I. DESCRIPTION AND OPERATION

Type and Cycle

Type

The engines are of the solid fuel injection type, and are designed to use a wide variety of fuels. They operate on the two-cycle principle in which two strokes of the piston (one complete revolution of the crankshaft) are necessary to complete the cycle.

Compression

The cycle begins with the upward movement of the piston from its lower dead center position. After the piston has covered the inlet and exhaust ports, the air in the cylinder is compressed.

Combustion and Expansion

As the piston approaches its upper dead center position, fuel is injected into the combustion space where it burns due to the heat of compression and the resultant expansion of burning gases forces the piston downward. Expansion of the hot gases forms the largest part of the power stroke and takes place nearly to the end of the downward stroke of the piston.

Exhaust and Scavenging

Toward the end of the expansion stroke, the piston uncovers the exhaust ports, allowing the burned gases to escape to the atmosphere thru the exhaust system. Immediately after the exhaust ports have been uncovered, or at about the time the pressure in the cylinder has dropped to atmospheric, the air inlet ports are uncovered and the scavenging air, under pressure in the air receiver, flows into the cylinder and forces the exhaust gases out the exhaust ports, thus filling the cylinder with fresh air for the next compression stroke.

Fuel Supply System

Supply System

The complete fuel system may be considered as consisting of the supply and injection systems. The supply system includes the fuel storage tank, daily service tanks (when used), fuel filter, built-in supply pump, supply reservoir, and the connecting pipes. Where preheating or centrifuging of the fuel is required, a preheater or centrifuge will be included in the supply system.

Operation of Supply System with Low Level Service Tanks

When the service tanks or main fuel storage tanks are located below the level of the supply reservoir, the built-in fuel supply pump is used to transfer the fuel from the tanks to the supply reservoir. An overflow line from the reservoir to the tank must be provided.

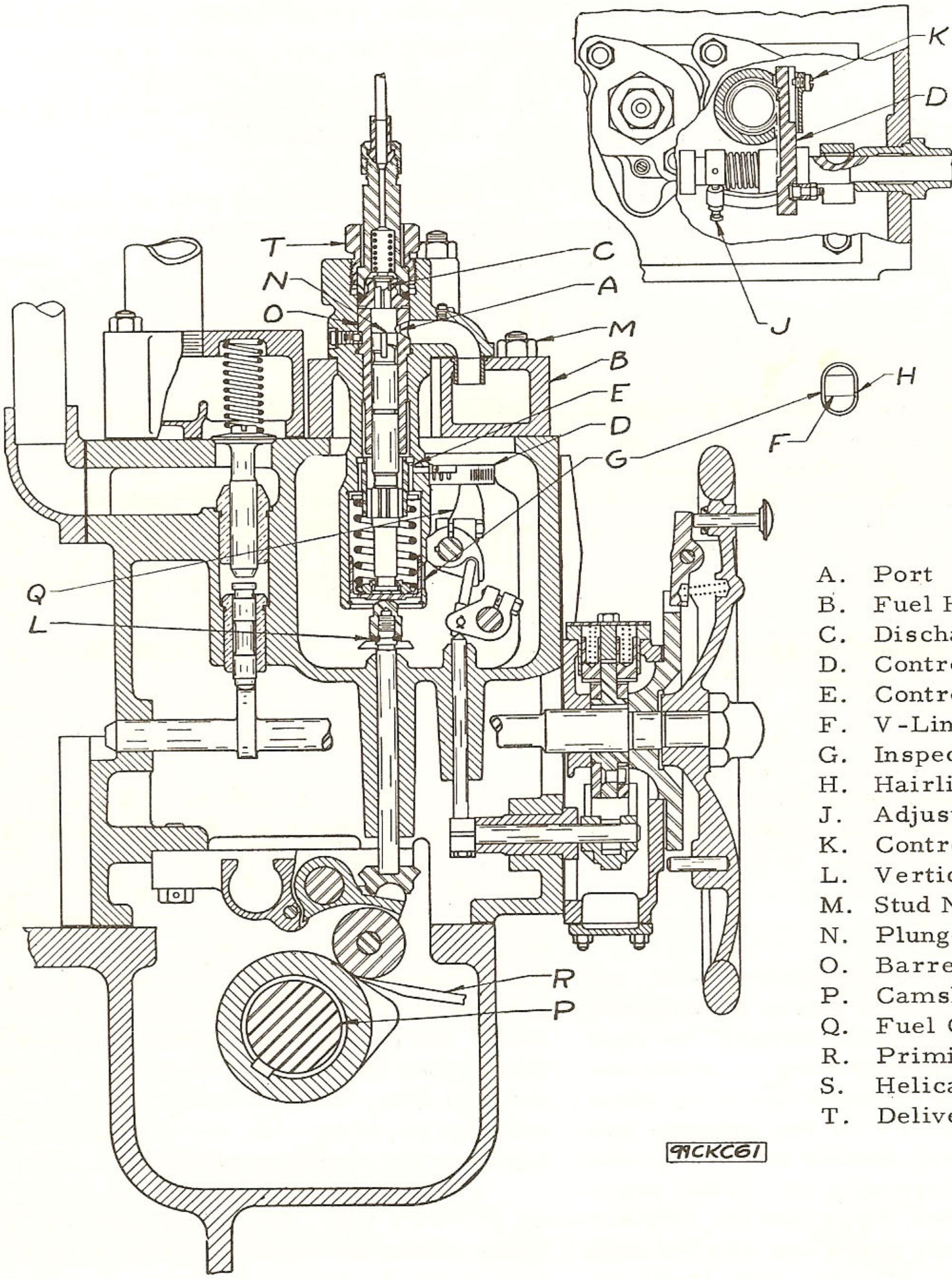
Piping Connections for Supply System with Low Level Service Tanks

The engine is arranged for the built-in supply pump to deliver fuel to the supply reservoir. The only piping necessary is to run a suction line from the tank to the "IN" connection on the filter, and to run a line from the overflow connection on the engine back to the tank.

Elevated Service Tanks

If an elevated service tank is used with a low level storage tank, the auxiliary fuel pump takes fuel directly from the main storage tank thru the suction line. The fuel is then forced upward thru the supply line and is discharged into the service tank. By means of gravity, the fuel is transferred thru the engine supply line and the fuel filter to the auxiliary fuel reservoir. The supply line must be provided with the fuel supply shutoff valve to permit inspection of the fuel filter and the auxiliary fuel reservoir and also to prevent the service tank from draining after the engine is stopped.

The service tank may be of either the open or closed type, depending upon the available space above the engine. When an open service tank is used, it must be located at least 6 feet above the level of the auxiliary fuel reservoir so as to produce the proper pressure in the reservoir. When a closed service tank is used, it may be located either more or less than 10 feet above the level of the auxiliary fuel reservoir. With either type of service tank, any surplus fuel from the tank is returned to the main storage tank by means of the overflow line. However, the pressure relief valve must be provided when a closed service tank is used. This relief valve maintains the proper pressure in the auxiliary fuel reservoir and it is set to open when this pressure exceeds approx. 5 psi.



A. Port
B. Fuel Header
C. Discharge Valve
D. Control Rack
E. Control Rack Pinion
F. V-Line
G. Inspection Window
H. Hairline
J. Adjusting Screw
K. Control Rack Setscrew
L. Vertical Adjustment Shims
M. Stud Nut
N. Plunger
O. Barrel
P. Camshaft
Q. Fuel Control Lever
R. Priming Bar
S. Helical Edge
T. Delivery Valve Holder Nut

Fig. 1. Injection Pump - Variable Ending "VE" Plunger

In all cases a drain line must be provided for transferring the drippage from the injection pumps and injection nozzles to a tank below the floor level. This tank may be relatively small, just a few gallons capacity (with provision for emptying) or it may be the main fuel storage tank, providing the fuel level in the storage tank never goes higher than the level of the pump housing.

Fuel Injection System

Injection Timing

Fuel is injected into each cylinder slightly ahead of upper dead center. The proper timing of the injection period in relation to the position of the piston is accomplished by meshing the camshaft gear train properly and by adjusting

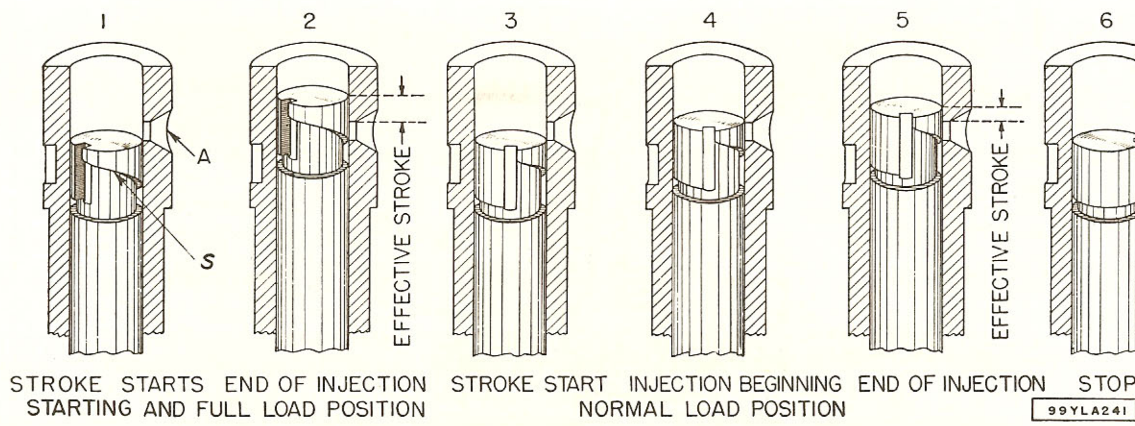


Fig. 2. Injection Pump Plunger Positions - "VE" Pumps

the camshaft with respect to the cam gear.

The cam gear and hub are so marked that the injection can be reset to its original position.

Arrangement of Cylinders and Fuel Injection Pumps

The cylinders and injection pumps are arranged in sequence. The cylinders are numbered 1, 2, 3, etc., beginning at the forward or scavenge pump end. The injection pump housings are stamped. The No. 1 pump is always at the forward end with No. 2, 3, etc., following in numerical order. If any of the pumps are removed from the housing, they should be replaced in their original arrangement.

Fuel Injection Pumps - Variable Ending "VE"

Variable ending univalve injection pumps are used on the first engine as listed below and thereafter. Refer to Fig. 1 and 2.

	Stationary	Marine
5 cyl.	824157	819841
6 cyl.	819452	819986
7 cyl.	820488	819833

The pumps have a single discharge valve (C). The plunger stroke is constant, being equal to the height of the nose of the cam on the camshaft (P). The amount of fuel injected depends only upon the length of the plunger stroke between the time the port (A) is covered by the top of the plunger (N) and the time it is uncovered by the helical edge (S).

On the downward stroke of the plunger (N) the space above the plunger is filled with fuel which enters thru the port (A) in the side of the barrel (O). The port (A) is directly connected to the fuel header (B). After the port is closed on the upward stroke of the plunger (N), fuel is forced out thru the discharge valve (C). It then travels thru the injection tube and valve and into the engine cylinder. Injection continues during the upward stroke until the helical edge (S) of the plunger uncovers the port (A). After the port is uncovered, the fuel is no longer injected into the cylinder but is discharged back into the fuel header (B) thru the port (A). The space below the helical edge (S) is always filled with fuel being connected with the space above the plunger by a groove in the side of the plunger. The plunger is free to rotate in the barrel. The period of injection varies depending upon the distance between the top of the plunger and the point on the helical edge which uncovers the port. The plunger rotation is controlled by the governor thru a rack (D) and pinion (E). Fig. 2 shows the injection pump barrel and plunger with the plunger at the beginning and end of its stroke for various load conditions.

Fuel Injection Pumps - Variable Beginning "VB"

Variable Beginning univalve injection pumps are used on the following engines and all thereafter.

5 cyl.	867346
6 cyl.	859953
7 cyl.	859046

These pumps, Fig. 3, have a single discharge valve. The plunger stroke is constant, being equal to the difference between the high and low points of the cam on the camshaft. The plunger always admits an equal amount of fuel oil from the supply system when it is at the bottom of its stroke. The amount of fuel oil injected depends upon the length of the plunger stroke between the point at which the port is

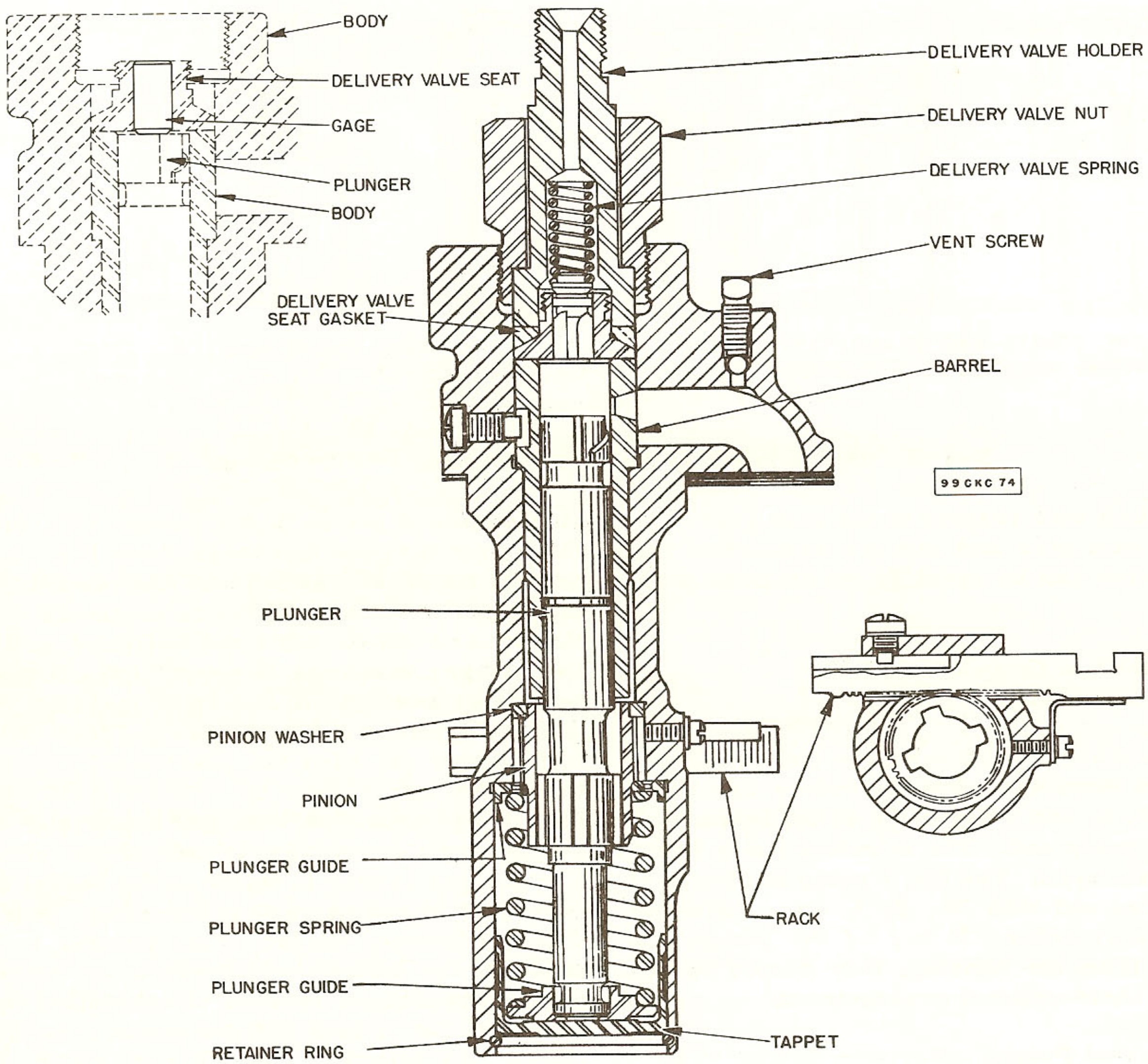


Fig. 3. Injection Pump and Setting Gage "VB" Pumps

covered by the helix of the plunger and the point at which it is uncovered by the circular groove around the plunger. The end of injection is always at the end of the plunger stroke. The beginning of injection is variable, being controlled by the governor.

On the downward stroke of the plunger, the space above the plunger is filled with fuel oil which enters thru the inlet port. The port is directly connected to the fuel oil header. After the helical edge of the plunger covers the port on its upward stroke, fuel oil is forced out thru the discharge valve, thru the injection tube and nozzle and into the cylinder. Injection continues during the stroke until the circular groove of the plunger uncovers the inlet port. When this occurs, fuel oil is no longer injected into the cylinder but is by-passed back into the fuel header. The circular groove is always filled with fuel oil, being connected with the space above the plunger by a vertical groove in the side of the plunger.

The plunger rotates in the barrel and is controlled by the governor thru a rack and pinion. Thus, the period of injection will vary, depending upon the distance between the circular groove and the point on the helix at the top of the plunger which covers the port.

Fig. 4 shows the injection pump barrel and plunger with the plunger in different positions for various load conditions. Note that less than a 1/4 turn changes the plunger position so that the effective stroke varies from "no fuel" to "full fuel" position. The effective stroke is that part of the plunger stroke during which the fuel inlet port is covered.

The rotary position of the plunger is controlled by the governor thru its linkage with the control rack of the pump. The control rack rotates the plunger thru the control gear, which

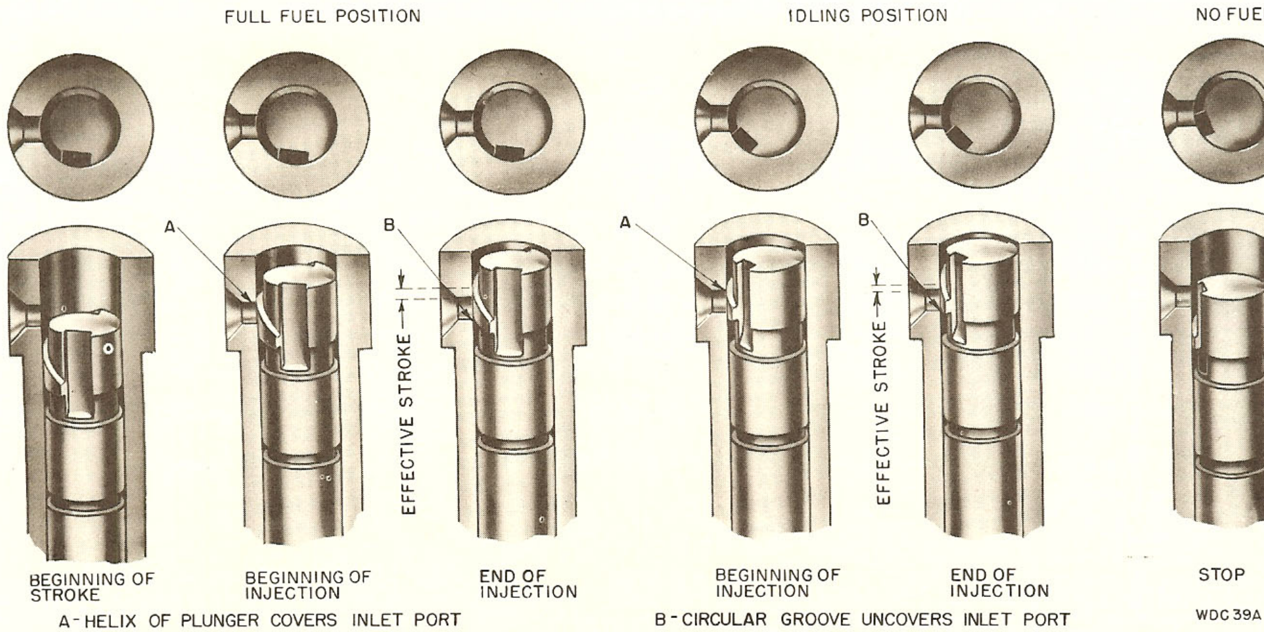


Fig. 4. Injection Pump Plunger Positions - "VB" Pumps

is splined to the plunger.

