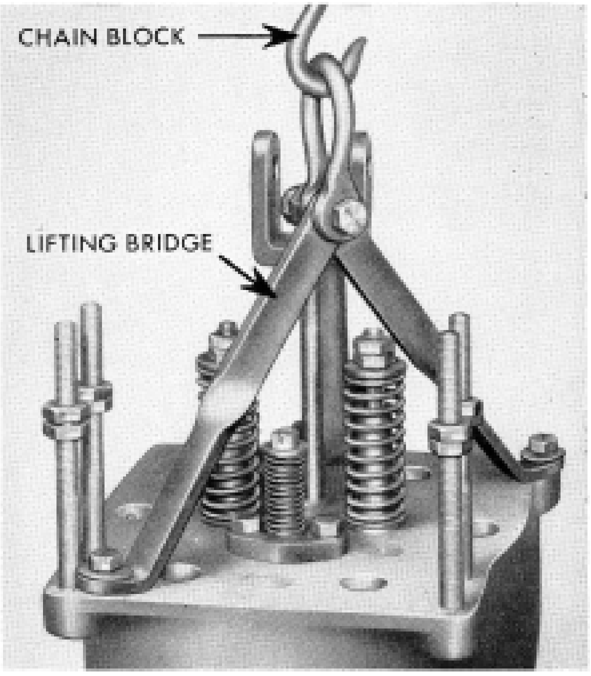


FIGURE 11-3

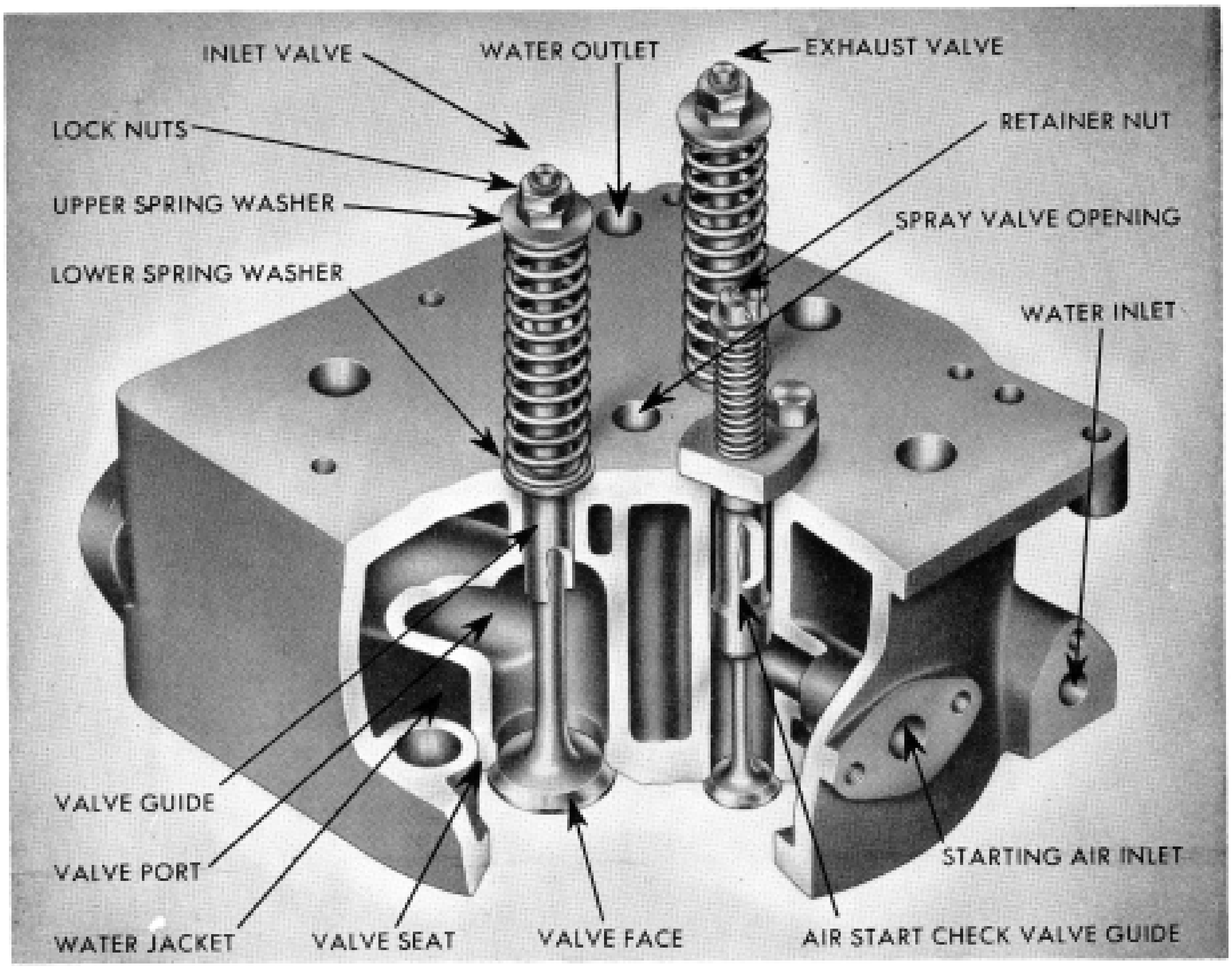


FIGURE 11-4

4. DISASSEMBLY OF THE CYLINDER HEAD:

Figure 11-4 shows that all valves are seated directly into the head casting. It also shows that the inlet and exhaust valve guides are pressed into the head. The air-start check-valve guide is held in place by two capscrews through the guide flange.

Remove the cotter pin and spring retainer nut from the stem of the air-start check valve. Remove the two nuts which attach the valve guide. It may be necessary to pry the guide loose in the same manner as the spray valve was loosened.

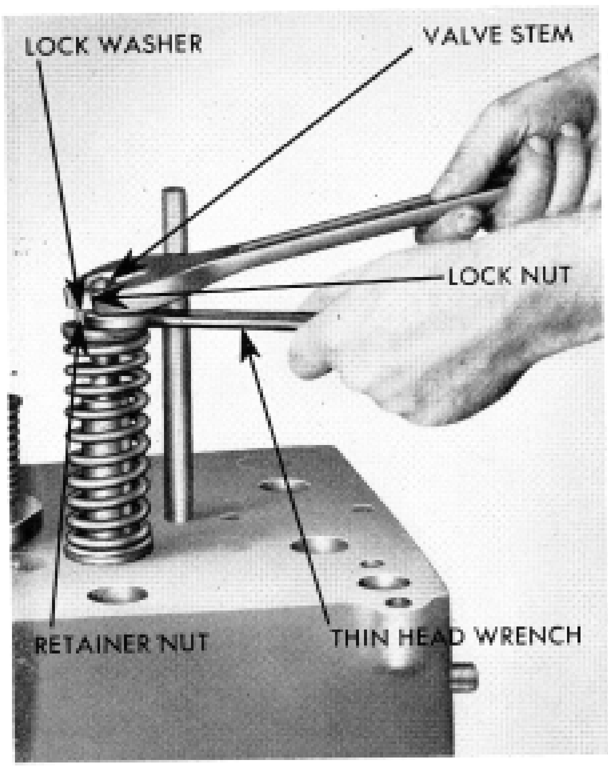


FIGURE 11-5

Loosen the double nuts on the stems of both the exhaust and inlet valves as shown in Figure 11-5. There is a special thin wrench, supplied with the engine, to hold the lower nut while the top nut is being loosened. A special type of lock washer is used between these two nuts and ordinary spring lock washers should not be used as a substitute. The valve spring is still under considerable tension as the last nut is screwed off the valve stem and care should be taken to avoid injury.

Clean out the valve ports and passages in the head. Clean the valve stems and head. Examine the spring for cracks or corrosion. If the valve seat, in the head, is burned or pitted it may look like the one shown in Figure 11-6. A valve that needs facing and grinding is shown in Figure 11-7.

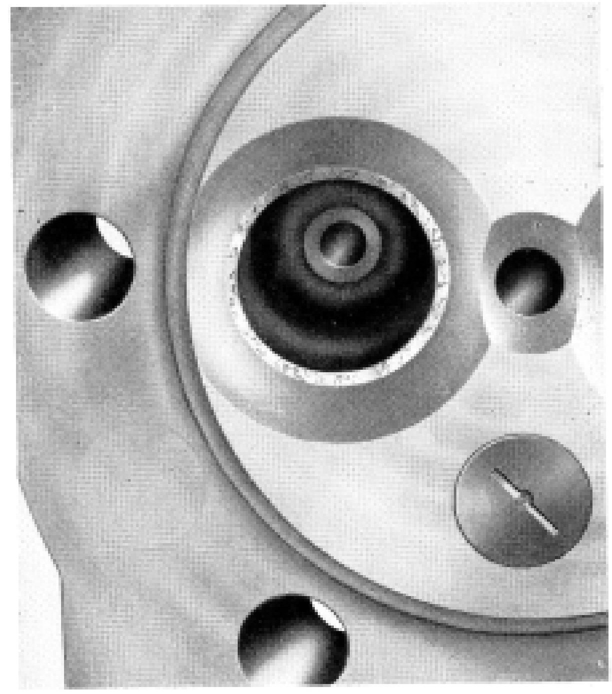


FIGURE 11-6

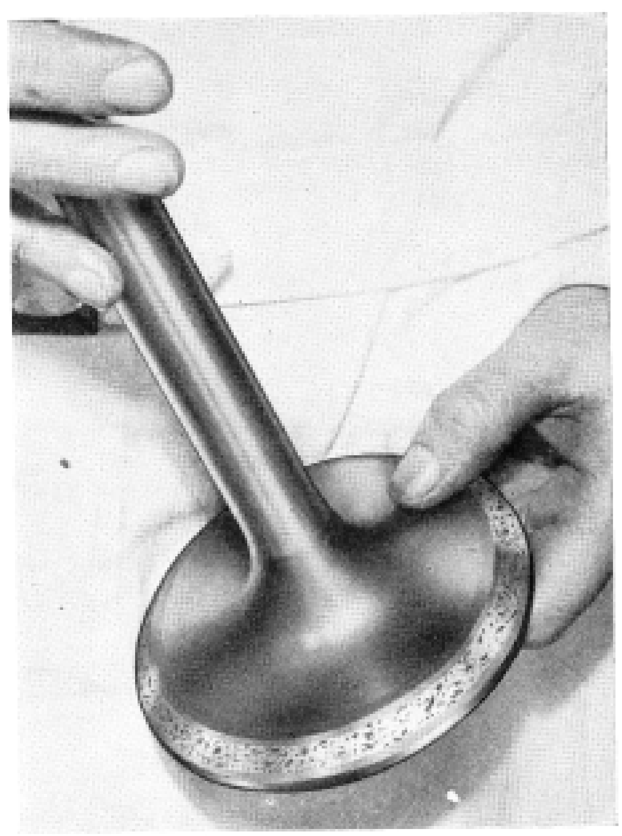


FIGURE 11-7

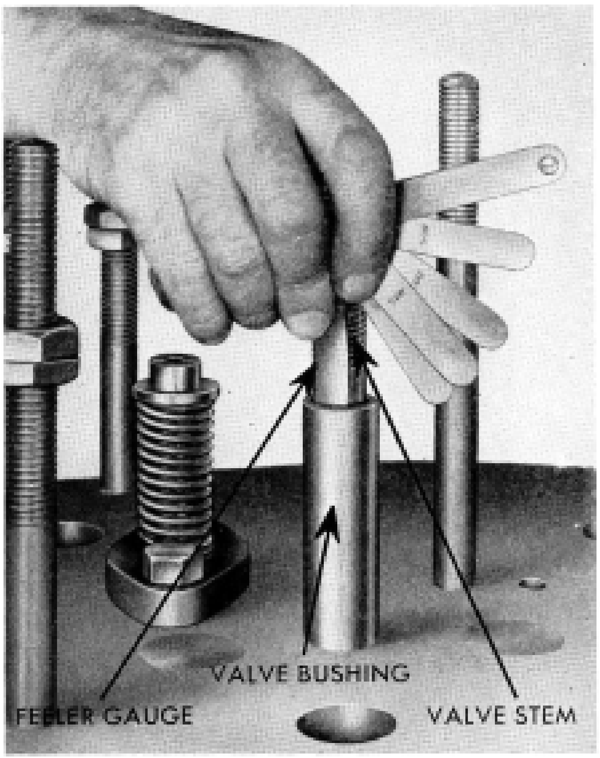


FIGURE 11-8

5. MEASUREMENT OF VALVES AND GUIDES TO DETERMINE IF RENEWAL IS NECESSARY: The clearance between a new exhaust-valve stem and a new guide should be from 0.004 to 0.005 inch. As the guide is reamed to ⅝ inch or 0.625 inch the valve stem will measure, when new, 0.620 to 0.621 inch.

Use an outside micrometer and measure the valve stem at several places over its length. As 0.010 inch is the maximum wear permitted, the valve should be renewed if the stem measures less than 0.610 inch.

To check the wear in the valve guide, insert a new valve stem and measure the clearance with a feeler gauge as shown in Figure 11-8. If more than 0.015 inch of feeler leaves can be forced between the guide and the valve stem, the guide should be renewed. The normal running clearance is 0.005 inch and the maximum allowable wear is 0.010 inch, making a total of 0.015 inch, which is the greatest permissible clearance.

The inlet valves are fitted a little closer due to their not being exposed to so much heat. The new inlet-valve stem will measure from 0.622 to 0.623 inch, making the discarding point 0.612 for the valve and 0.613 for the guide when making the same checks as were made on the exhaust valve.

The exhaust valve is made of a special alloy of heat-resisting steel, while the inlet valve is a chrome nickel forging. These valves should not be interchanged except in an emergency, as the inlet valve will not stand up as well when used in exhaust service.

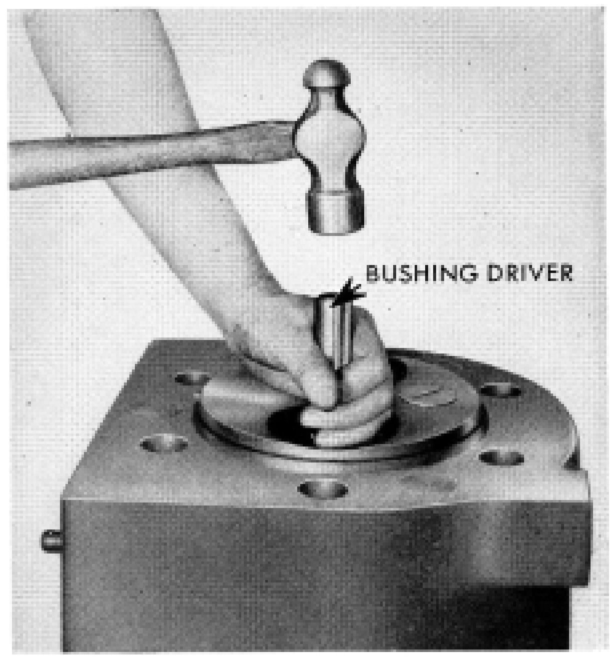


FIGURE 11-9

6. REPLACEMENT OF VALVE GUIDES: If renewal of the guides is necessary, set the head up on blocks as shown in Figure 11-9. Use a bushing driver made of a piece of one-inch cold rolled steel about 10 or 12 inches long and turned down to $\frac{19}{32}$ inch diameter for about two inches on one end. If a press is available, it can be used to force out the old guide. Otherwise, a heavy hammer can be used as shown in Figure 11-9.

Before the new guide is installed, coat the outside with a mixture of white lead and oil. Turn the head over and drive the new guide in as shown in Figure 11-10. The guide must be driven in until 3¼ inches extends out of the top of the cylinder head.

As the fit of the guide in the cylinder head is very tight, the bore of the guide is apt to be

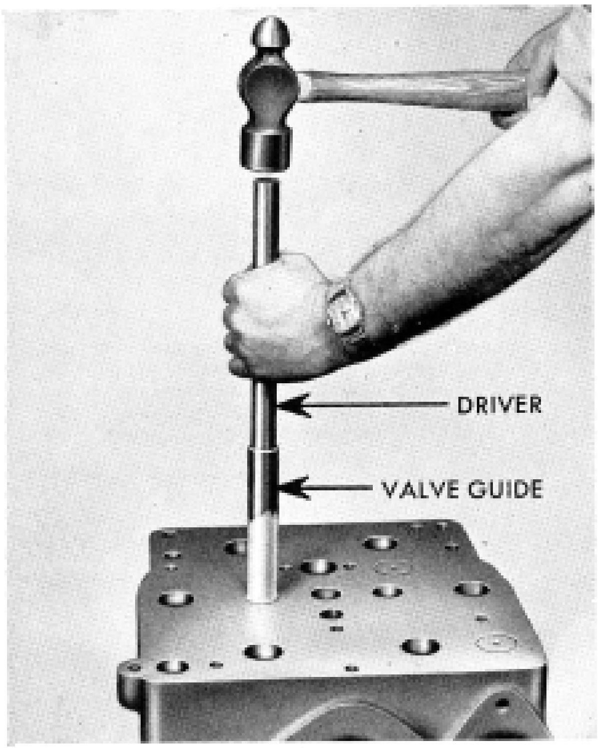


FIGURE 11-10

slightly distorted after installation. The hole in the guide should be reamed with a 0.625-inch parallel reamer as shown in Figure 11-11.

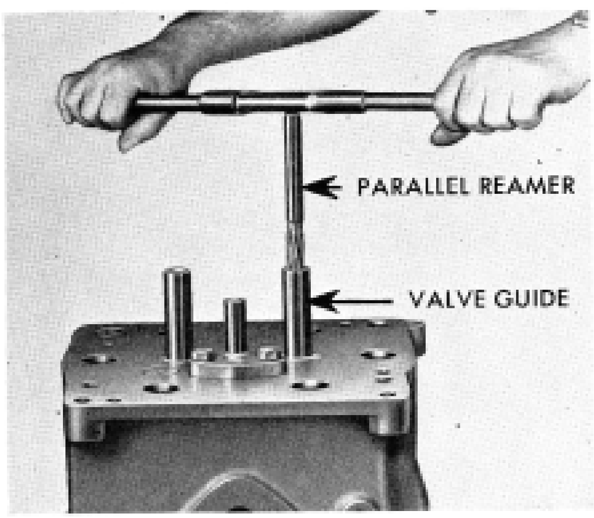


FIGURE 11-11

7. REAMING VALVE FACE AND SEAT: If the valve seat in the cylinder head is pitted as shown in Figure 11-6, it should be reamed to avoid excessive grinding. A standard 45-degree seat reamer and a ⅝-inch pilot to fit the guide are the tools required. The reamer

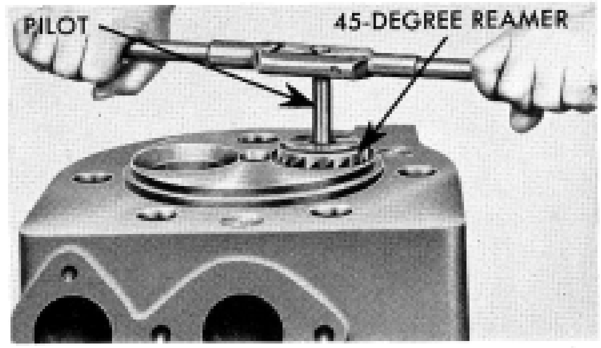


FIGURE 11-12

should be used as shown in Figure 11-12. Do not remove any more metal from the head than is absolutely necessary to obtain a clear seat.

If the valve face is pitted or burned as shown in Figure 11-7, the valve should be refaced in a valve machine or 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 face or the cylinder head seat, can be removed by grinding, but much more work will be required than if they have been properly refaced.

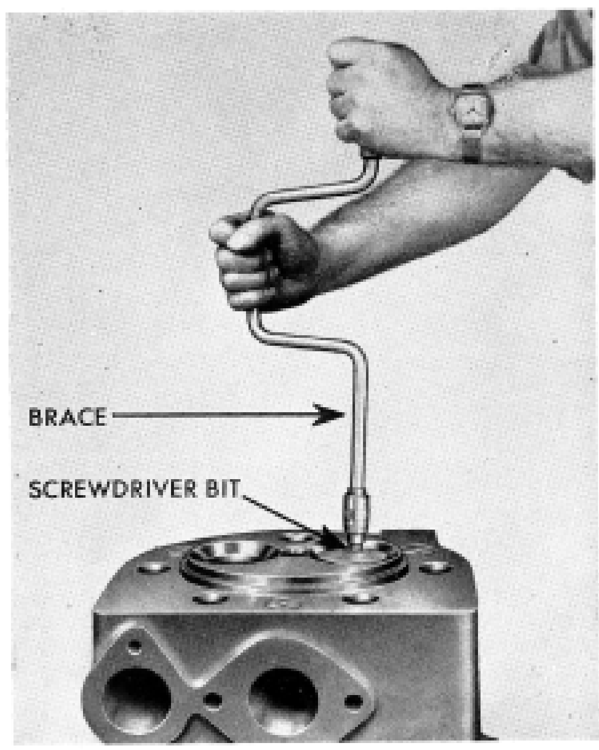


FIGURE 11-13

8. GRINDING VALVES: The purpose of valve grinding is to obtain a gas or air tight fit between the valve face and the seat. Set the cylinder head on blocks and coat the valve face with coarse grinding compound. There are many valve grinding devices available, but the most simple one can be made from a carpenter's brace or a speed wrench handle and a wide screwdriver bit. Use them as shown in Figure 11-13 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 compounds 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 to grind until the seat is smooth and free from any marks as shown in Figure 11-14. The valve face should look like the one shown in Figure 11-15.

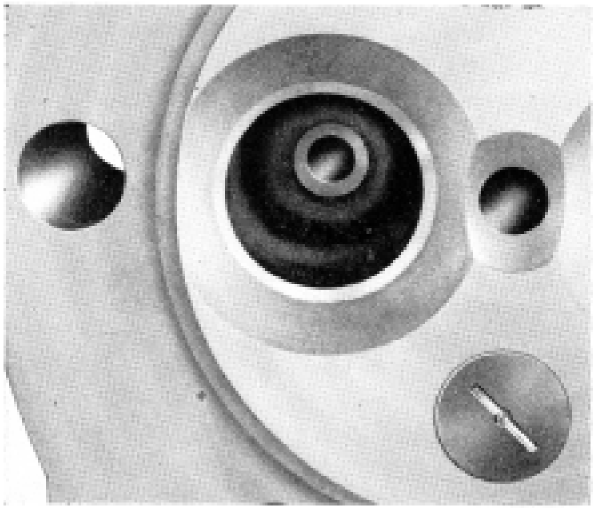


FIGURE 11-14

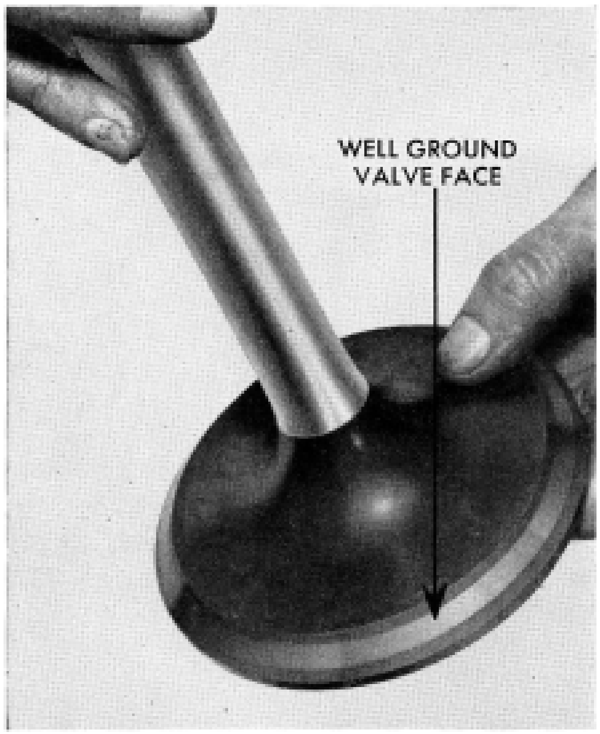


FIGURE 11-15

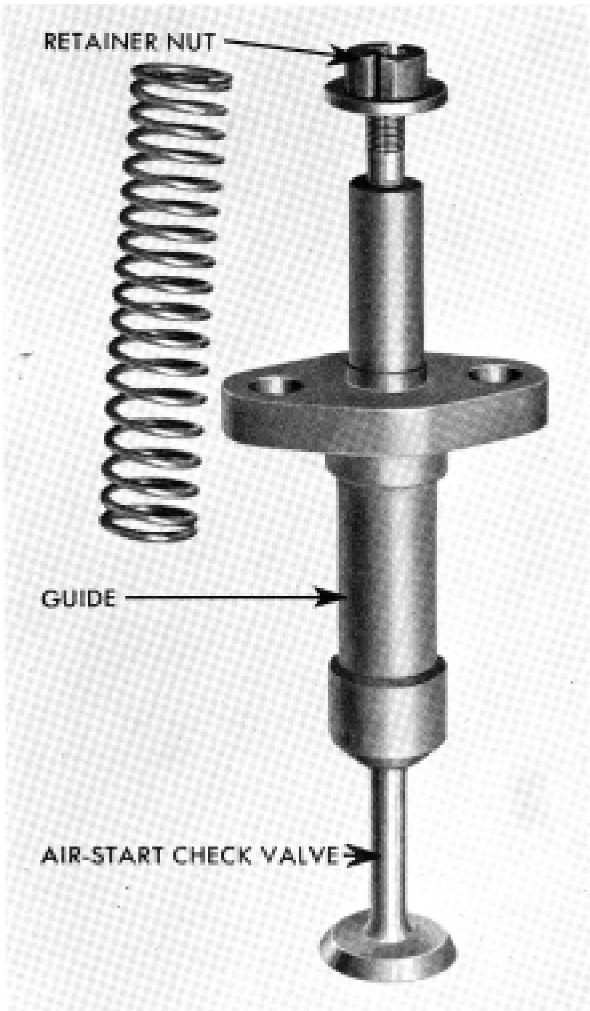


FIGURE 11-16

Wash the valve and seat 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 head. Press down firmly on the head of the valve and turn it approximately ⅛ of a turn. Remove the valve and if the fit is proper, part of each pencil line should be erased.

9. GRINDING AIR-START CHECK VALVE: This valve or its seat will seldom need facing or reaming. A few turns with fine grinding compound will be sufficient to assure a good fit. When grinding the check valve put in the guide to position the valve. Neither the valve stem nor the guide will require replacement, as the valve does not operate enough to wear these parts. Figure 11-16 shows this assembly.

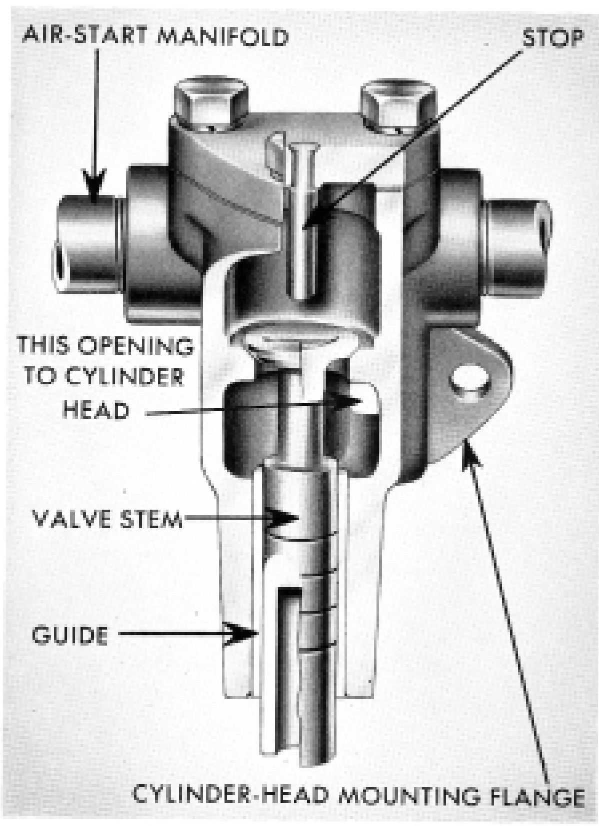


FIGURE 11-17

10. GRINDING AIR-START VALVE: Remove the cover plate, Figure 11-17. Coat the valve face with grinding compound and proceed as for grinding other valves. When a reasonably clear seat has been obtained, change to fine compound and complete grinding. Wash thoroughly and check as for other valves.

When grinding the air-start valves be sure that the lifter is not on the lobe of the cam. The operator will have to press down on the grinding device sufficiently to compress the air-start lifter spring, otherwise the valve will be held off its seat.

11. 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 11-18. 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 11-19. Continue grinding until a perfect ringed seat is obtained on both the valve face and the seat in the valve body.

12. ASSEMBLY AND SETTING OF THE RELIEF VALVE: Wash all parts thoroughly and assemble in the order shown in Figure 11-18. 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 11-20.

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.

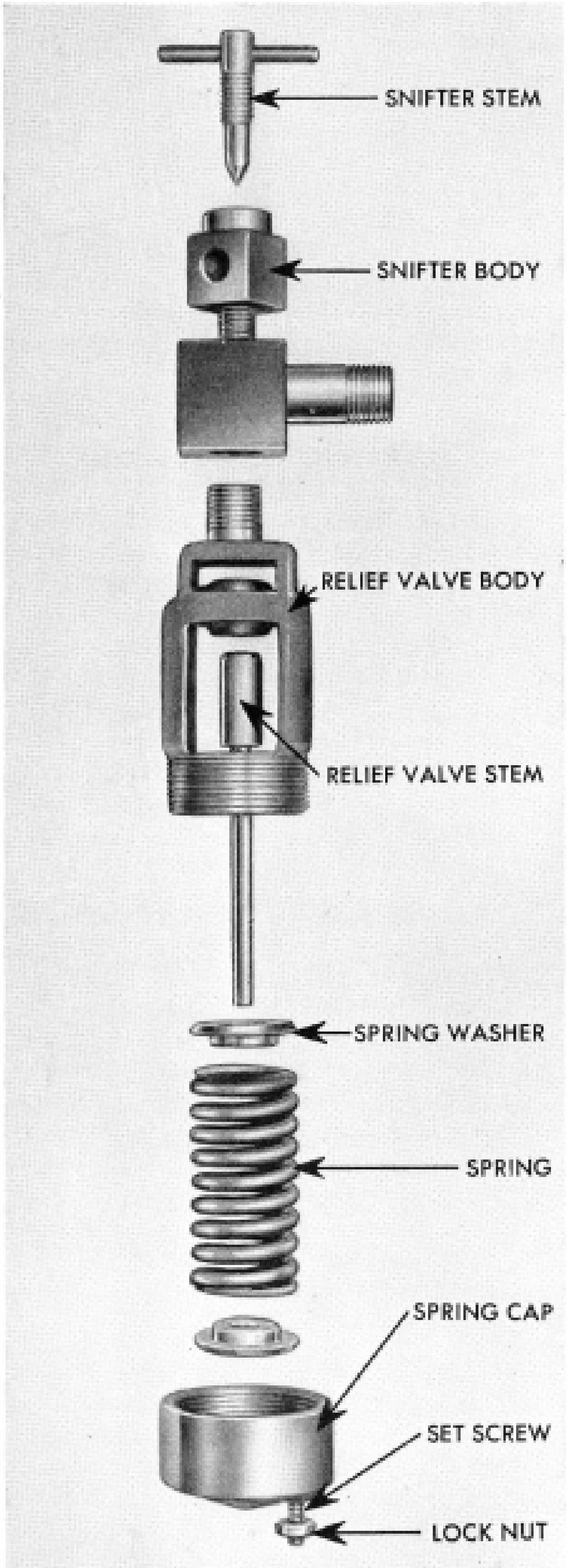


FIGURE 11-18

13. ASSEMBLY OF CYLINDER HEAD: Wash the head, valve guides and seats thoroughly. Clean off the valve faces and stems and insert them in the head after oiling the stems. Each valve must be installed in the seat it was ground to. Remember that exhaust and inlet valves are not interchangeable except in an emergency. Lay on the lower spring washer and the spring. When the upper spring washer is put on the end of the spring it will most likely be above the threaded end of the valve stem, and will have to be forced down to permit starting the first nut. This can be done by using the spray valve test handle, as shown in Figure 11-21, or any other convenient method. Care should be taken to make sure the tool used does not slip off the spring retaining washer, as the action of the spring will throw this washer and it may be lost.

After the first nut is screwed down put on the special lock washer and the second nut. When these nuts are locked there should be about one thread showing above the top of the upper nut.

The air-start check-valve guide is held in by the two cap screws in the flange and the spring can be compressed by hand to start the retainer nut. Be sure to install the cotter pin which goes through the retainer nut and the valve stem.

Raise the head up on blocks so that the valve heads are clear. Strike the stem of each valve several times with a brass or babbitt hammer to make sure the valves are free and closing properly.

14. INSTALLATION OF CYLINDER HEAD: Examine the copper cylinder-head gasket. If it has become brittle and hard 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 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.

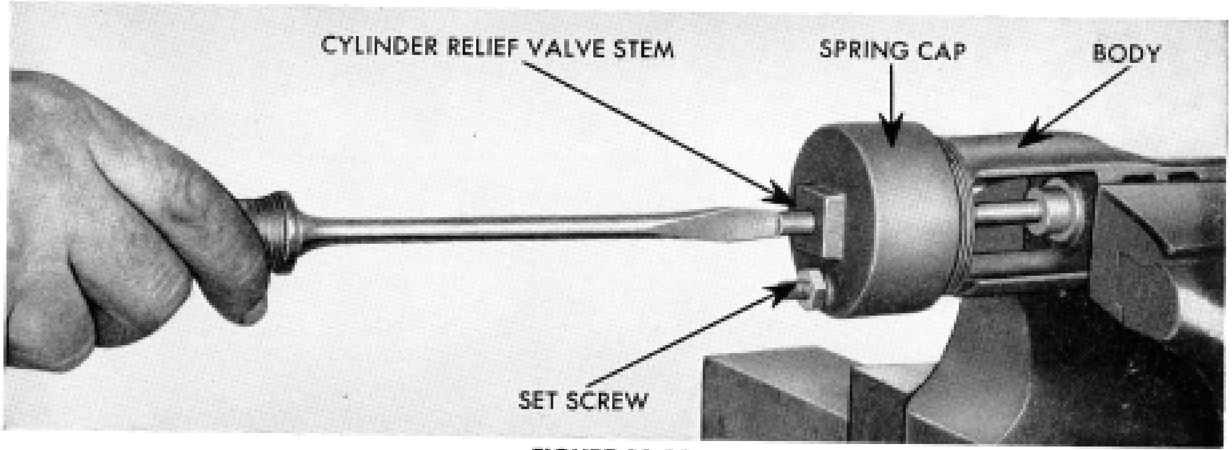


FIGURE 11-19

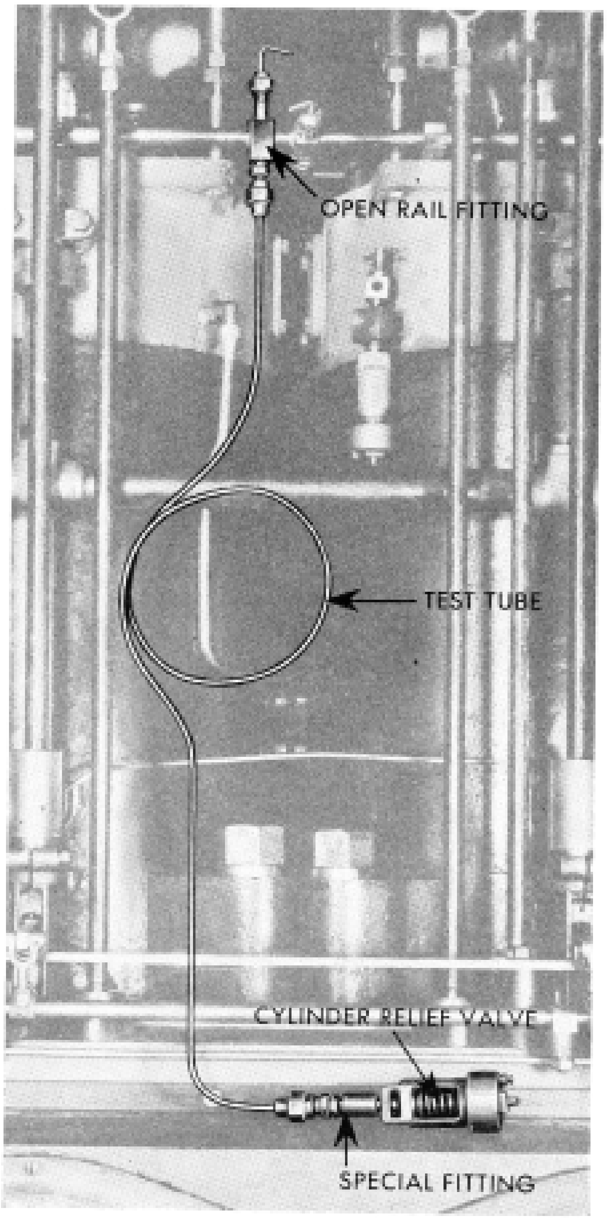


FIGURE 11-20

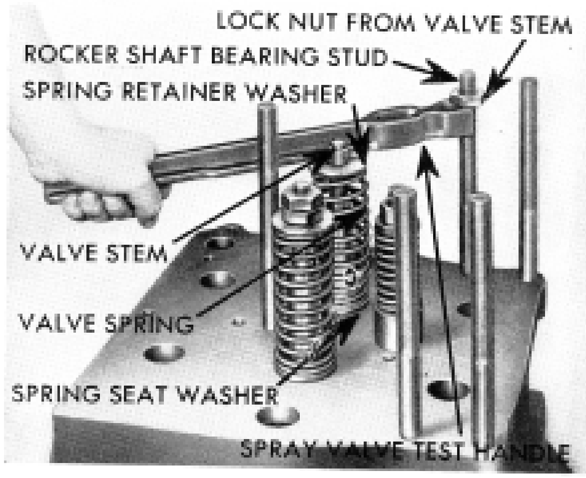


FIGURE 11-21

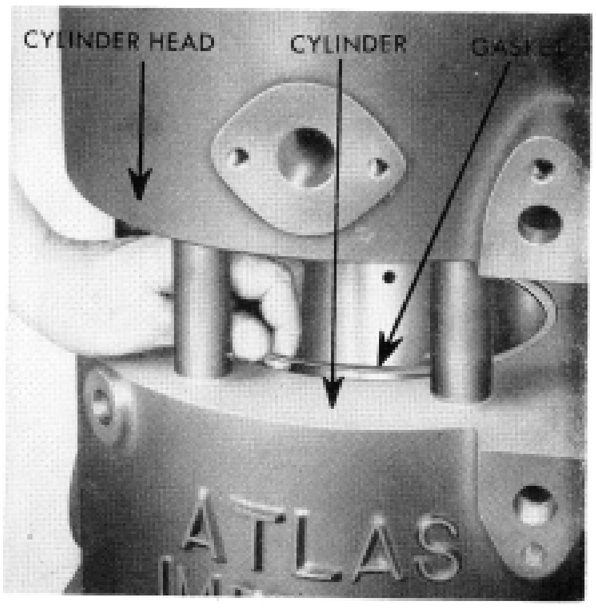


FIGURE 11-22

Lower the head and make sure it is sitting 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. Start all the cap screws that attach these various manifolds to the heads. Tighten these cap screws sufficiently to square the heads to the flanges of the manifolds but do not give the final tightening until after the cylinder-head nuts are drawn down. Screw all the head nuts down 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 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 finally tightened as much as it is possible for one man to pull on a four-foot bar.

Tighten all manifold cap screws. Replace the fuel rail clamp. Before attaching the by-pass, which carries the cooling water from the cylinder to the head, check to see if the two faces are parallel. There is a 1/16-inch-thick rubber gasket used at this joint which covers the face of the by-pass. If it is found that one face is out farther than the other a half-gasket may be used to correct this difference. Of course a complete gasket will be used as well.

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.

When 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 altered.

Connect the spray-valve tube to the rail fitting and the filter on the valve. This will correctly position the valve, after which the clamp nut can be tightened. Replace the spray-valve rocker, being sure to put the cotter pin in the fulcrum pin. The valves should now be timed. See Section 10.

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 laid away so that they will be in good 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 cylinder 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 ⅜ 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.

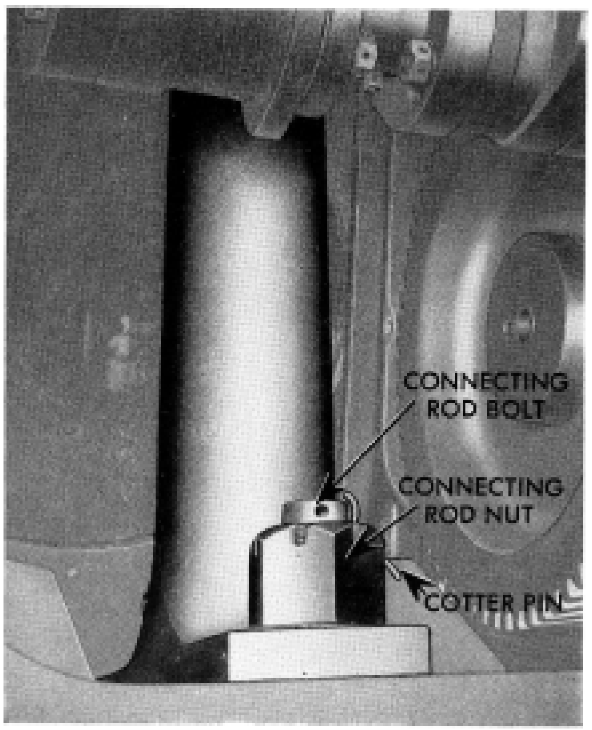


FIGURE 12-1

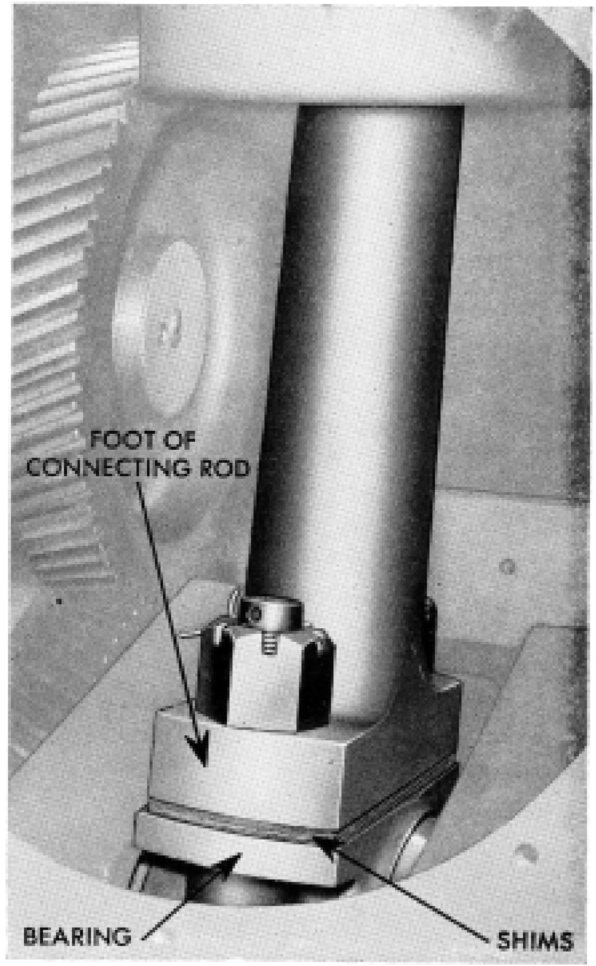


FIGURE 12-2

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 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.

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.

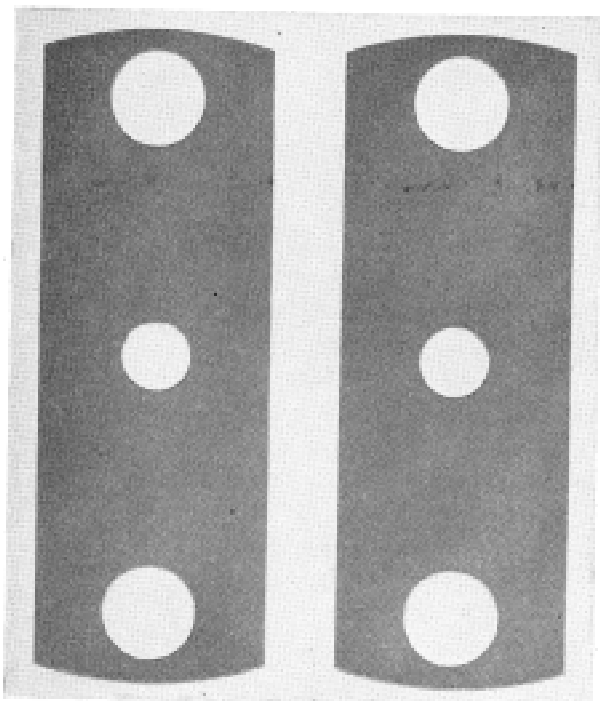


FIGURE 12-3

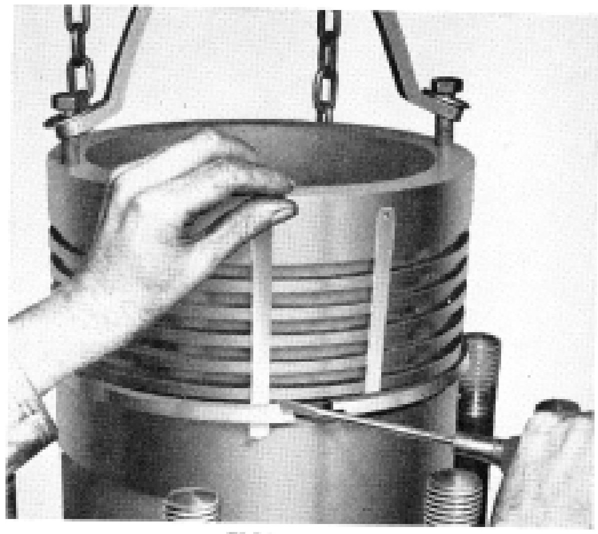


FIGURE 12-4

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

FIGURE 12-5

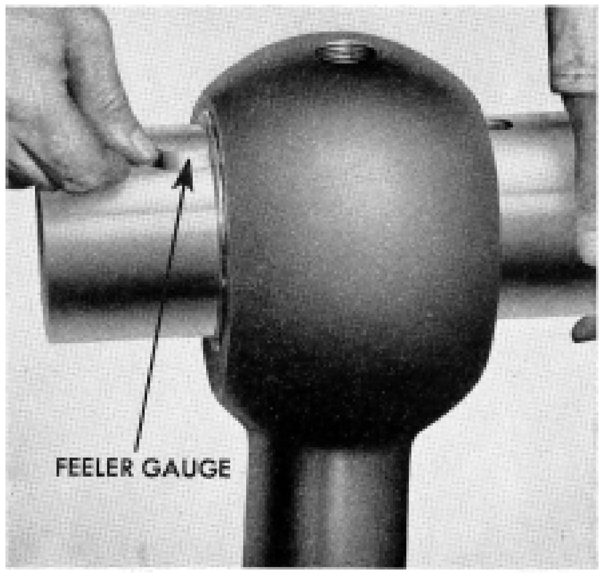


FIGURE 12-7

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 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 the 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.

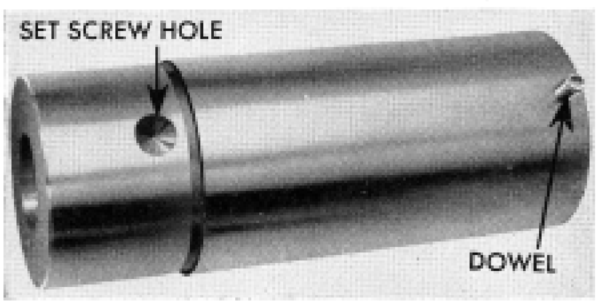


FIGURE 12-6

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 on 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.

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 1/4 inch thick or over with a 3/4-inch hole near the center will do. A 3/4-inch bolt about 12 inches long with three or more inches of thread on one end, a small strongback and two pieces of 3/4 or one inch square steel are all that is necessary to make 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 distance from each side of the connecting rod.

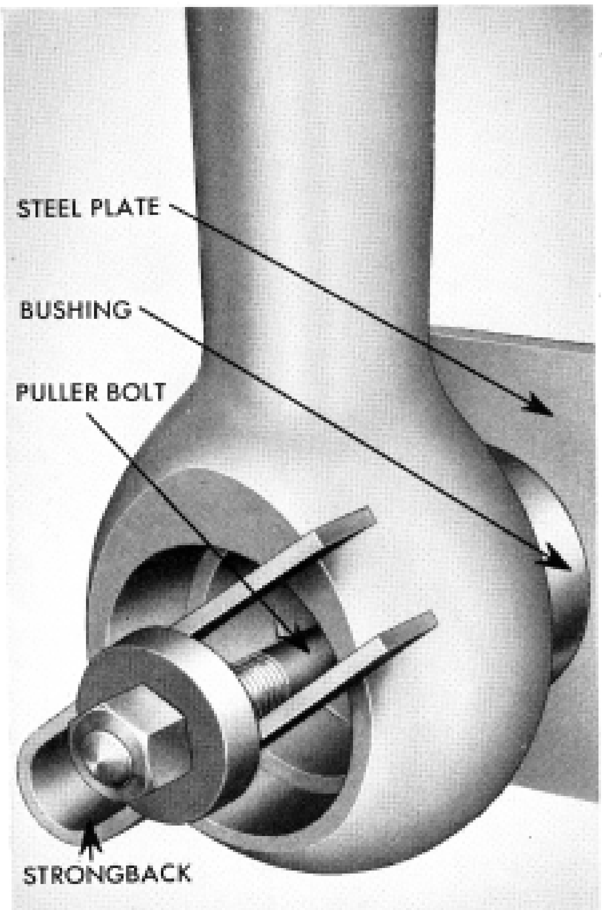


FIGURE 12-8

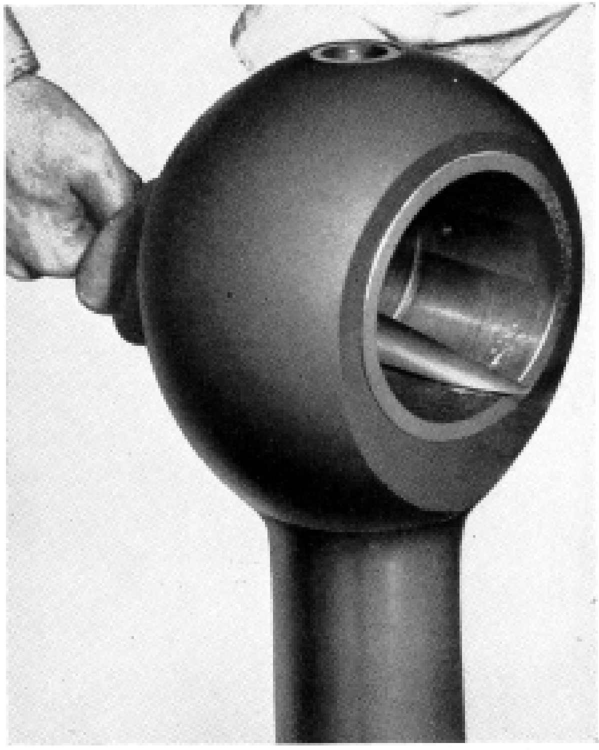


FIGURE 12-9

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.

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 occurs near the top ALWAYS CHECK THE RING CLEARANCES BELOW THE

CENTER OF THE CYLINDER. 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 cylinder diameter for NEW RINGS in the top two grooves. Example: for 7½-inch cylinder diameter: 7½ x 0.005 = 0.038 total clearance.

The end-gap clearance should NOT BE LESS than 0.003 per inch of the inside cylinder for NEW RINGS in the grooves below the top two grooves. Example: for 7½-inch cylinder diameter: 7½ x 0.003 = 0.023 inch total clearance.

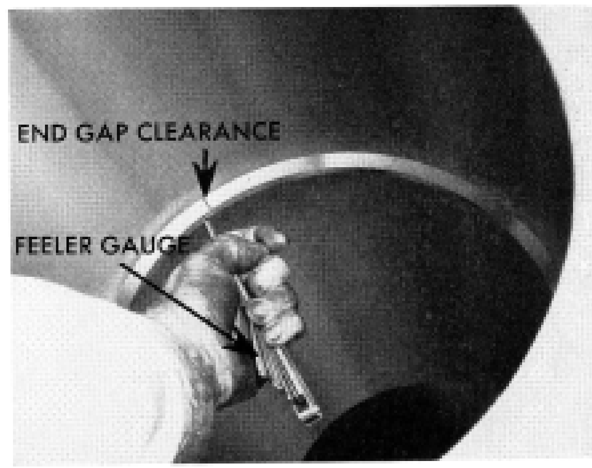


FIGURE 12-10

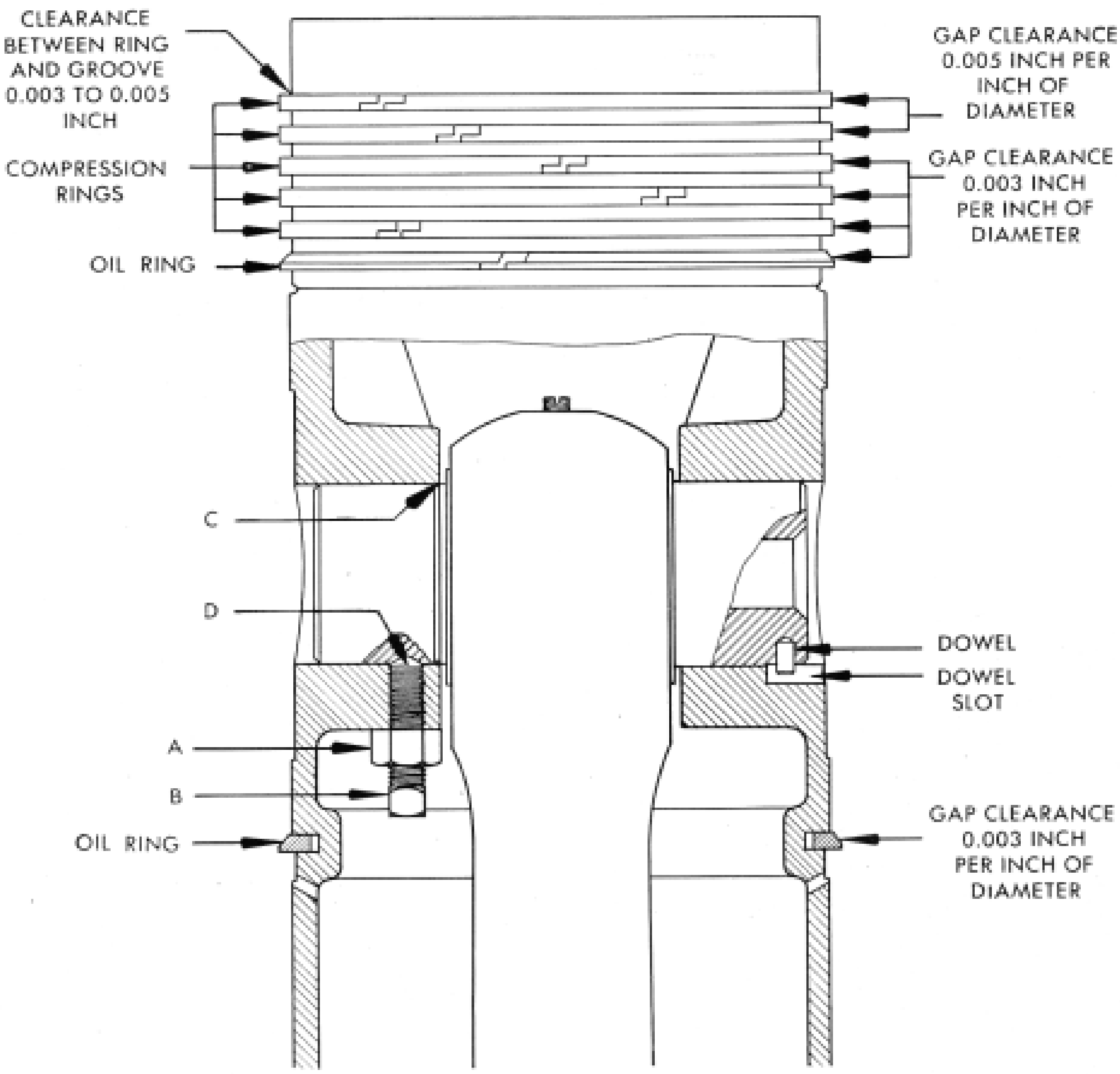


FIGURE 12-11

If the gap clearance of any ring exceeds 0.008 per inch of the cylinder 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. MEASURING CYLINDER BORE: Measurements of the cylinder bore should be taken and recorded in the log each time the pistons are removed. These periodic records give the operator a chance to spot any unusual wear in a particular cylinder and take steps to correct any trouble.

The cylinder bore should be measured at the top of ring travel and about six inches down the bore as well. Measurements should be taken both fore and aft and thwartships. The greatest wear will occur at the very top of ring travel and it is for this reason that the end-gap clearance of piston rings should always be measured with the ring well down towards the bottom of the bore. Use an inside micrometer to measure the bore as shown in Figure 12-12. The use of this micrometer is described in Paragraph 10 of Section 8. WARNING: When ordering pistons or rings for an engine that has been rebored always give the micrometer size of the cylinder taken at the very bottom of the bore.

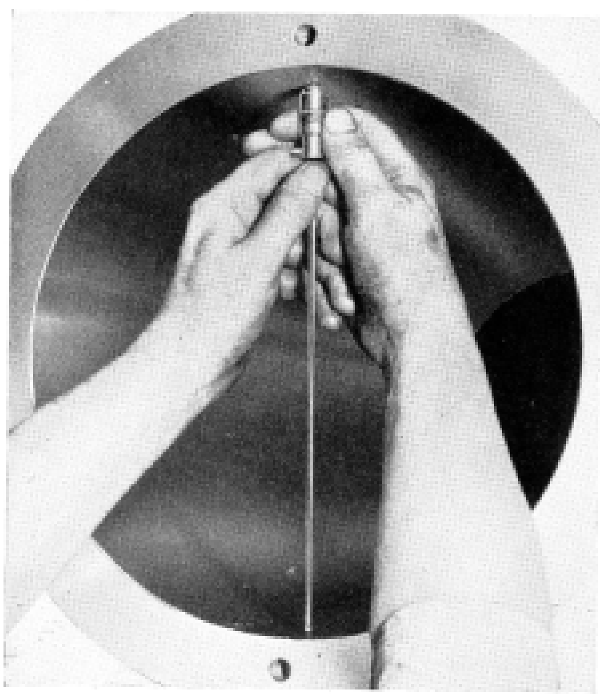


FIGURE 12-12

7. ASSEMBLY OF THE PISTON, CONNECTING ROD: 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

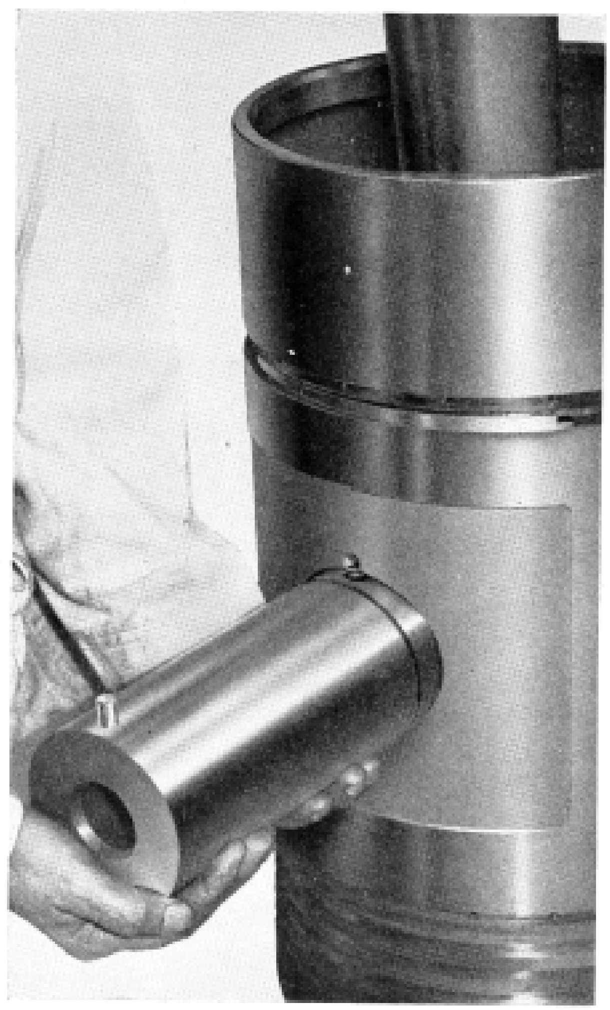


FIGURE 12-13

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 12-13.

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 have the shoulder on the piston pin about 1/64 of an inch 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.

8. ASSEMBLY OF THE PISTON AND CONNECTING ROD IN THE CYLINDER: Clean the cylinder walls, piston and connecting rod. Apply oil generously to the walls of the cylinder. Set in the piston-ring compressor, as shown in Figure 12-14. This compressor ring is usually found among the engine room equipment and assists greatly in entering the piston rings, in the cylinder, 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 cylinder. Compress this ring by drawing a piece of strong cord around the ring, bringing the ends of the ring together. This will allow the piston to lower into the cylinder until the next ring rests on the cylinder. Repeat this operation until all rings are entered.

Suspend the piston over the cylinder as in removal, see Figure 12-14. Assemble the piston rings on the piston as in removal, see Figure

FIGURE 12-14

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 cylinder. 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 IS LOST OR NONE IS 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.

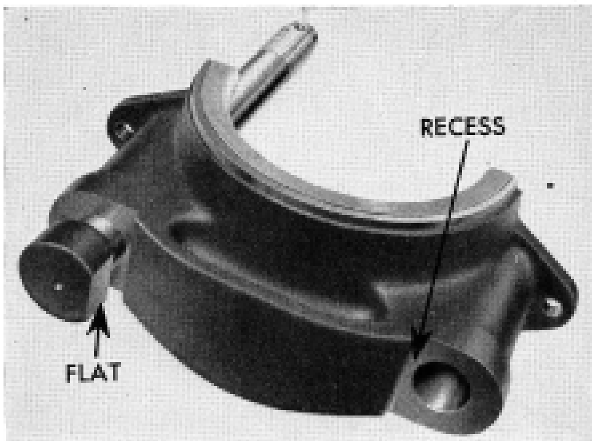


FIGURE 12-15

Lower the piston, making sure the spigot 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, make sure 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 several 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 cylinder to the top of the piston. The following table gives the measurements for various engine sizes:

Engine Bore and Stroke	Measurement
7½ x 10½	31/32 in.
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. Drive the connecting rod bolts up, MAKING SURE THE FLAT ON THE CONNECTING ROD BOLT ENTERS THE RECESS IN THE BEARING. See Figure 12-15. 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 three-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 spread the ends. Always use a cotter pin that is nearly the size of the hole. SMALL LOOSE COTTER PINS ARE DANGEROUS.

9. CYLINDER INSPECTION: The cylinder cleanout cover should be removed as well as the inlet water manifold. This will give access to the cylinder water jacket. Any scale or silt deposits can be removed by scraping. The cylinder lubricating pipes should be carefully inspected and the packing grommets renewed if necessary.

If the cylinder has been removed great care should be taken to have the mounting flange face and the top of the centerframe thoroughly clean before assembly. Some engines use a gasket at this joint while others use a crankcase sealer. We recommend Glyptal Lacquer as a sealer if no gasket is used.

The cylinders are aligned thwartships by fitting closely to a machined pad which extends down one side of the centerframe. The fore and aft positioning of the cylinders is governed to a great extent by the connecting rod bearing and is covered in Paragraph 9 of Section 13.

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.

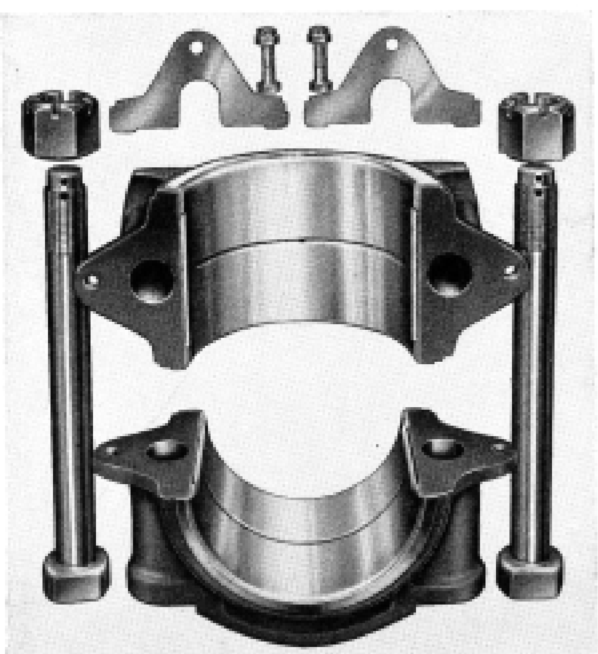


FIGURE 13-1

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

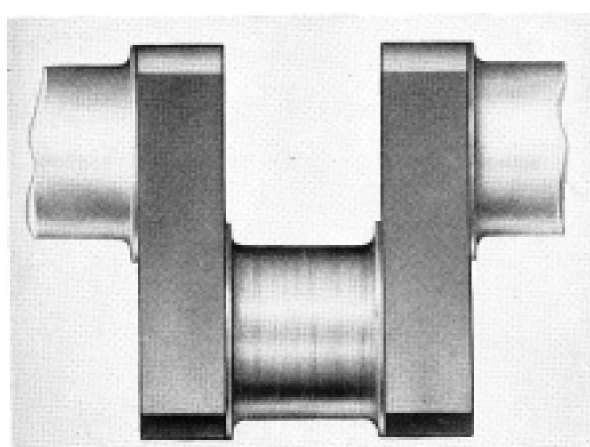


FIGURE 13-2

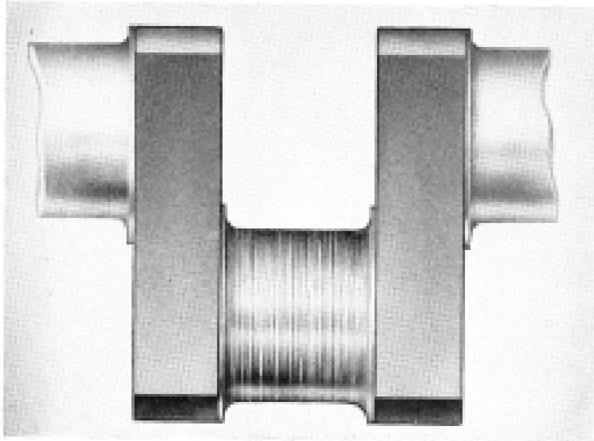


FIGURE 13-3

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.