"VE" Pump Plunger Adjustment

The delivery valve holder nut is removed and the injection tubing moved aside. The discharge valve and spring are also removed. Do not remove the valve cage packing. The setting gage is placed on the injection pump discharge valve cage as shown in Fig. 5.

The pump plunger height must be adjusted when an injection pump is changed on a cylinder. Proper adjustment is accomplished by adding or removing shims (L) in Fig. 1, so that the land (X), Fig. 5, is flush with the end of the gage body when the pump plunger is at the end of its stroke or at the high cam position.

Bar the engine thru the high cam position and determine the distance the land (X) is under or above the end of the gage body. The determined value is the amount of shims to add or remove for proper pump plunger position.

NOTE: The following paragraph applies only to engines equipped with injection pumps provided with an inspection window. This design was superseded by the setting gage described above. See Fig. 1.

The V-line (F) should just clear the bottom edge of the inspection window (G) when the cam roller is on the base circle of the cam. When this condition is obtained, injection begins when the center of V-line (F) on the plunger reaches hairline (H). This is the setting as made at the factory. Should the pump be removed for any reason, or should a pump replacement be made, adjustment must be such that the V-line (F) just clears the bottom edge of the inspection window when the plunger is in its lowest position, as noted above.

"VB" Pump Plunger Adjustment

The delivery valve holder nut is removed and the injection tube moved aside. The discharge valve and spring are also removed. Do not remove the valve cage packing. The setting gage is placed in the valve seat as shown in Fig. 3.

The pump plunger height must be adjusted when an injection pump is changed on a cylinder. Proper adjustment is made by adding or removing shims (L) shown in Fig. 1.

Bar the engine so that the piston of the cylinder being checked is at upper dead center $\pm 2^{\circ}$. Determine the distance the gage is under

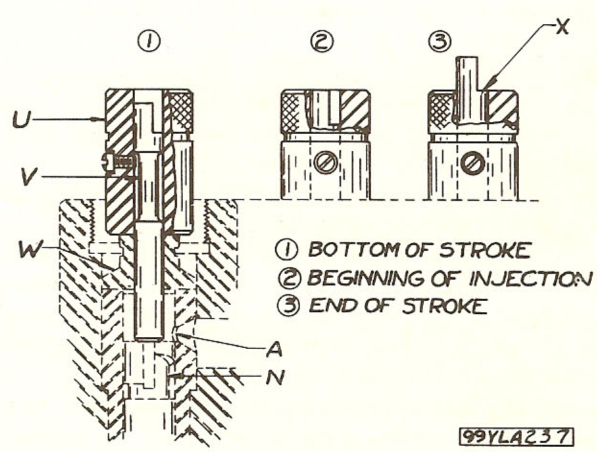
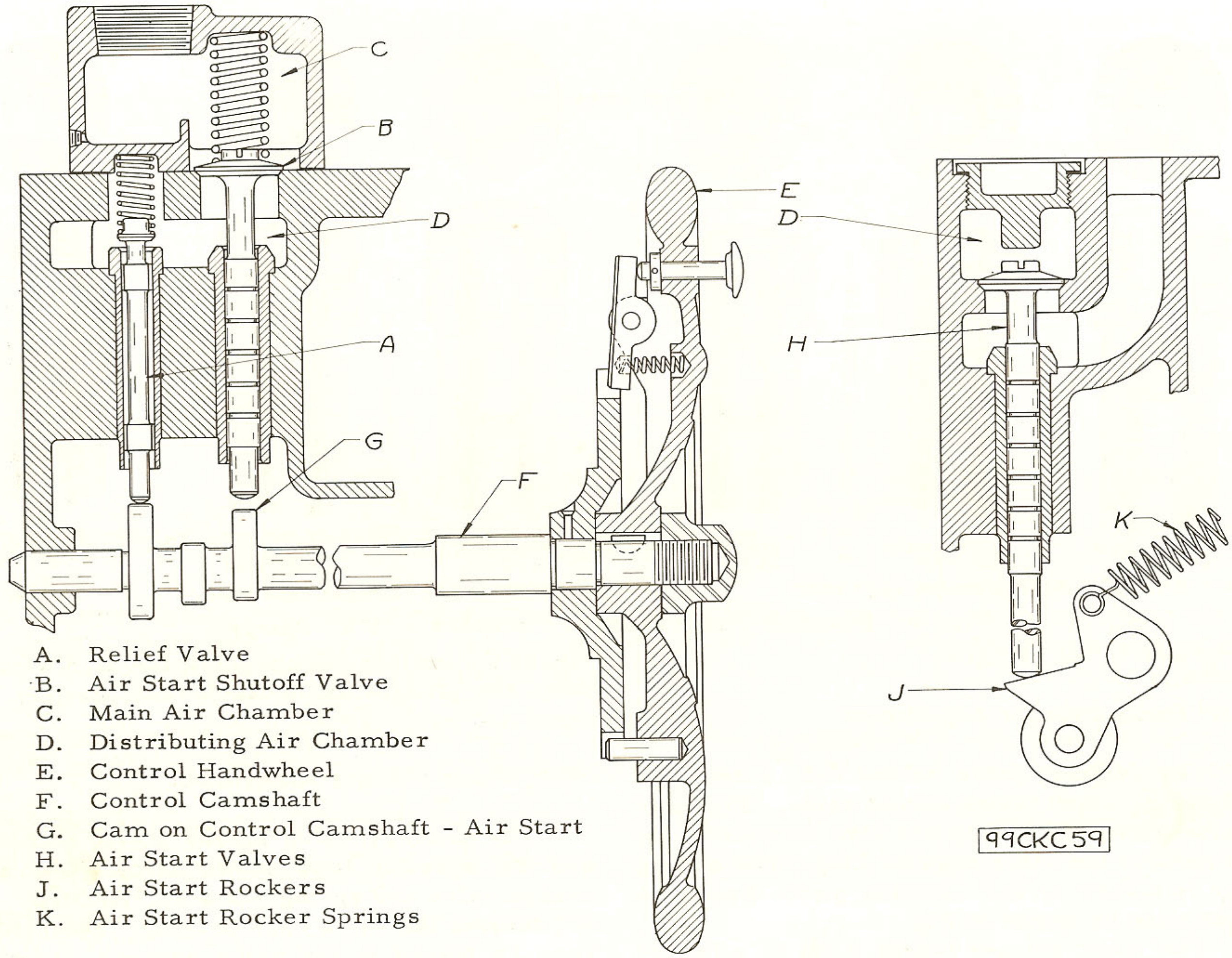


Fig. 5. Injection Pump Setting Gage "VE" Injection Pumps



A. Relief Valve
B. Air Start Shutoff Valve
C. Main Air Chamber
D. Distributing Air Chamber
E. Control Handwheel
F. Control Camshaft
G. Cam on Control Camshaft - Air Start
H. Air Start Valves
J. Air Start Rockers
K. Air Start Rocker Springs

Fig. 6. Air Start System - Stationary Engines

or above the valve seat. The determined value is the amount of shims to add or remove so that the gage is flush to the valve seat at high cam position.

Injection Pump Adjustment for Cylinder Load Balance

The duration of the fuel injection is also a measure of the quantity of fuel injected and is controlled by the governor.

For information regarding cylinder load balance, refer to page 28.

The adjustment for all cylinders is sealed at the factory and is not to be changed. If necessary, adjustment can be made by changing the position of the arm connecting the injection pump rack with the fuel control shaft.

Fuel injection nozzles are of the spring loaded differential type, set for an injection pressure of 2500 psi. For all other information on the operation and servicing of the nozzles, refer to instructions No. 2769, latest state.

Firing Order

5 Cyl.	
Starboard and Reverse Stat.	1-5-2-3-4
Port and Standard Stat.	1-4-3-2-5
6 Cyl.	
Starboard and Reverse Stat.	1-5-3-4-2-6
Port and Standard Stat.	1-6-2-4-3-5
7 Cyl.	
Starboard and Reverse Stat.	1-7-2-5-4-3-6
Port and Standard Stat.	1-6-3-4-5-2-7

Air Start System

General

Compressed air is used to start the engine. The system consists of the following units:

1. An independently or engine driven air compressor.

2. A tank or tanks for storing the compressed air.

3. A safety valve set to open, or an automatic compressor unloader valve set to operate at 250 psi.

4. The necessary pipe and fittings.

5. An air start mechanism built into the engine.

The air start mechanism of item 5 differs for the marine and stationary engines and the two types of mechanism are treated separately in the following paragraphs.

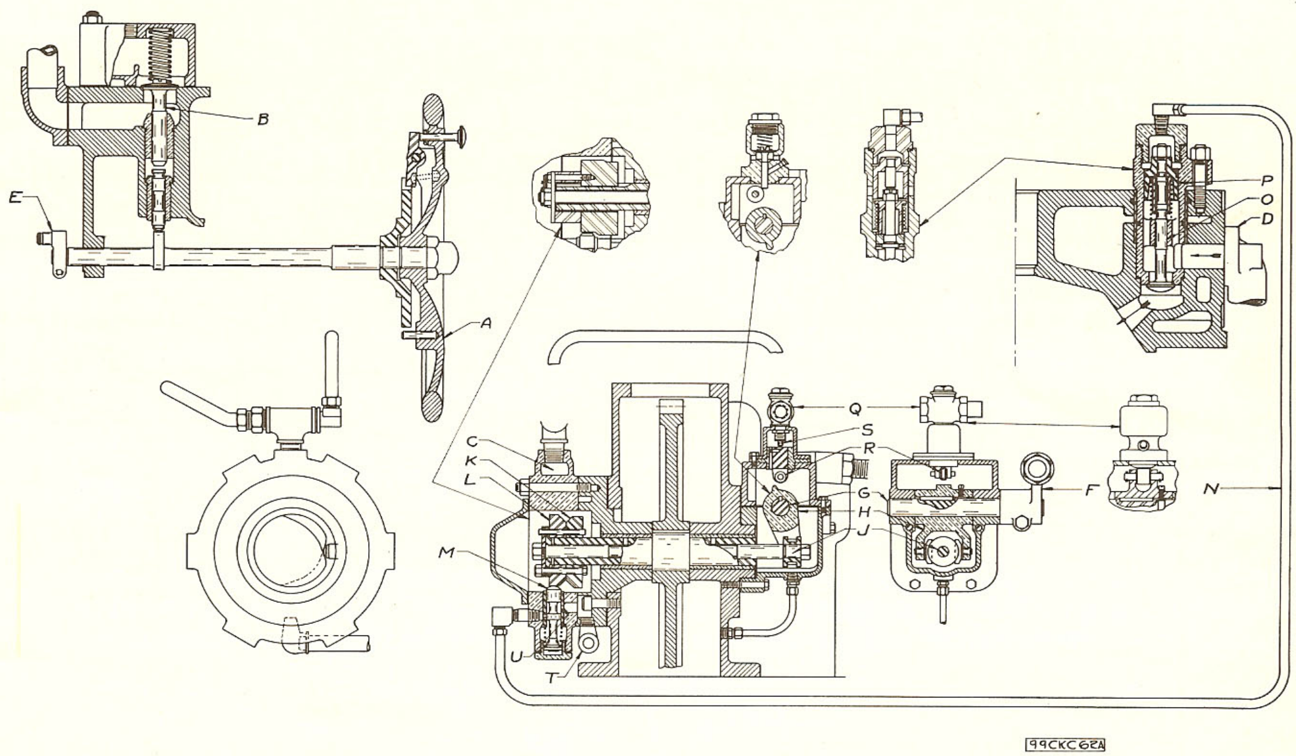
Air Start Mechanism - Stationary Engine

The following discussion applies to all stationary engines. See Fig. 6. The air start mechanism is located in the fuel and air valve housing to the rear of the injection pumps. The control wheel on stationary engines has three position, START - RUN - STOP. This handwheel actuates both the air starting and the fuel injection mechanism.

Before starting the engine, the main air chamber (C) is filled with high pressure air by opening the valve in the air line from the storage tanks. For continuous engine operation after starting, the air line valve is closed.

When the control wheel (E) is turned to "START" position, the air starting mechanism is put into operation to rotate the engine until firing begins. Cam (G) opens air shutoff valve (B) allowing high pressure air to flow into the distributing air chamber (D).

When the engine is stopped or is running, there is no high pressure air in the distributing chamber (D), and the air start valves (H) are held open by means of springs on the valve rockers (J). One air start distributor valve is



A. Control Handwheel
B. Air Start Shutoff Valve
C. Distributor Housing Air Chamber
D. Air Start Pipe Elbow
E. Control Shaft Crank
F. Reversing Arm
G. Air Cam Reversing Shaft
H. Air Cam Shifter Lever
J. Air Cam Shifting Shaft
K. Forward Air Cam
L. Reverse Air Cam
M. Distributor Pilot Valves
N. Pilot Air Tube
O. Check Valve
P. Check Valve Piston
Q. By-Pass Valve
R. Valve Operating Roller
S. By-Pass Valve Stem
T. Drain
U. Bleeder Port

Fig. 7. Air Start System - Marine Engines

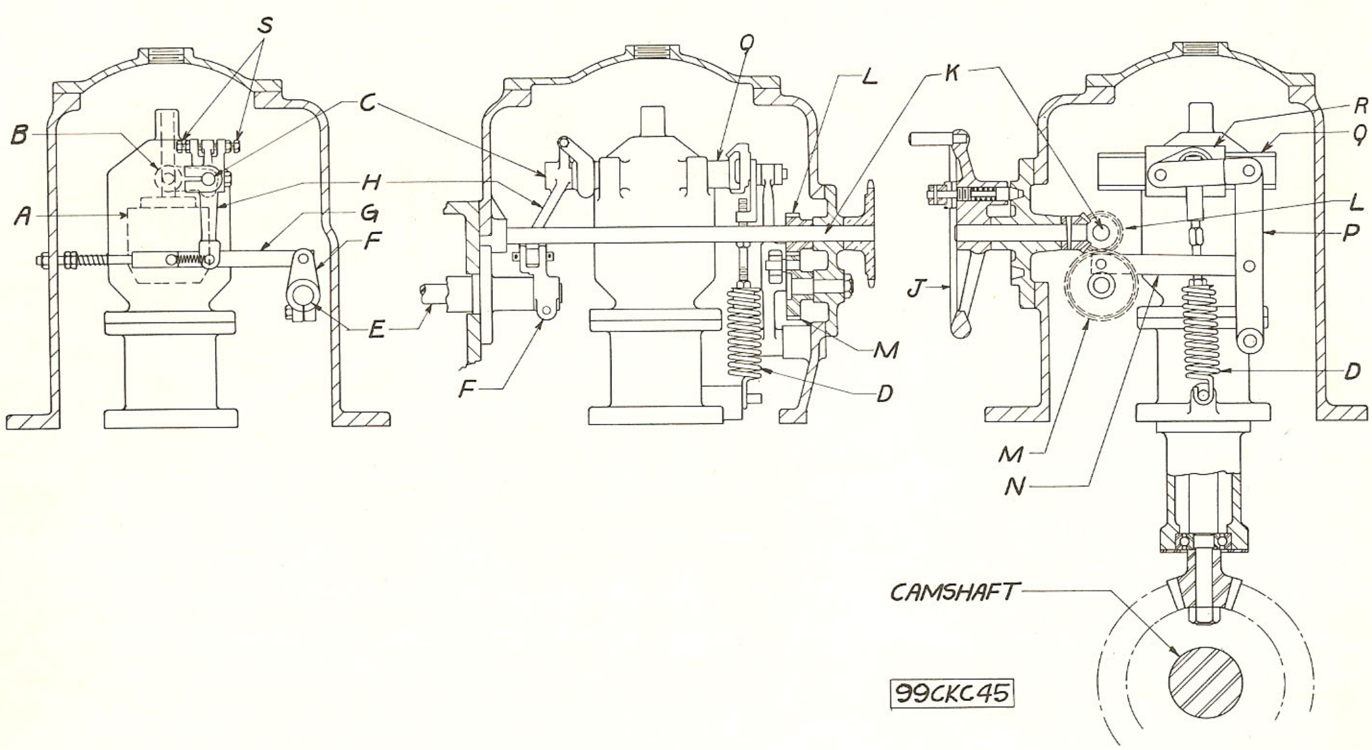
provided for each cylinder. When the high pressure starting air is admitted to the chamber (C), the air pressure closes all except one or two of the distributor valves. The position of the air starting cams determines which of these valves remains open to start the engine. At least one distributor valve is held open by means of its starting cam, and therefore, the engine can always be started instantly regardless of the crankshaft position. As the engine begins to rotate, the air starting cams revolve with the camshaft and actuate the corresponding valve rockers (J) which opens the air start valves (H). This allows the high pressure air to pass into the cylinders in the proper sequence.

When the engine attains sufficient rotative speed and firing begins, the control handwheel (E) is turned from "START" to "RUN." As the engine control handwheel is turned to the running position, the two cams on the control shaft (F) operate to close the main air shutoff valve (B) and to open the air start relief valve (A). The trapped air in the chamber is allowed to escape and the air start valves (H) are permitted to return to their normal position by the springs (K).

Air Start Mechanism - Marine Engines

A manually operated distributor type of air starter is used on the marine engines. (See Fig. No. 7.) The distributor is located on the upper base at the aft end of the engine.

When the control handwheel (A) is moved from "STOP" position to "START" position for the direction of rotation in which it is desired to start the engine, the following action takes



A. Governor Weight
B. Governor Yoke
C. Governor Control Shaft
D. Governor Spring
E. Injection Pump Control Shaft
F. Governor Control Arm
G. Governor Control Link
H. Governor Control Lever
J. Speed Control Handwheel
K. Speed Control Shaft
L. Speed Control Pinion
M. Speed Control Gear
N. Speed Control Link
P. Speed Control Lever Arm
Q. Governor Spring Arm
R. Governor Spring Arm Slide
S. Governor Yoke Adjusting Screw

Fig. 8. Pickering Governor - Marine Engines

place:

The air start shutoff valve (B) is opened admitting high pressure air to the air start header and distributor housing air chamber (C). The air start header is located on the control side of the engine, below air start pipe elbow (D).