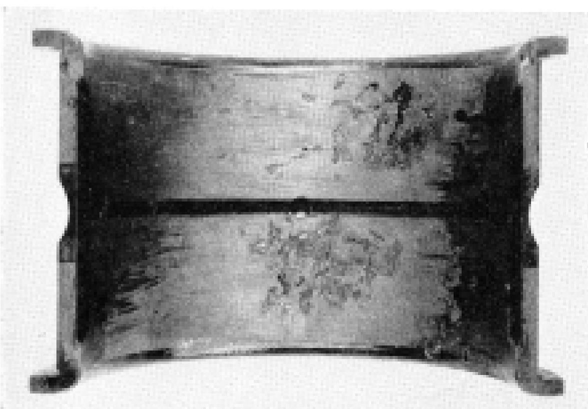


FIGURE 13-4

FIGURE 13-5

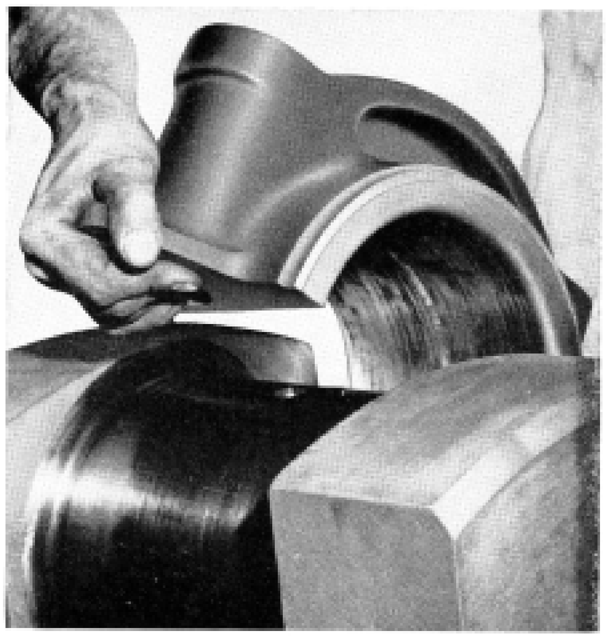


FIGURE 13-6

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 ¾ 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.

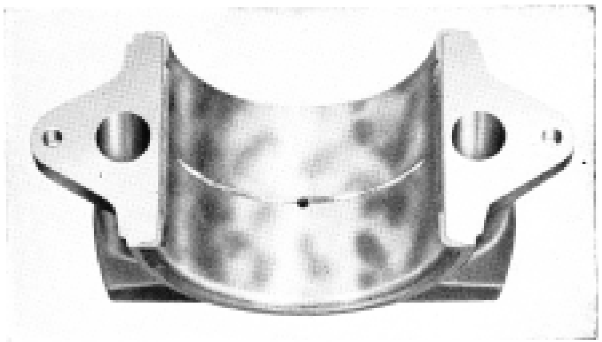


FIGURE 13-7

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 ¾ 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.

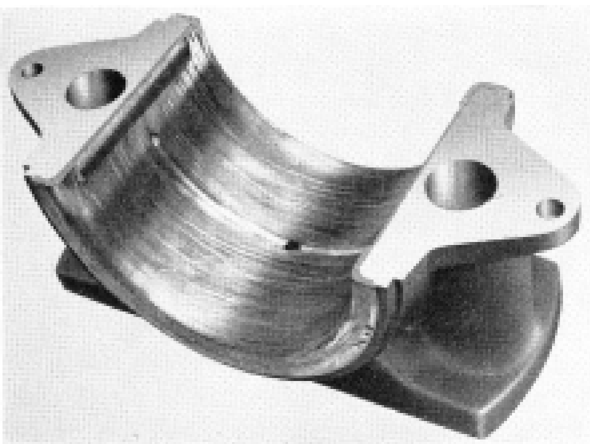


FIGURE 13-8

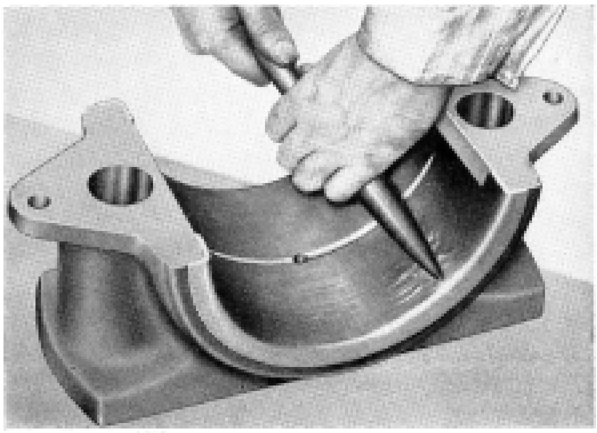


FIGURE 13-9

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.

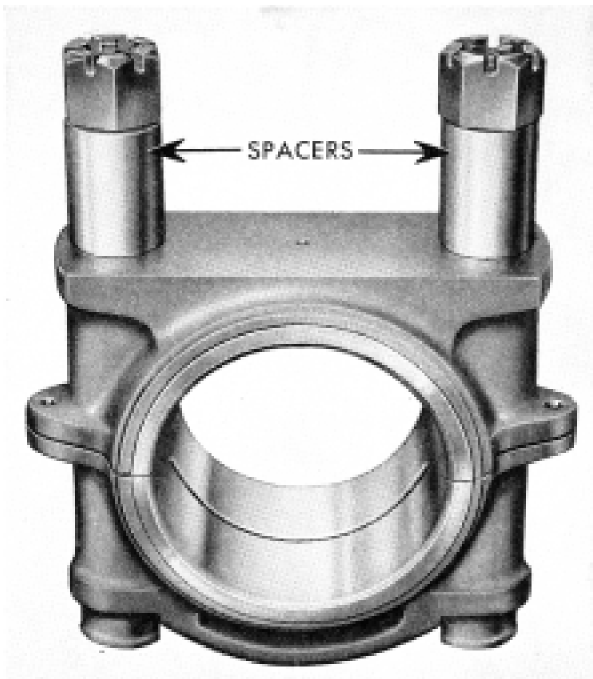


FIGURE 13-10

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.

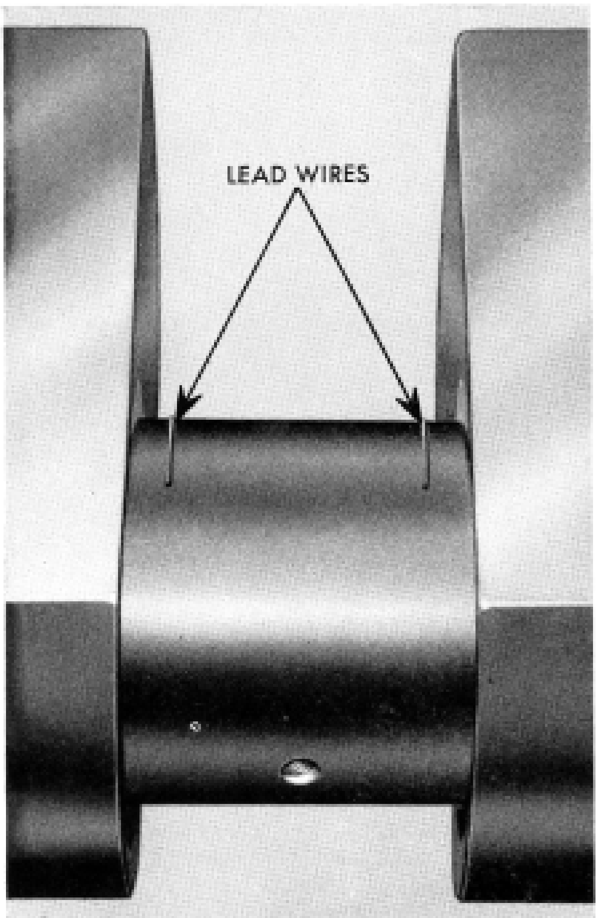


FIGURE 13-11

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.

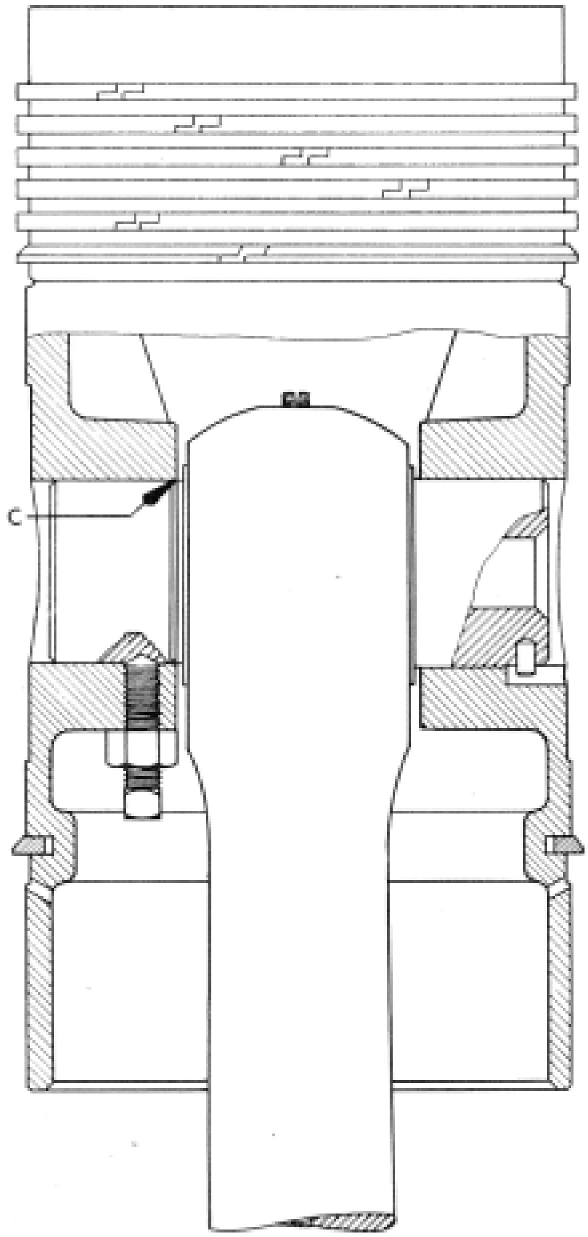


FIGURE 13-12

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 $\frac{1}{16}$ inch to $\frac{3}{32}$ 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

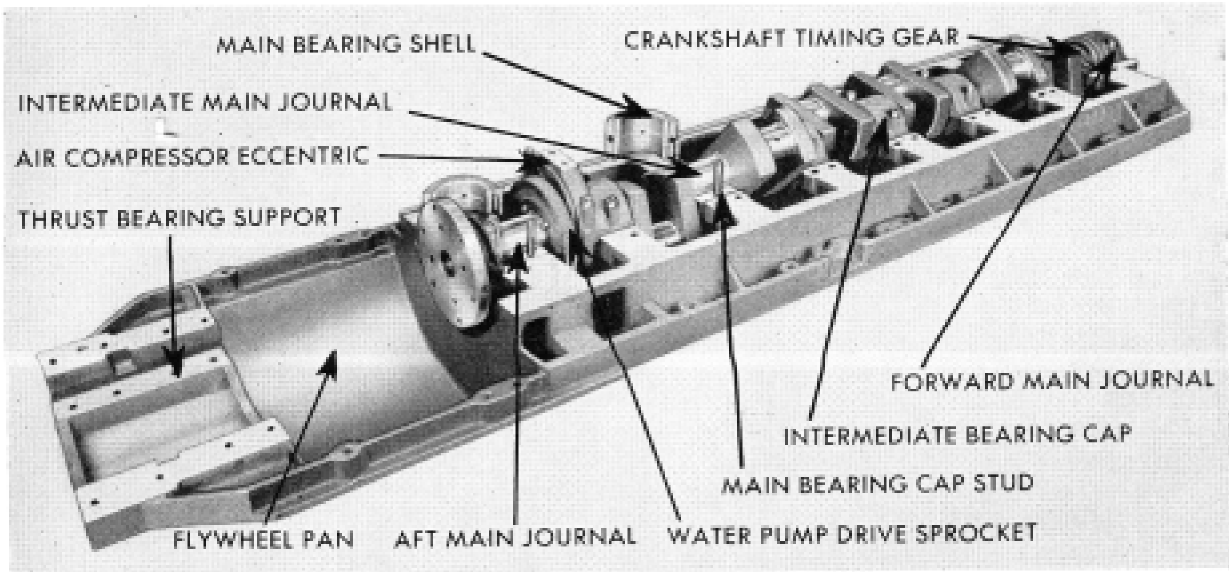


FIGURE 14-1

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 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 fewer bright bearing areas than the bottom shells.

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 intermediate gear and plate have to be removed before the forward 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 intermediate gear is replaced. THIS MUST BE DONE BEFORE THE INTERMEDIATE GEAR IS REMOVED, otherwise the operator will have to go through the lengthy procedure outlined in Paragraph 18 of Section 19 to retime the camshaft properly.

7. MARKING THE CAMSHAFT: Turn the flywheel to No. 1 cylinder top center (firing). This will be No. 1 top center with both valves closed. (If the cylinder heads are off and the valves can not be checked, it will be No. 1 top center with the fuel-cam lobe under the spray-valve lifter.)

Lay the edge of a steel scale against the machined face of the centerframe and press it firmly to the side of the camshaft gear. Scribe a line on the side of the gear parallel to the centerframe face. This line and the positioning of the flywheel must be accurate, as these checks are used when the gear train is replaced.

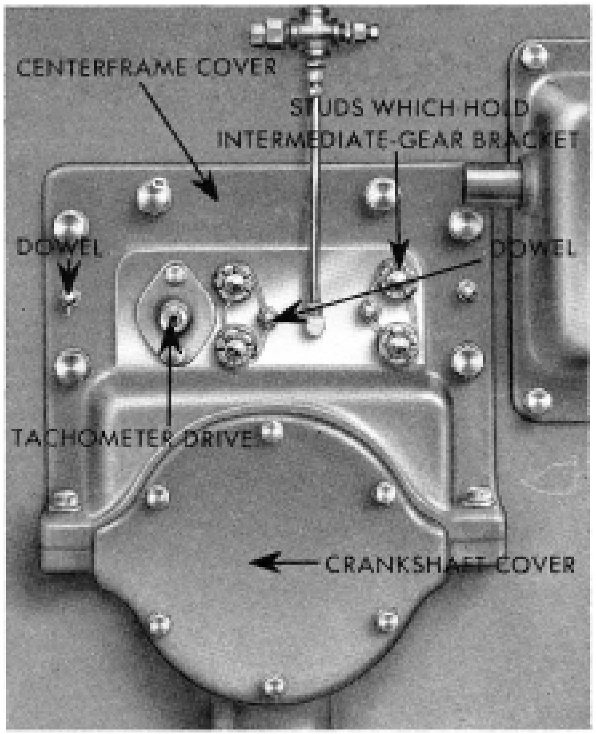


FIGURE 14-2

8. REMOVAL OF THE INTERMEDIATE GEAR, BRACKET AND COVER: Figure 14-2 shows that the forward end of the centerframe is closed by a cast cover which is doweled and held on by capscrews. To this cover is attached the intermediate gear bracket, which has four studs that extend through the centerframe cover. The bracket is also doweled to the cover so that the mesh of the gear train will not be altered during overhaul.

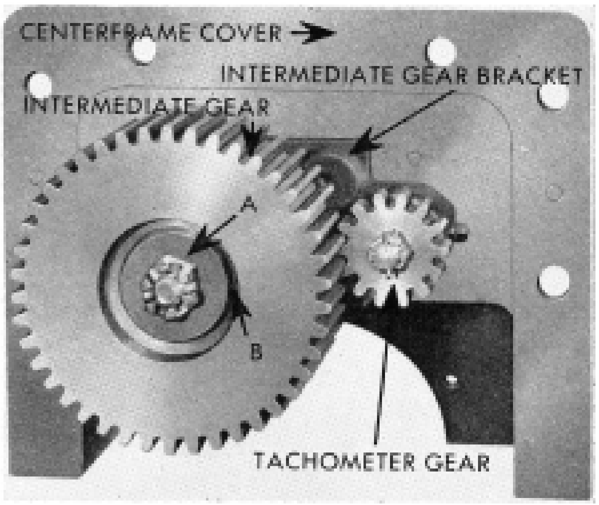


FIGURE 14-3

Replacement of major parts such as a crankshaft or any of the gears, might change the mesh of the gears. It would then be necessary to have the intermediate gear relocated and the bracket redoweled at a service depot.

Remove the crankshaft cover and the oil lead to the intermediate bearing. Disconnect the tachometer drive and withdraw the dowels in the centerframe cover. Refer to Figure 14-3, which shows the centerframe cover and intermediate gear and bracket. Remove the nut (A) and washer (B). Remove all the capscrews from the centerframe cover and it can be withdrawn, leaving the gear in place as in Figure 14-4. The front main bearing cap can now be removed.

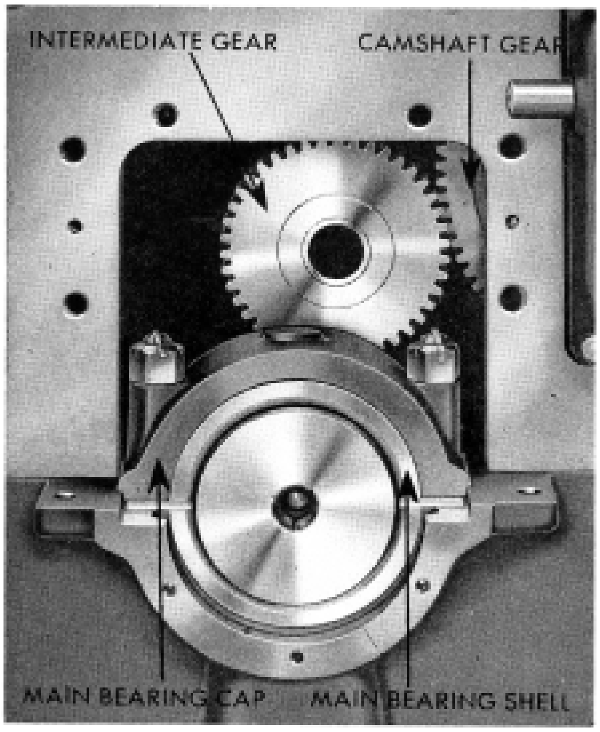


FIGURE 14-4

9. INTERMEDIATE GEAR BEARING: The gear is bronze bushed and rotates on a hardened steel pin which is fastened to the bracket. It is drilled to receive oil from the pressure system to lubricate the bearing. If the gear bushing is renewed it should be pressed into the gear and then reamed to exactly 1½ inches. This will give a running clearance of 0.003 to 0.004 inch.

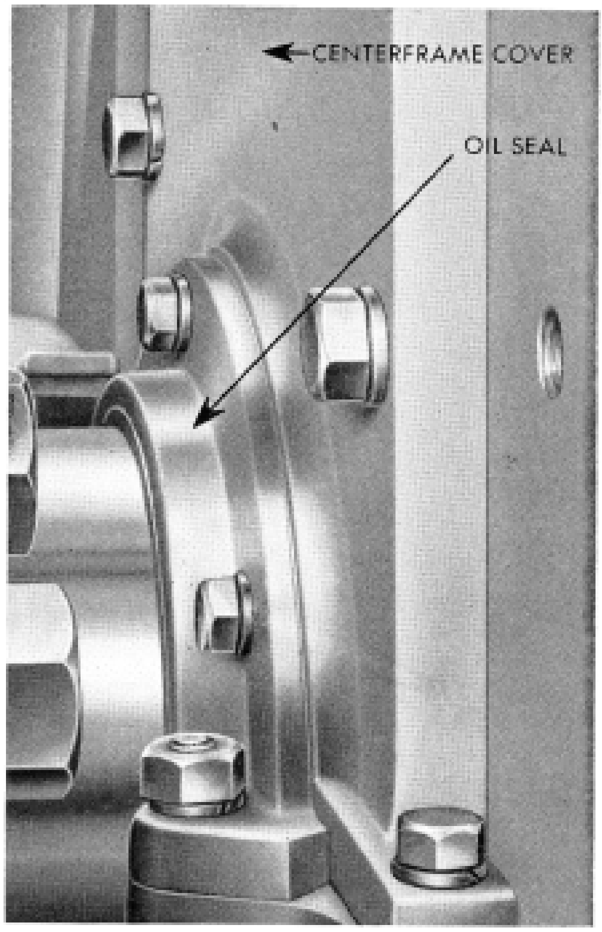


FIGURE 14-5

10. REMOVAL OF THE AFTER MAIN BEARING: The after end of the centerframe is closed off by the cover plate and oil seal shown in Figure 14-5. The oil seal is simply a grooved flange which fits against the cover plate on the top side, and the base on the bottom side. When it has been removed the felt in the groove should be examined and softened by "working" between the fingers if necessary. If it has become cracked or torn, the felt should be renewed. Remove the cover plate and the after main bearing cap can be taken off.

11. 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 capscrew into an oil hole in the journal, as shown in Figure 14-6. Slowly turn the flywheel and the head of the capscrew will roll the shell to the top of the journal where it can be lifted out.

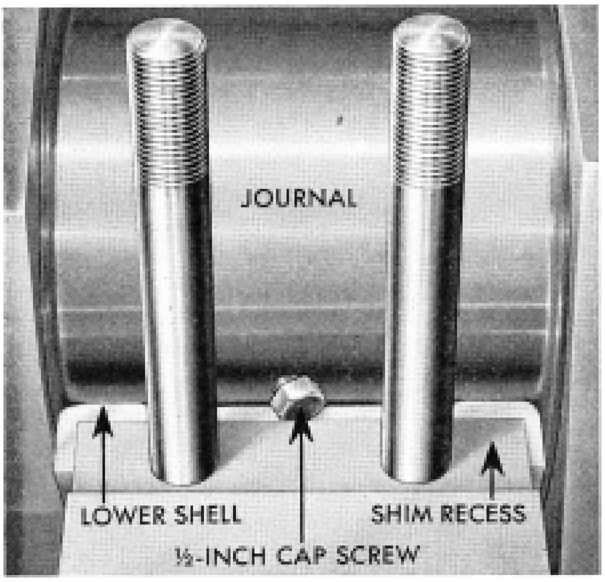


FIGURE 14-6

Examine the babbitt lining of the shells as described in Paragraph 4, this section. If the babbitt is found to be badly cracked or burned the shell will have to be replaced, but remember 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:

12. 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 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 capscrew 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 14-7.

Cut and bore several pieces of ½-inch iron in the shape shown in Figure 14-8, so that they

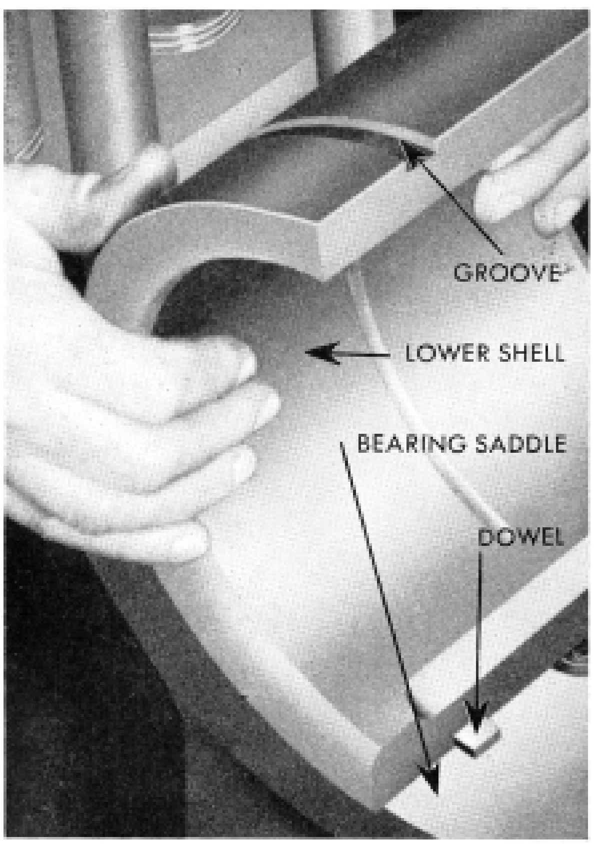


FIGURE 14-7

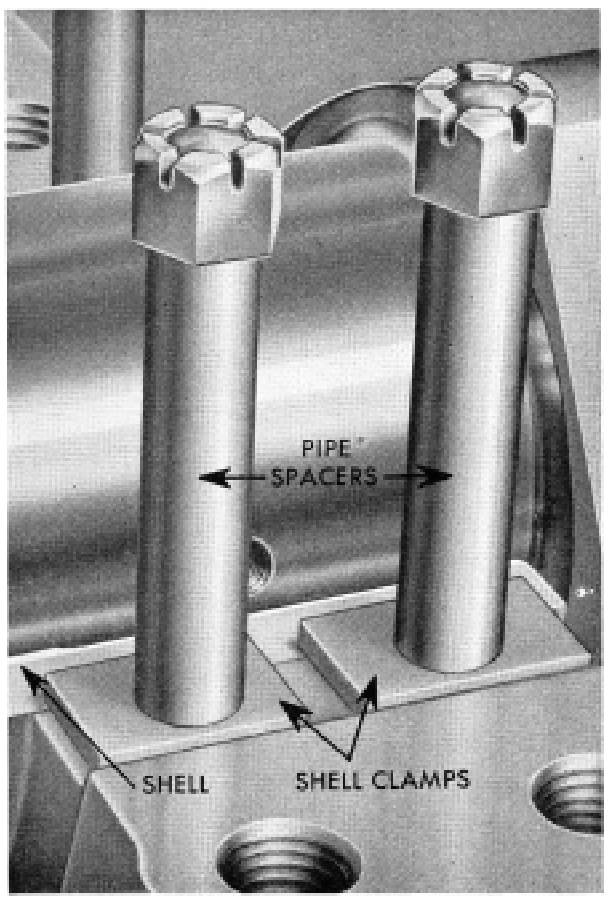


FIGURE 14-8

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 per cent of the bearing area is obtained the bearing can be considered as fitted and the alignment of the crankshaft should now be checked.

13. BRIDGE GAUGES: Most new engines are supplied with bridge gauges. This is the device shown in Figure 14-9 and it is simply an arched piece of metal which sets into the shim recess on each side of a main bearing.

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.

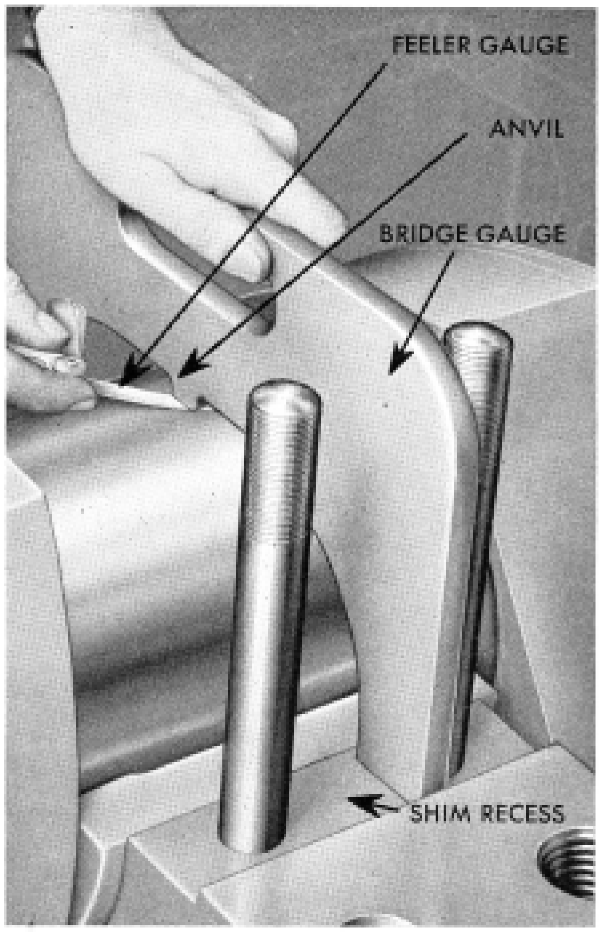


FIGURE 14-9

14. 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 14-10, 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.

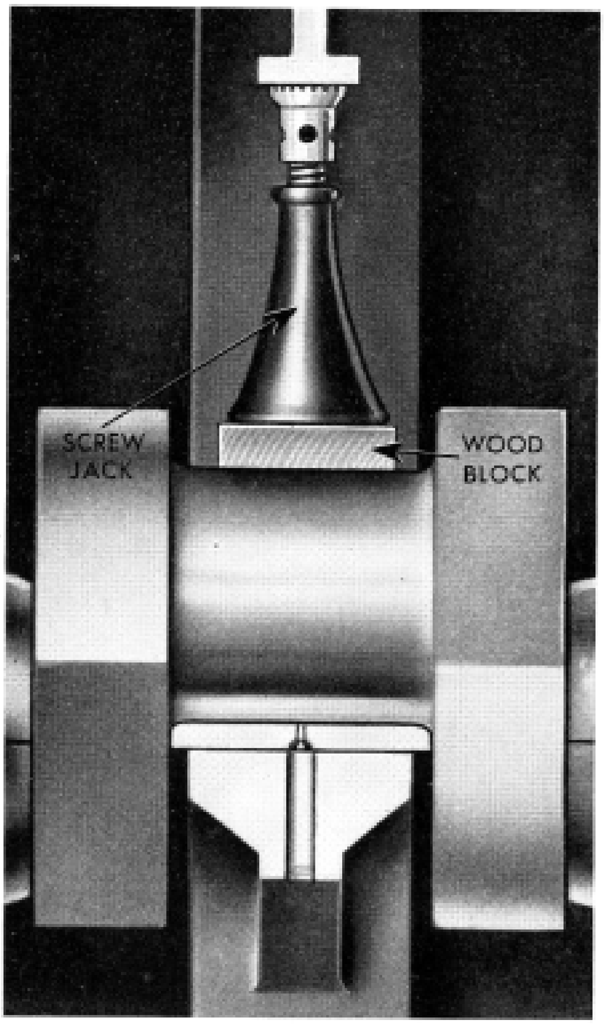


FIGURE 14-10

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 the 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, 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.

15. 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.

16. ASSEMBLY OF INTERMEDIATE GEAR: Turn the flywheel to No. 1 cylinder top center. Turn the camshaft so that the scribe mark, made before disassembly, mates perfectly with the same scale held in the same place as when the mark was made. Set in the gear as in Figure 14-4.

Clean the faces of the centerframe and cover and fit a new gasket between them. Start the bracket pin through the gear bushing and push the cover into place and drive in the two dowels. Check to make sure that neither the crankshaft nor the camshaft has moved from its mark. Tighten all the cap screws which attach the centerframe and crankshaft covers.

Put on the washer (B) and the nut (A), Figure 14-3, and secure the nut with a cotter pin. There should be at least 0.025 inch end movement to the gear.

17. BACKLASH: The combined backlash of the three gears should be between 0.012 and 0.016 inch and this can be measured by turning the camshaft gear in one direction far enough to take up all the slack. Next, turn the camshaft gear in the opposite direction so that all the slack is taken up. The amount of movement of a given point on the circumference of the camshaft gear is the backlash. This movement or slack should be equally divided between both gears. That is: if the combined backlash is 0.012 inch, the mesh of the intermediate gear should be about 0.006 inch slack to both the crankshaft and the camshaft gears. If it is found that adjustment is necessary, we suggest that it be made at a service depot by experienced mechanics.

18. ENGINE CHECKOVER: After any bearing work has been done and before the base covers are put on, go over the crankshaft assembly to make sure all nuts and cap screws are tight and secured with lock washers, cotter pins, or locking wire. See that no tools or rags are left in the base and bar the engine over at least two full revolutions to make sure that everything is clear.

After the engine has been run for twenty minutes or so, shut down and feel all bearings, connecting rods, and thrust bearings. If any bearings are warmer than the average they should be examined.

NOTE: To locate the correct fore and aft position of the crankshaft, refer to 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.