The control shaft crank (E), being connected to the reversing arm (F) by a rod, rotates the air cam reversing shaft (G). The air cam shifter lever (H) is keyed to the air cam reversing shaft (G). Thus, when the air cam reversing shaft (G) is rotated, the shifter lever (H) moves the air cam shifting shaft (J) and the proper cam into position for the rotation desired. Cam (K) is for forward rotation and cam (L) is for reverse rotation. As the cam rotates the distributor pilot valves (M) are opened and pilot air is admitted thru the pilot air tubes (N) to the respective check valves in the cylinders. As the air enters the space above the check valve piston (P), the piston is forced downward opening the check valve (O). The check valve (O) is balanced and cannot be opened by starting air from the air start header. It is opened, only, by the pilot air from the distributor pilot valve (M), and when opened, by this means, starting air from the air start header immediately flows into the cylinder.

After the engine has commenced firing, the control handwheel (A) is turned to the "RUN" position which closes the shutoff valve (B) and automatically bleeds the high pressure air from the system. With air pressure removed from the distributor pilot valves, springs hold the valves closed and free from contact with the cam. The drain (T) will take care of any condensation and will also aid in bleeding air from the system which will come thru the port (U).

The air distributor by-pass valve (Q) is used to automatically bleed high pressure air from the distributor housing when the engine is reversed. This valve (Q) is relieved by means of the cam action of the air cam shifter lever (H) upon the valve operating roller (R) which pushes the valve stem (S) of the valve upward.

Governing System - Pickering Marine Engines

A Pickering Governor is mounted adjacent to the fuel injection pump body. Refer to Fig. 8. This governor is of the flyball type and is driven from the camshaft by means of a flexible bevel gear drive. The governor holds the engine speed within narrow limits under varying load conditions but it may also be used to vary the speed over a fairly wide range.

When the load on the engine fluctuates, the engine speed tends to increase or decrease accordingly but the governor operates to overcome this tendency. The governor weights (A) are connected to the governor spindle. As the engine speed varies, the governor weights swing outward around the spindle in varying radii; this results in a corresponding upward or downward movement of the governor yoke (B). The movement of this yoke is retarded by the governor spring (D) which is designed to provide a specific resistance to the centrifugal force of the governor weights. Thus the governor yoke (B) is allowed to move only enough to produce a certain change of speed regardless of the load variation. The governor yoke is pinned to the control shaft (C) which turn-about its axis when the yoke moves up or down. This movement of the governor control shaft (C) is transmitted to the injection pump control shaft (E) by means of the governor control lever (H), the control link (G), and the control arm (F). When the injection pump control shaft (E) is rotated, the amount of fuel delivered to the cylinders by the injection pumps is varied accordingly.

With a constant load (torque) on the engine, the governor may be used to vary the speed over a considerable range. When the speed control handwheel (J) is turned, the control shaft (K) is also turned by means of meshing bevel gears on the two shafts. This rotates the speed control gears (L) and (M) accordingly. The speed control link (N) is pinned to the gear (M) and to the lever arm (P). Thus, the rotation of the gear causes the lever arm to swing about the fulcrum at its lower end. The governor spring arm (Q) is fastened to the governor control shaft (C), and the governor spring (D) is fastened to the spring arm slide (R). When the lever arm (P) is moved, the slide (R) moves along the spring arm (Q), and the effective length of the spring arm is changed. This causes the governor spring (D) to rotate the spring arm (Q) and the control shaft (C) which actuates the injection pump control shaft (E). Thus, the engine speed changes to correspond to the new position of the injection pump control shaft (E). The engine remains under governor control regardless of any change in the operating speed.

Adjustment of Pickering Governor

Refer to Fig. 8. The governor is adjusted at the factory to obtain the correct position of the control rack for the No. 1 fuel injection pump. All other pumps are adjusted to the No. 1 pump. The governor is adjusted by changing the angular location of the governor control lever (H) with respect to the control shaft (C);

the adjusting screws (S) are provided for this purpose. The governor and the No. 1 fuel injection pump are properly adjusted at the factory. The adjusting screws are wire sealed. This seal is not to be broken nor the adjusting screws moved in any way.

When the governor and the injection pumps are correctly adjusted, the engine will operate at rated rpm at full load. The governor is so adjusted that fuel cannot be delivered to the engine for more than 100% of full load. The no-load speed is from 6 to 10% greater than the full load speed. By means of the governor speed control, the engine speed may be reduced to approximately 120 rpm.

Governing System - Woodward Stationary Engines

The Woodward Governor is a rectangular case containing the complete mechanism, including the oil pump, the relay cylinder for operating the fuel control equipment, flyballs for timing, and link mechanism, etc. This unit is bevel gear driven from the camshaft.

The flyballs are small and serve only to indicate speed. The flyballs transmit the speed indication to a small valve, that is in perfect hydraulic balance, and it is this valve that controls the oil under pressure to move these mechanical parts required to relocate the fuel setting. Speed changes of less than 1/100 of one per cent will cause corrective movement of the fuel control mechanism.

The governor is stable, that is, it does not hunt when the load is added or taken off, which, in cases where accurate speed control is required, is very desirable. Tests show the governor capable of accepting full load from no load with a maximum speed reduction of 4% and returning to normal speed in approximately three seconds time. The same results are attained in the rejection of load from full load to no load.

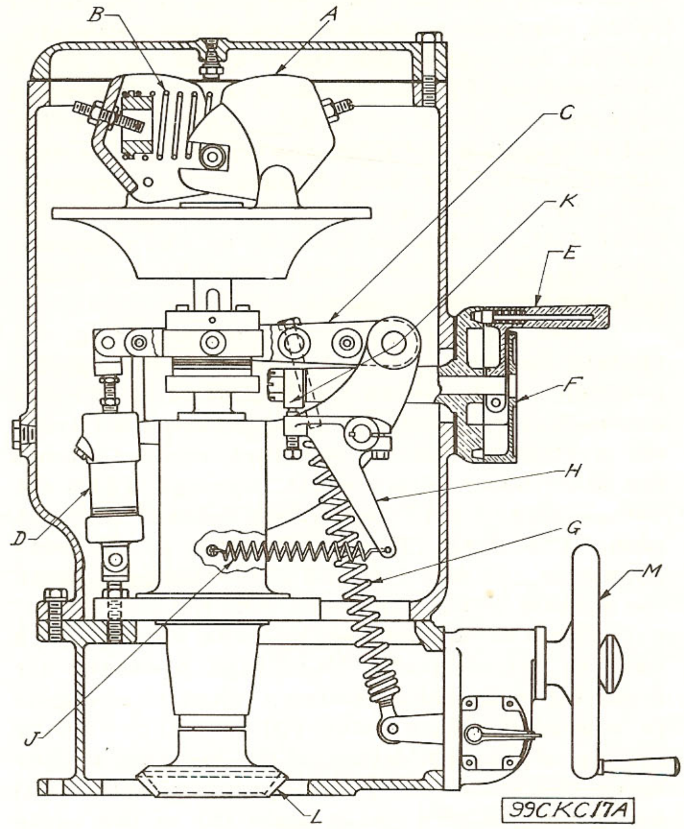
For more detailed information regarding this governor, refer to the Woodward bulletin at the back of this book.

Governing System - Fairbanks-Morse Stationary Engines

This governor, used on early engines, is of the flyball type, having a vertical spindle which is driven from the camshaft by a bevel gear. See Fig. 9. The governor has two weights (K) that are hinged to a circular disc that is keyed to the upper end of the spindle. A single tension spring opposes the weight. The spring is mounted horizontally and in such a position that its centrifugal force is balanced and does not affect governing.

A dash pot is provided to prevent hunting on sudden load changes and also a synchronizer to bring the engine into step with the other units with which it may operate in parallel.

The manual control on this governor is used as an emergency stop in case the control mechanism should stick or fail and the engine could not be stopped with the control wheel. Before starting the engine, the control handle (E) is placed at the "RUN" position which is marked on the dial (F). It is not necessary to return this control to the "STOP" position at any time that the engine is stopped. It can be left in the "RUN" position unless needed as an emergency stop.



A. Overspeed Governor Weight Spring
B. Overspeed Governor Weight
C. Overspeed Governor Stop Lever
D. Overspeed Governor Trip Lever
E. Overspeed Governor Trip Lever Spring
F. Overspeed Governor Trip Lever Shaft
G. Overspeed Governor Reset Handle
H. Overspeed Governor Reset Dog
J. Overspeed Governor Shutoff Arm

Fig. 9. Stationary Engine Governor (Fairbanks-Morse)

Overspeed Governor

The overspeed governor weight spring (A) is set to allow weight (B) to disengage lever (C) from the trip lever (D). See Fig. 10. The spring (E) pulls the lever (D) down, and a pin engages the shutoff arm (J) which cuts off the supply of fuel to the injection pumps. Before starting the engine again after the overspeed governor has been tripped, the reset handle (G) must be pushed back as far as it will go, which engages dog (H) against the pin on the trip lever (D), thereby returning the trip lever to its normal operating position with the stop lever (C). After the overspeed governor has been reset as described above, the engine can be started in the usual manner.

Lubricating System

The engines are equipped with a lubrication and piston cooling system in which a positive feed lubricator furnishes lubrication for the pistons, cylinder walls, scavenge pump sleeves, and the built-in air compressor rocker arm. See Fig. 11. A pressure system maintains a constant level in the force feed lubricator and supplies a continuous flow of oil to all other surfaces requiring lubrication, and also furnishes oil to the pistons for cooling.

Wet Sump Lubrication and Piston Cooling - See Fig. 12.

With this system one built-in gear type lubricating oil pump is used. This pump draws oil from the lower base suction header, the suction end of which extends to the lower base (Aft end for marine engines). The pump delivers oil under pressure thru the cooler and strainer from which it is piped to the main oil distributing header in the lower base. By means of branches from this header to each main bearing, and thru drilled passages in the crankshaft, connecting rods and piston pins, oil is delivered to the main, crankpin and piston pin

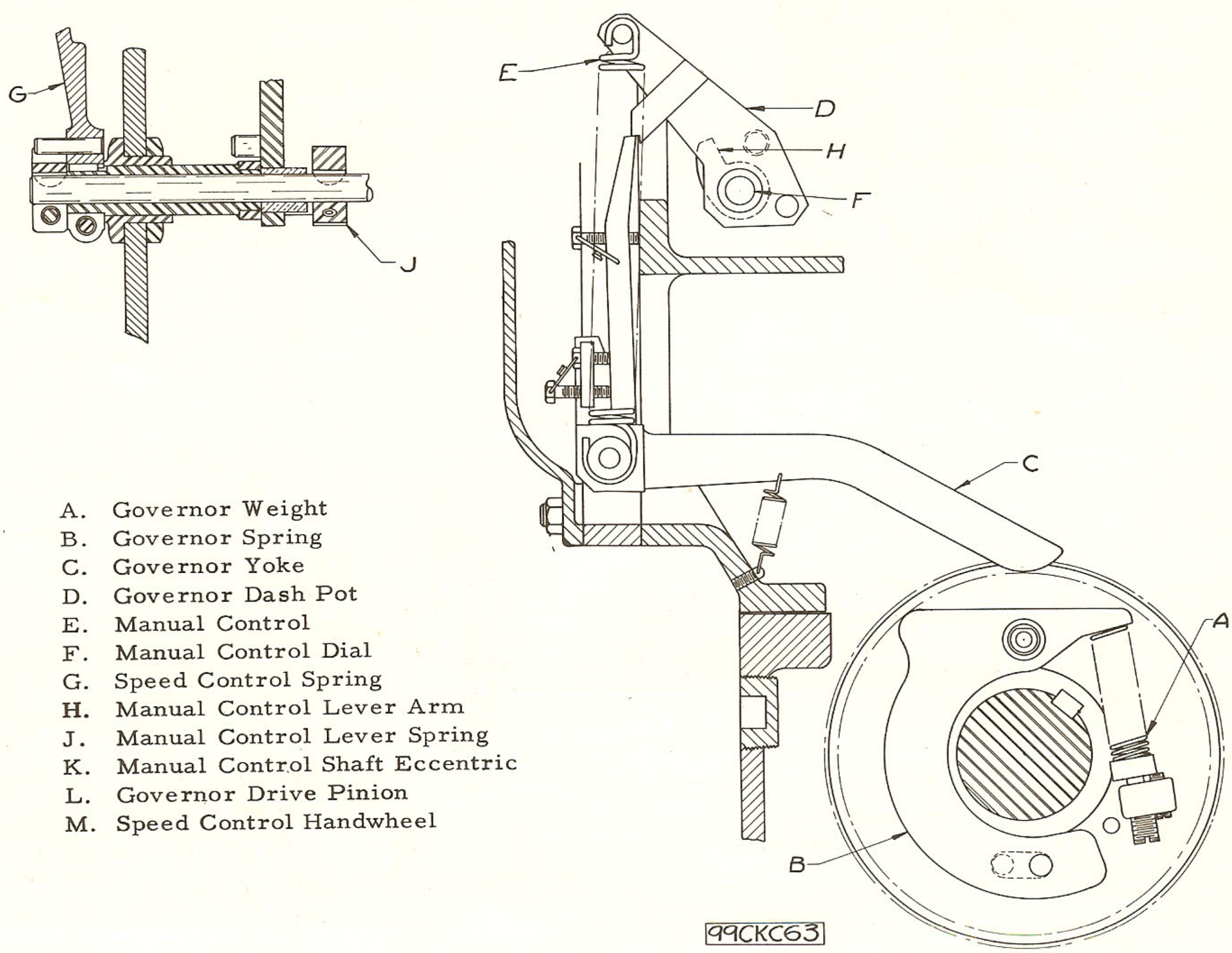


Fig. 10. Overspeed Governor

bearings and to the pistons for cooling. From the pistons, the oil is returned to the lower base.

A branch from the main header supplies oil to the injection pump, air start, governor drive, camshaft gears and bearings, and keeps the force feed lubricator filled. The lubricator supplies oil to the pistons and cylinder walls, scavenge pump sleeves, and several parts of the built-in auxiliaries. The overflow from the lubricator and the excess oil from the camshaft bearings maintain a level in the camshaft housing so that the injection and air start cams operate in a bath of oil.

The excess oil from the cylinder walls is removed by means of scraper rings located at the lower end of each cylinder. The oil is collected in a header and flows by gravity or is pumped thru a connection at the end of the engine to a cylinder drain oil tank. A transfer pump is used to convey the oil from the tank to the filter.

A small hand push pump is mounted on the operating side of the engine at the scavenge pump end. This pump supplies lubricating oil to the scavenge pump piston. See Fig. 13.

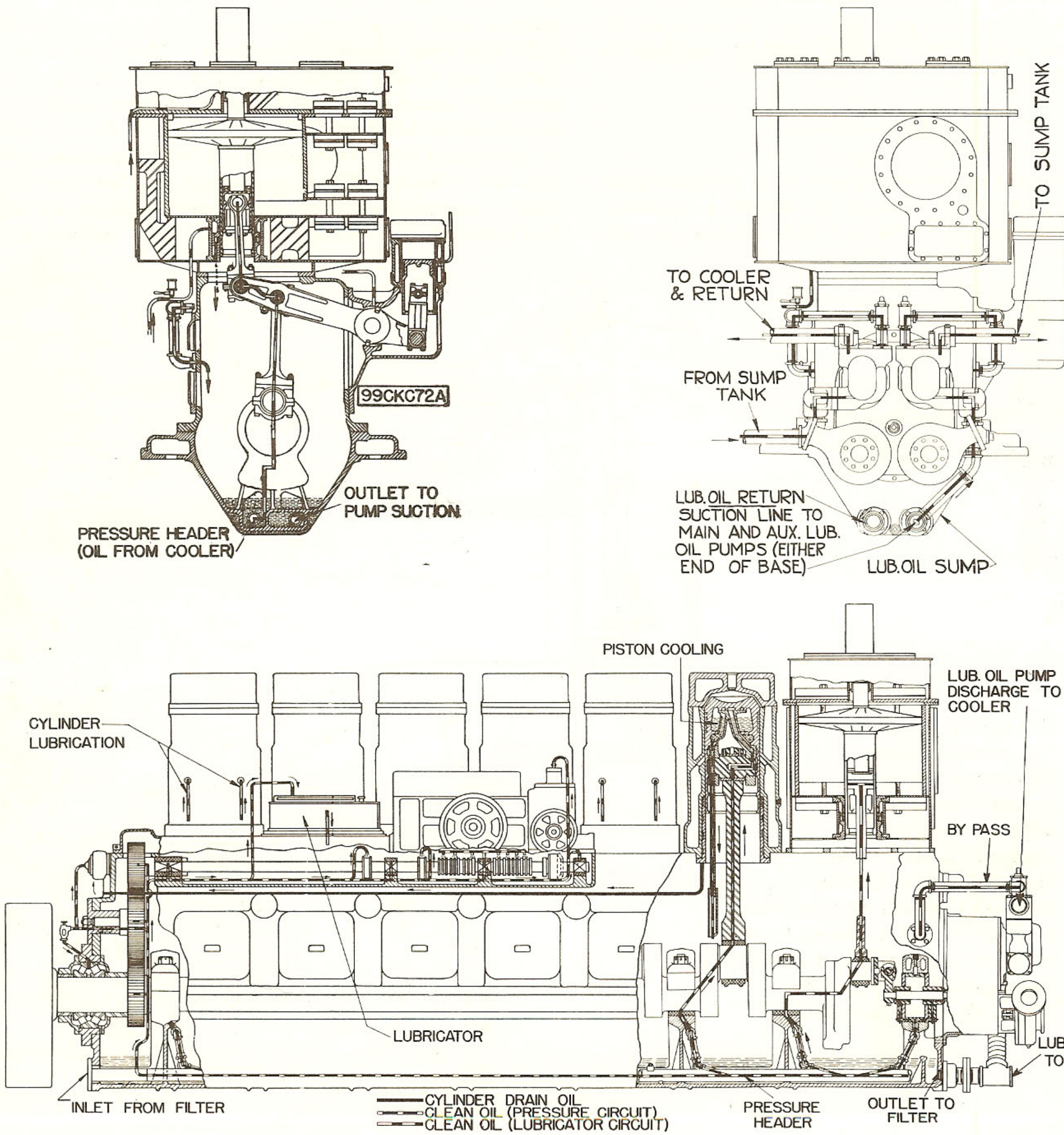


Fig. 11. Lubricating Oil Circulation Thru the Engine

NO. CYL.	H.P.	PIPE SIZES				G.P.M. CIRCU-LATED	GAL. OF OIL IN ENGINE
		A	B	C	D		
5	575	3	2	3	2	100	120
6	690	3	2	3	2	100	150
7	805	3	2	3	2	120	162

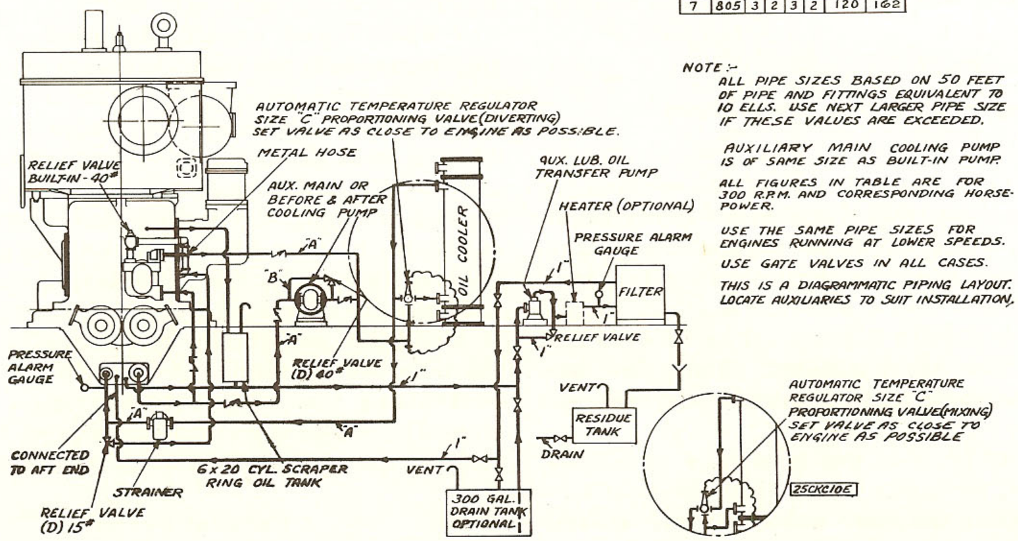


Fig. 12. Lube Oil Piping Arrangement - Wet Sump

Adding Oil to the System

Purified oil from the filter and "make-up" oil are added to the sump thru a connection at the forward end of the engine. The oil level in the sump is indicated by a bayonet type gage. The average total amount of oil per cylinder in the engine, not including outside piping, sump, etc., is approximately 26 gallons per cylinder. The bayonet gage for the "high" oil level should be marked when the oil level in the crankcase is 1" below the lowest point of the crankpin bearing when on lower dead center on the aft end of the engine. This marking will indicate the "high" oil level in the engine. The "low" oil level is 3" below the high level. Since engines are installed either level or with varying degrees of rake, the high and low level markings on this gage are made in the field at the time of engine installation. Do not mark this gage until after the engine has run long enough to fill the piston cooling oil pockets, etc.