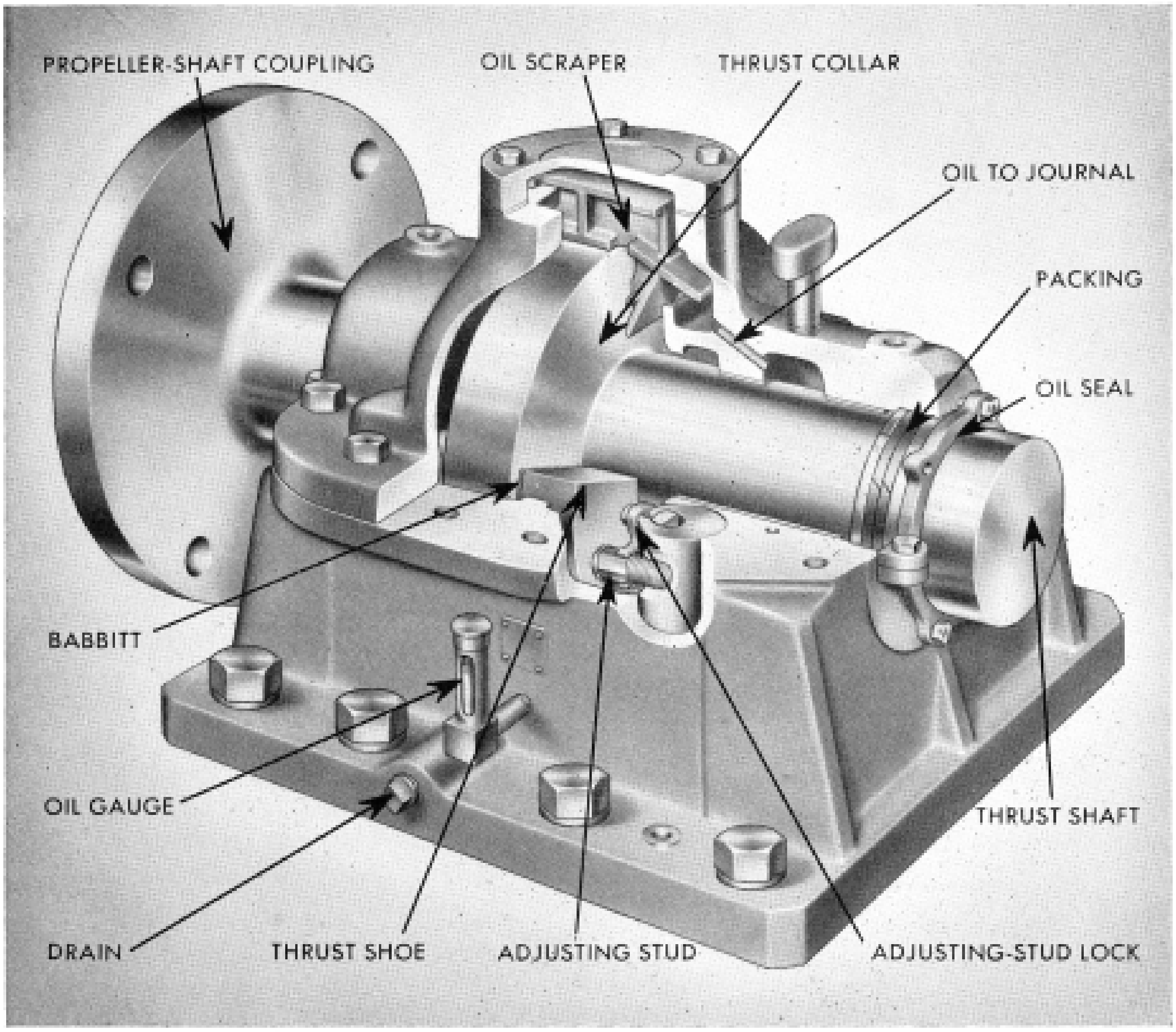


FIGURE 15-1

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.

The main journal is located ahead of the thrust collar and is oiled by the scraper and oil passage as shown in Figure 15-1. Always use an oil that meets the specifications stamped on the plate of the bearing.

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.

Slack off all four thrust adjusting studs, one of which is shown in 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 15-2.

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 two after 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.

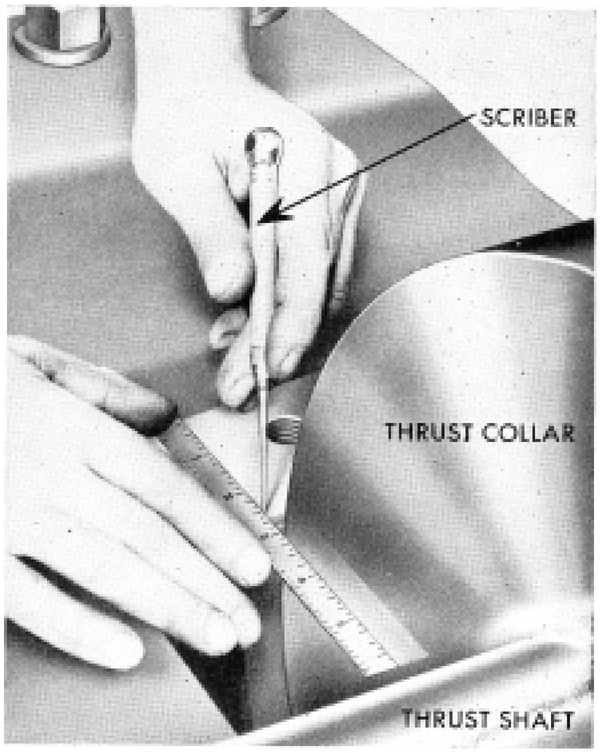


FIGURE 15-2

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
7½ and 8	0.009

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 15-3) TO THE FOUR ADJUSTING STUDS. The thrust shoe has been removed in this view to more clearly illustrate the adjusting stud and lock.

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 5. 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.

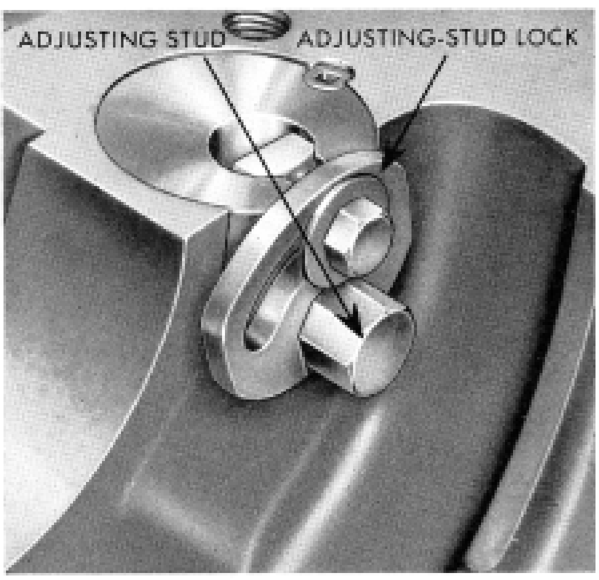


FIGURE 15-3

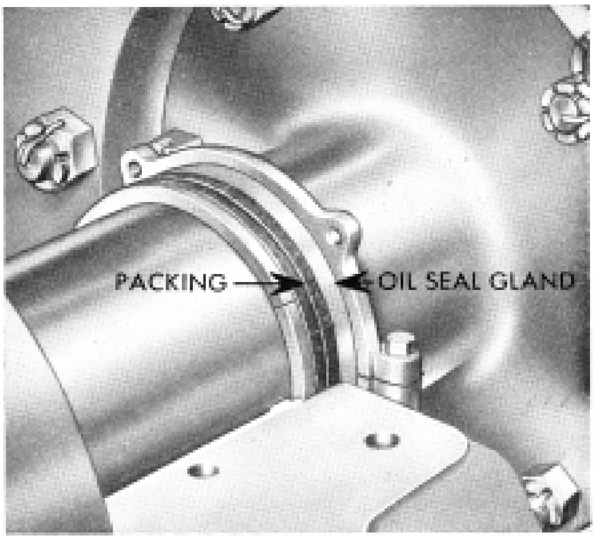


FIGURE 15-4

This readjustment should never position the crankshaft further ahead than half its total fore and aft movement.

6. OIL SEALS: After all adjustments are completed, examine the felt in the oil seals. If this has become worn and hard, replace with new felt. 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 $\frac{1}{16}$ inch, the entire bearing should be rebabbitted. This is work which should be undertaken only at a service depot.

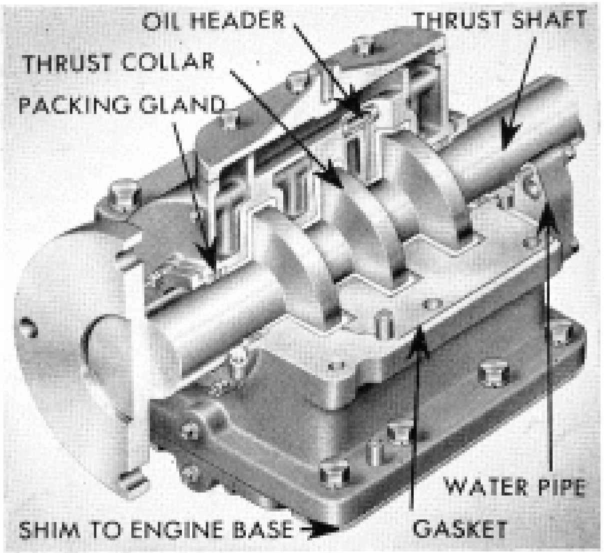


FIGURE 15-5

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.

The bearing is lubricated by oil led from the engine pressure system. This oil is returned to the base by means of a drain pipe extending from the bottom of the thrust bearing to the base.

The thrust shaft is sealed at both ends by stuffing boxes.These should not be kept tighter than is necessary to stop leakage. If difficulty is experienced in keeping the seals tight, it is probable that the drain pipe is obstructed and it should be removed and blown out.

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 runout 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 slightly.

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

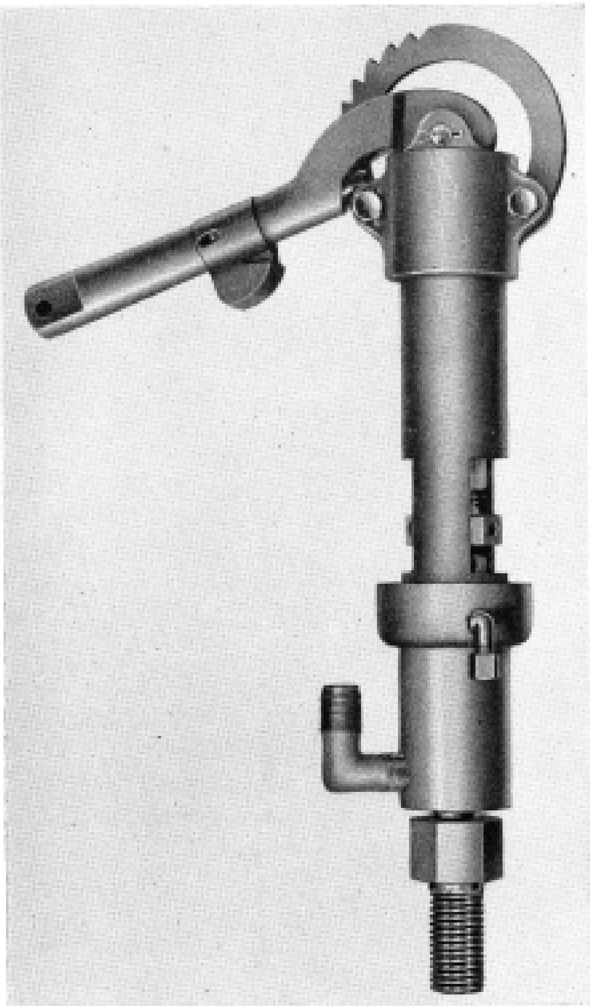


FIGURE 16-1

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.

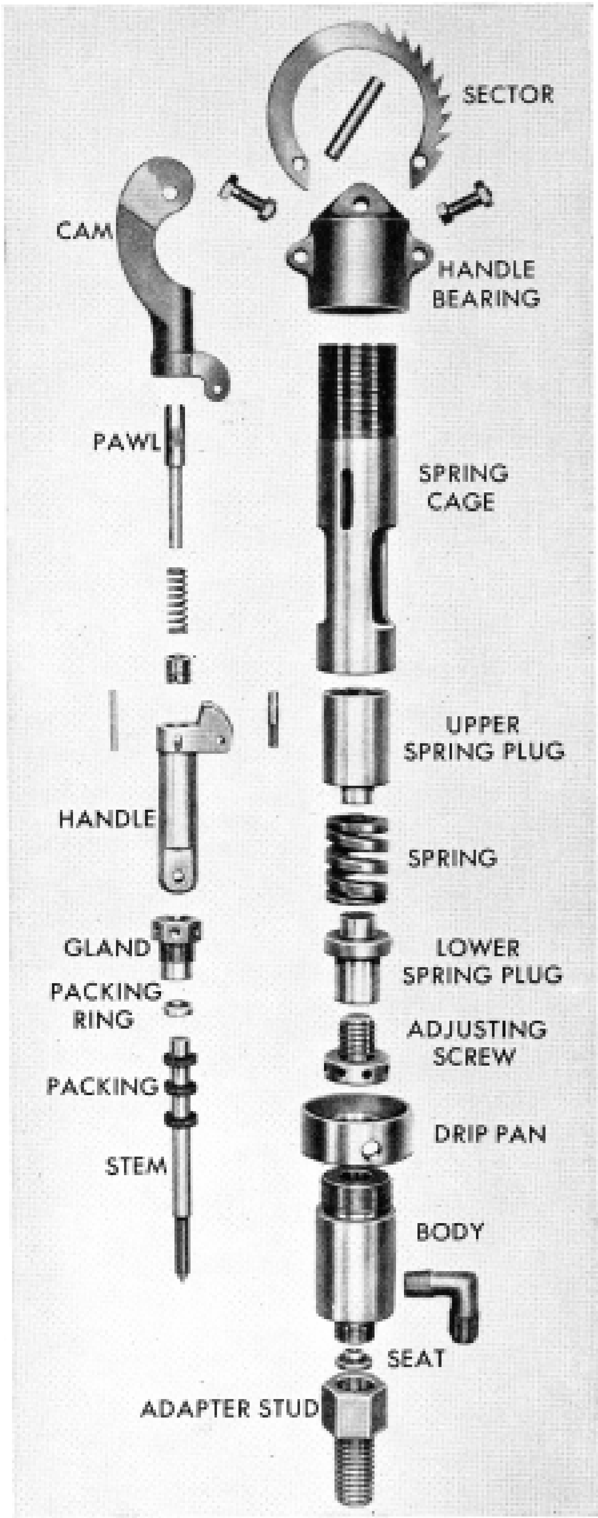


FIGURE 16-2

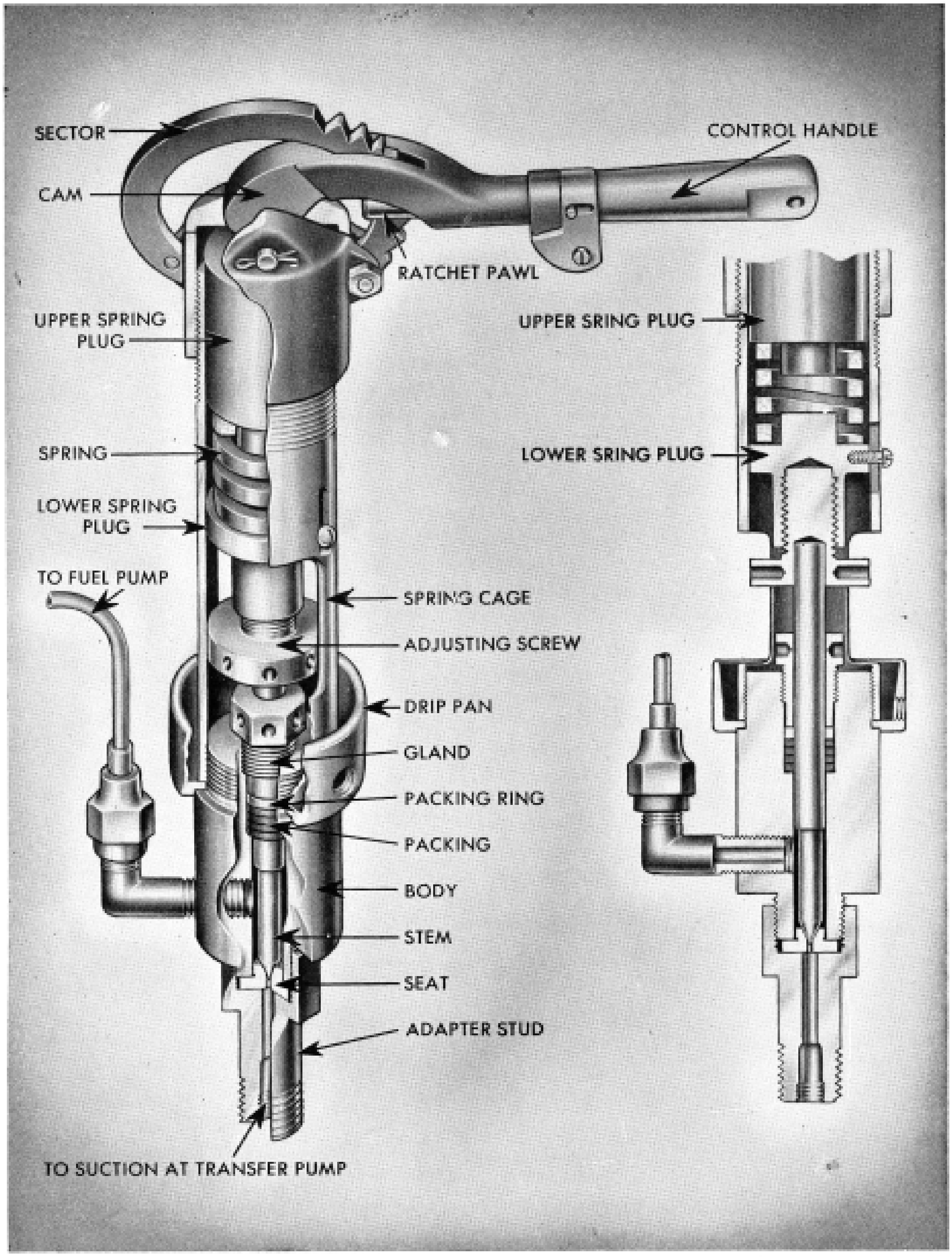

SECTOR
CONTROL HANDLE
CAM
RATCHET PAWL
UPPER SPRING PLUG
UPPER SRING PLUG
SPRING
LOWER SRING PLUG
LOWER SPRING PLUG
TO FUEL PUMP
SPRING CAGE
ADJUSTING SCREW
DRIP PAN
GLAND
PACKING RING
PACKING
BODY
STEM
SEAT
ADAPTER STUD
TO SUCTION AT TRANSFER PUMP

FIGURE 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. There should be at least one-half of the threads on the packing gland 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 tight as possible with a twelve-inch wrench. Slacken off the gland a

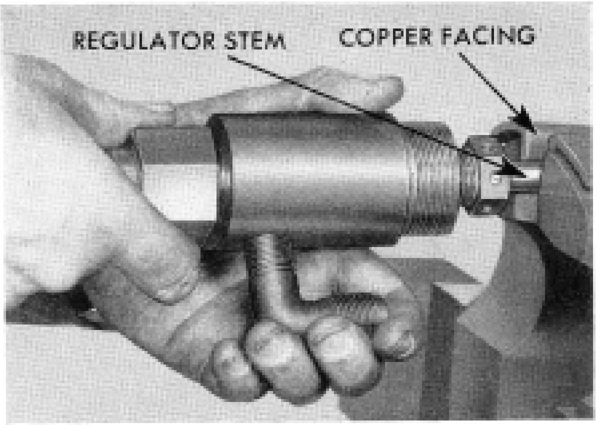


FIGURE 16-4

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.

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

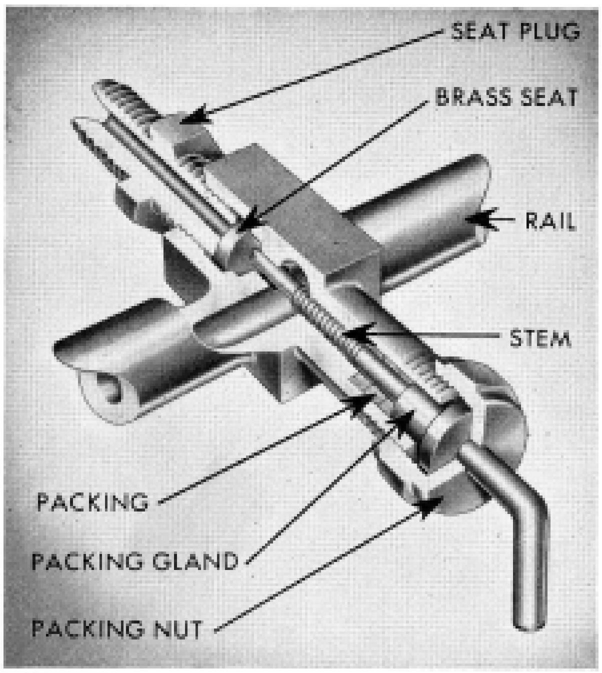


FIGURE 16-5

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 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 clearance of the valves in their cages and the plungers in their barrels will not permit the presence of foreign matter or rust in the pump. Dirt will retard the action of the valves and cause erratic distribution of fuel to the cylinders, and faulty maneuvering. Salt water will corrode the hardened pump plungers and barrels and should therefore be kept out of the system if possible. Efficient strainers and filters are supplied and these will protect the pumps from dirt and water, providing they are cleaned frequently and kept in condition.

The plungers and barrels of these pumps 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 plunger and barrel as a set.

13. TESTING FOR LEAKING VALVES: Before the pump unit is taken apart the valves should be checked as follows: Close all isolating valves. Disconnect the discharge line of the fuel-pressure regulator. Raise the regulator handle as high as it will go and pump up 4,000 or 5,000 pounds fuel pressure with the hand pump. If the regulator discharge line is not leaking, and the fuel pressure in the common rail drops, the high-pressure discharge

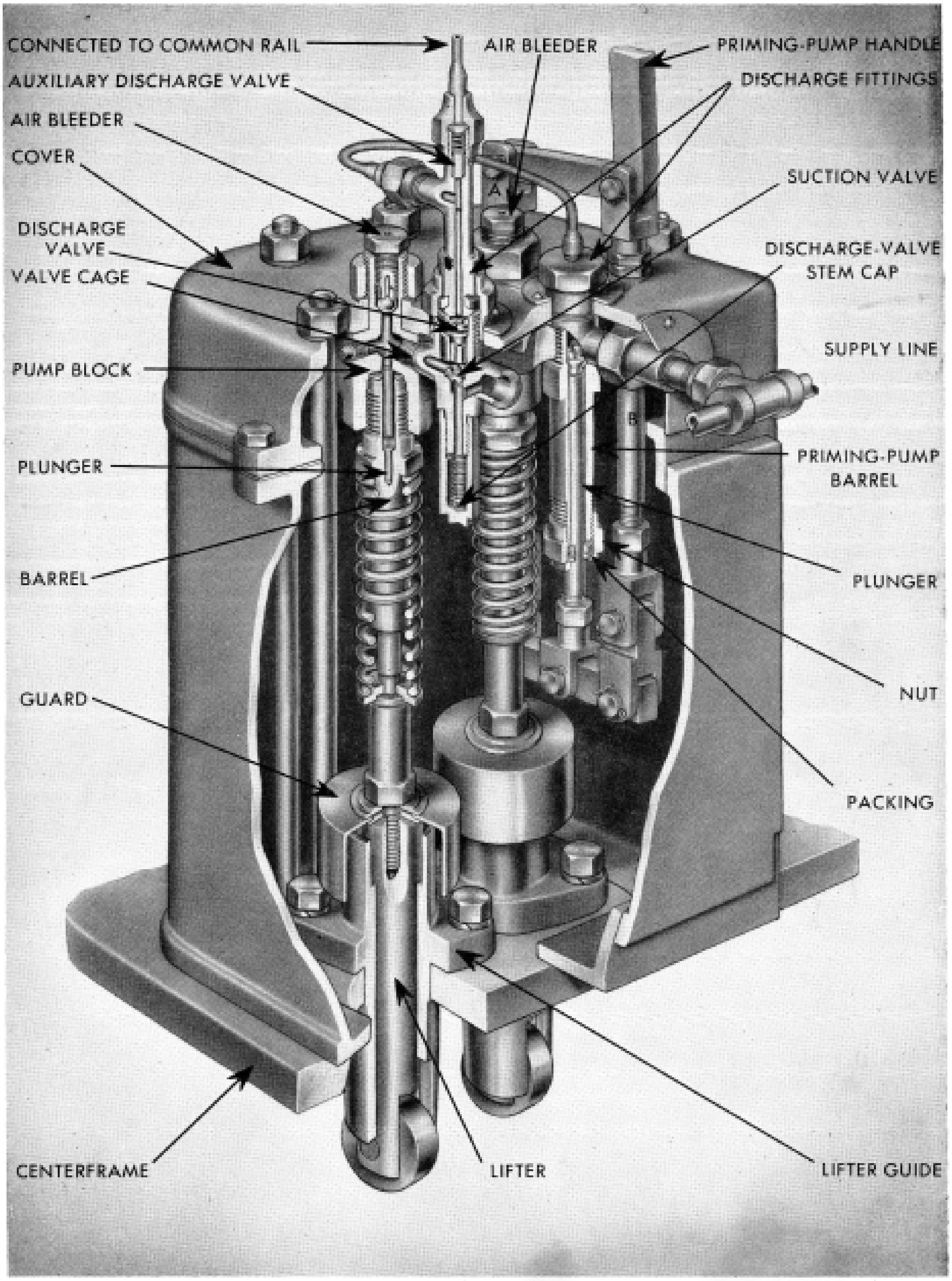

CONNECTED TO COMMON RAIL
AIR BLEEDER
PRIMING-PUMP HANDLE
AUXILIARY DISCHARGE VALVE
DISCHARGE FITTINGS
AIR BLEEDER
COVER
SUCTION VALVE
DISCHARGE VALVE
DISCHARGE-VALVE STEM CAP
VALVE CAGE
A
SUPPLY LINE
PUMP BLOCK
B
PRIMING-PUMP BARREL
PLUNGER
BARREL
PLUNGER
NUT
GUARD
PACKING
CENTERFRAME
LIFTER
LIFTER GUIDE

FIGURE 16-6

valves are leaking. If there is any doubt about the isolating valves holding, they can be checked by removing the tube from each valve to its spray valve.

14. DISASSEMBLY: Reference to Figure 16-6 will show that the two high-pressure pumps and the priming pump are attached to the cover plate of the unit. This can be removed by disconnecting the fuel supply line to the fuel rail. A small manifold, made up of pipe fittings, leads the fuel from the supply line to the suction fittings of the valve cages. It should be noted that the two unions which connect the manifold to the valve cages are not standard pipe fittings.

The pump block, to which is attached the pump barrel and valve cage, has a threaded spigot which extends through the cover. Removal of the nut on this spigot and the discharge fitting, will free the pump unit. The plunger and barrel should not be removed from the pump block unless they have been damaged. If they are renewed, be sure to use a copper gasket to seal the joint between the barrel and the block. Examine the pump springs for cracks or corrosion.

15. SERVICING THE HIGH-PRESSURE VALVES: Figure 16-7 shows one of the valve cages which are screwed into the pump block by a taper thread. The cages should not be removed unless necessary, as it is sometimes difficult to obtain a tight joint. If the cage is removed the tapered threads should be well tinned before assembly to assure a fuel-tight joint.

The suction valve is held closed by a light spring and the stem is covered by a cap to prevent leakage. The flat on one side of the stem is to permit the fuel to pass freely from the cap to the suction chamber. This valve may be ground with fine grinding compound, but both the cage and valve must be washed thoroughly before assembly.

The discharge valve is hardened and fits on a hard seat which is pressed into the cage. This valve is so positioned that it acts as a stop for the suction valve. If leaking, it may be ground, but owing to its hardness this is seldom necessary.

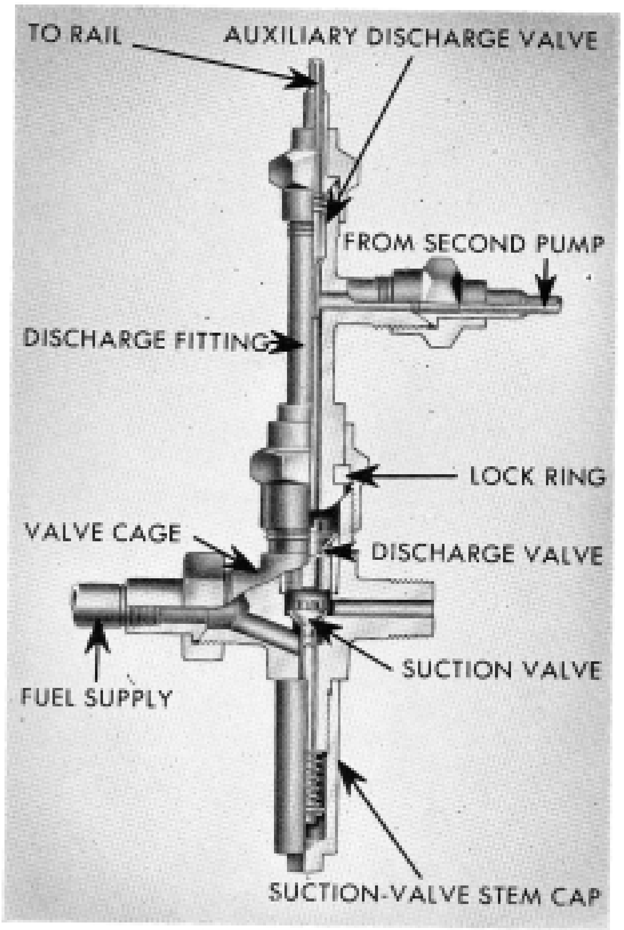


FIGURE 16-7

16. REMOVAL AND SERVICING OF THE PRIMING PUMP: The priming pump, shown in Figure 16-8, screws into 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 16-8 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 so as to retard the movement of the plunger.

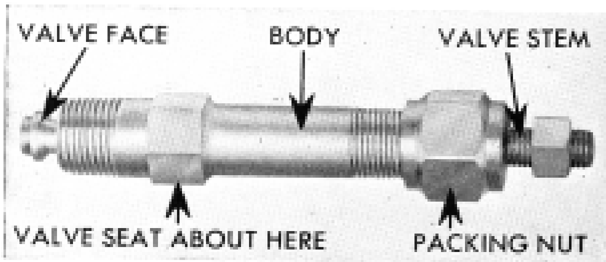


FIGURE 16-8

The valve can be reground, if leaking, by using fine grinding compound. To pack the stem use two or three turns of 1/8-inch twisted graphite packing. When screwing the pump barrel into the block, be sure that the copper gasket is in place.

Reference to Figure 16-6 shows an adjustment on the mechanism which operates the priming pump. The fork on the handle marked (A) should not touch the cover, as the head of the plunger will be held off its seat. The rod marked (B) can be lengthened if it is necessary to raise the fork (A).

17. DISCHARGE FITTINGS: These fittings which are attached to the tops of the valve cages act as a stop for the lift of the discharge valves. The fitting on the forward pump has a short jumper tube which connects to the side of the after discharge fitting but below the auxiliary discharge valve shown in Figure 16-7. This valve may be ground, if necessary, with fine grinding compound but should be cleaned out thoroughly before assembly. The spring on top of this valve is held down by the compression fitting directly above it, and, as it is small, care should be taken that it is not lost when disconnecting the tube that goes from the fitting to the common rail.

18. LIFTERS: The lifters are carried in guides which bolt to the centerframe. They end at the top in a hardened steel stud which lifts the pump plunger and also holds on a cup-shaped metal guard that prevents any fuel leakage from entering the base.

19. RUNNING CHECK ON HIGH-PRESSURE PUMP: There will be a slight fluctuation of the fuel gauge needle when the engine is running, corresponding to the fuel pump strokes. The operator will become familiar with the action of the gauge and therefore will be able to note a change in the speed of these fluctuations. If one pump cuts out the needle will move only half as many times per minute as if the two pumps were working.

A further check to determine if both pumps are functioning is to remove the caps from the stems of the suction valves. The stems should be rising and falling with each stroke. Do not leave these caps off too long, as there will be an excessive fuel leak down the flat side of the valve stem.

If a pump cuts out, first try bleeding the air from the pump head while the engine is running. If this fails, the discharge fitting should be removed and the valves inspected.

20. AIR BLEEDING: Whenever the high-pressure pump assembly has been drained of fuel, it is necessary to bleed the air from the system before the pump will function properly. Open the bleeder valves on the pump heads and work the priming-pump handle until solid fuel (fuel without air bubbles) escapes from these valves. Next open the fitting on the 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 system. During this procedure, all isolating valves should be closed.