Cylinder oil scraper rings remove oil from the system at the rate of approximately one gallon per hour per cylinder. Purified or new oil must be added at a sufficient rate to maintain the proper oil level. Check the level hourly.

Cooling Water System

General

An adequate supply of clean cooling water is essential for satisfactory operation of these engines. Only clean, soft water, that is, water free from scale forming ingredients, should be used in the cooling system as even a thin layer of scale or dirt on the cylinder jacket walls will act as an insulator and cause overheating and possible breakage. Either of two systems may be employed: open or closed. The closed system for all installations is recommended. When only river water, which is dirty, muddy, or sandy, or hard water containing an excessive amount of scale forming material is available for cooling, the closed system must be used.

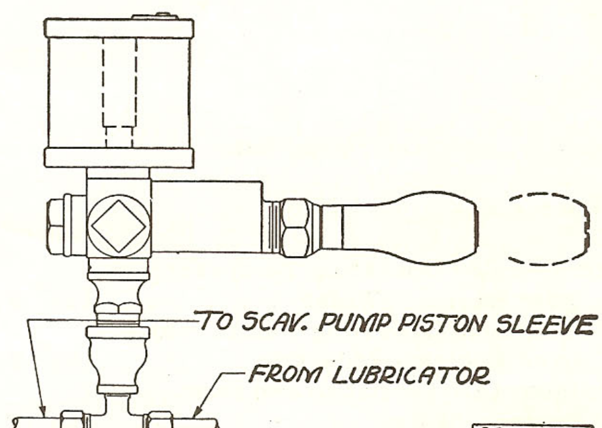


Fig. 13. Hand Push Pump

The two systems are described in detail.

The cooling water system on these engines consists of the cooling water passages in the cylinders, heads, and exhaust manifold, and the necessary equipment for circulating and cooling the water.

Closed Cooling in a Marine Installation

When this system is used, the engine is fitted with two built-in reversible centrifugal water pumps. One of these pumps circulates clean soft water thru the engine water jackets, exhaust manifolds and a suitable heat exchanger. This is a closed circuit. The flow of the water should not be restricted. Full flow insures more uniform temperatures and reduces the possibility of steam pockets.

The second built-in pump is used to circulate sea, lake, or river water thru the heat exchanger to cool the soft water of the closed water circuit. A by-pass should be installed in the raw water circuit to permit the by-passing of all or a part of this water around the heat exchanger. This provides a suitable means of controlling the temperature of the soft cooling water.

If separately driven pumps, or pumps other than the ones described above, are used for the cooling water circuits, they should be chosen with a capacity of 30 gallons of water per brake horsepower hour against a head of 50 feet. The temperature differential of the inlet and outlet water should not exceed the values given under Operating Instructions. The soft water temperature is regulated by by-passing a part of the soft water around the cooler. On stationary installations separately driven water circulating pumps are ordinarily used.

Open Cooling

When open cooling is used (which is not recommended) the built-in pump circulates soft river or lake water, or water from a hot well directly thru the engine water jackets from whence it is discharged. A water temperature of 140° F. is the maximum allowable with this type of cooling, and with a temperature differential of 10° F. When this arrangement of cooling is used, the cylinder, cylinder heads and exhaust manifolds must be closely watched to avoid the possibility of excessive scaling of the interior surfaces. As an effective means of controlling the water temperature, provision should be made for returning the waste water to the suction of the circulating water pump.

Exhaust System

The exhaust system consists of the necessary equipment to conduct the gases from the cylinders to the atmosphere.

Scavenging System

Scavenging air is supplied to the cylinders under a pressure of from 1 to 2 psi by means of a built-in scavenging pump. An air receiver connecting the discharge from the scavenging pump to the air inlet ports for each cylinder provides the system for distributing scavenging air to the cylinders. The air is admitted to the cylinders during the period that the air inlet ports are uncovered by the pistons.

II. OPERATING INSTRUCTIONS

Operating Data

Temperatures

Recommended Operating Temperature from Engine - Water	135° F.
Recommended Operating Temperature from Engine - Lube Oil	160° F.
Maximum Differential to and from Engine - Water	10° F.
Maximum Differential to and from Engine - Lube Oil	20° F.
Recommended Differential to and from Engine - Water	5-6° F.
Exhaust - Maximum	550° F.

Pressures

Scavenge Air	1-2 psi
Lube Oil	12-15 psi
Compression Pressure . . .	440-500 psi
Firing Pressure - Maximum . .	860 psi

Before Starting the Engine

The instructions under this section should be followed closely when preparing for the first start or for a start after a prolonged shut down. When the engine is operating regularly, this routine may be modified as conditions warrant.

Check the Installation

Check all auxiliaries before the engine is started. Make a final check of the complete installation. See that the engine is properly aligned and fastened securely to the foundation. See that all nuts are tight and provided with cotter pins or lockwashers where necessary. Open the compression relief valve and bar the engine over several revolutions to make sure that all moving parts are free.

Air Start System

Check the air start system to make sure that it has been properly installed. Blow out all air lines before final connection is made at the engine to free them of dirt, scale, etc. Make a final connection to the air line and charge the tanks to 250 psi. Inspect the lines for leaks and remedy them if any are found. Check the relief valves to make sure that they open at the proper pressure.

When the stationary engine has been shut down for a period longer than one month, remove all air check valves in the cylinder heads and all air start valves in the fuel and air valve housing, and clean the stems with crocus cloth. Lubricate the stems when replacing the valves.

When a marine engine has been shut down for a considerable period, lubricate the air start check valves in the cylinder heads. Disconnect the pilot air tube from the check valve and pour in a teaspoonful of oil thru the opening.

Cooling Water System

Fill the cooling water system and inspect all joints for leaks, remedying them if any are found.

The water should always be drained after stopping the engine if there is danger of freezing.

Lubricating System

Fill the system with lubricating oil, as recommended by a reputable oil company.

The lubricating oil should be free flowing and suitable for the engine and the conditions under which it is to operate.

Before adding any oil to the system, and especially to the engine, make sure that all pipes and tanks are clean and free of dirt, scale and water. Disconnect the inlet to the main supply header in the lower base. Remove one of the cover plates from the upper base, and arrange the supply pipe to discharge thru a strainer. Remove the bag and reconnect the oil lines. Fill the system.

Wet Sump System

Remove one of the crankcase cover plates and pour oil into the crankcase until the level is one inch below the lowest position of the connecting rod cap. This is the level at which the high level marking is made on the bayonet oil gage, and requires approximately 26 gallons of oil per cylinder. If the system is being filled for the first time, mark the bayonet gage as outlined under I. "Lubrication."

Start the independently driven oil pump and set all valves so that the entire system is in operation. With this pump in operation, all pressure supply lines will be filled with oil, and oil will overflow from the lubricator into the camshaft housing. The overflow from the camshaft housing is such that the cams operate in a bath of oil. Operate the independently driven oil pump for about five minutes to insure the lubrication of all moving parts.

Priming

The engine driven lubricating oil pumps should be primed as follows:

Two discharge openings are located at the top of the pump body. The main discharge pipe is connected to one of these openings. The other opening is used for the relief valve overflow or is covered by a blind flange.

Remove the flange or pipe fitting (as the case may be) from one of these openings. Remove the nut on the end of the valve rod and then remove the spider, discharge valve and valve spring. Fill the discharge chamber with clean oil and lift the valve rod so that the suction chamber below the suction valve will also be filled. The suction chamber cannot be primed unless the suction line has a foot valve. Fill the pump to the level of the discharge valve and replace the valve rod and the discharge valve, spring and spider. Replace the nut on the valve rod and fill the pump discharge chamber thru the openings in the spider and replace the blind flange or discharge pipe fitting.

Fill Lubricator

Fill the lubricator to the overflow level with the grade of oil to be used in the pressure lubricating system.

Prime Lubricator Tubes

Disconnect the longest lubricator tube at its connection to the engine and crank the lubricator until oil flows from the tube. Reconnect the tube and crank the lubricator again for about 50 turns. Watch the oil level in the lubricator and pour in more oil if necessary.

Crank Lubricator Before Every Start

Give the lubricator about 50 turns after a shutdown of one hour or more. This will insure positive lubrication to all surfaces fed by the lubricator immediately after the engine is started.

Hand Pump Lubricator at the Scavenging Pump

Fill the hand push pump lubricator at the scavenge pump, and pump until increased resistance indicates that the pipes are full. Continue to pump for several strokes. This lubricates the scavenging pump piston sleeves for the starting period.

For best results, the pump should be operated slowly and the handle pulled out completely before pushing it back. See Fig. 13.

Clean Fuel Tanks and Piping

Before filling the fuel tanks and other parts of the system, the tanks should be cleaned of all water and other accumulations and the piping blown our or flushed out with fuel oil.

Fill Storage Tank

Fill the fuel storage tank and inspect for leaks. Use an approved fuel oil.

Fill the Fuel Supply Reservoir

If low level daily service tanks are used, remove the pipe plug from the top of the reservoir, and pour in strained fuel oil until the reservoir is full. Replace the plug. When using an overhead tank, open the valve in the line from the tank to the filter; remove the 1/8" pipe plug from the top of the fuel reservoir to vent the air. When the fuel has passed thru the filter and filled the pump housing and reservoir, replace the vent plug and proceed to prime the injection pumps and valves as outlined below.

Priming the Fuel Supply Pump

Remove the suction valve plug (see Repair Chart of the Repair List Section), withdraw the suction valve and pour in strained fuel oil until the passages are full.

Prime Injection Pumps and Injection Nozzles

With the fuel supply pump and reservoir filled, proceed as follows to prime the injection pumps and valves.

Make sure that the valve at the air starting supply lines at the engine is closed. Loosen the vent screw in the injection nozzles (Instructions 2769, latest state, in back of book). Place the point of the injection pump priming bar (R) (see Fig. 1) under the end of the injection pump roller. With the aid of this priming bar, pump the plunger up and down until fuel oil, free from bubbles, is seen to flow from the valve under the vent screw. If the pumps will not prime after following the foregoing procedure, the discharge valve (C) may be stuck. Remove the delivery valve holder nut (T) so that the injection tubing and fittings may be pushed aside. The discharge valve (C) and spring are then removed and cleaned. Replace the valve, spring and tubing and prime the pump.

NOTE: The plunger must be at the low point of its stroke in order to permit priming the pump. If the plunger is not at its low point, the inlet port will be covered and the pump chamber cannot be filled with fuel. Bar the engine over slowly for part of a revolution to uncover the port and allow the pump to fill with fuel. When priming the pump, the control wheel should be in the "RUN" position.

CAUTION: The cupped lower end of the injection pump tappets are carried on spherical seats located on top of the injection pump rockers. In using the priming bar, be careful that these spherical seats are not allowed to loosen and drop down into the camshaft housing.

Auxiliaries

All auxiliary equipment should be carefully inspected to see that each unit has been properly installed and suitably arranged with reference to its function in the general machinery arrangement. Inspect the switchboard to see that all connections have been correctly made. Start each electrically operated auxiliary to see that it receives proper current and functions normally.

Controls

Set the engine controls as follows:

Stationary Engines fitted with Woodward Governor:

Engine Control Wheel	Stop
Governor Load Dial	10

Stationary Engines fitted with Fairbanks-Morse Governor:

Engine Control Wheel	Stop
Manual Control Lever	Run

Marine Engines fitted with Pickering Governor:

Engine Control Wheel	Stop
Speed Control Handwheel . . .	*Mark "3"

* Mark "3" is halfway between "SLOW" and "FAST" and the engine operates at about half speed when the handwheel is in this position.

NOTE: The starting positions of the different controls may be varied as determined by experience, however, the control wheel should always be in the "STOP" position.

Relief Valves

Close the compression relief valves.

Barring Device

Disengage the barring device. It is essential to always disengage the barring device immediately after having used it.

Cooling Water System

Open such valves in the cooling water system that are necessary for the particular installation. If the engine is not equipped with built-in pumps, start the auxiliary independently driven cooling water pump.

Fuel System

Regulate such valves in the fuel system as are necessary to place the system in operating condition.

Determine if the fuel system is operating properly. Check the operation of the fuel supply pump by watching the fuel pressure gage. The pressure should be from 5 to 8 psi.

Air Start System

Open all valves in the air start system that are necessary for the particular installation.

Starting the Engine

When the foregoing instructions have been carried out, the engine is ready for starting. Quickly turn the control wheel from the "STOP" position past the "RUN" position (Stationary Engines) or past the "AHEAD" or "ASTERN" position (Marine Engines) to the limit of movement in "START" position. As soon as the engine starts firing, shift the control wheel to the "RUN," "AHEAD," or "ASTERN" position as the case may be.

To aid starting when extremely cold, the engine is equipped for the use of starting cartridges.

In case the engine does not start firing almost immediately, shift the control wheel back and forth between "START" position and the operating position, but if the engine does not start firing after several attempts, do not exhaust the supply of starting air. First, make sure that fuel is being injected. Then, remove two or three of the starting cartridge plugs from the cylinder heads. On marine engines, first remove two or three of the "safety valves" from the cylinder heads and insert the "starting cartridge holders." (After the engine is started and warmed up, stop the engine and replace the "safety valves.") Ignite and insert the starting cartridges and replace the plugs. Then repeat the starting procedure as outlined previously.

After the Engine is Running

These instructions apply particularly to the first start or to a start after a long shut down. When the engine is operating regularly, this routine may be modified as conditions warrant.

Charge the Air Tanks

Close the air shutoff valve in the starting air line at the engine. Recharge the air tanks, then close the valves at the tanks.

Check Cooling Water System

Determine if the cooling water system is operating properly. Adjust the water flow so that the cooling water outlet temperature does not exceed the values tabulated under "Operating Data."

Check Lubricating Oil System

Determine if the lubricating and piston cooling oil system is operating properly. See that the lubricating oil pump is maintaining the oil level up to the height of the over-flow in the lubricator. Watch the pressure gage in the lubricating system, and the thermometers at the side of the crankcase on the control side (when used). The pressure and temperatures should be within the values tabulated under "Operating Data." Circulate all of the cooling water thru the oil cooler and by-pass all or a part of the lubricating oil to control the temperature.

Check the Fuel System

Determine if the fuel system is operating properly. Check the operation of the fuel supply pump by watching the fuel pressure gage.

Checking Operation

Run the engine at slow speed for about 10 minutes watching the operation closely during this period. Then shut down and remove the crankcase cover plates on one side. Check the main, connecting rod and piston pin bearing temperature by hand and inspect for sufficient lubrication on pistons, cylinders, etc. Replace the cover plates and start the engine again and run for about 30 minutes and recheck. If the engine is operating properly, apply the load gradually. Watch the operation closely.

Maneuvering - Marine Engines

Open Air Valves

The air valve in the air line at the engine and the valve at the storage tank must be wide open while maneuvering.

Set Air Compressor Unloader

If maneuvering is to continue for some time, the air compressor unloader must be set so that the air supply will be continually replenished while the engine is in operation.

Reversing Procedure

The only controls used in maneuvering the engine are the main engine control handwheel and the governor speed control handwheel. The procedure outlined below is to be followed regardless of the direction of rotation.

Reduce Engine Speed

When reversing, reduce the engine speed by turning the governor speed control handwheel in a clockwise direction on a starboard engine or in a counterclockwise direction on a **port** engine.

Stop Engine

After the engine speed has been reduced sufficiently, turn the engine control handwheel to the "STOP" position. The engine must come to a complete stop before being restarted in the opposite direction of rotation.

Restart Engine in Opposite Direction

When the engine has completely stopped, turn the engine control handwheel to the "START" position in the opposite direction of rotation. Then, when the engine has gained sufficient rotative speed, turn the engine control handwheel to the running position at "AHEAD" or "ASTERN," as the case may be. Adjust the engine speed with the governor speed control handwheel.

If the engine refuses to start in the opposite direction of rotation, return the engine control handwheel to the "STOP" position and open the compression relief valves in the cylinder heads. Then, close the relief valves and turn the engine control handwheel to the "START" position in the desired direction as explained above.

Stopping the Engine

To stop the engine, merely turn the control handwheel to the "STOP" position.

Crank Lubricator by Hand

While the engine is slowing down, give the lubricator about 50 turns to provide extra cylinder lubrication during the shutdown period.

Circulate Oil Thru the Engine

Before the engine is stopped, start up the auxiliary lubricating oil pump and continue to circulate oil thru the engine five to ten minutes after the engine has stopped or until the latent heat is removed.

Circulate the Cooling Water

Continue to circulate the cooling water thru the engine water jackets for the same period of time that the lubricating oil is circulated.

III. INSPECTION ROUTINE

Inspection

Inspect the engine and its equipment regularly. It is an excellent plan to have a regular inspection routine. To assist operators in making up a suitable routine, the following is offered.

Routine

This routine is offered as a suggestion for the average installation. Systematic care of the whole installation reduces the cost of maintenance. After making a careful study of the requirements of each installation, an inspection and maintenance routine should be established and adhered to rigidly.

Daily Routine

Under "After the Engine is Running" will be found certain duties which should be performed immediately after every start.

Inspect the fuel level in the storage tank.

Fill the daily service tanks as required.

Inspect for sufficient water in the cooling system.

Check for sufficient oil in the lubricating system.