SECTION 17
SPRAY VALVES
AND OPERATING MECHANISM

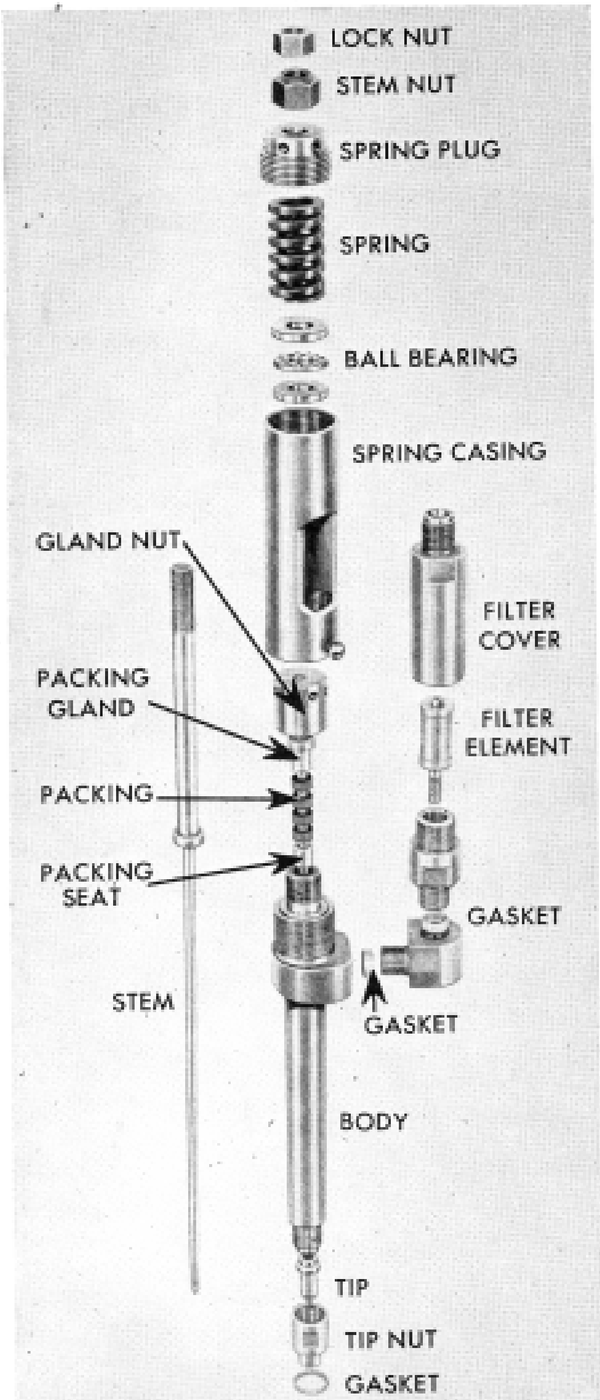


FIGURE 17-1

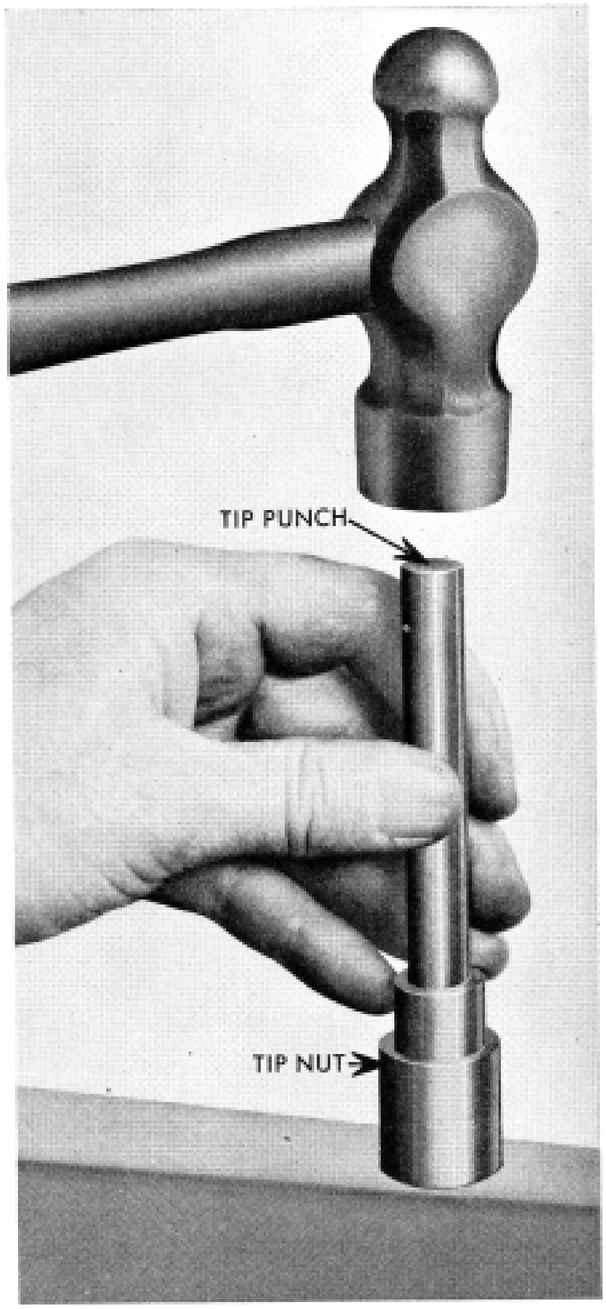


FIGURE 17-2

1. DISASSEMBLY OF SPRAY VALVES: Remove parts in the order as shown in Figure 17-1. When removing the tip from the tip nut

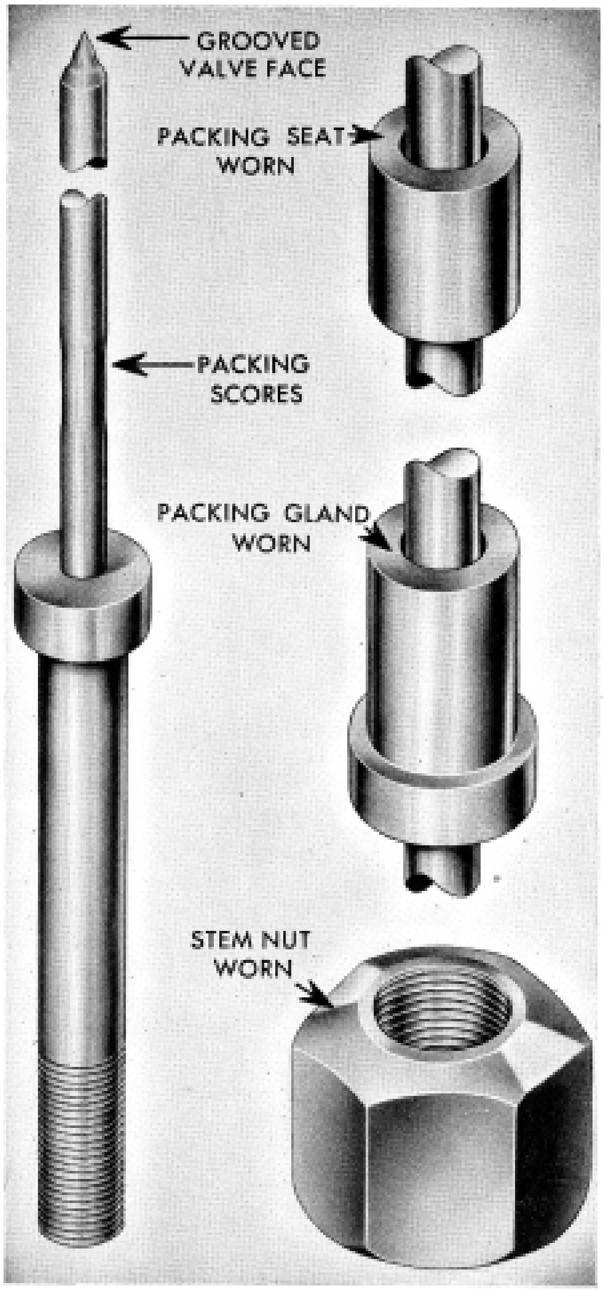


FIGURE 17-3

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.

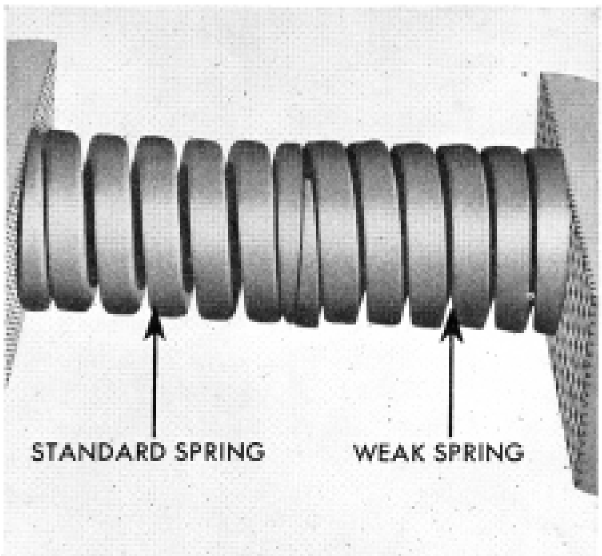


FIGURE 17-4

4. TESTING SPRAY-VALVE TIPS: If the tips are marked 5-8-30, this means that there are five holes of 0.008 inch diameter at 30 degrees angle. These hole sizes are very important as a tip with holes worn 0.001 inch oversize will deliver approximately one-eighth more fuel each time the valve opens.

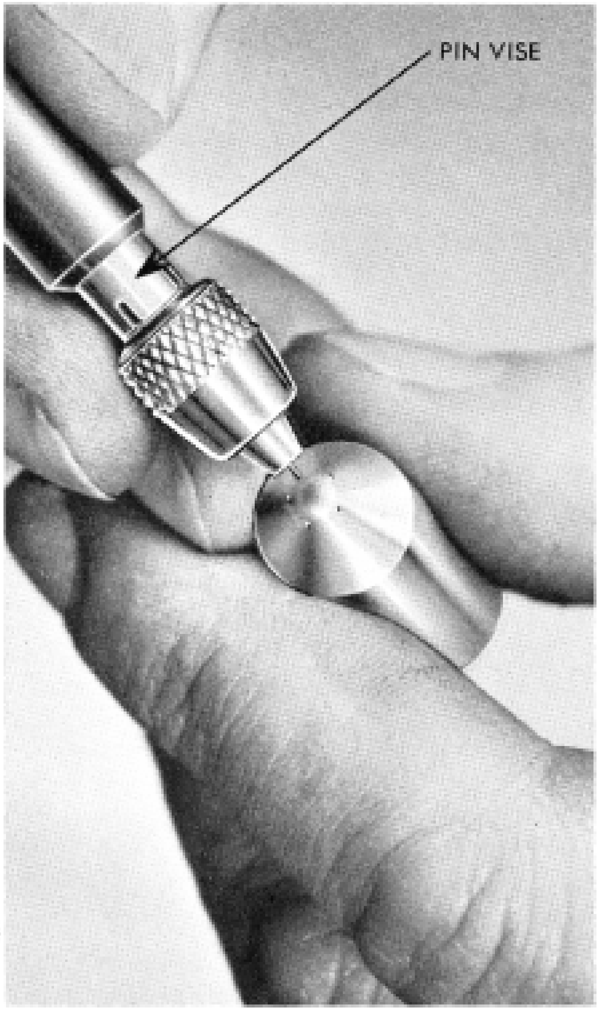


FIGURE 17-5

Insert 0.008 inch wire in a pin vise and clean out all the holes thoroughly as shown in Figure 17-5. Change the wire to 0.009 inch and WITHOUT FORCING try all the holes again. If the 0.009 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

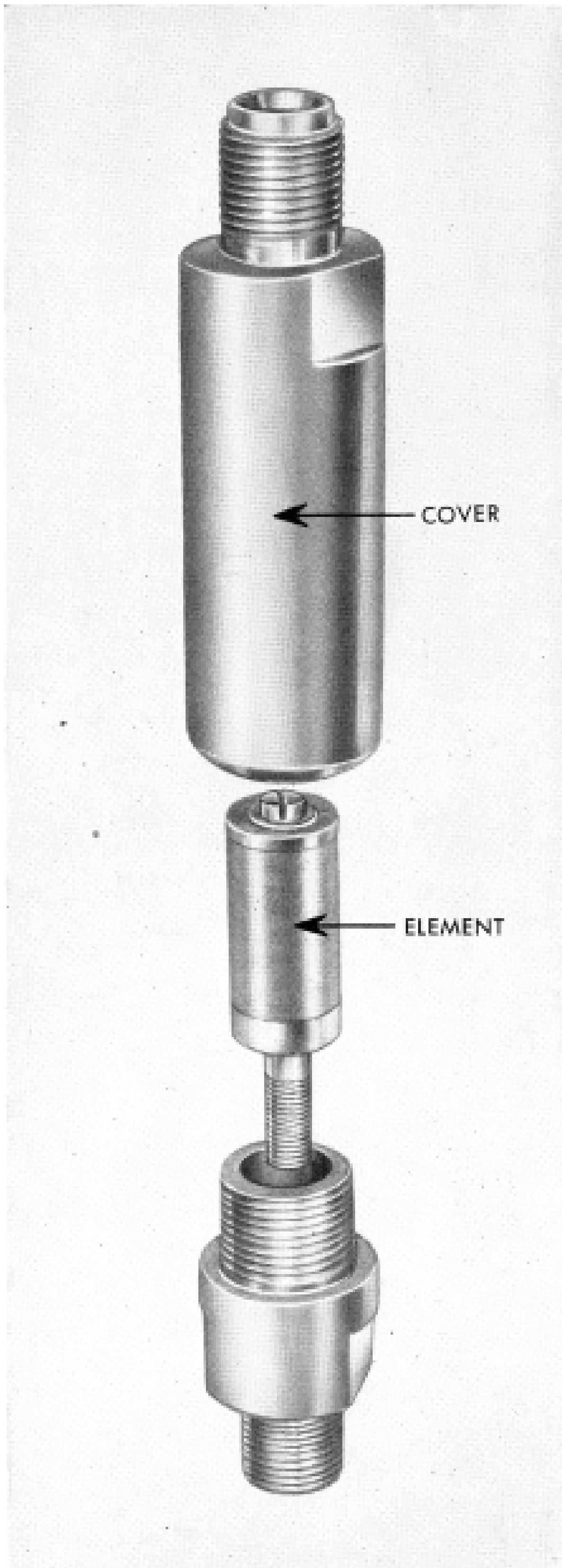


FIGURE 17-6

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

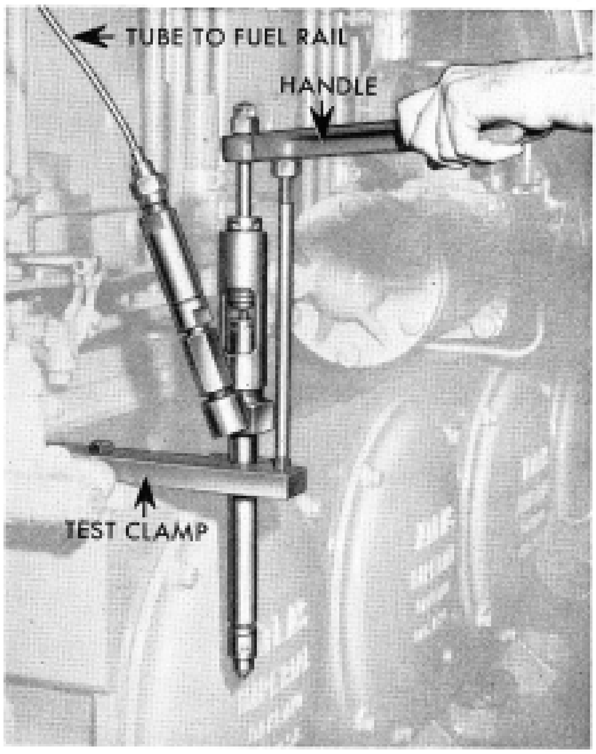


FIGURE 17-7

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 1/16 of an inch. This means that the spring is 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 NOR 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.

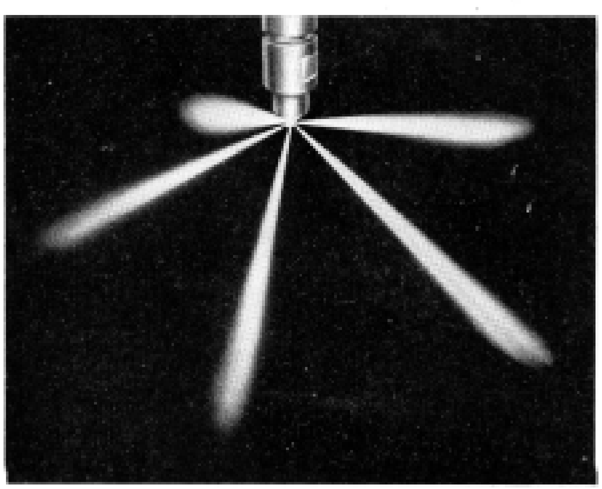


FIGURE 17-9

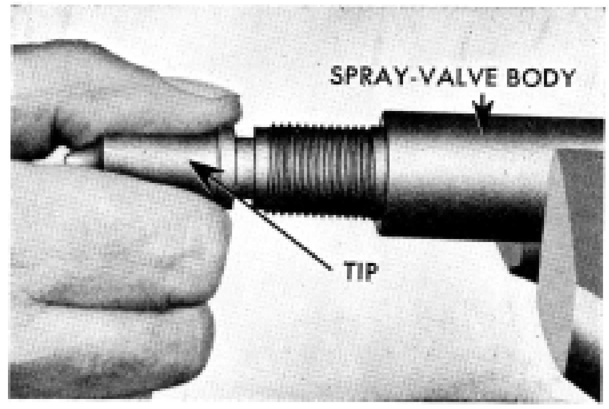


FIGURE 17-10

7. 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

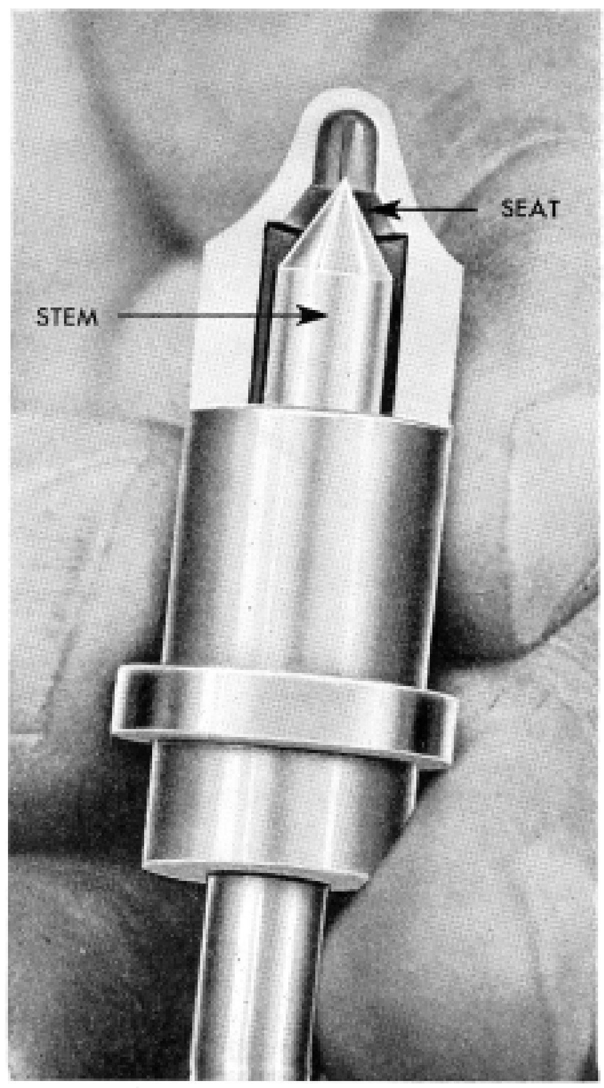


FIGURE 17-11

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 $\frac{1}{32}$ 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.

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 crank pit door and examine the roller on the lower end of the lifter. If either the roller or the pin is flat or damaged as shown in Figure 17-13 repairs should be made as follows:

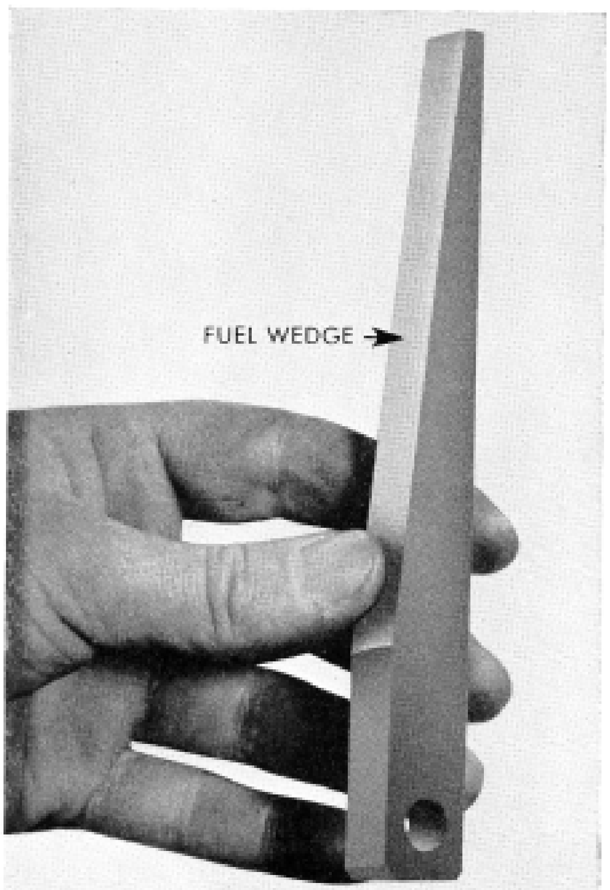


FIGURE 17-12

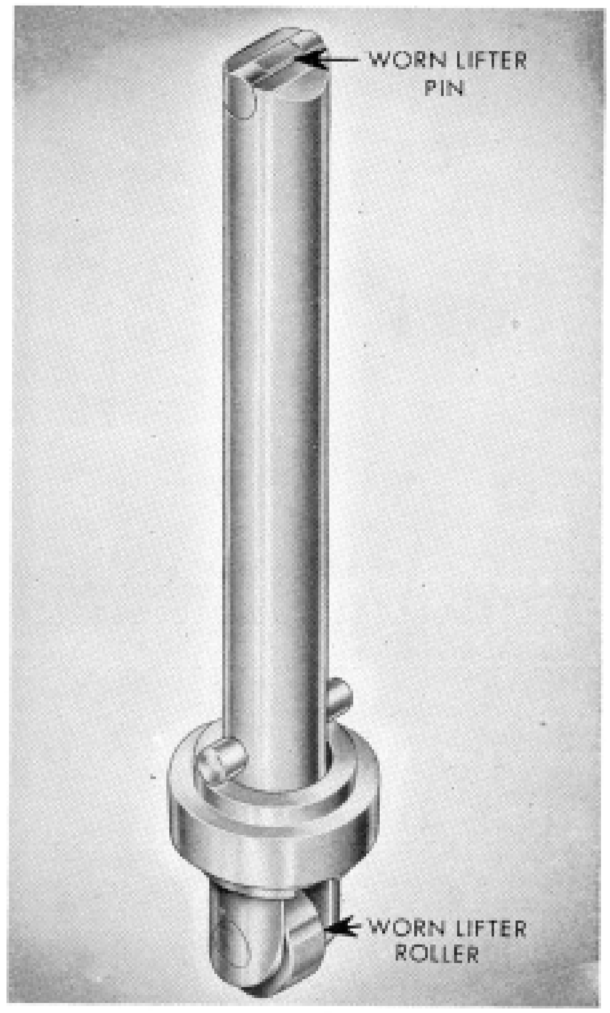


FIGURE 17-13

Remove all the wedge shaft bearing nuts, (letter "B" shown in Figure 17-14). After all wedges have been taken out and the governor disconnected, lift off the wedge shaft. Remove the two cap screws which hold down the spray-valve lifter guide. The lifter guide will pry up to remove but be sure and hold the lifter so that it does not fall into the base and damage the oil lines.

If the lifter pin is worn, grip the lifter in a vise and drive out the pin. Turn it so that the flat spot is not exposed and drive it in again and rivet over the edge of the hole so that the pin cannot come out.

To remove the lifter 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 them about 1/32 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 SIDE of the lifter body. Remove the shim and smooth the ends of the pin with a file.

11. 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 dull ones are all worn down equally. It is a good rule to replace all cam lobes rather than one or two.

12. REPLACEMENT OF FUEL CAM LOBE: Cut and remove the locking wire shown in Figure 17-15. Cut and remove the locking wire from the cam cluster locating set screw shown in Figure 17-16. Shift the camshaft aft, which is the ahead running position, and force the fuel cam cluster forward. Remove the 3/8 inch cap screw and pry out the astern cam lobe. It will be necessary to remove the two 1/2 inch cap screws which hold this cluster together so that the fuel cam disc and the exhaust cam may be separated. The special nut, on the end of the 3/8 inch cap screw, and the ahead fuel cam lobe can be removed.

Insert the new lobes and the special nut. Screw in the 3/8 inch cap screw but do not tighten. Assemble the cluster and tighten the two 1/2 inch cap screws well. Move the cluster into place and tighten and lock the locating set screw.

Using a two or three pound hammer and a bronze or brass drift, drive each lobe down well into its slot and tighten the 3/8 inch cap screw, but DO NOT USE OVER A SIX INCH CRESCENT WRENCH. Use new lock wire to secure the cap screws.

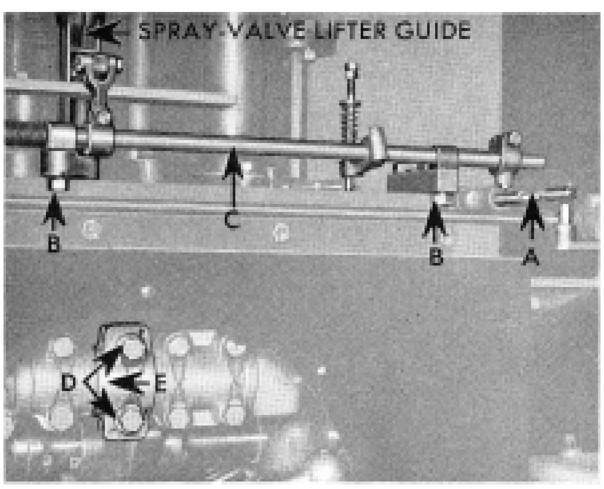


FIGURE 17-14

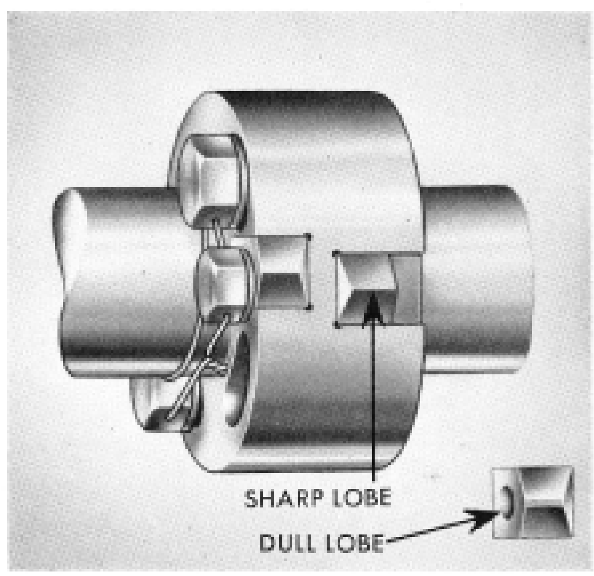


FIGURE 17-15

13. 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.

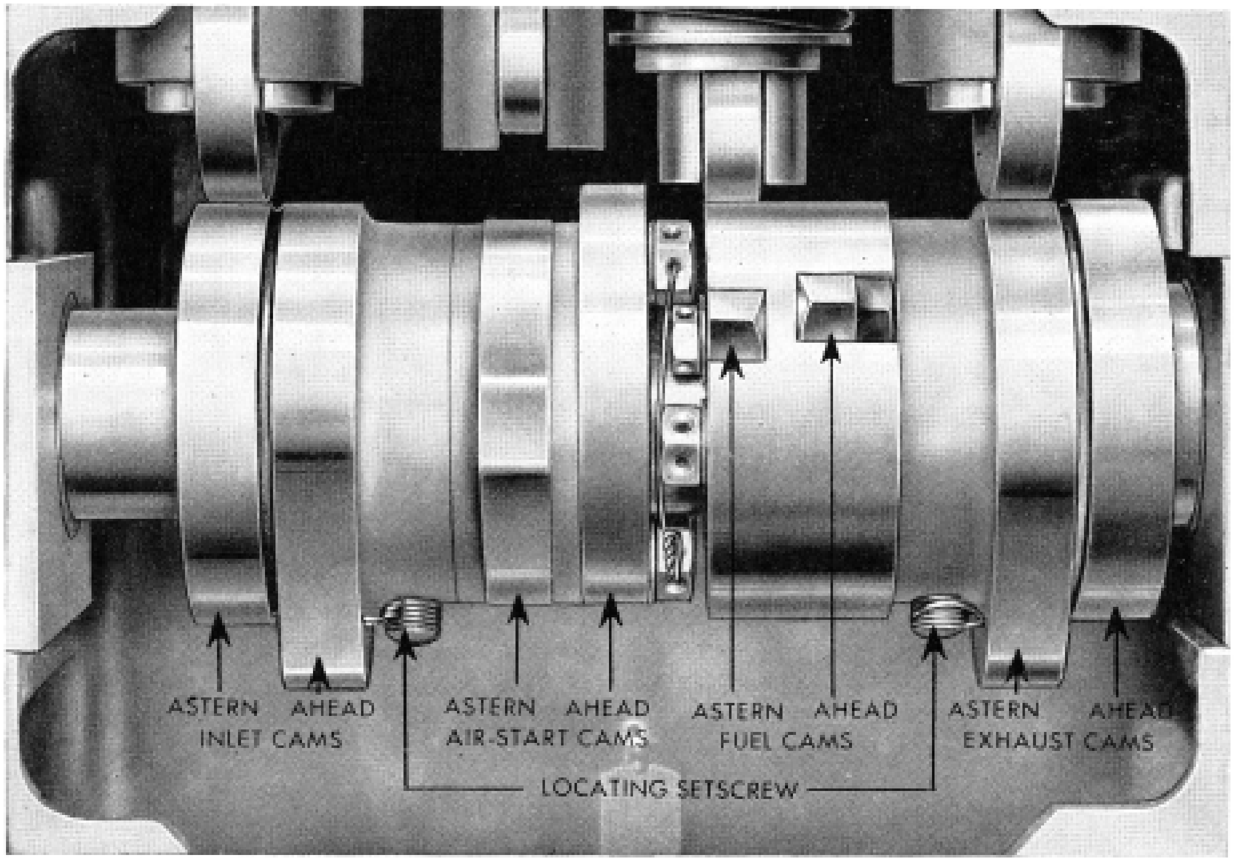


FIGURE 17-16

SECTION 18
CONTROLS

1. CONTROL GROUP: The control group consists of the following parts which are covered in this section. Control Unit, Paragraph 2. Master Valve, Paragraph 8. Camshaft Shifting Device, Paragraph 3. Fuel Cut-out, Paragraph 10. Cut-out Release, Paragraph 11. Brake and Rocker Ram Pilot Valve, Paragraph 4. Master Valve Pilot Valves, Paragraph 9. Flywheel Brake, Paragraph 5. Governor, Paragraph 12. Rocker Shaft Ram, Paragraph 6.

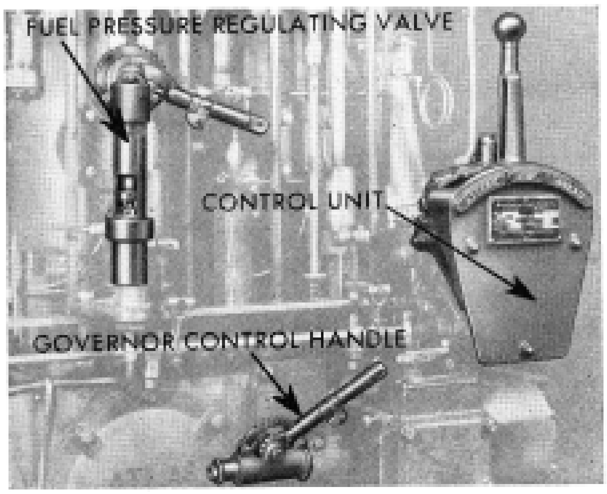


FIGURE 18-1

2. THE CONTROL STAND: Figure 18-1 shows the controls located at the forward end of the engine. There, also, are the pressure regulator and the governor control handle. The control unit shifts the camshaft from ahead to astern, operates the flywheel brake and valve rocker shaft ram, operates the vent valves which control the master air valve on the air starting manifold, and also withdraws the fuel wedges and releases the fuel cut-out mechanism.

3. CAMSHAFT SHIFTING MECHANISM: The actual shifting of the camshaft from ahead to astern requires only one-half of the total movement of the control lever shown in Figure 18-2. This permits the control lever to be moved from the running position to the stop position without moving the camshaft and is accomplished by the use of the slotted link shown in Figure 18-2. The adjustment of this link should not be tampered with except when replacement of these parts in the field makes such adjustment necessary.

When the control lever is placed in the run ahead position the camshaft is moved aft and the clearance between the shifter collar and the camshaft bearing should not be less than 0.025 inch. When the control lever is moved to the run astern position the camshaft is ahead and the clearance between the cam gear hub and camshaft bearing should not be less than 0.025 inch. These clearances will not require attention during normal operation but renewal of related parts could change the linkage so that adjustment would be necessary. As this would only occur during a major overhaul we suggest that such adjustments be made at a service depot.

4. ROCKER SHAFT RAM AND FLYWHEEL BRAKE PILOT VALVE: The pilot valve shown in Figure 18-3 controls both the valve rocker shaft ram and the flywheel brake, as these two auxiliaries operate together. When the control lever is moved to the stop position the flywheel brake is applied and the valve rocker shafts are turned, thereby raising the inlet and exhaust valve lifters clear of the cams in preparation for a shift of the camshaft.