On wet sump engines, check the oil level in the crankcase every hour. The scraper rings remove oil from the system at a rate that will drain the system in approximately 24 hours.

Readings of all indicating instruments such as gages, thermometers, meters, etc., should be taken at regular intervals as determined by the engineer, and an accurate hourly record kept.

Drain water and sludge from the lubricating oil filter.

Filter the "wiper oil" as required.

Check the oil level in the thrust bearing on marine installations.

Check and record the exhaust temperature.

If an exhaust washer is used, blow out the drain pipes.

Check the lubricator feeds every shift.

Check the operation of all cooling water and lubricating oil alarms every shift.

Weekly Routine

Remove crankcase cover plates immediately after the engine is shut down, and check the bearing temperatures by hand to determine if they are normal. Inspect cylinders, pistons, etc., for proper lubrication. Examine connecting rod and main bearing bolts and cotter keys, also the piston pin bracket stud nuts. Replace crankcase covers.

Drain any water and sediment from the lubricator.

Drain the air tanks and lines of water and oil accumulations.

Clean lubricating oil strainers.

Filter all the oil in the crankcase. (Wet sump engines.)

Clean fuel strainers and filters.

Drain water and sludge from the fuel oil day tanks.

Check for scale in water jackets. Clean thermocouples and check exhaust temperatures.

Monthly Routine

Inspect and clean exhaust equipment and exhaust pipe lines. Exhaust accumulations in ports and manifolds should be removed.

Drain water and sludge from fuel oil storage tank.

Inspect and clean the valves of the built-in air compressor, if the condition of the air compressor warrants.

Drain the lubricator and wash out with lubricating oil.

Check the operation of the piston rings thru the exhaust ports.

Check the operation of the injection nozzles in the test stand. If they are working satisfactorily, do not disassemble them. See Instructions 2769, latest state, in back of book.

Remove inter-cooler water gasket covers on built-in air compressor and clean jackets.

Clean the oil heaters, if used.

Quarter-Annual Routine

Drain the entire lubricating and piston cooling system, and wash out thoroughly with lubricating oil, all parts in which sediment might collect. This applies to the force feed lubricator, crankcase, oil cooler, filter, pumps and piping. The oil should be filtered and returned to the system. This procedure is to be followed if the condition of the oil shows contamination.

Wash out the fuel reservoir with fuel oil.

Inspect the fuel supply pump valves.

Inspect and clean the fuel injection nozzles. Reseat if necessary. Read instructions 2769, latest state, in back of book.

Flush the cooling water system using a high pressure source, or follow the recommendations of the manufacturer of the softening system.

Inspect the scavenging pump cylinder and piston for accumulation of foreign matter, and clean if necessary. Also, clean all ports and valves in the scavenge pump and the passages in the air receiver.

Check all coupling bolts, shafting, steady bearings, etc.

Check all hold down bolts.

When the engine is in standby service, or is not in regular daily operation, remove all air start valves in the fuel and air valve housing, and all air check valves in the cylinder heads and clean the stems with crocus cloth. Lubricate the stems when replacing the valves.

Semi-Annual Routine

Pull the pistons for inspection and cleaning. Clean the ring grooves thoroughly. Examine the connecting rod and piston pin bearings.

Examine the cylinder walls. When cleaning the cylinders, place a piece of canvas over a piston ring and insert in the bottom of the cylinder to catch carbon and dirt. Clean exhaust ports. Check exhaust port bridges to see whether they have extended beyond the cylinder surface. If so, they should be stoned down until they are even with, or .001" to .002" below the cylinder surface.

Inspect and clean all water piping, circulating pump and cooling equipment.

Flush and thoroughly clean the fuel oil system. Clean the main fuel tank.

If the engine is so equipped, inspect the zinc plugs and plates in the cooling system. Clean, and replace if necessary.

For engines in regular daily operation, remove the air start valve in the fuel and air valve housing and all air check valves in the cylinder heads and clean the stems with crocus cloth. Lubricate the stems when replacing the valves.

Annual Routine

Check the alignment of the engine, intermediate shaft and propeller shaft.

Clean out the fuel storage tanks.

Care of the Engine Room

Cleanliness is an important item in engine operation. It is our observation that a clean, well kept engine room lessens the likelihood of trouble with the machinery.

IV. SERVICE INSTRUCTIONS

Main Bearings

Main Bearing Adjustment

Adjustment of the main bearing is necessary when there is excessive clearance between the crankshaft and the bearing shell. Excessive clearance may be indicated by loss of pressure in the lubricating and piston cooling system. The proper clearance is .003" to .005" and may be measured by means of a feeler gage slipped between the crankshaft journal and the upper bearing shell. If the clearance is found to be excessive, adjustment of the bearing is necessary. Proceed as follows:

1. Remove the main bearing caps and remove sufficient shims to give the proper clearance of .003" to .005". The thickness of the main bearing shims is as follows: Thin .006", medium .020", thick .064". Care should be taken to see that the shims are fitted snugly to the crankshaft journals as otherwise an oil leak will occur at this point with considerable reduction in oil pressure.
2. Replace the caps and tighten the nuts securely. Replace the cotter pins with new annealed pins.
3. With the engine again in operation, note the bearing temperatures from time to time.

After making any adjustment of the main bearings, a strain gage should be used to check the crankshaft alignment. If necessary, the support bearing (stationary engines) or the thrust bearing (marine engines) should be relocated.

Main Bearing Removal

When the bearing cap, upper half of the bearing shell, and the shims have been removed, the lower half of the bearing shell may be rolled out after first relieving it of the weight of the crankshaft by means of a small jack placed under the nearest crankweb.

If a jack is not available, the lower half of the bearing may be rolled out by inserting a hardwood stick or a brass rod into the oil hole of the crankshaft and barring the crankshaft over slowly.

New Bearing Shells

It will be necessary to fit the lower shell to its bed in the lower base and to fit the upper shell to the bearing cap. The shells must be scraped and lapped to give a good bearing surface, and special care must be taken in scraping the lower shell so that it receives its proper share of the crankshaft load. (Use Timesaver compound #80 made by Timesaver Products Co., 31 S. Des Plains St., Chicago, Ill. or the equivalent.)

Apply the load gradually and inspect the new bearing at intervals after the engine has been started.

Crankpin Bearings

Crankpin Bearing Adjustment

Adjustment of the crankpin bearing is necessary when there is excessive clearance. To check this clearance, remove the upper base handhole cover, and, with the end of a bar placed under the connecting rod cap, attempt to move the bearing up and down; determine any radial (up and down) movement between the crankpin bearing and the crankshaft. The bearing should be well lubricated when this check is made. With an oil film on the bearing, the radial movement referred to should be barely noticeable. At the same time, the bearing should have free end play.

If the bearing is found to have excessive radial clearance, remove sufficient shims to give a normal clearance. The thickness of the crankpin bearing shims is, as follows: thin, .006"; medium, .032", thick, .064". Replace the cap, tighten the nuts and again check the clearance. If satisfactory, and the bearing has free end play, replace the used cotter pins with new annealed cotters.

After this adjustment is made and the engine is running, note the bearing temperatures from time to time.

Piston Clamps

With each engine, two piston clamps are furnished for supporting the piston and connecting rod in the cylinder while a crankpin bearing is being removed. When a crankpin bearing is to be removed, fasten the two clamps to the lower end of the cylinder wall with the capscrews provided, allowing the end of the clamp to project up into the cylinder bore. Remove the connecting rod bolts, bearing cap and shims. As the crankshaft is barred over, the piston will rest on the clamp, and the bearing box may be removed as the crankshaft is turned into the proper position. This manner of supporting the connecting rod and the piston makes it unnecessary to remove the cylinder head and the connecting rod when renewing the crankpin bearing. Be sure to remove the piston clamp as soon as the crankpin bearing is reassembled, otherwise serious damage will result to the piston and cylinder.

Crankpin Bearing Renewal

Both box and cap must be scraped to a good fit on the crankpin, and must have about .018" to .032" end clearance. Always insert the cotter pin in the holes at the end of the connecting rod bolts and spread the ends of the pin well apart. There are two holes in the bolt for the cotter pin, either of which may be used, thus allowing a closer adjustment. When a new crankpin bearing has been fitted to an engine, inspect it at intervals after the engine has been started, and load gradually applied.

Pistons

Removing Pistons

The pistons may be withdrawn after removal of the cylinder heads, crankpin bearings, and the cylinder oil baffles. Two 3/4" tapped holes in the top of the piston permit the use of eyebolts in lifting the piston. Be sure to place the connecting rod guide at the foot of the rod, otherwise the scraper rings will be damaged.

Piston Rings

During the periodic inspection of the pistons, clean the carbon from the grooves. The rings must work freely in their grooves. If the rings are gummed in the grooves, use a solvent to free the rings. Wash off the solution after the parts are loosened. Clean all parts and lubricate thoroughly before replacing them in the engine. If any stuck rings have to be removed from the grooves, clean the grooves. Install new rings.

Piston Pin

The piston pin is held in place in the piston by means of the piston pin bracket. To remove the connecting rod and piston pin, first remove the piston pin bracket cap. Carefully clean all of the oil pockets and oil the bearing thoroughly before reassembling. When replacing the parts, see that they are put in their original places, and particularly that the connecting rods have not been reversed in their relation to the pistons.

Piston Pin Bushing Renewal

When replacing a piston pin bushing, drill out the two dowels that hold it in position, remove the old bushing and drive the new one into place. Two new holes then must be drilled for the dowels. To insure a good bearing for the piston pin, the bushing should be scraped, allowing from .004" to .006" clearance at the top of the pin. The bearing surface should extend over two-thirds of the lower part of the bushing.

When the piston pin bushing is renewed in the field, it must be scraped so that the piston pin, the bushing should be scraped, allowing from .004" to .006" clearance at the top of the pin. The bearing surface should extend over two-thirds of the lower part of the bushing.

When the piston pin bushing is renewed in the field, it must be scraped so that the piston will be properly aligned with the foot of the connecting rod. To check the alignment, place the piston pin in the connecting rod, and measure the distance from the foot of the rod to the pin at each end of the pin. Use a straight edge placed across the foot of the connecting rod, parallel to the piston pin, or stand the connecting rod on a surface plate for making these measurements. Scrape the bushing until the two measurements are the same.

Piston - Cylinder Head Clearance

Adjusting Cylinder Head Clearance

The cylinder head clearance may be adjusted by adding or removing shims at the joint between the foot of the connecting rod and the connecting rod bearing box. The connecting rod bolts must be removed to make the adjustment.

Checking Cylinder Head Clearance

The most accurate method of checking the clearance is to take the compression pressure by means of an indicator. The indicator cock should be installed in the tapped hole used for manual compression relief valves (stationary engines). On marine engines, the indicator cock should be installed in the same holes in which the spring loaded safety valves are located.

Compression Pressures

The compression pressures should be taken while the engine is hot, and should be within limits shown under "Operating Data." The variation of the compression pressures should not exceed 25 psi. The full load firing pressure should not exceed the value given under "Operating Data."

Checking Cylinder Head Clearance

A close check of the piston-cylinder head clearance may be made as follows: Immediately after the engine has been shut down, remove the injection valves of the cylinders to be checked. Bar the engine over until one of the pistons is near the top dead center, and insert two pieces of soft lead wire thru the valve opening, opposite each other, in such a manner that they will come between the cylinder head and the sloping portion at the top of the piston. Then bar the engine past upper dead center, remove the wires, and measure their thickness, which will be the actual piston-cylinder head clearance. The clearance at the closest point should be from .0625" to .094" with engine cold. Repeat the process on the other cylinders.

Injection Timing - "VE" Injection Pumps

Stationary Engines

The timing gears are marked as follows: One tooth on the crankshaft gear and the two meshing teeth of the intermediate gear are marked with the letter "O," and one tooth of the intermediate gear and the two meshing teeth of the camshaft gear are also marked with the letter "O."

Camshaft Gear - See Fig. 14.

The complete camshaft gear is made up of the gear hub and the gear rim. The gear hub is keyed to the camshaft, and the gear rim and hub are clamped together by means of bolts and nuts. Two setscrews provide a means for shifting the hub and camshaft with relation to the gear rim to obtain the proper timing.

After the cam gear has been assembled, the injection pump setting is adjusted. First, bar the engine over until the No. 5 piston (5 and 6 cyl. engines) or the No. 7 piston (7 cyl. engine) is in the upper dead center position. (Refer to "Arrangement of Cylinders," page 3 for cylinder numbering.) The piston is in the upper dead center position when the flywheel mark is aligned with the upper base to lower base joint on the control side of the engine. Then place a protractor against the No. 5 crank cheek (5 and 6 cyl. engines) or the No. 7 crank cheek (7 cyl. engine) and rotate the flywheel toward the control side the one engine (opposite the standard rotation) until the protractor shows the designated crank cheek to be 10° before upper dead center.

Loosen the six nuts which bolt the camshaft gear rim to the hub. The two setscrews provide

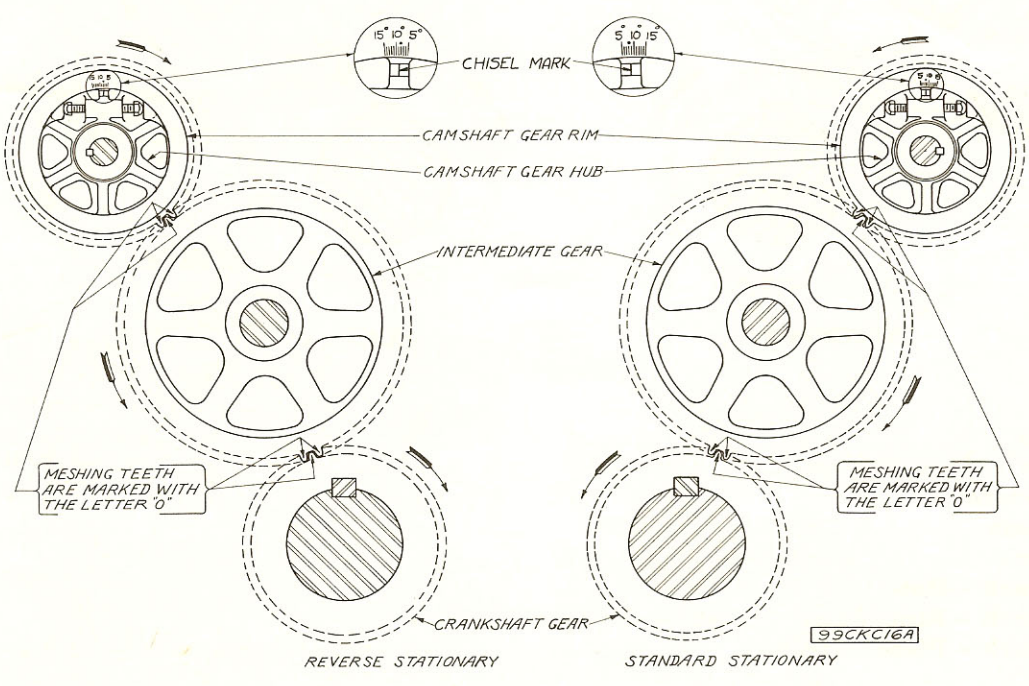
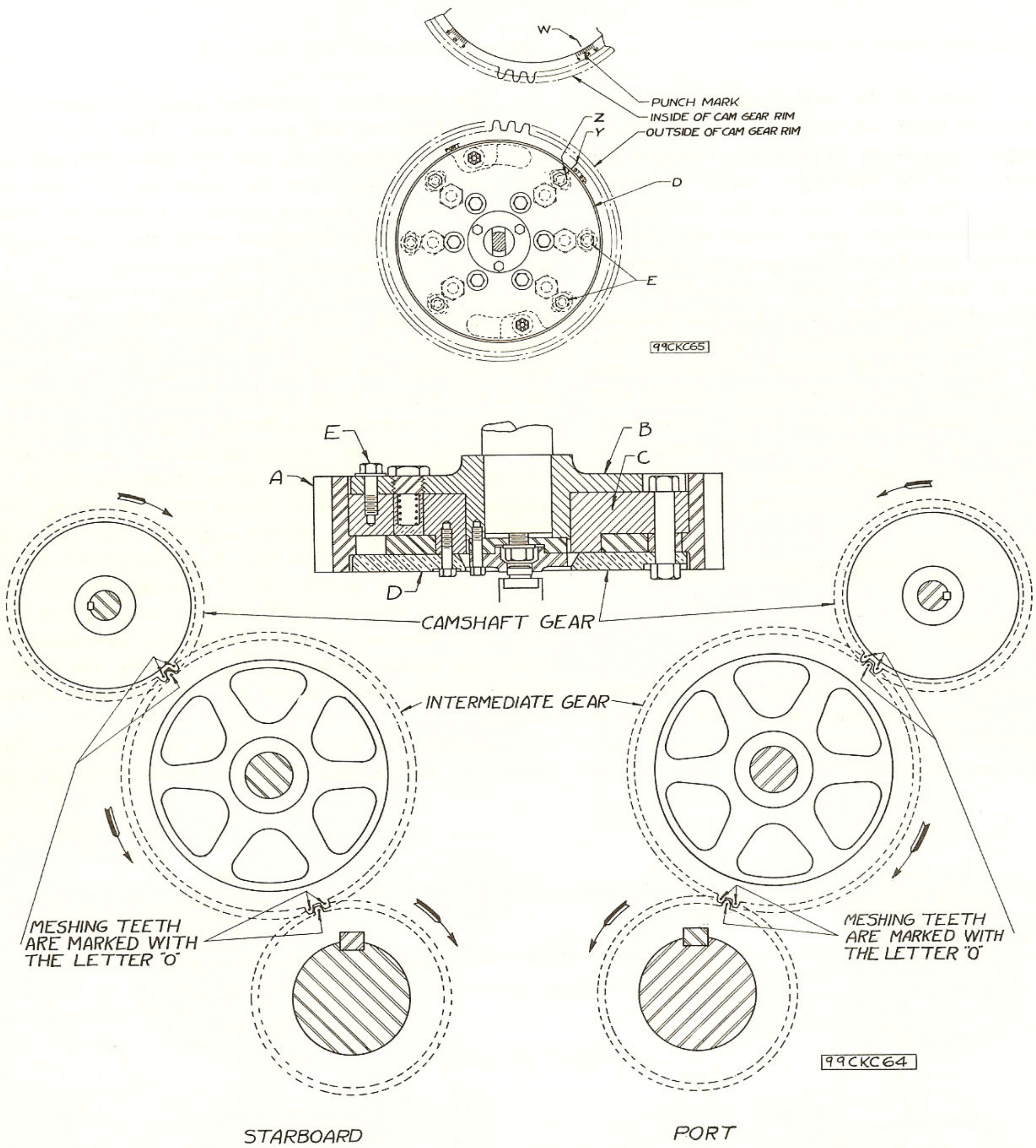


Fig. 14. Camshaft Timing - "VE" Injection Pumps - Stationary Engines



A. Gear Rim
B. Gear Hub
C. Driving Plate
D. Cover Plate
E. Capscrew
W. Chisel Mark - Hub
Y. Chisel Mark - Rim
Z. Chisel Mark - Plate

Fig. 15. Camshaft Timing - "VE" Injection Pumps - Marine Engines

a means for shifting the hub and camshaft with relation to the gear rim to obtain the proper timing. Turn the gear hub in a counterclockwise direction on an AR2 rotation engine, or in a clockwise direction on an AR1 rotation engine, until the injection pump plunger is at the beginning of injection. The plunger is at the beginning of injection when the end of the setting gage indicator (v) is flush with the top of the gage body as shown at (2). Check again to be sure that the crank cheek is 10^{o} ahead of upper dead center and that the setting gage indicates that the plunger is at the beginning of injection.