This pilot valve, Figure 18-3, is mounted on the control bracket or stand, and is actuated by a cam which moves with the control lever. Full air pressure from the storage tanks is constantly on the head of this valve which keeps it closed when the control handle, and also the cam lobe, is in either of the running positions. As the control handle is moved into the stop position, this valve is opened and admits air into the lower chamber of the valve body. This lower chamber is connected directly to both the flywheel brake and the valve

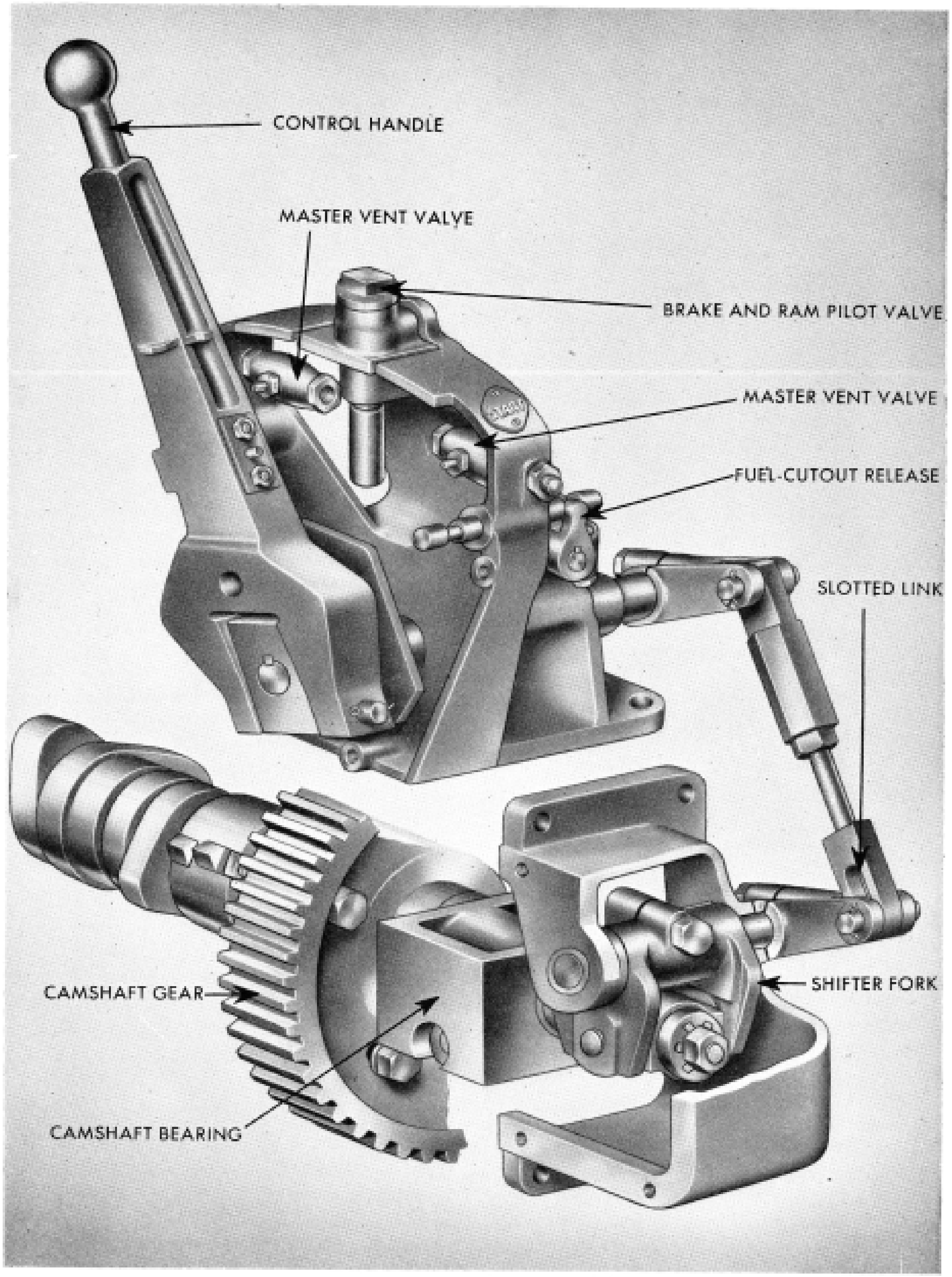

CONTROL HANDLE
MASTER VENT VALVE
BRAKE AND RAM PILOT VALVE
MASTER VENT VALVE
FUEL-CUTOUT RELEASE
SLOTTED LINK
SHIFTER FORK
CAMSHAFT GEAR
CAMSHAFT BEARING

FIGURE 18-2

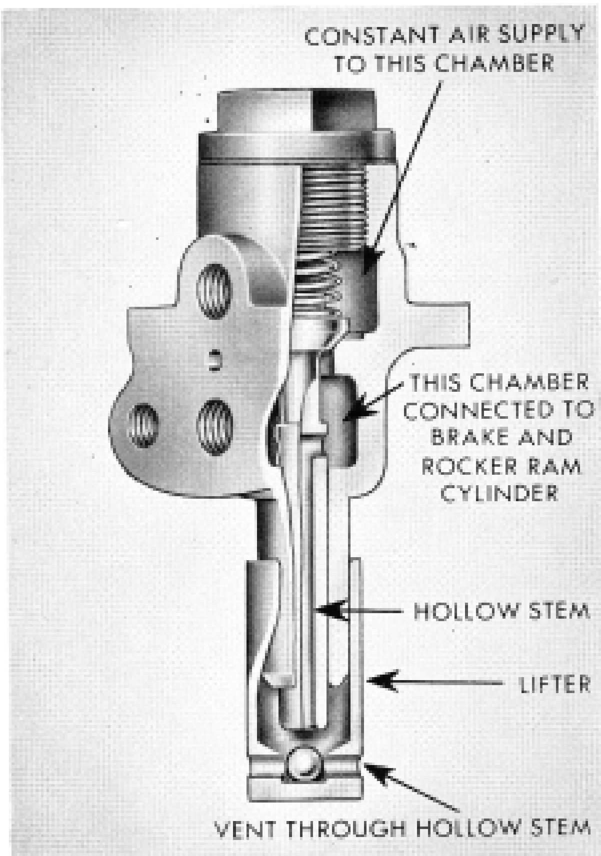


FIGURE 18-3

rocker shaft ram, and as air is admitted both units are operated. This valve is open when the control lever is between the (X) marks, Figure 18-4.

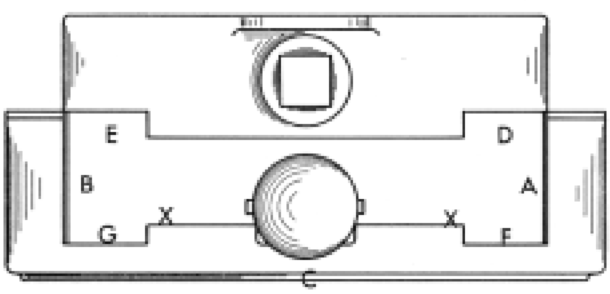


FIGURE 18-4

As the control lever is moved from the stop position into either of the running positions the valve is closed, thus shutting off the air supply to the lower chamber of the valve body, the brake cylinder, and rocker shaft ram. These units and air lines still retain pressure, and in order to return them to normal running position the air lines must be vented or opened to the atmosphere. This is accomplished through a hollow valve stem, Figure 18-3, which opens into the lower chamber of the valve body, and is sealed at the bottom by a ball. When the valve is open and admitting air to the brake and ram this ball is held tight against the bottom of the valve stem by the valve lifter, thereby preventing the air from escaping at this point. When the control lever is moved into either run position the lifter is lowered, first closing the valve and then opening the hollow valve by allowing the ball to drop away from the valve stem, thus permitting the venting or escaping of air from the lower valve chamber down through the hollow valve stem and to the atmosphere through holes in the valve lifter.

If leaking, the valve may be ground with fine valve grinding compound and care should be taken to have all parts thoroughly cleaned before assembly. This valve and its operating mechanism are positioned during manufacture so that no further adjustments are necessary.

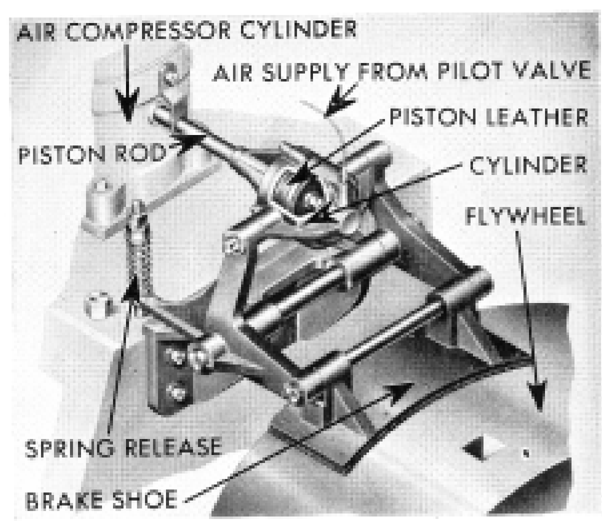


FIGURE 18-5

5. FLYWHEEL BRAKE: This brake is shown in Figure 18-5 and consists of an air cylinder mounted in a rocker arrangement which in turn is supported by a bracket bolted to the centerframe. The piston rod extends out past the air cylinder and contacts the air compressor cylinder, thus making the piston stationary. Therefore, when air is admitted to the cylinder, the cylinder itself moves away from the stationary piston, and through the rocker arrangement, forces the brake shoe against the flywheel rim.

When the air supply is cut off and the air line vented, a spring forces the air cylinder, rocker and brake shoe back to their normal position. The piston cup-leather should be renewed if it becomes cracked or scored, and the various bearings of the rocker and bracket should be kept well lubricated. The brake lining should be renewed if it becomes glazed or badly worn.

Do not allow water, oil or grease to collect on the flywheel rim, as the efficiency of the brake will be greatly impaired and slow maneuvering will result.

6. ROCKER SHAFT RAM: The various parts of the ram are shown in Figure 18-6. The two piston seals require renewing if they get scored or cracked. They are made of synthetic rubber and should always be installed with the cups pointing to their respective ends of the cylinder. Air is prevented from escaping around the piston rod by a synthetic rubber air seal which should be renewed whenever excessive leakage occurs. The gland which holds this seal in place is provided with an oil hole which should be attended to as outlined in Section 6.

The length of the piston stroke is controlled by the piston being stopped at the cylinder head, the total stroke being $6\frac{5}{8}$ inches. The position of the rocker shaft relative to the ram piston can be adjusted by screwing the fork up or down on the piston rod. This fork should be adjusted so that when the ram piston is at the bottom of the stroke the valve rocker shaft connecting forks are pointing straight up.

At the bottom of the ram cylinder there is a spring loaded pawl which engages a notch in the piston. This pawl acts as a safeguard to lock the ram piston in the running position in case the air is turned off while the engine is operating.

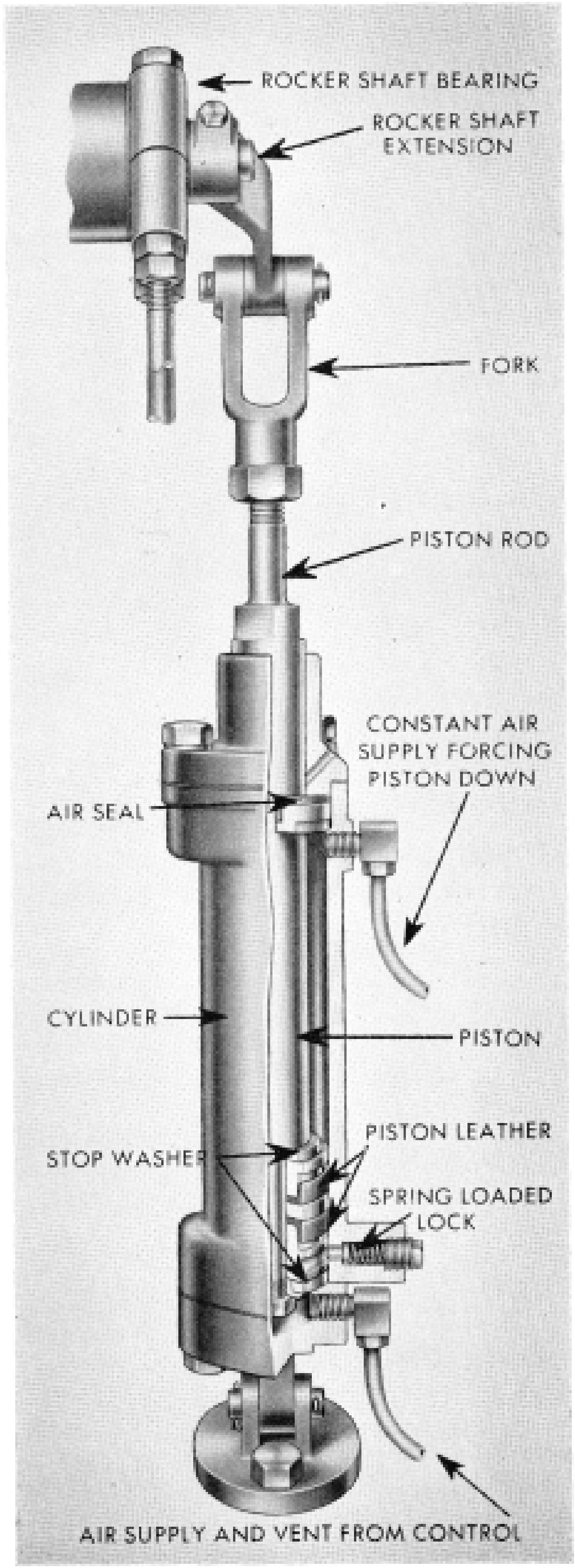


FIGURE 18-6

7. AVOID ABUSES OF THE CONTROL MECHANISM: Assume that the engine is operating in the ahead position and an immediate reverse is required. The control lever is moved to the stop position. As it passes the (X) mark, Figure 18-4, the pilot valve controlling the rocker shaft ram is opened. As soon as the lever leaves the stop position on the way to the reverse position the camshaft starts to shift. If sufficient time has not been given for the rocker shaft ram to complete its stroke the valve lifters will not be raised, therefore it is possible for the side of the cam lobes to be forced against the lifter rollers, causing damage.

This is one of the reasons why the operator must wait in the stop position until the rocker shaft ram has completed its stroke and the engine has stopped turning. The balance of the maneuver can then be made with safety. Experience will indicate the length of this slight pause and in some installations it may be possible to move the lever directly from one running position to the other, providing this is done slowly.

8. MASTER VALVE: This valve, Figure 18-7, is described in Paragraph 24 of Section 5. It controls the supply of air between the storage tanks and the air starting manifold. There are no adjustments but the valve should be taken apart during overhaul and thoroughly cleaned. The valve face and seat may be ground with fine grinding compound if necessary. When the valve is dismantled it will be found that there are two piston rings on the valve piston. These should be checked for clearance both in the cylinder and the ring lands. The piston, piston rings and cylinder should be well cleaned, as moisture in the air will cause corrosion and rust. Care should be taken to see that all parts are well cleaned before assembly.

9. MASTER VALVE VENT VALVES: These two valves, mounted on the control bracket, simply vent the chamber above the piston of the master air valve on the air starting manifold, and are described in Paragraph 24 of Section 5. They are located at either side of the control unit and operate by the movement of the control lever into either (E) or (D), Figure 18-4. They can be ground with fine grinding compound if necessary but should require little attention if the air system is kept clean and free from dirt particles.

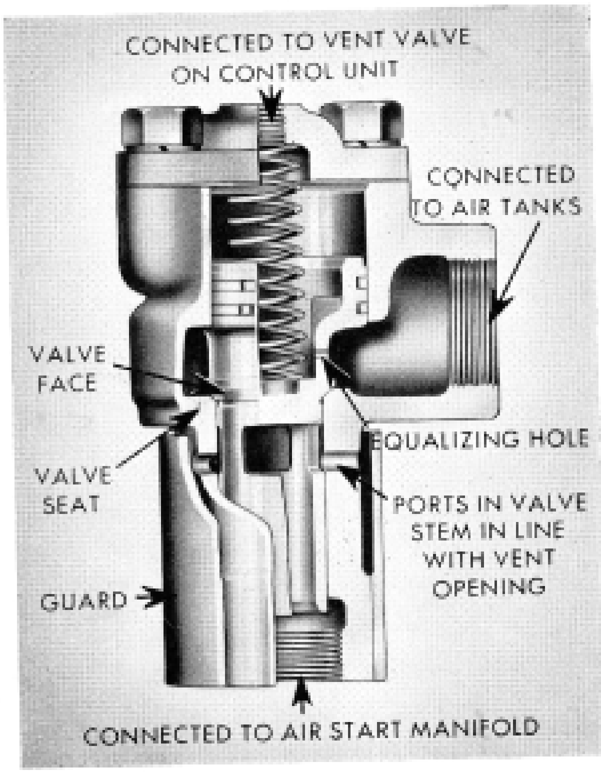


FIGURE 18-7

10. FUEL CUT-OUT MECHANISM: This device, shown in Figure 18-8, takes the control of the fuel wedge shaft away from the governor whenever the control lever is moved out of either run position. The lever (A) is raised by the cam (B). This action when transmitted through the forked rod (C) to the slotted arm (D), and being fixed to the wedge shaft withdraws the wedges by turning the wedge shaft a part of a turn. In normal run position forked rod (C) is not in contact with arm (D) and thus permits the wedge shaft to be turned by the governor independent of the fuel cut-out.

The adjustment of the double nuts on rod (C) should be such that the wedges are withdrawn sufficiently to stop the engine and yet leave some clearance between the nuts and the face of slotted arm (D) when the wedges are full in (full speed).

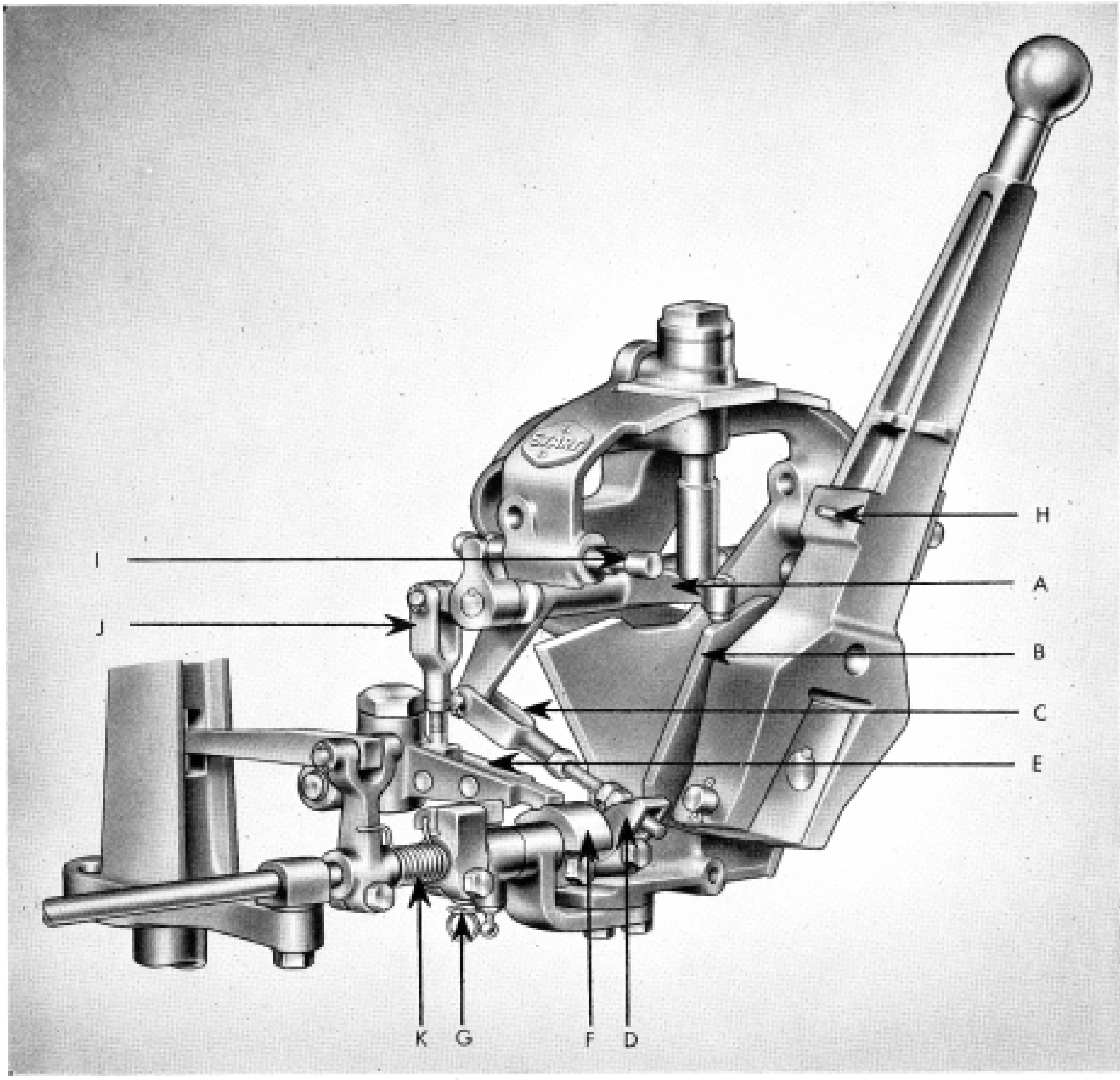


FIGURE 18-8

When the control lever is moved out of either run position and the wedge shaft is turned, withdrawing the fuel wedges, the latch (E) which normally rides on the surface of the hold-out collar (F) is pulled down into the notch in the hold-out collar by the spring (G). In this manner the wedge shaft is positively held out until the engine is started again.

11. FUEL CUT-OUT RELEASE MECHANISM: When the engine is being started the control lever is moved to either end of the slot in the control panel. During this movement the spring loaded pawl (H), Figure 18-8, goes up against the pin (I). When the control lever is pressed in towards the engine, to open the master air valve, the pawl (H) drops into the groove in pin (I). As soon as the engine has gained starting momentum on air, the control lever is moved out of the starting position and into the run position. This motion withdraws pin (I) which in turn releases the latch (E) through the fork rod (J). The spring (K) now turns the wedge shaft into the full speed position and the latch again rides on the surface of the hold-out collar. The fork rod (J) should be adjusted so that when the latch (E) is engaged in the hold-out collar, pin (I) will be in such a position that the pawl (H) in the control lever goes up

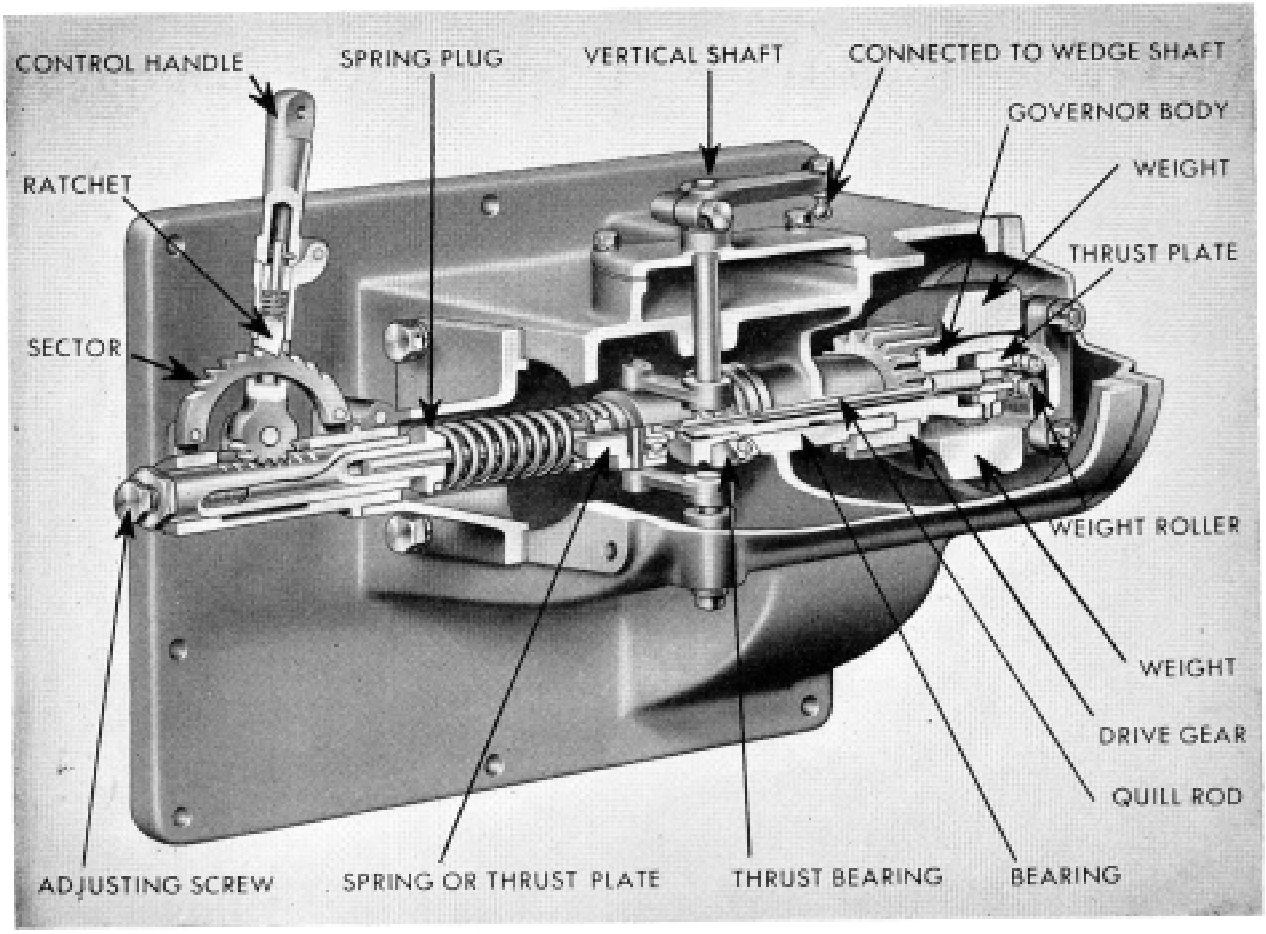


FIGURE 18-9

against the full diameter at the end of the pin (I) when the control lever is moved to either end of the slot (positions A or B, Figure 18-4). Then when the control lever is moved into the start position (D) or (E), Figure 18-4, the pawl (H) must snap into the groove in pin (I) so that this pin will be withdrawn far enough to release the latch from the hold-out collar as the control lever is moved from the start to the run position (positions F or G, Figure 18-4).

12. GOVERNOR: The governor, Figure 18-9, is mounted on the centerframe near the forward end, and is driven by the camshaft gear.

The governor weights are equipped with rollers which bear against a thrust plate in the center of the governor body. As the governor revolves, centrifugal force tends to throw the weights outward, thus creating pressure against this thrust plate which is free to slide in the body, but is keyed so that it turns with the body. The force created by the weights against the plate is transmitted through a quill to a roller type thrust bearing mounted in a cage which bears against the governor spring, and by a pin through the cage, actuates a fork on the vertical shaft which, in turn, connects to and controls the fuel wedge shaft.

The engine speed is governed by the tension of the governor spring and can be regulated by the control handle to give various speeds from idle to full. The governor action is to reduce engine speed by pulling the fuel wedges out, so therefore, the more tension on the spring the harder it is for the weights to fly out and reduce the speed. Tension on the governor spring can also be regulated by means of the adjusting screw, and should be set to give the proper engine R.P.M. as indicated on the name plate. This adjustment should be made with the control handle in the last notch. The engine should then idle at the proper speed when the control handle is in the first notch. Another thrust bearing is used to take the thrust of the governor body, and is retained by an adjustable collar. This collar should be adjusted to give 0.008 "to 0.010" clearance between the bearing and collar.

If the governor has a tendency to "hunt," that is a constant increasing and decreasing of engine speed, the cause may be found in one or more of the following places:

A. Governor weight rollers may be tight or have a flat spot which will tend to restrict the movement of the weight. If rollers appear to have flat spots they should be replaced.

B. Fuel wedge shaft and connecting linkage may be binding or there may be a misaligned bearing on the governor vertical shaft or wedge shaft. It is very important that these parts be kept free and not allowed to bind.

C. The torsional spring on the fuel wedge shaft may be weak or poorly adjusted.

D. The buffer springs on the fuel spray valve pushrod may not be adjusted evenly. One of these springs adjusted too tight will have too much dampening effect and will tend to throw the wedge out each time the lifter raises the pushrod.

E. The engine may not be balanced properly, causing the governor to be overworked in trying to smooth out the variation due to one or two overloaded cylinders.

When replacing parts or re-assembling, always make sure that 0.004 "to 0.005" backlash is allowed between the governor and camshaft gears. This can be done by shifting the governor housing on the centerframe and then redoweling.

SECTION 19

CAMSHAFT AND CAMS

1. CAMSHAFT: The camshaft, which is made of two-inch ground steel shafting, rotates in bronze bushed bearings which are supported in the centerframe between each pair of cylinders. Some of these bearings are lubricated by the pressure oil system while others are oiled by reservoirs which catch some of the oil thrown off by the connecting-rod bearings. The camshaft bearings are machined cast iron blocks which are a driving fit into recesses cut in the webs of the centerframe. These blocks are secured in the centerframe by a long cap screw. There are renewable bronze bushings pressed into the blocks which form the bearing area for the camshaft. These bushings are reamed after being pressed in to give a running clearance of from 0.006 to 0.007 inch.

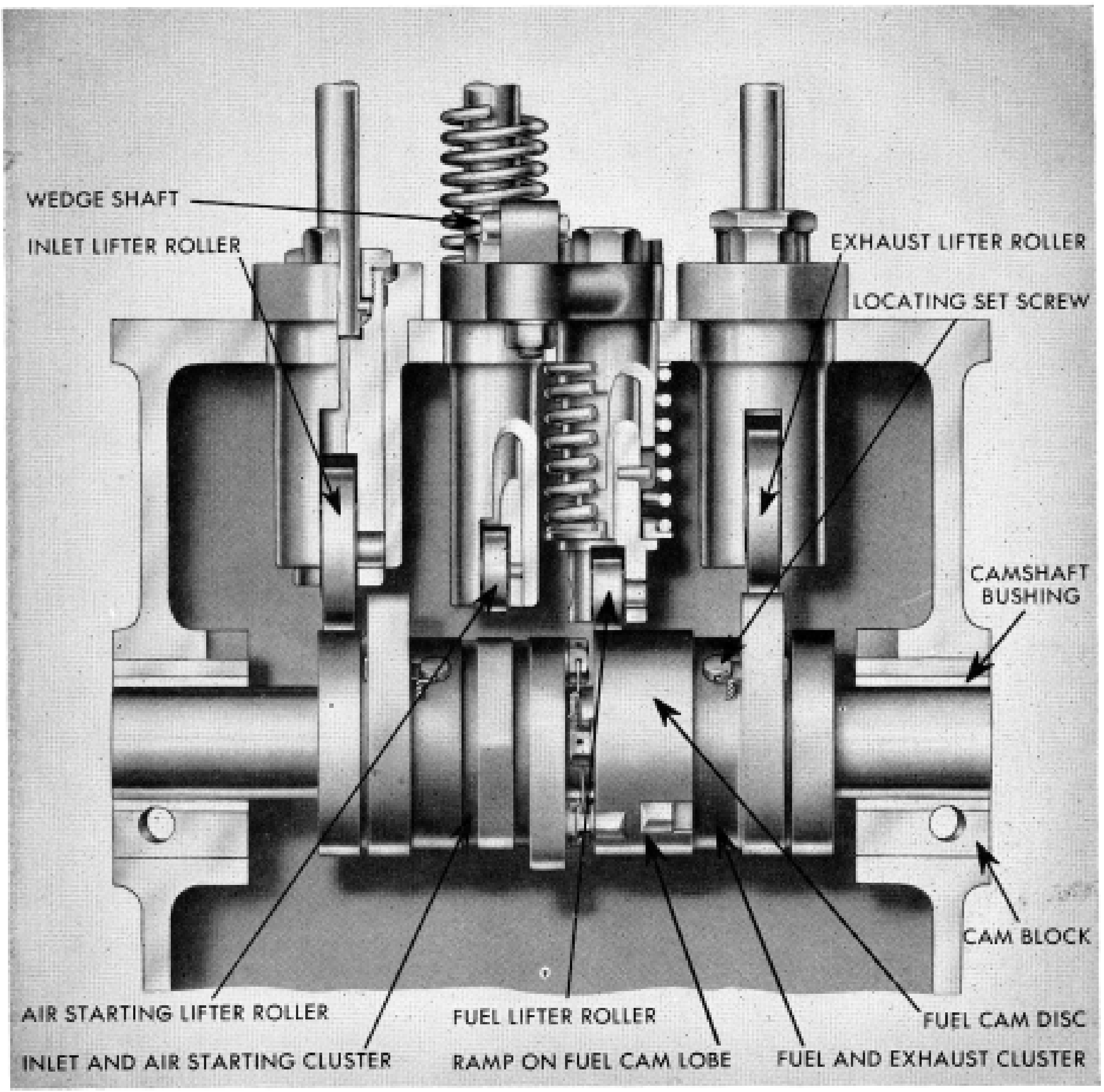


FIGURE 19-1

CAUTION: New bushings must have the oil holes drilled in them after they are pressed in and these holes must lead into the longitudinal oil grooves which are cut in the bearing area. This means that the oil grooves must be lined up with the oil holes in the cast iron block before the bushing is pressed in.

SERVICE NOTE: The renewal of camshaft bearings or the replacement of any cams requires the removal and stripping of the camshaft. This is work which should be undertaken only at a service depot where skilled mechanics and the necessary equipment are available. Later on in this section we give detailed instructions to anyone doing this work.

2. CAMS: The case-hardened steel cams for each cylinder are grouped in two clusters, the exhaust and fuel cams forming one group and the inlet and air-start cams the other. The cams are a tight sliding fit on the camshaft and are driven by keys which position them for the correct firing sequence. The hub of each cluster is drilled and tapped for a set screw which engages a groove cut in the camshaft, locating the cluster in a fore and aft direction. These set screws are locked by threading locking wire through each set screw and through holes drilled in the adjacent cam lobe. A special set screw wrench is supplied with the engine.

Each cam cluster is held together by two cap screws which are threaded into the outside cam of each cluster, see Figure 19-1. The heads of these cap screws are drilled and should always be locked with wire.