The various parts of the cam gear are marked and adjusted as outlined above when the engine is shipped from the factory. Thus the foregoing procedure applies only when repair parts are being installed in the cam gear assembly.

Marine Engines - "VE" Injection Pumps

The gear train marking for the marine engine is the same as for the stationary engine. The timing gears are marked as follows: One tooth on the crankshaft gear and the two meshing teeth of the intermediate gear are marked with the letter "O," and one tooth of the intermediate gear and the two meshing teeth of the camshaft gear are also marked with the letter "O." However, since the marine engine is directly reversible and the injection is approximately 10^{o} before upper dead center, the camshaft gear is designed to give the proper timing for both directions of rotation.

Camshaft Gear - See Fig. 15.

The camshaft gear is made up of the gear rim (A), the gear hub (B), the driving plate (C), and the cover plate (D). The gear hub (B) is securely keyed to the camshaft. The driving plate (C) is locked to the gear hub (B) by means of six capscrews (E) thru slotted holes in the gear hub. These slotted holes allow the gear hub and the camshaft to be shifted in relation to the gear rim. The gear rim (A) drives the driving plate (C) and the gear hub (B) thru the medium of a suitable slip mechanism. When the engine rotation is reversed, the gear rim (A) rotates (slips) between the driving plate (C) and the cover plate (D) 31-1/2 degrees to make the timing correct for the new direction of rotation. When the end of the slip movement has been reached (for either direction of rotation), the various parts of the gear form a rigid assembly for positive camshaft rotation.

The front face of the gear rim (A) is marked at the factory with the chisel mark (Y); the cover plate (D) is marked with the chisel mark (Z). The gear rim and the driving plate are in position for forward rotation of the engine when the marks (Y) and (Z) are together. The position for reverse rotation is obtained by turning the gear hub (B) with respect to the gear rim (A). On a port engine, the mark (Y) would be near the work "Port." (The starboard gear is used for illustrative purposes.)

After the cam gear has been assembled and checked as explained above, the injection pump setting is adjusted. First, bar the engine over until the index piston (No. 5 for the 5 and 6 cylinder engines and No. 7 for the 7 cylinder engines) is in the upper dead center position. The index piston is in the upper dead center position when the flywheel mark is aligned with the upper base to lower base joint on the control side of the engine. Then place a protractor against the No. 5 crank cheek (5 and 6 cylinder engines) or the No. 7 crank cheek (7 cylinder engine) and rotate the flywheel toward the control side of the engine (opposite the standard rotation) until the protractor shows the designated crank cheek to be 10^{o} before upper dead center. Turn the crankshaft gear hub (B) until the marks (Y) and (Z) are lined up together. Loosen the six capscrews (E) and turn the gear hub (B) in a counterclockwise direction on a port engine, or in a clockwise direction on a starboard engine, until the No. 5 injection pump plunger (5 and 6 cylinder engines) or the No. 7 injection pump plunger (7 cylinder engine) is at the beginning of injection. The plunger is at the beginning of injection when the end of setting gage indicator (V) is flush with the top of the gage body as shown at (2) (see Fig. 5). Check again to be sure that the crank cheek is 10^{o} ahead of upper dead center and that the setting gage indicates that the plunger is at the beginning of injection. While doing this, it may be necessary to hold the gear rim (A) and the cover plate (D) in position to keep marks (Y) and (Z) in line. Check again to be sure that the crank cheek is 10^{o} ahead of upper dead center, that the setting gage indicates that the plunger is at the beginning of injection, and that the marks (Y) and (Z) coincide. Then lock the gear hub and the driving plate together by tightening the capscrews (E). Opposite the 10^{o} graduation mark on the back of the gear rim (A), place the chisel mark (W) on the gear hub (B). The injection timing is then set 10^{o} ahead of top dead center. The engine may then be started and the operation of the engine checked.

The various parts of the cam gear are marked and adjusted as outlined above when the engine is shipped from the factory. Thus the foregoing procedure applied only when repair parts are being installed on the cam gear.

Injection Timing - "VB" Injection Pumps

Stationary Engines - Gear Train Markings

With No. 1 piston on upper dead center, the one marked tooth on the crankshaft pinion meshes with the two marked teeth on the intermediate gear, and the one marked tooth on the intermediate meshes with the two marked teeth on the camshaft gear. See Fig. 16, illustrating the camshaft gear and the gear train markings.

The complete camshaft gear is made up of the gear hub and the gear rim. The gear hub is keyed to the camshaft, and the gear rim and hub are clamped together by means of bolts and nuts. Two setscrews provide a means for shifting the hub and camshaft with relation to the gear rim to obtain the proper timing.

A pad on the camshaft gear hub carries a chisel mark. The camshaft gear rim is graduated in one degree graduations for five degrees on each side of the centerline which is opposite the chisel mark on the gear hub.

When the chisel mark on the pad of the camshaft gear hub is directly in line with the center graduation marked "O" on the camshaft gear, the marks determine the high point position of the injection cam in relation to the upper dead center of the corresponding piston. When the chisel mark on the camshaft gear hub is in line with the prick punch mark on the camshaft gear rim, factory setting is indicated.

When the chisel mark on the camshaft gear hub is directly in line with the "O" on the camshaft gear rim, and the gear train is meshed properly, No. 1 injection pump plunger will be at high point of cam and the No. 1 piston will be on upper dead center.

When the chisel mark on the hub lines up with the prick punch mark on the gear rim, and the gear train is meshed properly, the No. 1 pump plunger will be at high cam between zero and 5 degrees before the No. 1 piston reaches upper dead center. The actual setting varying with the particular engine. High cam should be at upper dead center $\pm 2^\circ$.

Adjustment of Injection Timing - See Fig. 16.

The factory setting is obtained when the punch mark above the graduations on the cam gear rim is directly in line with the chisel mark on the gear hub. If necessary, the injection timing of the engine may be altered by shifting the camshaft and cam gear hub with respect to the gear rim. First, bar the flywheel over until the index piston is at the upper dead center position. Then loosen the capscrews thru the slotted holes in the cam gear hub and shift the camshaft and cam gear hub with relation to the

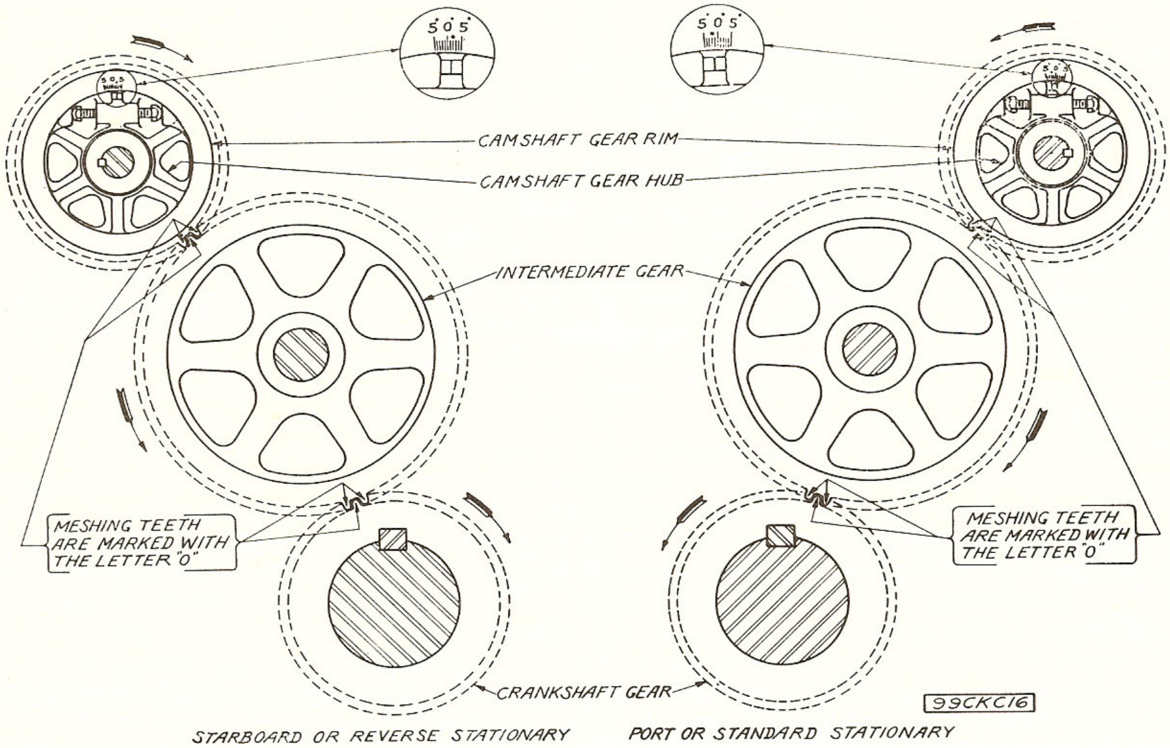


Fig. 16. Camshaft Timing - "VB" Injection Pumps

gear rim as required. The time of injection is advanced by holding the cam gear rim stationary and shifting the camshaft and gear hub in the direction of rotation of the engine; the time of injection is retarded by shifting the camshaft and gear hub in the opposite direction. Tighten the capscrews in the cam gear hub and check the operation of the engine.

> CAUTION: Do not change the injection timing by more than 1° at a time and check the engine operation after each such change. Since the firing pressures of the cylinders are affected when the time of injection is advanced or retarded, these pressures must be checked after each such change is made. (See Operating Data for limiting values of the firing pressures.)

Cylinder Exhaust Ports

When a piston is removed for inspection and cleaning, a check of the port bridges should be made with a straight edge, and a feeler gage, to determine that no growth of the bridges above the cylinder surface has taken place. If growth has occurred, the port bridges and cylinder surface adjacent to the exhaust port must be stoned or ground even with the surrounding cylinder surface. Although it is inadvisable to relieve the ports below the surrounding surface, a slight relief of .001" to .002" will do no harm. Slightly round the edges of the port openings with approximately a 1/16" radius.

When any growth occurs, it indicates higher than normal exhaust temperatures. The condition of the injection nozzles, the exhaust equipment, and the engine load should be investigated.

Fuel Injection Nozzles

The injection nozzles must be either cleaned or reseated from time to time for leaky nozzles will result in dark, smoky exhaust and irregular engine operation.

The frequency with which the nozzles must be ground will vary with the installation. Clean the tip once a month unless its condition indicates that this is too frequent. Complete cleaning and regrinding of the needle to its seat need be performed only when the operation of the engine indicates that it is necessary.

Refer to Instructions 2769, latest state, for complete information regarding the cleaning, grinding, or servicing of the nozzles.

Injection Pump Removal - See Fig. 1

If, for any reason, an injection pump is to be removed from the fuel and air valve housing proceed as follows: First, disconnect the fuel control rack (D) from the fuel control lever (Q) and remove the rack from the injection pump. Now, after removing nuts (M), the injection pump can be removed, as a unit, from the fuel and air valve housing.

In further disassembly of the pump, it is not necessary to remove the setscrew (K). (Fig. 1). If, however, this screw is removed be sure that it is replaced, and securely locked before replacing the pump on the engine.

Injection Pump Replacement - See Fig. 1

With the pump completely assembled, with the exception of the fuel control rack, it may be mounted in position on the engine and the nuts (M) replaced. The control rack (D) may now be inserted and meshed with pinion (E). The teeth of pinion (E) and rack (D) are such that they cannot be meshed incorrectly. The pinion should be turned to the proper position before inserting the rack. Complete the assembly by connecting the control rack with the control shaft lever. The adjusting screw (J) (Fig. 1) should be set to give exactly the same reading on the No. 1 pump. The adjustment (J) for the No. 1 pump is locked and is not to be changed. Refer to "Balancing the Load on the Cylinders."

> CAUTION: The injection pump body and the injection pump timing pointer are stamped with the cylinder numbers 1, 2, 3 etc. beginning at the scavenge pump end. The No. 1 pointer and No. 1 pump body, etc. should be assembled together and should be placed on the engine in their proper order. The pump serial number is also stamped on the body and on the pointer.

Exhaust Temperatures

The exhaust temperatures should not exceed the value given in "Operating Data." A variation in exhaust temperatures between individual cylinders would not necessarily be due to a variation in the quantity of fuel injected. The injection pump setting should not be changed to correct temperature variation.

Exhaust temperatures should be taken with the pyrometer equipment which is usually ordered with the engine. At the time the engine is installed, a record of the exhaust temperature of each cylinder with engine operating at full and variable loads, should be made. If any sudden change in the exhaust temperatures for any one cylinder is observed, the cause should be investigated and corrected.

Balancing the Load on the Cylinders

When the engine leaves the factory, all cylinders are in correct load balance and all injection pump control rack settings are exactly the same. This condition of perfect balance should remain unchanged for an indefinite period of engine operation. Before making any change first check the condition of the injection nozzles. Make sure that the tips are clean and that all nozzles are set for the same injection pressure. Also, make sure that accurate exhaust temperature readings are taken. Thermocouples must be clean as the presence of a thin film (1/32" thick) of carbon will alter the recorded temperatures.

A fairly accurate check of the load balance can be obtained by inspecting the position of the injection pump control racks. The pointer on the pump body should indicate the same graduation on each rack. The pumps are all calibrated so that each pump delivers the same amount of fuel at the same rack setting.

Force Feed Lubricator

The force feed lubricator supplies positive lubrication to the power cylinders, scavenge pump sleeves, and the built-in air compressor rocker arm. Each power cylinder has two feeds. The following table lists the number of drops per minute of the various feeds when the engine is running at its rated speed of 300 rpm.

Feed	Drops per Minute
Power Cylinders	28
Scavenge Pump Sleeve - Upper	7
Scavenge Pump Sleeve - Lower	28
Air Compressor Rocker Bracket	7

To check the feeds, first count the number of impulses per minute with the engine running at rated speed of 300 rpm. (This can be most accurately done by counting the impulses for a period of five minutes and dividing by five.) Use a stop watch. Divide the desired number of drops per minute by the number of impulses per minute as found above. The result of this division is the number of drops per impulse at which the feeds should be set.

When the number of drops per impulse has been determined, the lubricator feeds should be so set. This is accomplished by turning the adjusting buttons to the right (clockwise) to decrease the flow and to the left (counterclockwise) to increase the flow. The lubricator has an adjusting button for each sight feed.

Adjustment can be made at a lower engine speed by reducing the number of drops per minute proportionate with the speed.

For further information regarding repairs and service, refer to the Madison-Kipp bulletin in the back of this book.

Built-in Centrifugal Cooling Water Pumps

The pump shaft is mounted on ball bearings that are lubricated from the engine pressure system. The packing gland must be sufficiently tight to prevent leaking and the packing renewed occasionally. Do not screw the gland up too tight as this is sure to cause heating and will burn out the packing. It is best to tighten the nuts on the packing gland with a wrench, sufficiently to set the packing, and then release the nust until they can be turned with the fingers.

Rotary Lubricating Oil Pumps

Pumps for the stationary engine are non-reversible. Pumps for the marine engines are fitted with reversing valves to permit a positive flow of oil for either direction of pump drive shaft rotation. The valve may be inspected by removing the discharge fittings from the top of the pump body.

Bilge Pump

Covers are provided for valve and piston inspection and for removal of sludge. Piston and packing may be renewed or tightened.

Snifter Valve

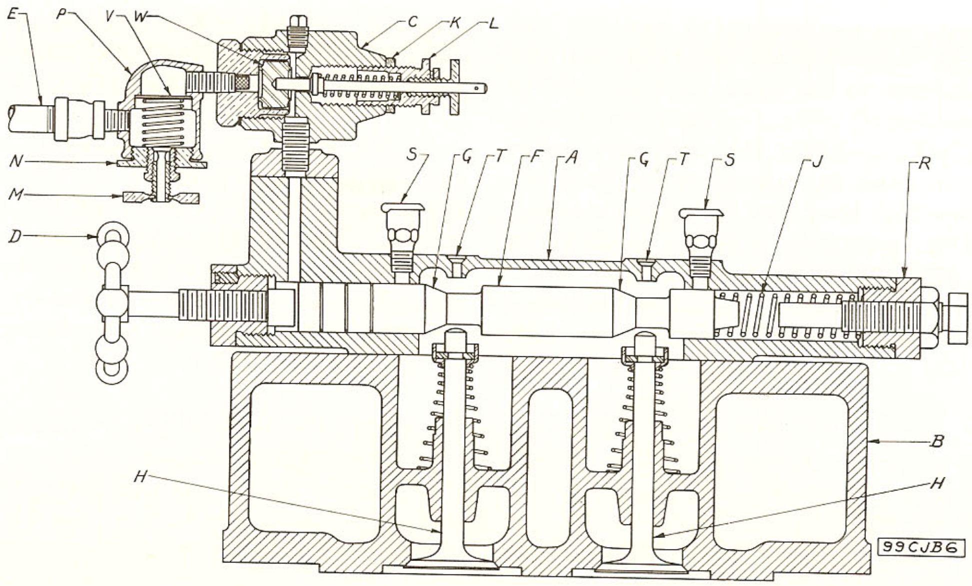
Both the water circulating pump and the bilge pump are equipped with manually operated snifter valves to admit air into the system to prevent water logging.

Fuel Supply Pump

The fuel supply pump should be inspected occasionally and the suction and discharge valves reseated if necessary. To remove these valves, unscrew the plugs directly behind the fuel reservoir.

Air Compressor and Automatic Unloader

Covers are provided over all valves to facilitate their removal for inspection, cleaning,



A. Unloader Mechanism
B. Air Compressor Cylinder Head
C. Unloader Pilot Valve
D. Handwheel
E. Air Pressure Pipe
F. Unloading Shaft
G. Taper Section
H. Air Suction Valve
J. Spring
K. Cap Locknut
L. Screw Regulating Cap
M. Drain Valve Handle
N. Cover
P. Strainer
R. Plug
S. Oil Cups
T. Open Holes
V. Felt
W. Piston

Fig. 17. Air Compressor Unloader

and reseating.

Automatic Air Compressor Unloader
See Fig. 17.

The automatic air compressor unloader comprises an unloader mechanism (A) which is mounted on the air compressor cylinder head (B), a "Curtis" unloader pilot valve (C), for automatic operation of the unloader mechanism, and a 1/4 inch air pressure pipe (E) from the air storage tank to the pilot valve.

If necessary, the unloader may also be operated manually by means of handwheel (D).

The unloader mechanism consists of a spring-loaded unloading shaft (F) which is moved axially by handwheel (D) or by air pressure from the pilot valve (C). When thus moved, taper sections (G) on the shaft (F) engage the stems of air suction valves (H) and hold the valves open. This action unloads the compressor. When handwheel (D) is unscrewed, or the air pressure drops sufficiently, spring (3) returns the shaft (F) to its original position. This allows the valves (H) to close and the compressor will again operate.