3. FUEL CAMS: The fuel cam consists of a case-hardened steel disc which has a slot milled in each side. The renewable fuel cam lobes, one for each rotation, fit into these slots and are secured by a cap screw and a special square nut. There is a chamfer or ramp on one side of each lobe which permits the fuel lifter roller to slide up on the cam lobe when the camshaft is shifted. The fuel-cam lobes are assembled for each cylinder, with the ramps toward each other.

To remove the fuel-cam lobes, loosen the exhaust-cam set screw and slide that cluster along the camshaft as far as possible. The cap screw which clamps the lobes in place can now be removed and the lobes withdrawn. On some engines it may be necessary to separate the exhaust- and fuel-cam discs in order to get the special nut on the end of the cap screw out of the slot in the cam disc.

The holes in the fuel-cam disc for the attaching cap screws are slotted to permit close adjustment of the fuel cam as outlined in Section 10, Paragraph 22.

4. CAMSHAFT DRIVE GEAR: The drive gear hub, at the forward end, is fastened to the camshaft in the same manner as the cam clusters. It is driven by a key and is located fore and aft by a set screw which engages a groove cut in the camshaft. The drive gear mounts on a flange and spigot on the hub. The holes in the gear, for the attaching cap screws, are slotted to permit close adjustment of the camshaft as outlined in Paragraph 18 of this section.

5. FUEL-PUMP ECCENTRICS AND LUBE-PUMP DRIVE GEAR: The after high-pressure fuel-pump eccentric is pressed onto the camshaft and is driven by a key. The lube-pump gear and the forward fuel eccentric are capscrewed to the after eccentric.

6. BILGE-PUMP ECCENTRIC: The after camshaft bearing is enlarged to accommodate a sleeve which is a sliding fit on the camshaft and is driven by two keys which act as splines. Onto this sleeve is pressed the eccentric which drives the bilge pump. This set-up permits the bilge-pump eccentric to remain in the same fore and aft position while the camshaft is shifted during engine maneuvers.

7. RENEWAL OF LIFTER ROLLERS: The lifter rollers may be replaced if necessary by removing the lifter. The roller pin is a light press fit in the lifter and can be driven out with a small bronze drift. When the new roller and pin have been installed, burr the top and bottom of the pin hole, in the lifter, slightly to prevent the pin from coming out. Try the lifter in the guide to assure its being free. It may be necessary to file the holes to obtain running clearance between the lifter and the guide, which should be from 0.002 to 0.003 inch.

8. REMOVAL AND STRIPPING OF CAMSHAFT: The following paragraphs are instructions for the removal, disassembly, assembly, and installation of the camshaft.

9. RIGHT- AND LEFT-HAND ENGINES: The cams are assembled on the camshaft in four different arrangements, depending upon the hand and direction of rotation of the engine. NOTE: In twin screw installations the **right-hand** engine is on the **port side** of the vessel and the **left-hand** engine is on the **starboard side.** In single screw installations a right-hand engine is used.

10. CAM LAYOUT: The direction of rotation of the engine is determined by the hand of the propeller that it is driving. Standard rotation for Atlas engines is inboard, that is, the tops of the flywheels of both engines turn in toward the center of the vessel, but in special cases outboard rotation is used. The correct cam assembly for any given engine, regardless of hand of the engine or direction of rotation, may be determined from the following:

(a) On right-hand engines the exhaust- and fuel-cam group is forward on the shaft and the inlet- and air-start group is aft.

(b) On left-hand engines the inlet- and air-start cam group is forward and the exhaust-fuel group is aft.

(c) On all engines the fuel- and air-start cams are adjacent to the cylinder center lines.

(d) On all engines the ahead cams of each pair are forward and the astern cams are aft.

(e) The camshaft rotates in the same direction as the crankshaft.

(f) As the camshaft rotates, the lobe of the exhaust cam for that rotation leads the keyway and the lobe of the inlet cam trails the keyway.

(g) The lobe of the air-start cam and the lobe of the fuel cam are on the same side of the shaft with respect to the keyway as the lobe of the exhaust cam.

11. CAMSHAFT REMOVAL:

(a) Remove centerframe covers, including housings for rotary-pump drive and governor drive.

(b) Remove bilge-pump connecting-rod cap and block up high-pressure fuel-pump lifters.

(c) Remove camshaft-shifter linkage and housing.

(d) Remove pushrods and valve lifters. (Lifters and guides may be left in place if lifters are raised clear of cams and clamped in place.)

(e) Remove camshaft-bearing retaining screws.

(f) Loosen the cylinder retaining nuts on the camshaft side of the engine. (The cylinder retaining studs tend to clamp the camshaft bearings in the centerframe.)

(g) 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.

12. CAMSHAFT DISASSEMBLY: After the camshaft has been removed from the engine the cam set screws and clamp bolts are loosened and the drive gear, cams, and bearings may then be successively removed from the forward end. The cams are a light tap fit on the shaft and should slide freely, but if it should be necessary to drive them off, only a babbitt hammer or brass drift should be used. Any burrs on the shaft, particularly at the keyways, must be carefully dressed down with a file. If this precaution is not taken the cams may seize as they are removed; forcing them the remainder of the distance will score the shaft.

13. CAMSHAFT ASSEMBLY AND INSTALLATION: When the camshaft is being re-assembled 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 in the reverse order of their removal, and all clamp bolts and set screws secured and wired.

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 engine should next be timed, in accordance with the detailed instructions in Paragraphs 18, 19, and 20, after which the rotary pump and governor assemblies may be replaced.

14. VALVE OPENING AND CLOSING: The correct valve timing for the engine is given in the following table.

- Air-start valve
  - Opens 4 degrees before top center
  - Closes 40 degrees before bottom center
- Inlet valve
  - Opens 5 degrees before top center
  - Closes 35 degrees after bottom center
- Exhaust valve
  - Opens 35 degrees before bottom center
  - Closes 5 degrees after top center
- Fuel-spray valve
  - Opens—See engine nameplate
  - Closes—See engine nameplate

15. SPOTTING THE PISTON: Before proceeding with the discussion on valve timing, the following instructions regarding the correct method of spotting a piston should be considered. Whenever a piston is to be spotted for valve setting, it should be brought into position by turning the engine in the direction of rotation for the valve being timed. If the engine is turned past the desired position, it should be turned well back in the opposite direction, and then again brought up to the required point. This is necessary in order to take up all gear backlash.

16. FLYWHEEL MARKINGS: The position of the piston may be determined from the flywheel pointer and the markings stamped on the flywheel rim. Top center for each piston is marked and stamped with the corresponding piston numbers, and degree marks are stamped on each side of top center.

17. POINTER LOCATION: The location of the flywheel pointer should be checked occasionally by "splitting the center." With one of the cylinder heads removed, crank the engine to a point about 20 degrees off top center. Measure the exact distance from the top of the cylinder 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 cylinder 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.

18. CAMSHAFT TIMING: In order to time the engine it is necessary to first establish the correct relation between the crankshaft and the camshaft and then to adjust the pushrods to open and close the valves at the correct points. The camshaft-crankshaft relation is determined by the mesh of the gear train and by the position of the camshaft gear on its hub.

If the engine is to be re-assembled with the original crankshaft gear, camshaft gear and hub, the camshaft can be correctly timed after an overhaul as follows: Before disassembling the gear train spot No. 1 cylinder exactly on top center (firing) or top center with both valves closed. With a steel scale held firmly against the machined side of the centerframe, scribe a line across the side of the camshaft gear, parallel to the centerframe face. When re-assembling, mesh the gears with the crankshaft and the camshaft in the same relative position, that is, with No. 1 cylinder on exactly top center and the line on the camshaft gear in line with the same scale held against 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 cylinder at top center.

(b) Set the camshaft gear relative to its hub so that clamping bolts are approximately in the center of the slots. Orient camshaft gear so that old dowel holes will not interfere with re-doweling.

(c) Turn the camshaft (with intermediate gear out of mesh) so that the inlet and exhaust lifters of No. 1 cylinder are each raised an equal distance. (NOTE: The piston was set at T.C. as in this position both valves should be open an equal distance. The intermediate gear and centerframe end cover assembly should be moved sufficiently to take the intermediate gear out of mesh with the camshaft gear.)

(d) Holding crankshaft and camshaft in above positions and allowing the 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 a $^{31}/_{64}$-inch hole through hub in line with dowel hole in gear and ream to 0.497 inch–0.498 inch for dowel.

After determining the correct relation between the camshaft and crankshaft the pushrods must be adjusted as follows:

19. INLET AND EXHAUST VALVE TIMING:

(a) Spot piston at 5 degrees before top center at the end of the exhaust stroke.

(b) Adjust inlet pushrod so that valve is just opening.

(c) Spot piston at 5 degrees after top center on the suction stroke.

(d) Adjust exhaust pushrod so that valve is just closing.

(e) Check clearance between 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 blow-by and destruction of valves and seats.

(f) Adjust stop screws above valve ends of rockers. These screws prevent the valve ends of the rockers from lifting when the rocker-shifting cylinder operates. They should be adjusted for $^{1}/_{32}$-inch clearance when the shifting cylinder is in the operating position and the cam rollers are down on the base circle of the cams. THEY MUST NEVER BE SCREWED DOWN WITHOUT ANY CLEARANCE SO THAT THE VALVE CANNOT SEAT.

(g) Check and record closing point of inlet valve and opening point of exhaust valve. These points should fall within 5 degrees of the position given in the timing table.

(h) Adjust and record inlet and exhaust valves for the other cylinders as above.

20. AIR-START VALVE TIMING:

(a) Remove cover from air-start valve for cylinder No. 1 and hold valve down firmly on its seat.

(b) Spot piston at 4 degrees before top center at the end of the compression stroke and adjust the pushrod so that the valve is just opening. Check the closing point, which should fall within 5 degrees of the position given in the table. (See Paragraph 14.)

(c) Adjust and record air-start valves for the other cylinders as above.

21. FUEL-SPRAY VALVE TIMING: See Section 10.

SECTION 20
LUBRICATING OIL AND TRANSFER PUMPS

1. DESCRIPTION OF PUMPS: Figure 20-1 shows the pressure lube oil pump and Figure 20-2 shows the sump 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 20-3 and 20-4 show how this crescent shifts when the rotation is changed, by following the rotation of the idler.

2. SUMP PUMP: As stated in Paragraph 1 the sump pump shown in Figure 20-2 is identical with the pressure pump except that it has a relief valve which discharges into the atmosphere. This valve is to safeguard the pump if the crescent is slow in reversing its position when the engine changes rotation, causing a pressure to be built up against the foot valve in the suction assembly. Any continual discharge from this valve would demand that the engine be shut down immediately and the sump pump opened up for inspection.

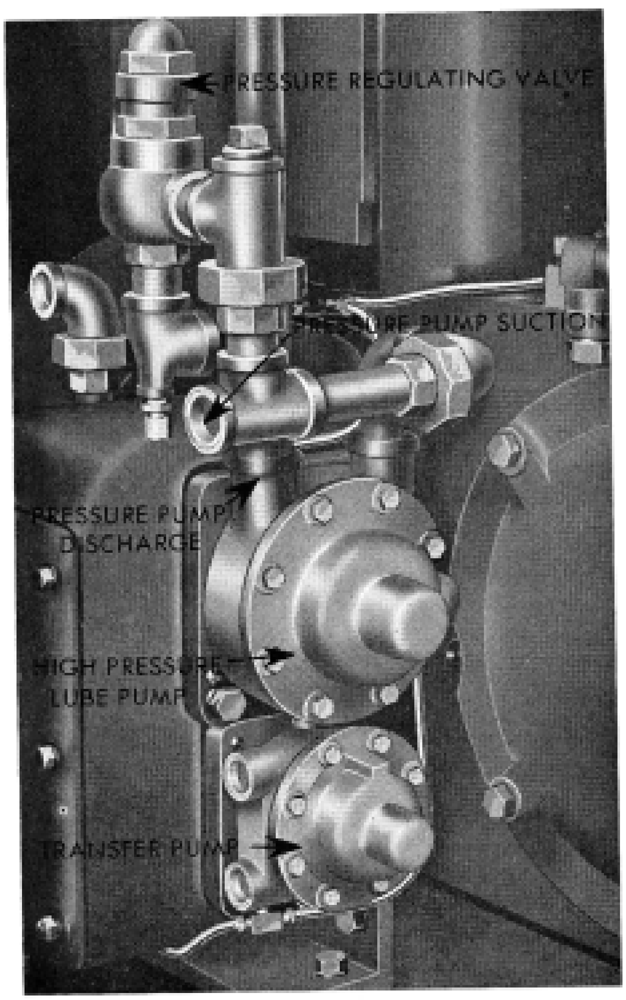


FIGURE 20-1

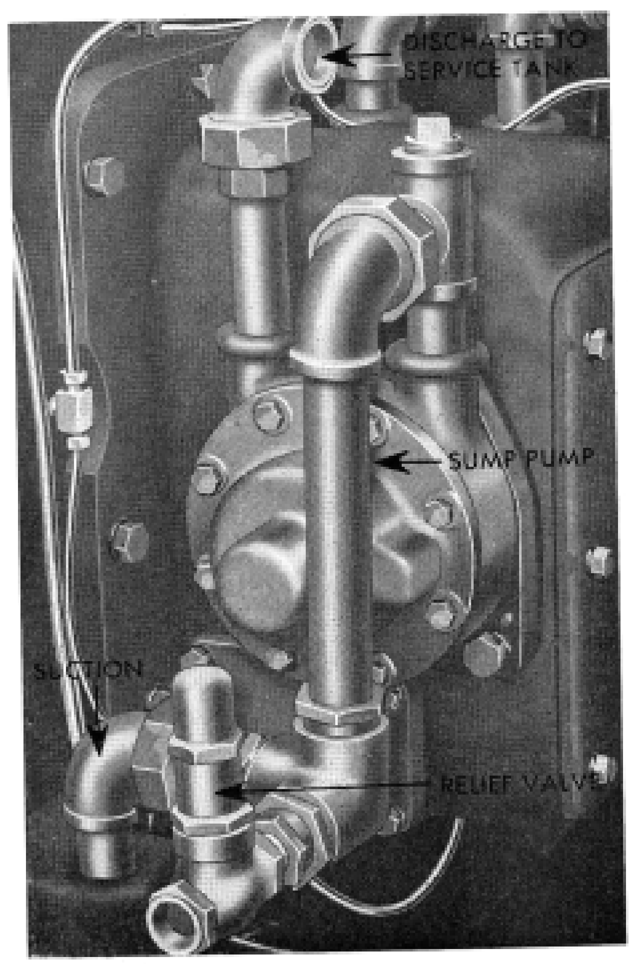


FIGURE 20-2

3. FUEL TRANSFER PUMP: Figure 20-1. This pump is exactly the same in principle and operation as the two lube pumps except that there is an external drain arranged so that fuel leakage cannot find its way into the crankcase. The drain is shown in Figure 20-5 and SHOULD NEVER BE PLUGGED.

4. 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 re-installed on the engine and repairs made at a base where the necessary equipment is available. Figure 20-5 shows the adapter plates which hold the bushings of the pump shafts.

5. 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.

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.

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.

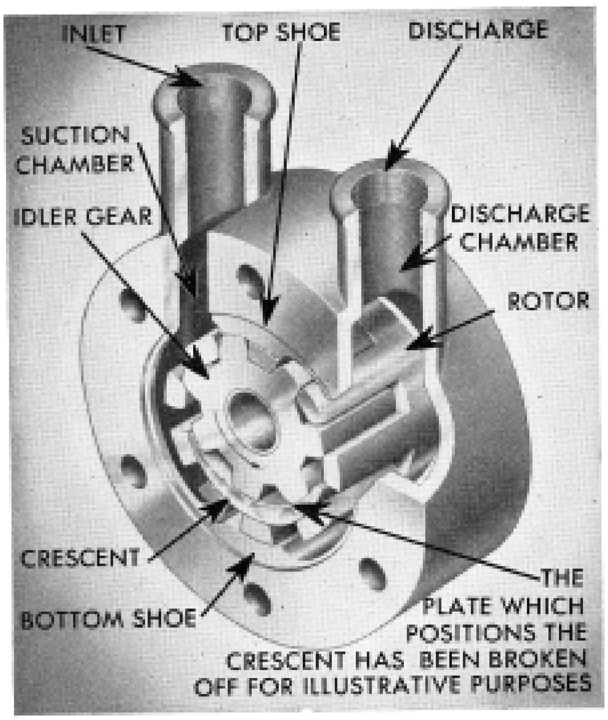


FIGURE 20-3

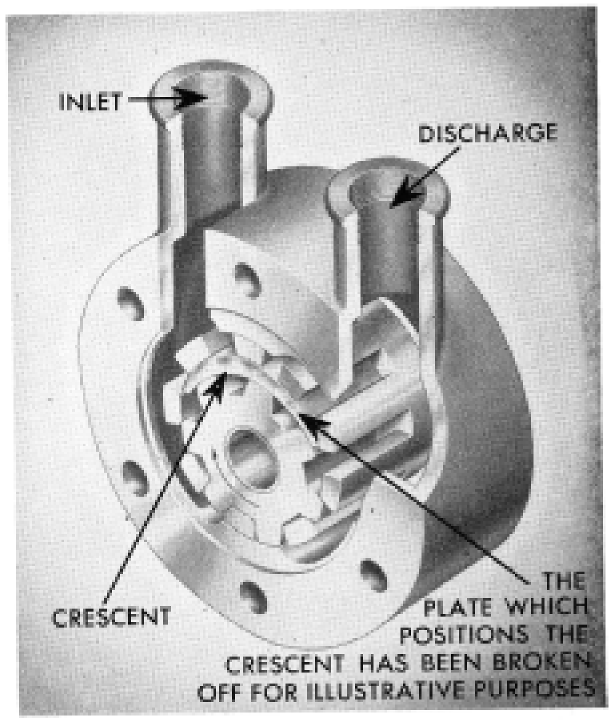


FIGURE 20-4

7. LUBE OIL FILTERS: The oil from the pressure pump next passes through the filters shown in Figure 20-6. These filters 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 filter 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 filter. It is good practice to scrape these filters 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 four hours of running. This filter has a built-in by-pass valve which opens at about 18 pounds pressure if the screen of the filter clogs up. However, this is only a safety device and the filter should be cleaned regularly.

8. OIL COOLER: This cooler, shown in Figure 20-7, is also the water inlet manifold and its construction is described in Section 3, Paragraph 12. It will require little attention except cleaning and the necessity of this will be governed by the type of water used for cooling.

9. CLEANING THE COOLER: If a raw-water cooling system is used and the water is heavily laden with silt the cooler should be taken apart at least once each year.

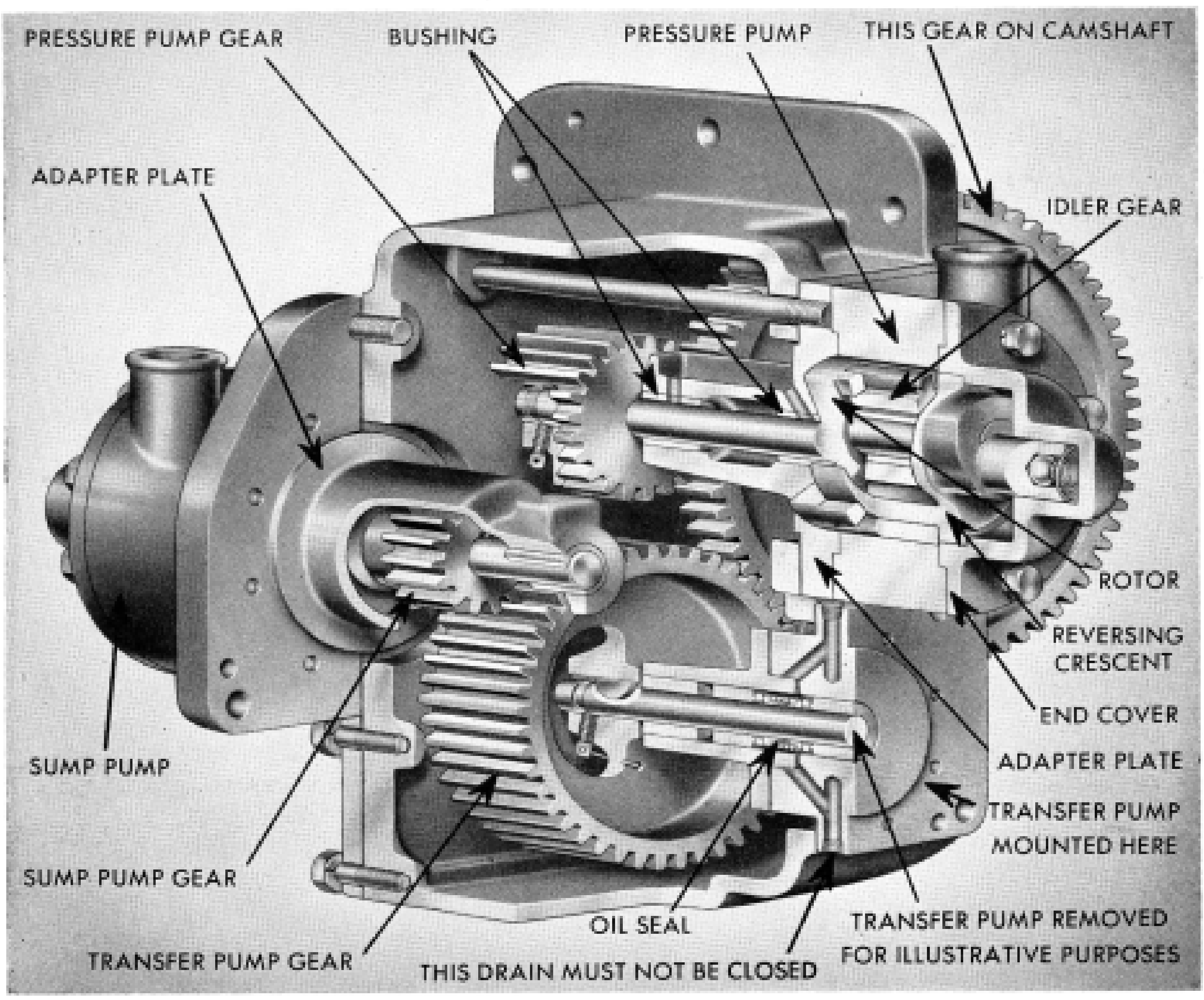


FIGURE 20-5

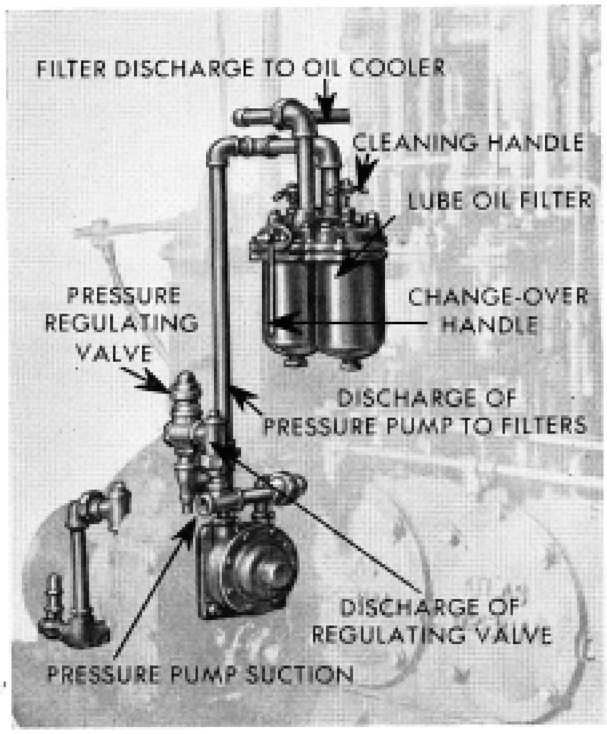


FIGURE 20-6

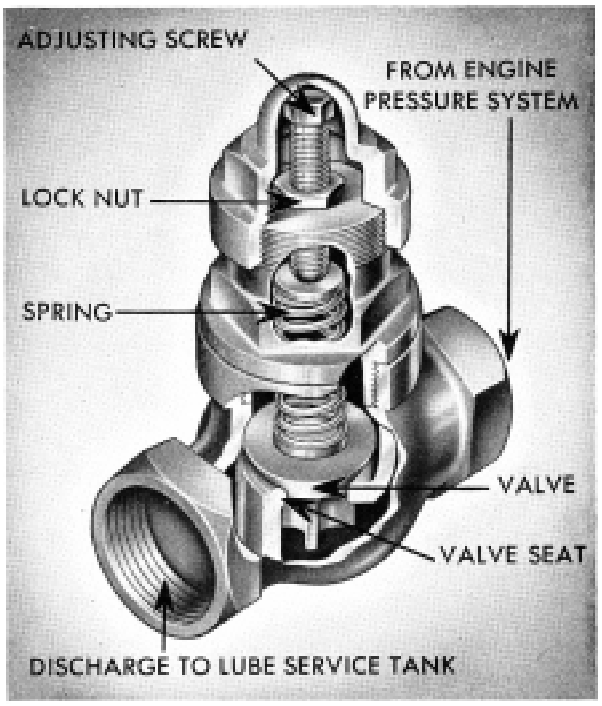


FIGURE 20-8

Remove the packing gland, packing and flange from each end of the manifold and the cooler may be withdrawn and the manifold cleaned out. There will be no need to remove the core pipe from the center of the cooling pipe. Use new flax packing when replacing the glands.

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 20-8 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:

(D) Faulty crankshaft bearing
(E) Worn pump parts
(F) Oil too thin.

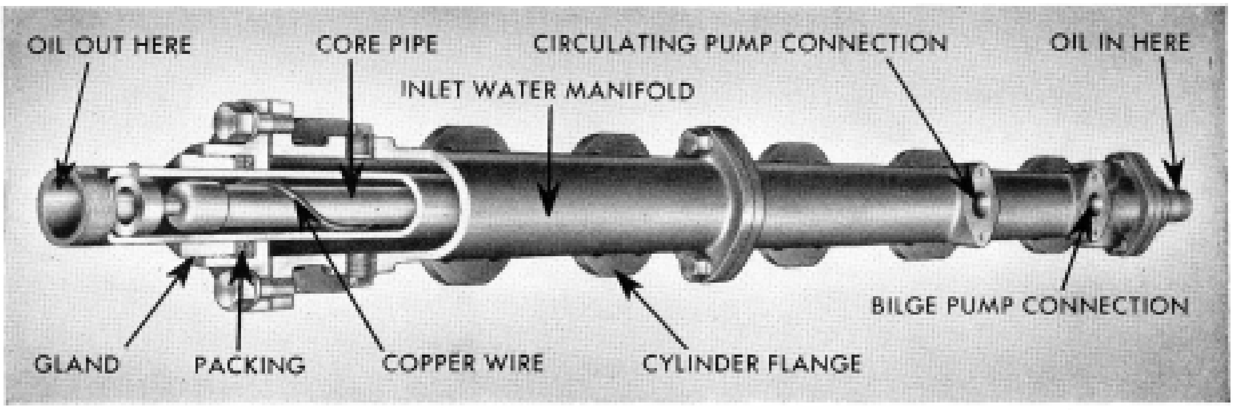


FIGURE 20-7

As shown in Figure 20-6 this valve is connected into the discharge of the pressure lube pump and the filters. The discharge of the valve is piped back into the pressure pump suction.

11. REMOVAL OF THE SUMP PUMP SUCTION ASSEMBLY: Disconnect the two unions in the sump pump suction line. Remove the two cap screws from the sump hole cover and withdraw the suction assembly. Thoroughly clean the screen and examine the ball check. This check is used to keep the sump pump primed during the time the engine is not in operation. If any fittings or pipe of this assembly are renewed be sure that the overall dimensions are retained, as the location of the suction in the sump is governed by the combined length of these various parts. This suction assembly is shown in Figure 20-9.

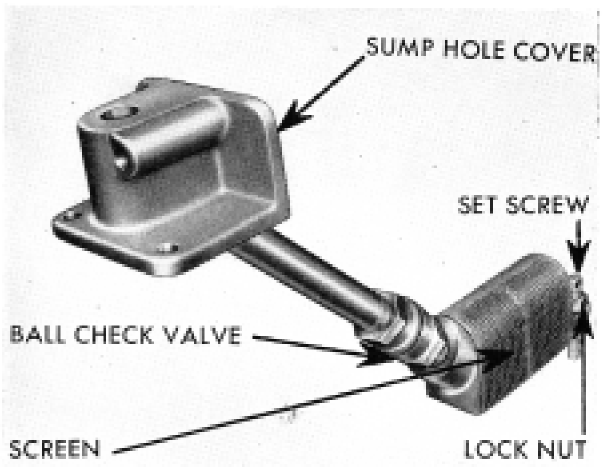


FIGURE 20-9

12. ASSEMBLY OF SUMP PUMP SUCTION: Be sure the ball check is installed right side up. That is, the ball must have its seat on the lower end. A set screw in the end of the screen bears down against the base to prevent vibration of the screen and pipe. It can be reached by removing the cover plate on the opposite side of the base and can best be adjusted as follows: with the screen in place and the supporting cover bolted down, screw the set screw down against the base with the fingers. Remove the cover plate and screen assembly and screw the set screw in one more turn, locking it with the jam nut. Replace screen and cover assembly and renew the cover gasket unless the old one is in good condition. Replace the section of piping leading to the pump suction, making sure that both unions are well tightened.

13. CLEANING THE BASE: While the sump pump screen is out for inspection the base should be cleaned out thoroughly. Remove all the crank pit doors. Wash off the crankshaft, bearing caps, connecting rods, crank pin bearings and crank pits with fuel oil and rags, NOT WASTE. Clean in and around the camshaft and cams, as many parts in these assemblies rely on splash for lubrication. When everything is clean, BE SURE ALL FUEL OIL IS REMOVED FROM THE BASE AND THAT NO RAGS ARE LEFT IN.

14. CLEANING 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.

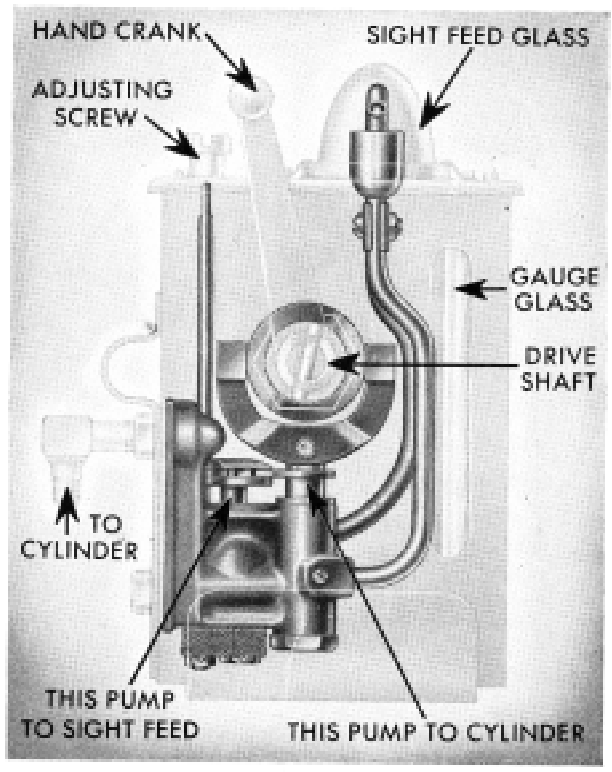


FIGURE 20-10

15. MECHANICAL LUBRICATOR: This lubricator is mounted on a bracket on the after end of the engine and is driven by a rod from the bilge pump eccentric. It supplies oil to the cylinder walls. Its operation is described in Paragraph 19 of Section 2 and the adjusting screws are shown in Figure 20-10.

Each feed is set for 20-25 drops per minute for new engines. After the rings and cylinders 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. As the drive shaft is located just above the center of the case, it is necessary to keep the oil level at least half way up in the glass so that the eccentrics, which drive the pumps, receive lubrication. This filling of the lubricator should be made a part of the engine room routine, as serious damage will occur to the pistons, rings and cylinder walls if it is allowed to run dry.

SECTION 21

AIR COMPRESSOR AND UNLOADER

1. DISASSEMBLY OF CYLINDER HEAD: Drain the engine. Disconnect the tube leading to the unloader. Remove the cylinder-head nuts and the cap screws that attach the water by-pass. Disconnect the union in the discharge line. Lift off the head.

2. OPERATION OF THE 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 when the air 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 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 passage (F) onto the diaphragm. The air pressure bends the diaphragm down, which moves the rod (G) against the stem of 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), allowing the suction valve of the compressor to operate.

3. ADJUSTMENT OF THE 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 (I). For normal operation this wing nut should be unscrewed far enough out 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) and withdraw the rod and spring. Remove the nut (M) and take out the screen (N). Smear 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: Remove the unloader and bracket. Remove the two lock nuts and spring and retainer from the stem of the suction valve. Examine the seat and face of the valve. If they are pitted or badly ridged they should be refaced, but this is seldom necessary. The valve guide can be renewed in the same manner as those in the cylinder head, see Section 11. The valve may be ground in the normal way. The spring should be renewed if there are any signs of corrosion.

5. ASSEMBLY OF SUCTION VALVE: After the suction valve is installed be sure that the double nuts on the stem are well tightened. Work the valve up and down several times to assure its being free in the guide. When attaching the unloader be sure that there is some clearance between the diaphragm rod and the stem of the valve. This may be adjusted by loosening the lock nut which tightens against the bracket. Screw the unloader in or out of the bracket until sufficient clearance is obtained and then tighten the lock nut.