Be sure to connect pipe (E) to the air storage tank. Air taken from the compressor or discharge line is so hot that it interferes with the action of the valves in the unloader pilot valve.

To increase or decrease maximum working pressure, loosen cap locknut (K) and screw regulating cap (L) in to increase pressure, and out to decrease pressure. Then tighten the cap locknut.

The unloader valve is adjusted to cut out at 250 psi and cut in at 225 psi.

If the unloader does not operate properly, disassemble and wash the parts in a solvent. Trouble is generally caused by dirt. Be sure to reassemble with the parts in proper place.

Occasionally, drain the strainer (P) of accumulated moisture by turning drain valve handle (M) in a counterclockwise direction. The strainer should be removed, when conditions warrant, and cleaned. To do this, unscrew the cover (N) and remove the two screens and pieces of felt (V) and wash the parts in fuel oil or kerosene. It is advisable to replace the old felt with a new piece. When reassembling, see that the piece of felt is placed between the two screen discs.

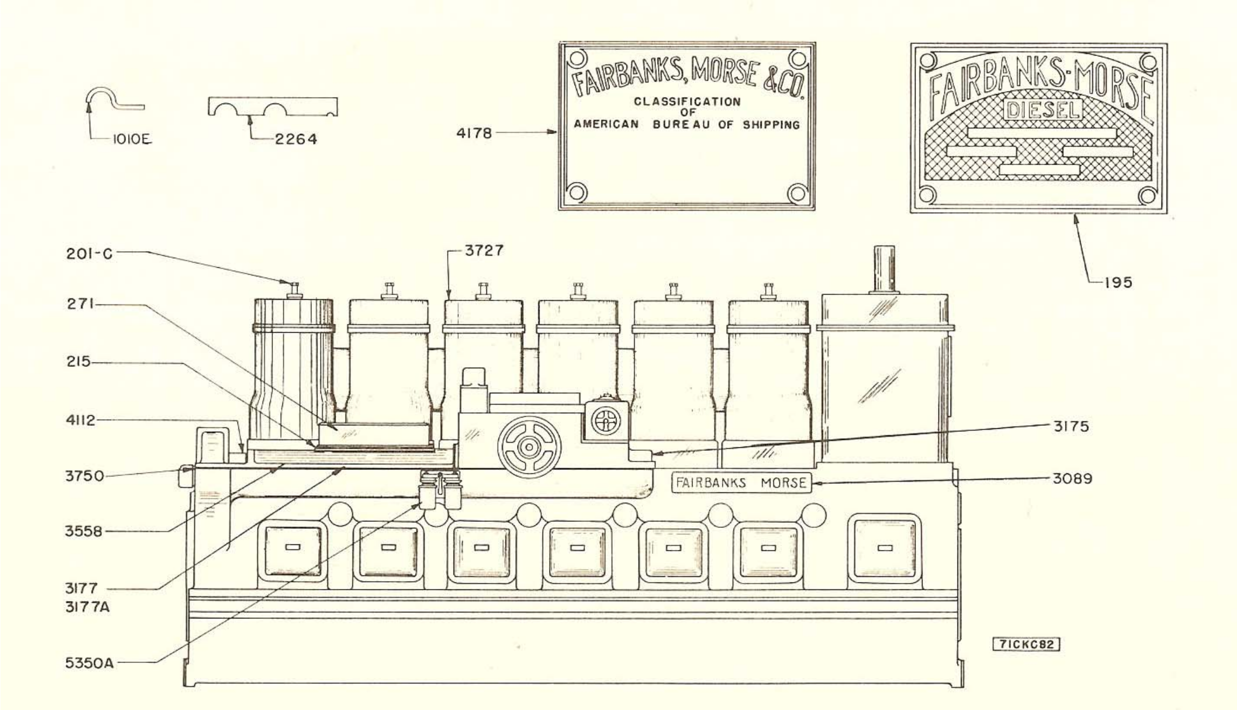
Before attaching the unloader to the air compressor cylinder, see that the shaft (F) is thoroughly lubricated and moves freely in its bearings. It may be necessary to remove the shaft (F) by first removing the plug (R), and the spring (J), in order to be sure that the oil is thoroughly distributed over the shaft bearings, for the initial start. After the unloader is in operation, the oil cups (S) take care of the shaft lubrication. See that they are filled regularly.

Occasionally, put 2 or 3 drops of oil into the open holes (T). These oil holes are for supplying lubricant to the cones (G) on the unloader shaft, and to the compressor suction valves (H).

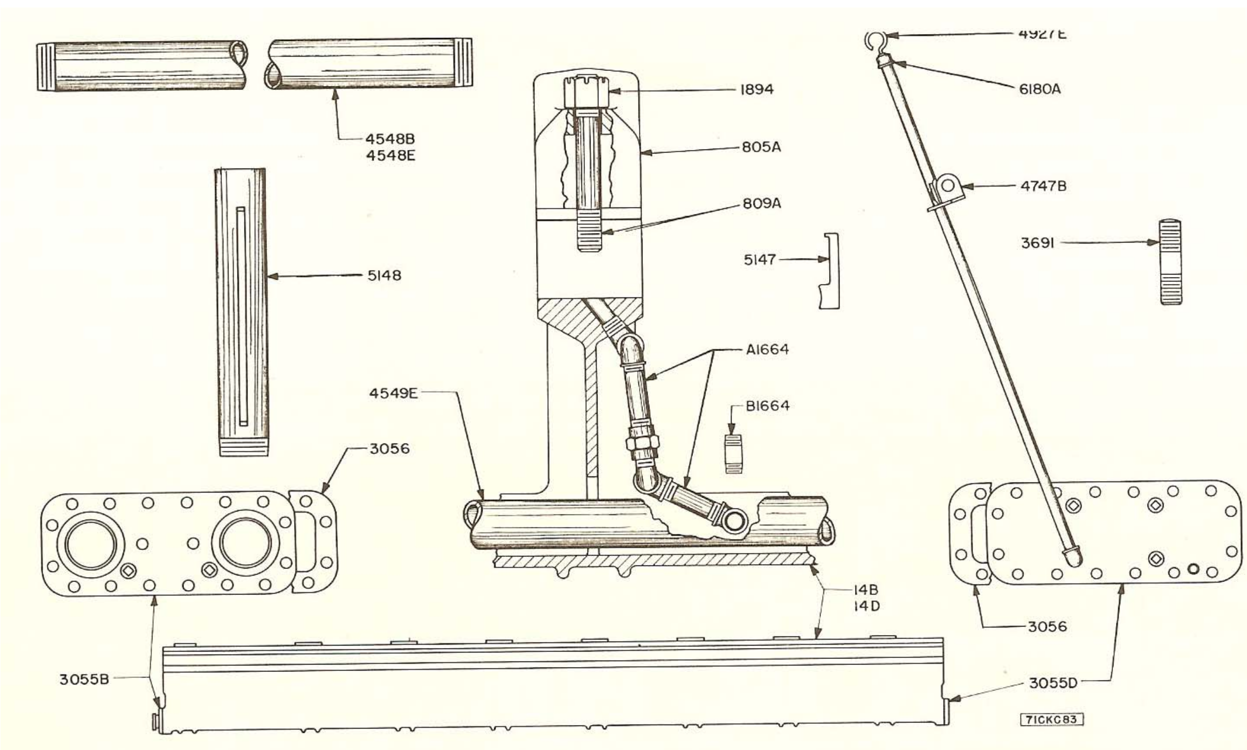
Air Start Mechanism

Removal of Valves - See Fig. 6 and 7.

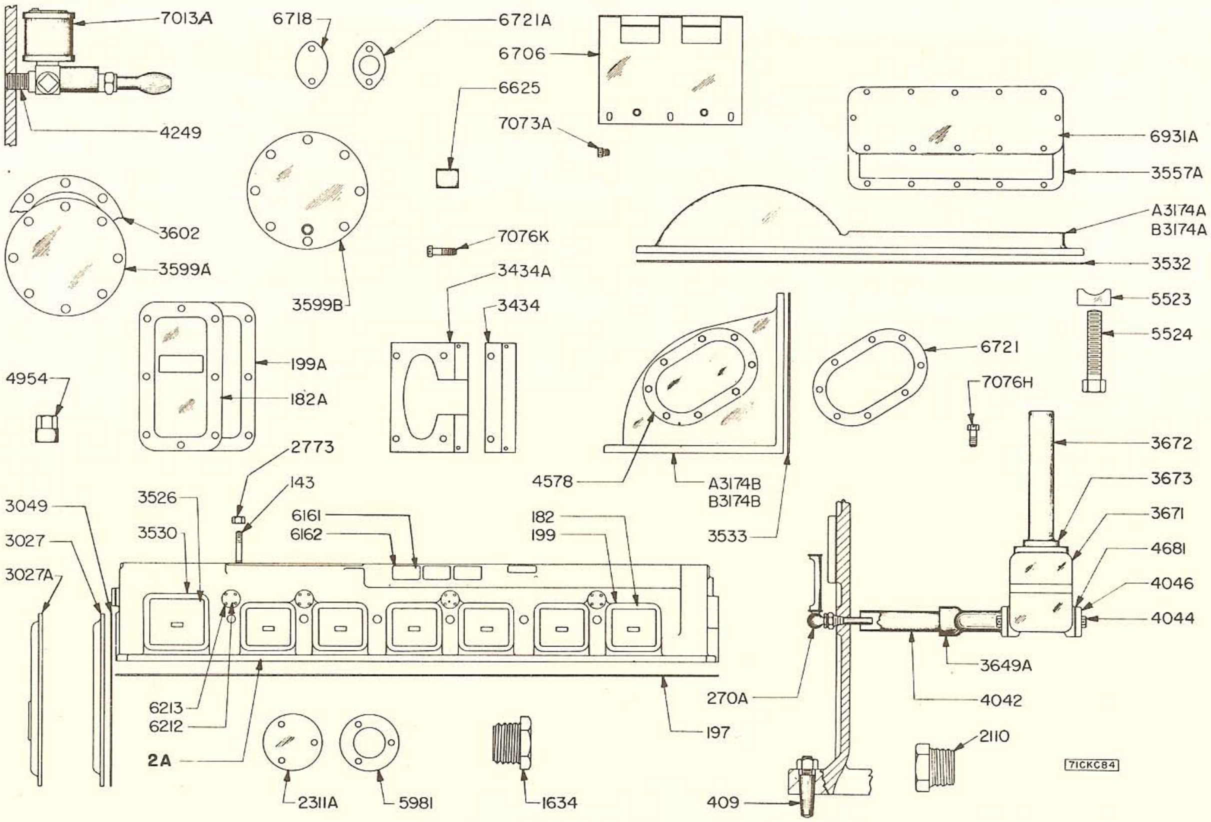
The air start shutoff valve and air start valves may be removed by taking off the air start shutoff valve cover and the air start valve cover. The marine engines have a shutoff valve but do not have an air start valve. The valves should be inspected occasionally and should be cleaned and reseated if necessary.



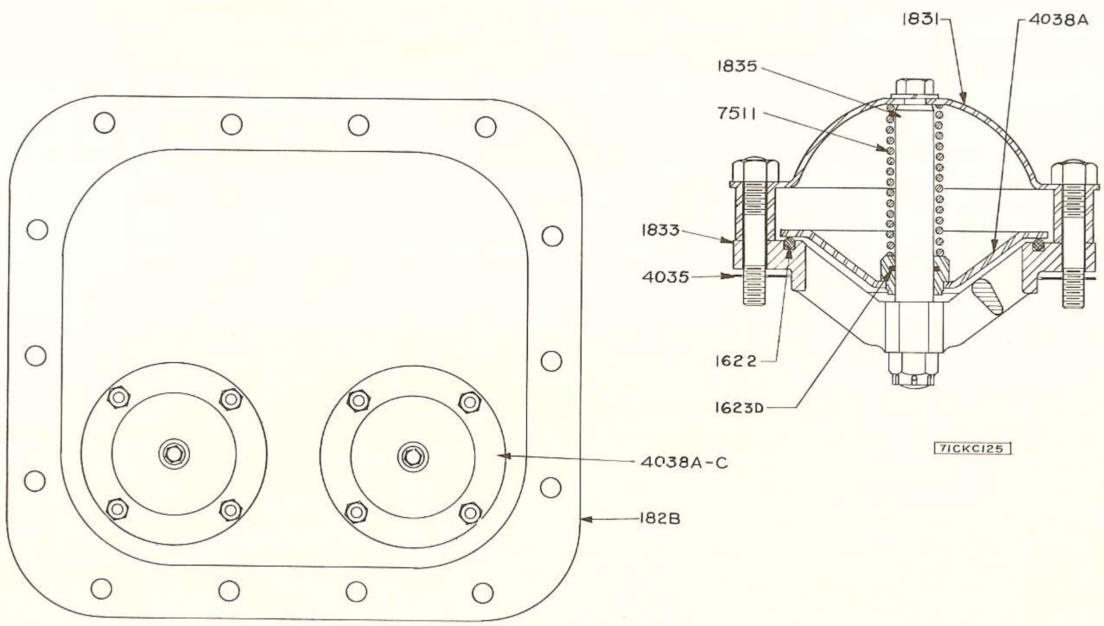
Section 1 — General Engine Parts



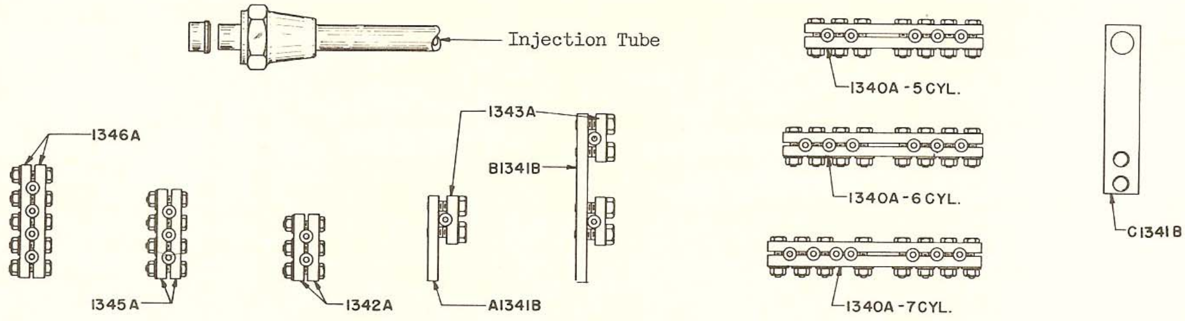
Section 2 — Lower Base



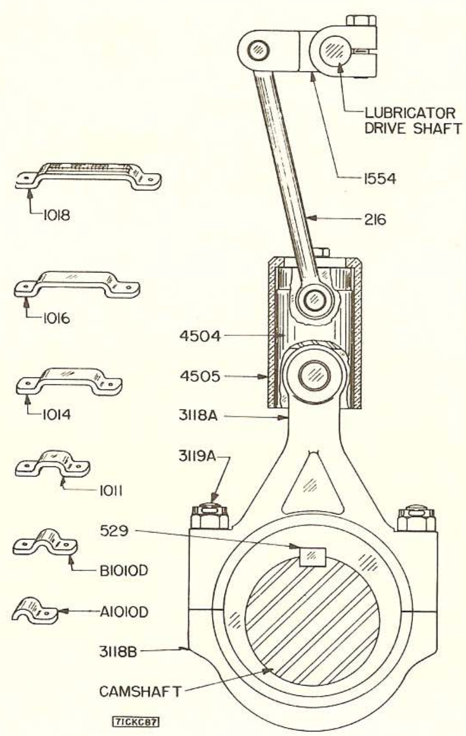
Section 3 — Upper Base



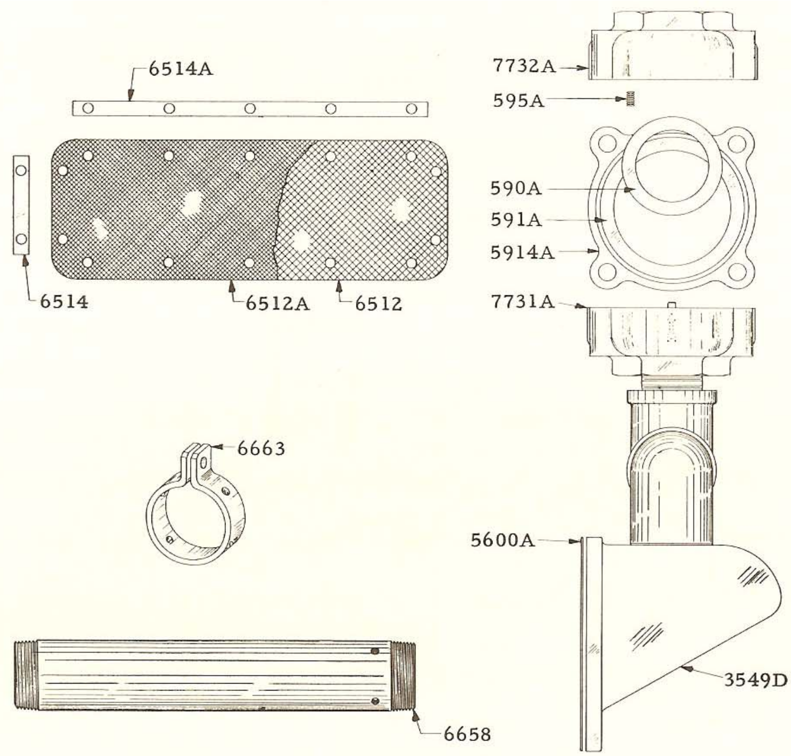
Section 4 — Crankcase Cover Relief Valve