6. DISASSEMBLY OF THE DISCHARGE VALVE: Remove the two cap screws which hold the discharge cover. Lift out the guide cap and the spring and collar. The guide and valve will lift out together. Examine the fit of the valve stem in the guide. If the stem and the guide are worn sufficiently to permit the valve to wander on the seat, both should be renewed. The valve and seat may be ground in the normal manner if the guide is used to position the valve correctly. There is a slot in the stem of the valve by which it can be turned with a screwdriver.

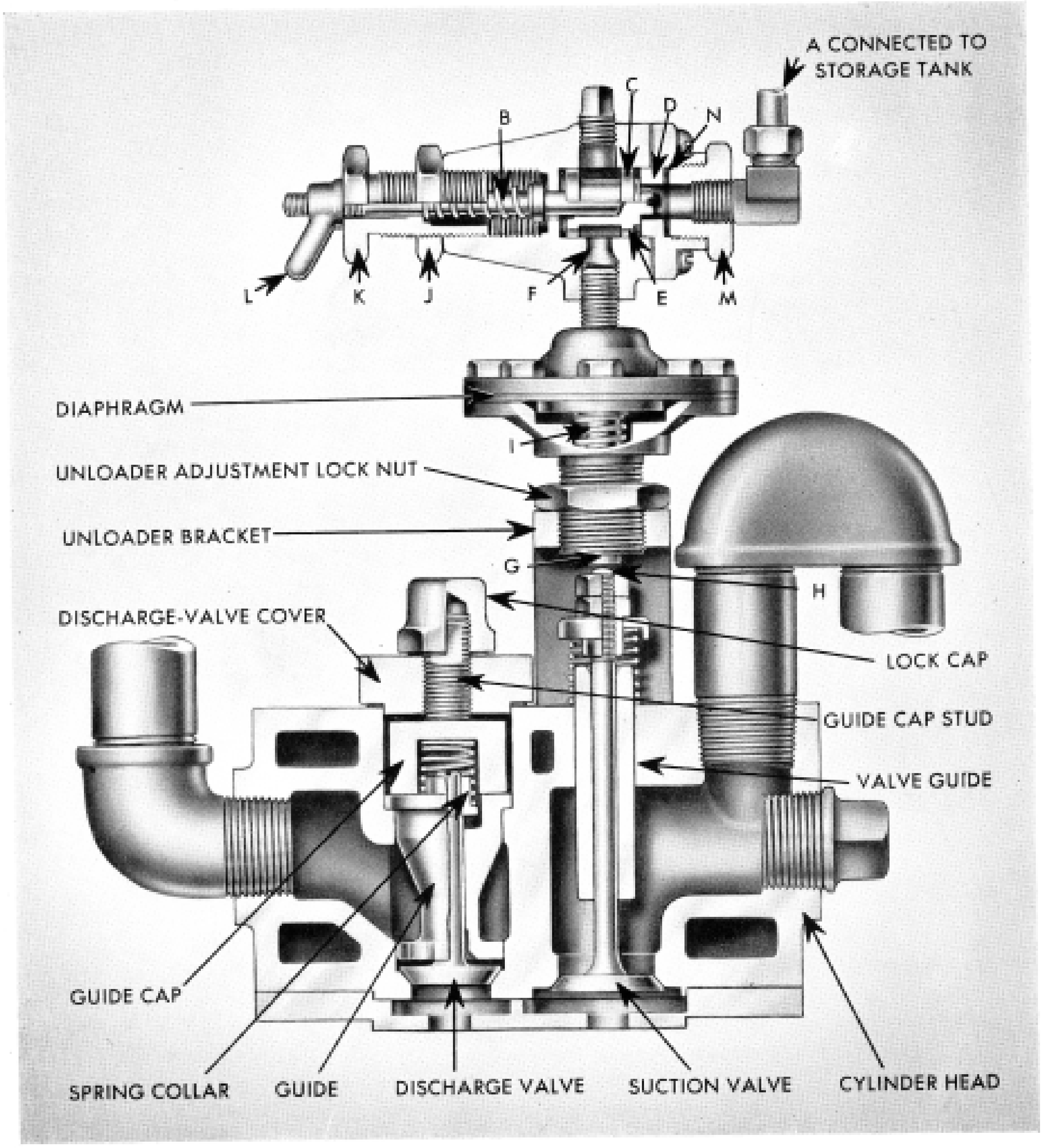


FIGURE 21-1

Examine the shoulder on the valve stem which holds the spring collar. If this is worn down so that the collar touches the guide, the valve should be renewed. Examine the spring for corrosion and renew if necessary.

7. ASSEMBLY OF THE DISCHARGE VALVE: After the valve has been ground and all parts cleaned thoroughly, replace the valve, guide, collar and spring. Set in the guide cap. Loosen the lock cap and unscrew the guide cap stud in the valve cover. Install a new copper asbestos gasket between the cover and the cylinder head and tighten the two attaching cap screws evenly.

Screw down the guide cap stud so that the guide cap is held firmly in place. Lock the stud with the lock cap.

7. DISASSEMBLY OF THE 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 the piston pin is held in by a set screw which threads through the piston-pin boss and engages a spotted hole in the pin. Slacken the lock nut and screw out the set screw. The pin may be driven out with a bronze drift. The pin has several holes bored from the bearing area into the hollow center. See that they are clean, as oily vapor finds its way through these holes to supply lubrication.

The pin should be a driving fit in the piston and should have from 0.001 to 0.002 inch clearance in the connecting rod bushing. If it is necessary to renew this bushing it can be driven out with a drift and the new one installed by pressing it in with a vise. It should be reamed to proper clearance after it is pressed in.

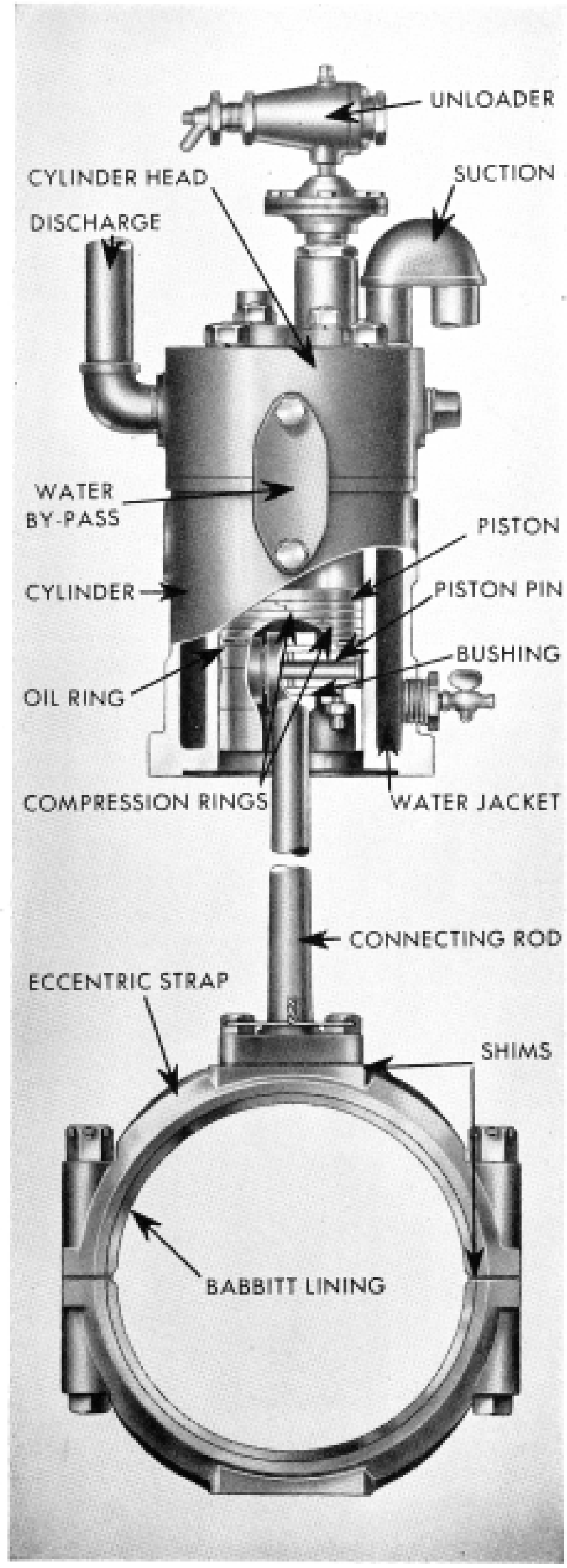


FIGURE 21-2

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 oil ring. 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 lower ring is designed for oil control and is known as a ventilated ring. The piston groove of this ring has 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 CONNECTING ROD: After the pin has been driven in be very sure the shallow hole in the piston pin is directly under the hole in the piston-pin boss. Tighten the set screw and the 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 0.009 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 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.

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 tightly. 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 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 $\frac{1}{64}$ 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

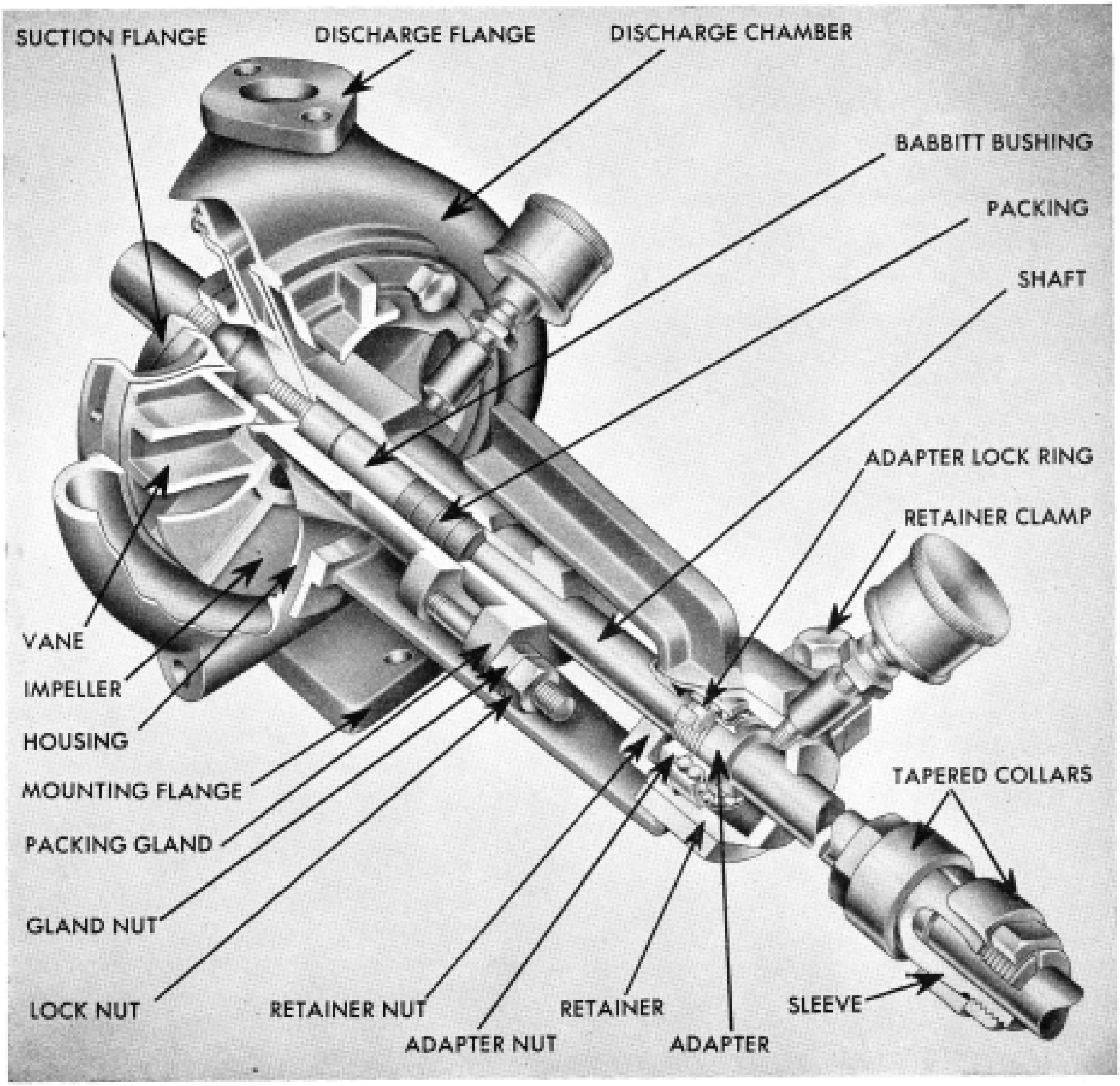


FIGURE 22-1

1. CENTRIFUGAL PUMP: This type of pump is shown in Figure 22-1. It is driven by silent chain from the crankshaft and will require little in the way of service providing it is lubricated frequently. However, if the pump is removed and taken apart, great care must be taken when positioning the impeller in the pump during assembly. The alignment of the pump on the engine is equally important.

2. REMOVAL OF THE PUMP: Disconnect the suction and discharge flanges. Figure 22-1 shows a nut on either side of the tapered collars of the compression coupling. Hold each collar with a large pipe wrench and slacken the adjacent nut. The collars can then be driven off the tapered sleeve, which will release its grip on the shafts. Slide the coupling along one shaft or the other so that the shaft ends are exposed. Remove the cap screws from the mounting flange and the pump can be lifted off. There may be shims between the pump mounting flange and the engine base. Do not lose any of these, as they are used when aligning the pump later.

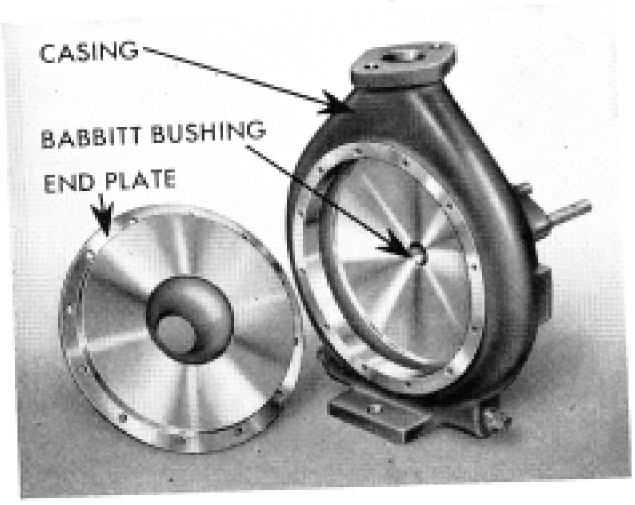


FIGURE 22-2

3. DISASSEMBLY OF THE PUMP: Take off the end cover plate shown in Figure 22-2. Remove the lock and gland nuts, Figure 22-1. Unscrew the retainer nut and loosen the retainer clamp. Remove the retainer grease cup, and the shaft, impeller and retainer can be slid forward far enough to get a wrench on the adapter nut. The adapter is a tapered, split sleeve which carries the inner race of the ball bearing. As the adapter nut is tightened, it forces the race of the ball bearing onto the taper on the adapter. As the ball race can not expand, the sleeve is clamped tightly to the shaft by the action of the race sliding up the taper on the sleeve.

Bend over the lock lugs on the lock washer and remove the adapter nut. Using a small bronze drift, drive the inner ball race off the sleeve. The retainer, adapter and ball race can now be slid off the end of the shaft.

4. EXAMINATION OF PARTS: The shaft may be worn in the packing way. The renewal of the shaft will be governed by the trouble experienced in keeping the packing tight. The impeller and shaft are balanced after assembly and therefore should be treated as a unit. The shaft is carried on a babbitt-lined bronze bushing which presses into the pump casing. Enter the end of the shaft which is not worn into the bushing and measure the clearance. If this is greater than 0.020 inch the bushing should be renewed.

Examine the impeller for broken vanes and also for bright wear spots which would show that it has been rubbing against the casing. If the impeller is chipped badly enough to throw it out of balance, it should be renewed.

Examine the ball race. If the balls or either the inner or outer races are marked and rough, they should be renewed.

5. REPLACING A WORN BUSHING: The old bushing can be driven out with a drift. The grease hole in the casing should be cleaned out thoroughly. The new bushing can be drawn into place with a long bolt and washers. Care should be taken so that the inner face of the pump housing is not damaged during this operation.

6. ASSEMBLY OF THE PUMP: When any replacements that are necessary have been made, wash all parts thoroughly. Put in the shaft and impeller and slip on the packing gland but do not pack the pump. Put on the retainer nut, the adapter nut, and the lock washer. Put the ball bearing on the adapter, being sure the taper in the inner ball race matches the taper on the adapter.

Reference to Figure 22-1 shows that the outer ball race is held in the retainer by the retainer nut forcing the race against a shoulder. The ball race can be pressed against this shoulder by hand. With both the retainer and adapter nut ahead, and out of the way, assemble these various parts as shown in Figure 22-1. Press the impeller against the face of the casing and scribe a line on the shaft at the threaded end of the adapter. We now have the position where the adapter must be clamped to the shaft.

Pull the shaft ahead so a wrench can tighten the adapter nut. As this nut is tightened the ball race is forced up on the taper, clamping the sleeve to the shaft. As the nut is being tightened, try the ball bearing by revolving it.

It is possible to distort the inner race by forcing it too far on the taper and the operator should stop tightening the nut just before this occurs. The sleeve will then be sufficiently clamped to the shaft.

Bend the locking lugs down on the adapter nut and slip on the retainer. Tighten the retainer nut firmly.

The paper gasket that goes between the end plate and the casing, Figure 22-2, should be 0.010 inch thick. After all the screws attaching the end plate are tightened, try the end movement of the shaft. This clearance should be between 0.015 and 0.030 inch. If this clearance is less than 0.015 inch it can be increased by using a thicker gasket. If the clearance is greater than 0.030 inch we suggest remachining of the cover in a machine shop. The pump can be used until this work is possible with only a very slight loss in efficiency.

As the impeller tends to pull toward the suction opening it is necessary to have most of the clearance between the end plate and the impeller. Position the shaft so that the impeller just clears the casing, and tighten the retainer clamp cap screw.

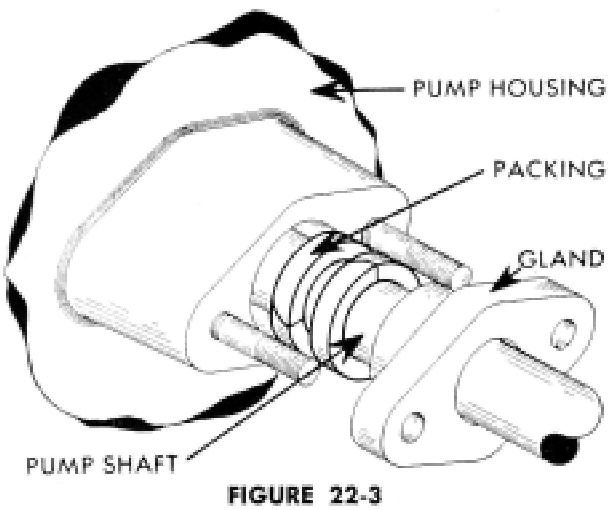


FIGURE 22-3

7. PACKING THE PUMP: All of the old packing should be removed and new packing rings cut from well-greased ⅜-inch square flax. Each ring should be cut just short of reaching around the shaft once and the ends should be cut on an angle. Stagger the joints as shown in Figure 22-3. DO NOT TIGHTEN THE GLAND UNTIL AFTER THE ENGINE IS RUNNING and then only enough to stop leakage.

8. INSTALLATION OF THE PUMP: Slide the compression coupling along the pump shaft so that several inches of the shaft is exposed. Set the pump on the mounting shims, if any, and screw in the cap screws in the mounting plate. Lay a scale or straight edge along the top of both the pump shaft and the driven shaft. This will check the alignment on the horizontal plane. Adjustment can be made by adding or subtracting shims from under the pump. Next lay the straight edge along the side of both shafts and check the alignment from a vertical viewpoint. The cap screw holes in the mounting flange are large enough to permit slight movement to correct any misalignment.

When the alignment in both planes is correct, attach the suction and discharge flanges.These should be square and even with the pump and should not be forced into place. After the flanges have been attached and the pump firmly fastened down, the compression coupling should slip easily from one shaft to the other. DO NOT SPRING THE PUMP SHAFT TO ENTER THE DRIVEN SHAFT INTO THE COUPLING. Find out what is causing misalignment and correct it.

Position the coupling half way on each shaft and tighten the two nuts which force the collars onto the tapered sleeve of the coupling.

9. LUBRICATION OF THE PUMP: The grease cup which supplies the packing area should be turned down a part of a turn each hour. Some type of waterproof grease should be used in this cup. The grease cup in the bearing retainer should be turned a part of a turn each four hours.

10. CHAIN DRIVE ADJUSTMENT: The centrifugal pump is driven by a silent chain from a sprocket on the crankshaft. This chain makes a three-cornered loop over the crankshaft sprocket, the pump-shaft sprocket, and an idler sprocket which is used to tighten the chain. Figure 22-4 shows that the teeth of the sprockets do not go through this type of chain.

It is apparent that if the chain becomes slack it will tend to climb the sprockets, thereby causing undue wear. These chains will give many years of trouble-free service if they are kept in proper adjustment.

The idler sprocket is carried on a roller bearing which is mounted on an eccentric hub. This hub is part of a shaft which is supported on bearings in the chain housing. There is a plate keyed onto this shaft which has several holes,

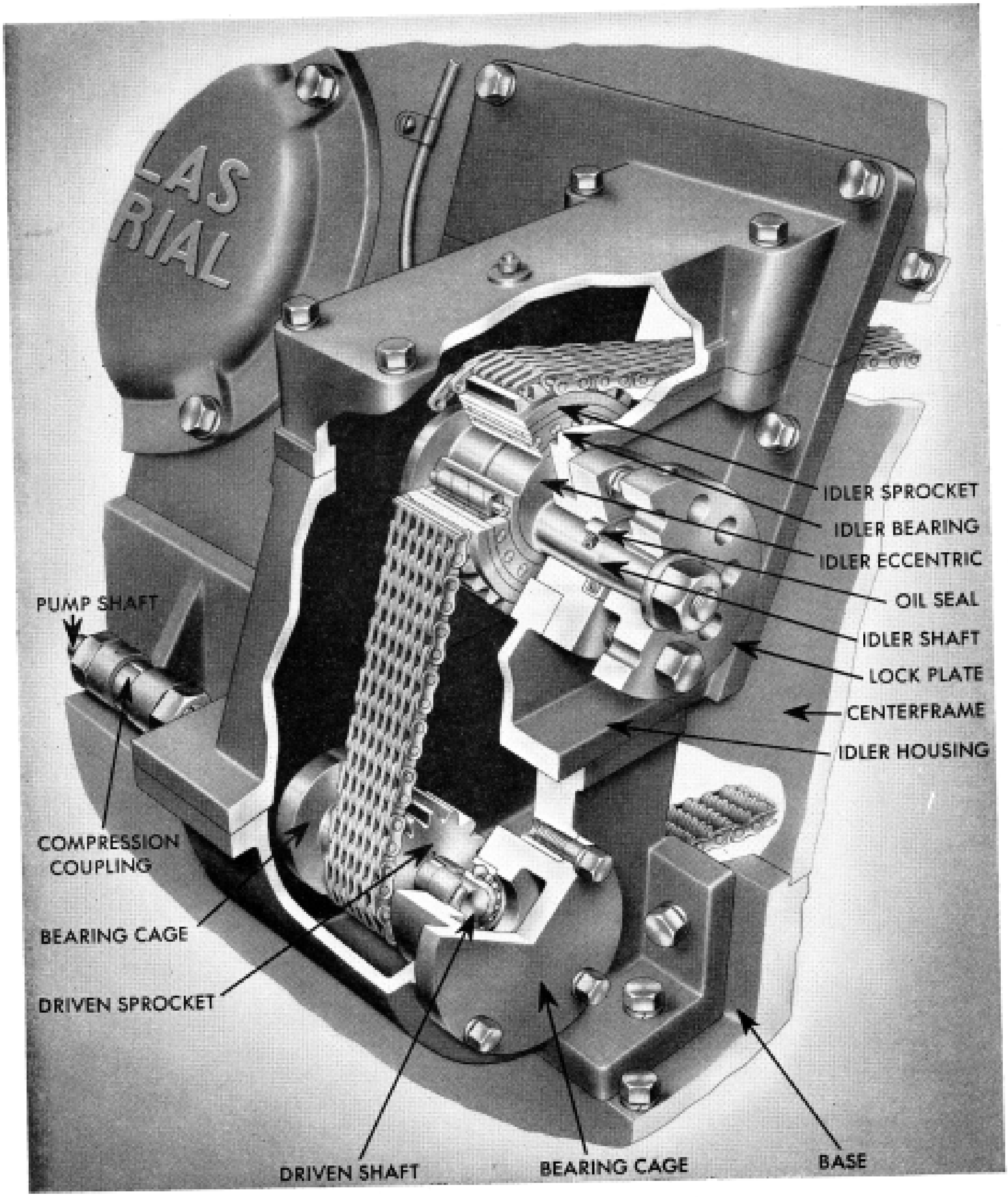


FIGURE 22-4

bored around the circumference. Reference to Figure 22-4 will show that as the idler shaft is turned the eccentric hub and idler sprocket describe an arc which will tighten or loosen the chain, depending on which way the shaft is turned. A cap screw in the outside plate is used to lock the shaft in position after the adjustment is made.

Remove the top cover plate of the chain housing. Hold a rule alongside the chain between the idler sprocket and the crankshaft sprocket. Pull the chain up and down as far as possible by hand and note the total up and down movement when measured at right angles to the lay of the chain. This should be from 1 to 1¼ inches. This adjustment should be checked once every three months.

The eccentric hub is set at its lowest or shortest position during manufacture and by the time all the adjustment is used up, it is likely that the chain is stretched sufficiently to warrant renewal.

11. SERVICING THE BILGE PUMP: This pump, which lies across the after end of the engine and is driven by an extension of the camshaft, should be removed if work on the pump body or plunger is necessary. The valves may be serviced with the pump in place.

12. REMOVAL OF THE PUMP: Disconnect the suction and discharge pipes. From the operating side of the engine, remove the cotter pins and two nuts which clamp the eccentric strap halves together. There will be shims between the halves which should be carefully laid away. Remove the three cap screws which attach the pump mounting flange to the center frame and the pump and connecting rod can be lifted clear of the engine.

13. EXAMINATION OF PARTS: The plunger may be worn rough in the packing way and if too much trouble has been experienced in keeping the packing tight the plunger should be renewed. Examine the crosshead pin which connects the plunger and the connecting rod. If the eye in the plunger and the pin have a total clearance of $\frac{1}{32}$ inch or more, the fork on the connecting rod and the plunger eye should be reamed and an oversized pin fitted.

Examine the babbitt in the eccentric strap for cracks. Clean out the oil reservoir and passage and assemble the strap on the eccentric hub. The strap can be fitted like a bearing by removing shims from each side until the operator can just feel the strap beginning to bind

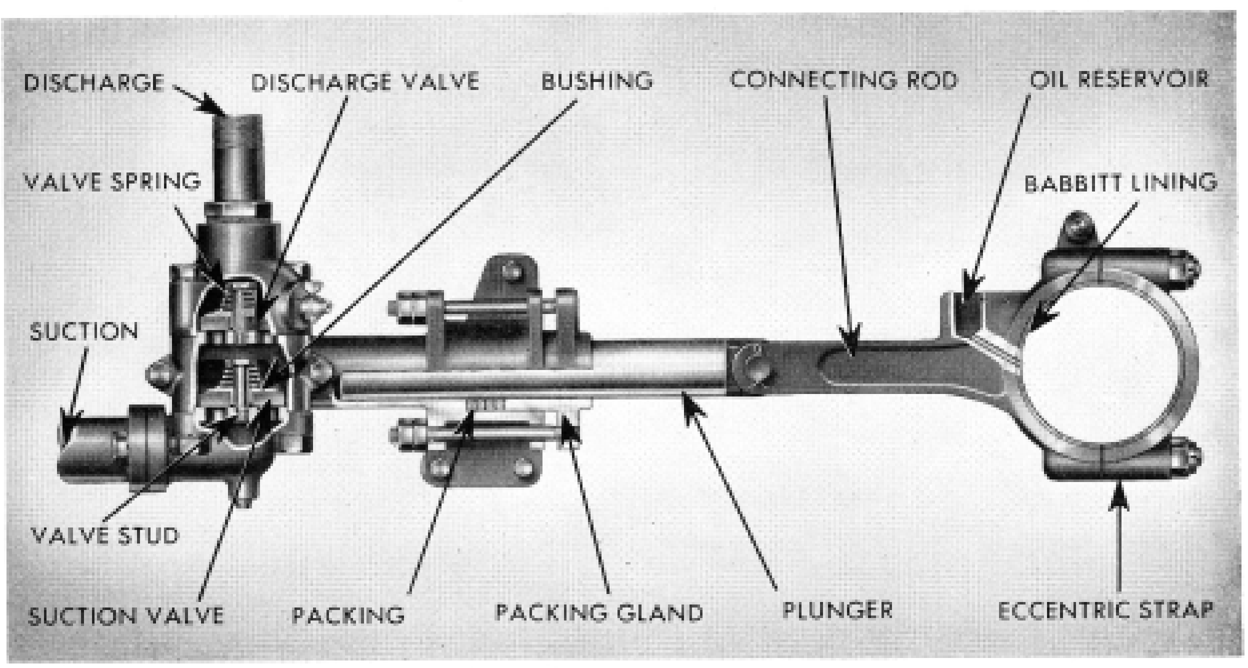


FIGURE 22-5

on the hub. Then sufficient shims are replaced on each side to give a running clearance which should be between 0.004 and 0.006 inch.

The strap should next be checked for end clearance on the hub. This should be at least 0.015 and must be obtained with the halves bolted securely together. Clearance can be obtained by scraping the side of the babbitt lining, but this should only be necessary if the strap has been rebabbitted.

CAUTION: The strap must be assembled and all clearance checks made with the two halves bolted together as they were taken apart. The outer half must not be turned a half turn.

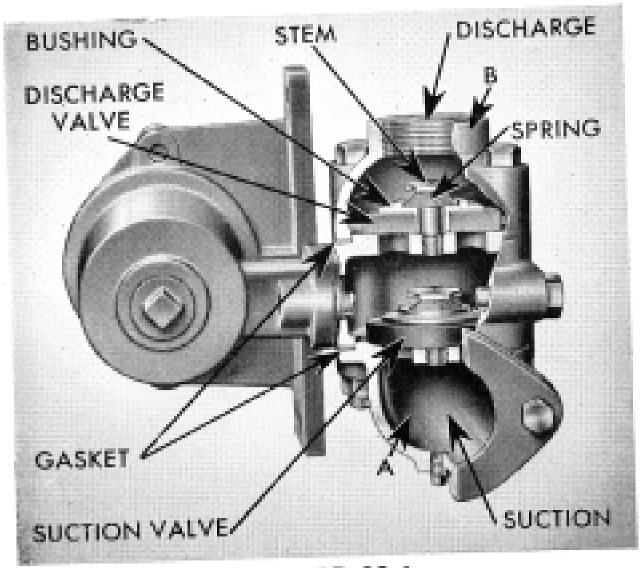


FIGURE 22-6

14. DISASSEMBLY OF THE VALVES: Figure 22-6 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 suction valve seat is part of the suction bonnet. The removal of the discharge bonnet exposes the discharge valve.

Unscrew the valve stem from the seat, which releases the fiber or rubber valve and spring. Examine the stem and bronze bushing which fit into the valve for wear. If these parts are $\frac{1}{32}$ inch loose, they should be renewed. The grid-like seat, upon which the valve seats, should be smooth and free from ridges or grooves. If the springs are corroded, they should be renewed.

15. ASSEMBLY OF VALVES: The valve studs should be well tightened into the seats. Lift the valves by hand to make sure the bushings are free on the studs. 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 tight, without these spigots entering, the bonnet will be warped, making it impossible to attain a tight joint.

16. PACKING THE PUMP: A good grade of well-lubricated flax packing $\frac{3}{8}$ inch square should be used. This packing should be cut into lengths just long enough to go around the plunger once. The ends should be cut on an angle and the packing gland should not be tightened until the engine is running and then only enough to stop leakage.

17. ASSEMBLY OF THE PUMP: After the pump has been attached to the engine, make sure that the flanges which attach the suction and discharge pipes are square and even with the flanges on the pump. If these are forced into place by the cap screws, strains will be set up in the pump housing which may cause damage.

Try the fore and aft movement of the eccentric strap. If this has been lost during assembly it is a sure sign that some part of the pump is misaligned. This fore and aft clearance of the eccentric strap must be obtained before the job is completed.

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, as listed in the paragraphs on Short Submersion. Anything done to 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. Most of the water should pass out of the relief valve openings. Put one quart 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 walls. Remove the complete high-pressure fuel pump assembly and fuel-regulating valve. Leave in fuel oil until cleaning is possible.

5. CONTROL LEVER BOX AND ROCKER-SHAFT RAM: Remove the lever control unit and leave in fuel oil until cleaning is possible. Thoroughly oil or grease all steel or iron parts of the rocker-shaft ram.

6. CRANKSHAFT AND PISTON PINS: Remove all centerframe 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 wrist-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 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 centerframe 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 centerframe 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 broken, or fuel filter 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 Smoky Exhaust Item #2, this section.
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 in stop position. Open air starting tank and the vent valve which controls the master air valve on the starting manifold. If air blows out snifter valve of any cylinder, 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 and the control lever at stop, 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 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.

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