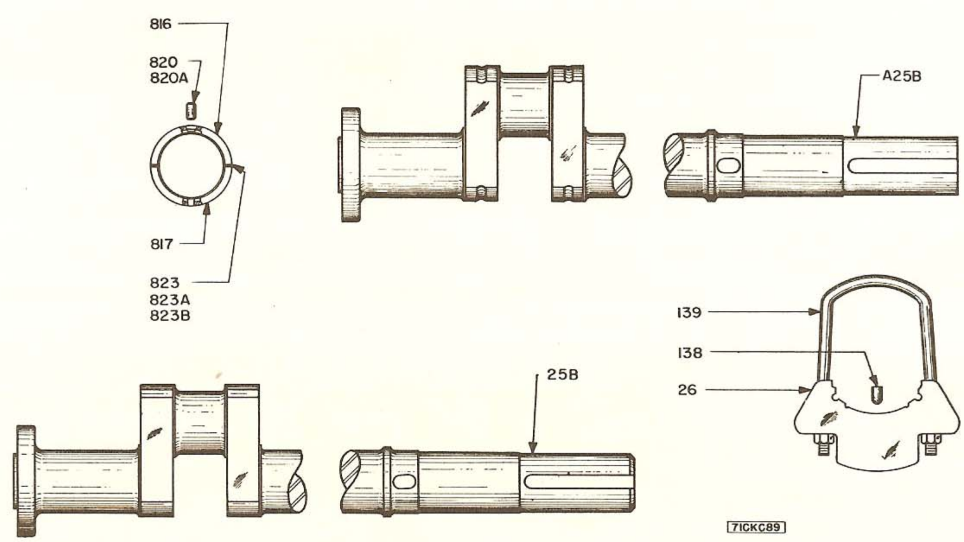
Section 5 —— Injection Tubes and Clamps



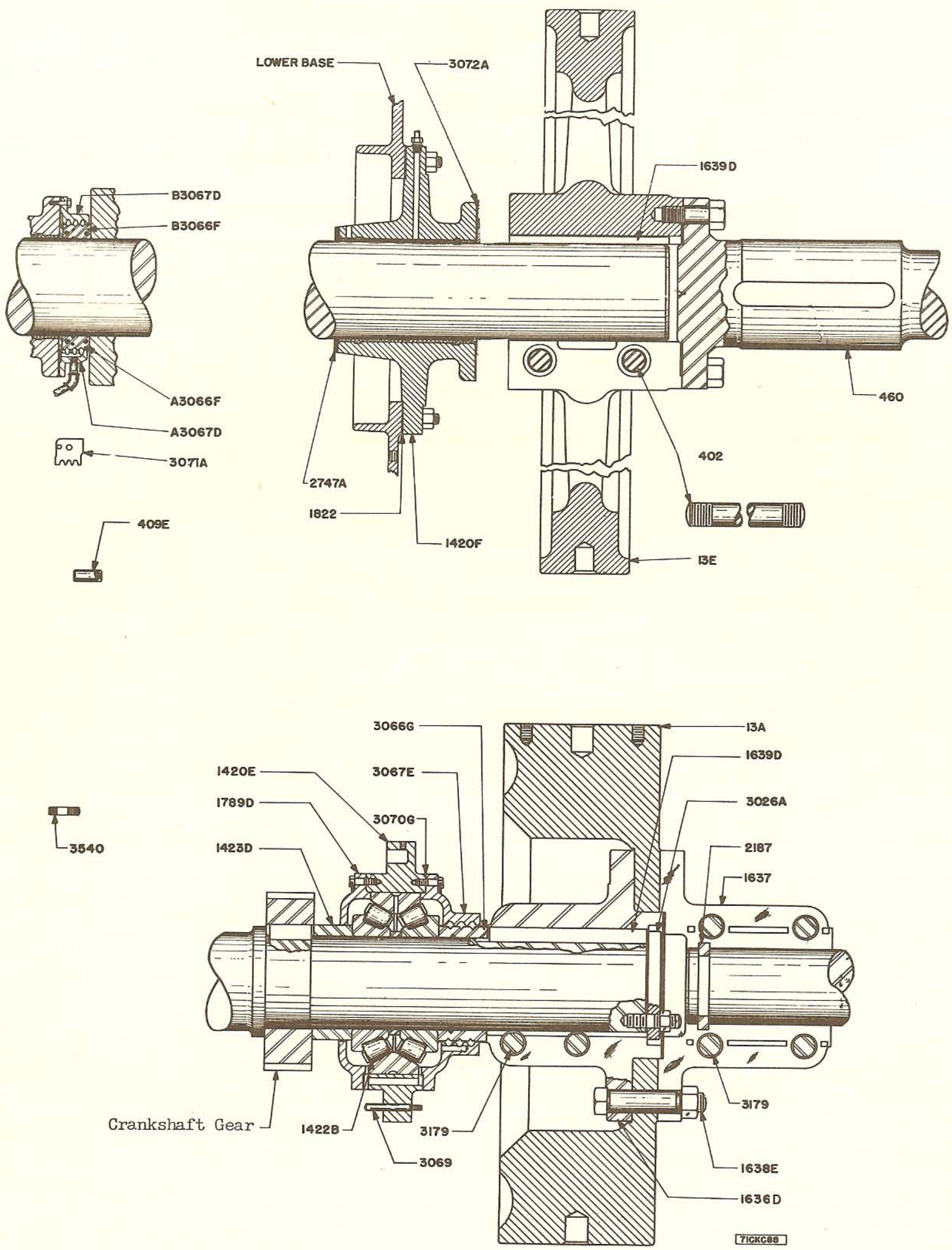
Section 6 —— Lubricator Drive and Tube Clamps



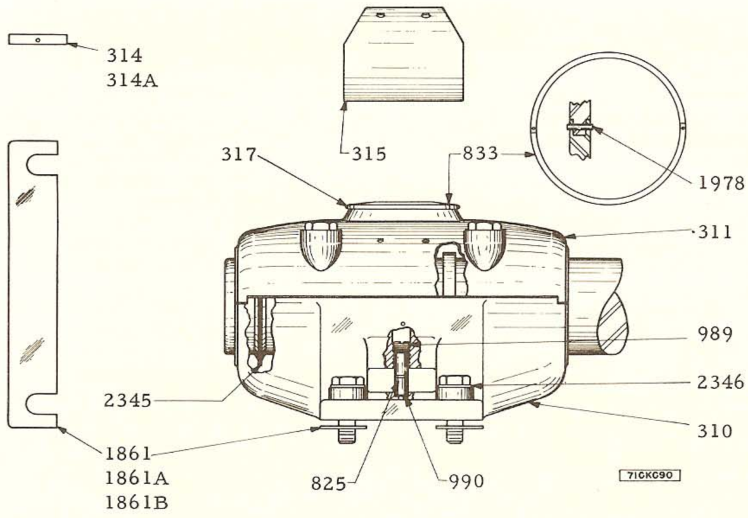
Section 7 —— Scavenge Pump Crankcase Breather



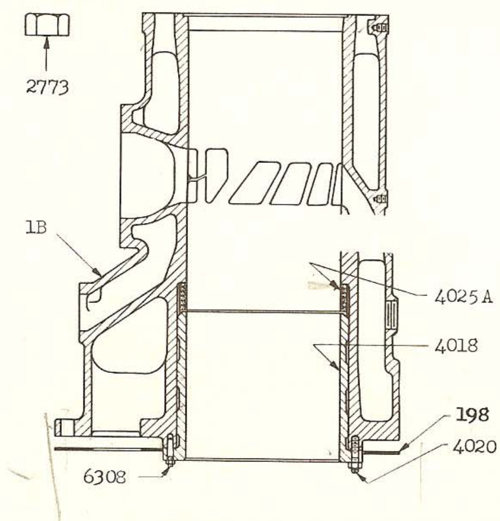
Section 8 —— Crankshaft and Main Bearing Shell



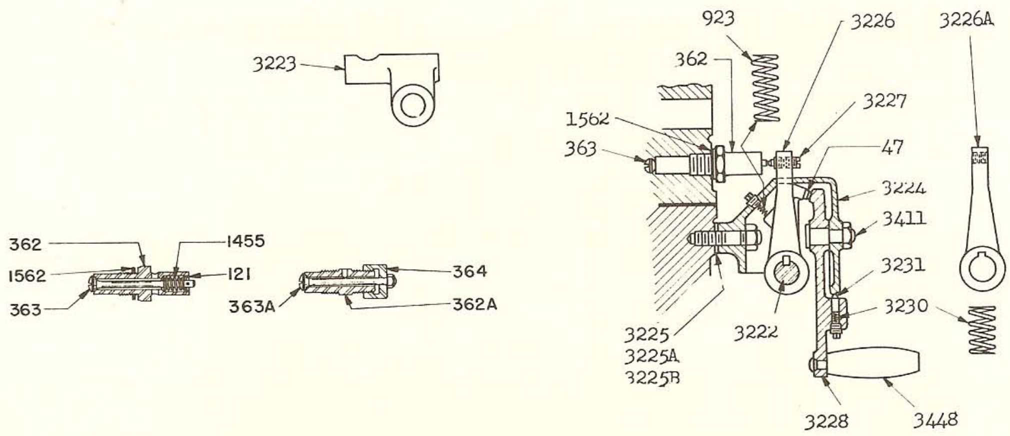
Section 9 — Flywheel, Aft and Thrust Bearings



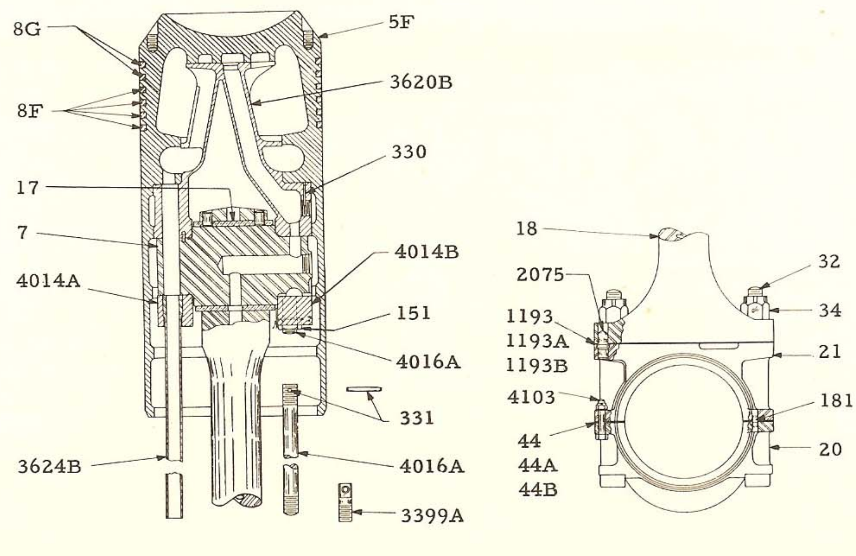
Section 10 — Outboard Bearing



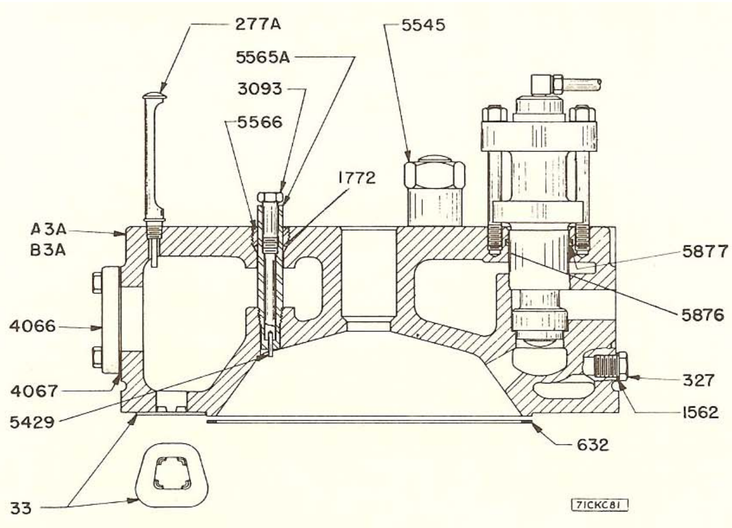
Section 11 — Cylinder



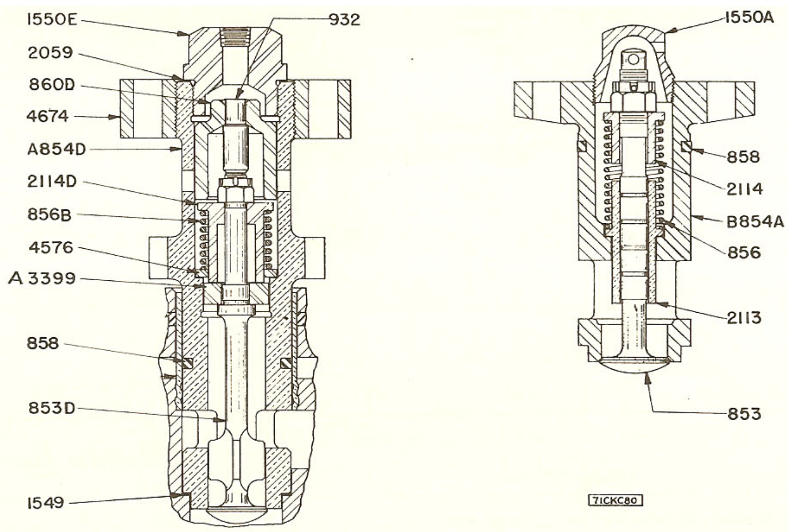
Section 12 — Compression Relief Valve



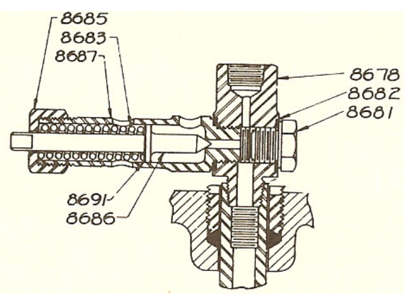
Section 13 —— Piston and Connecting Rod



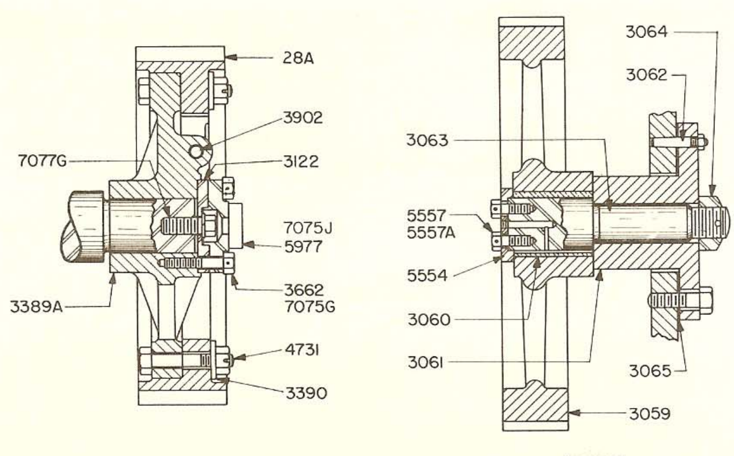
Section 14 —— Cylinder Head



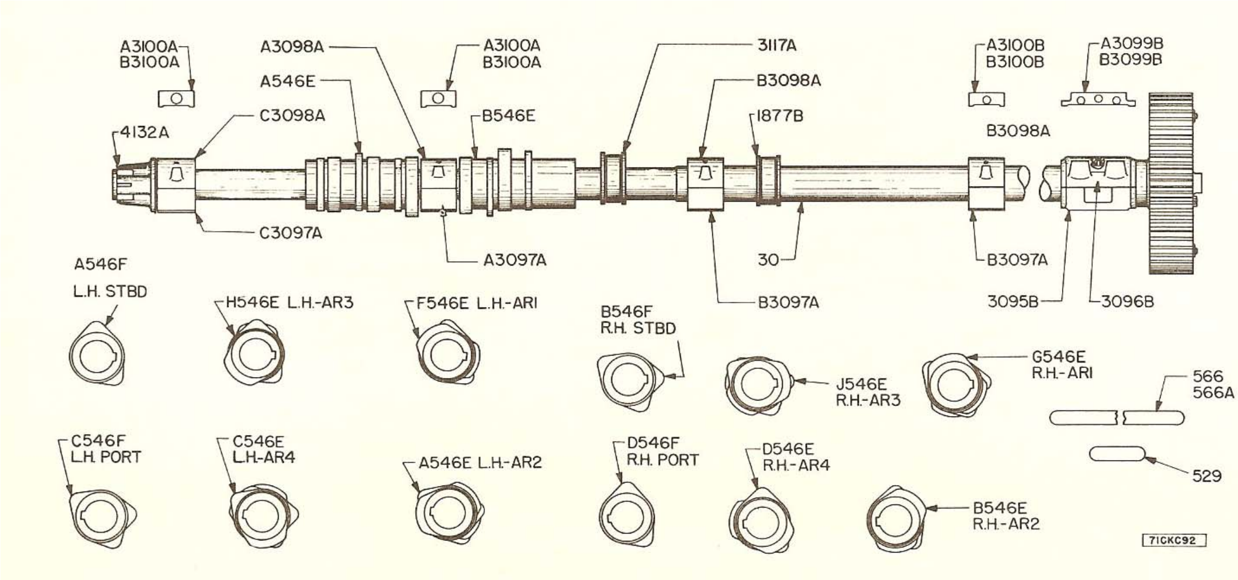
Section 15 — Air Start Check Valve



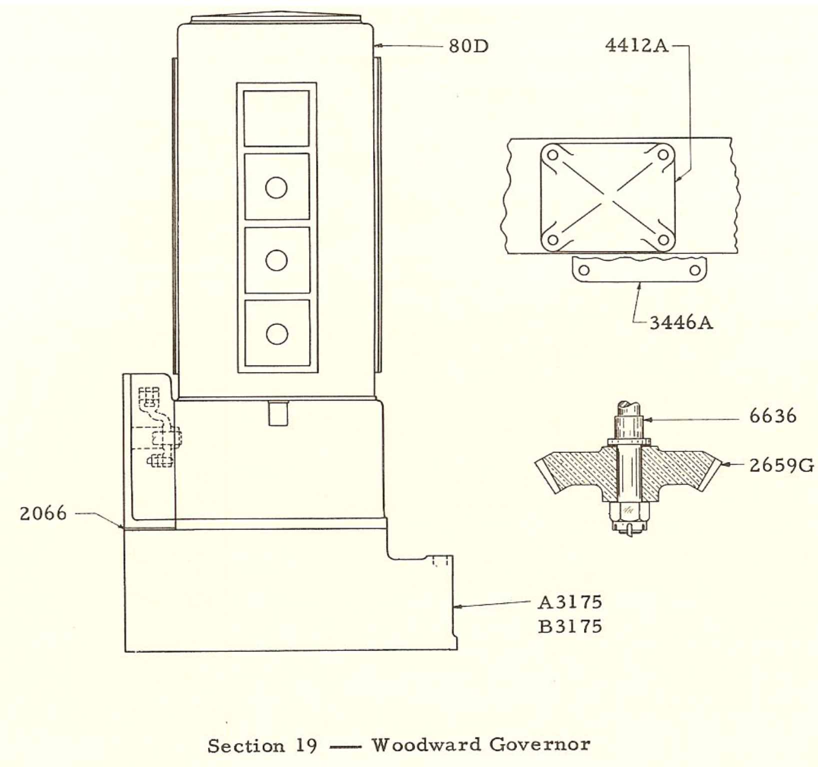
Section 16 — Spring Loaded Safety Valve



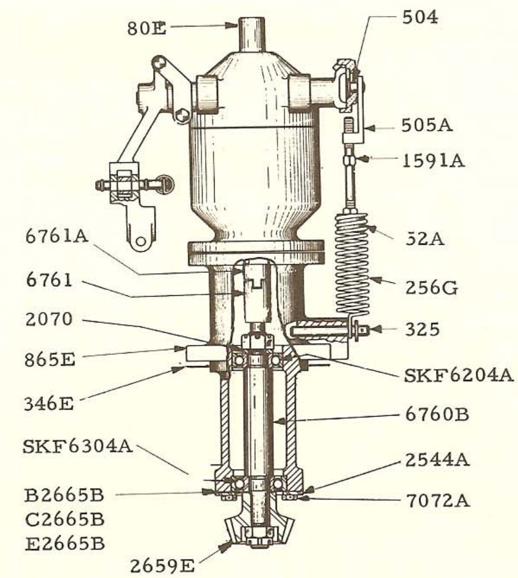
Section 17 — Camshaft Gear



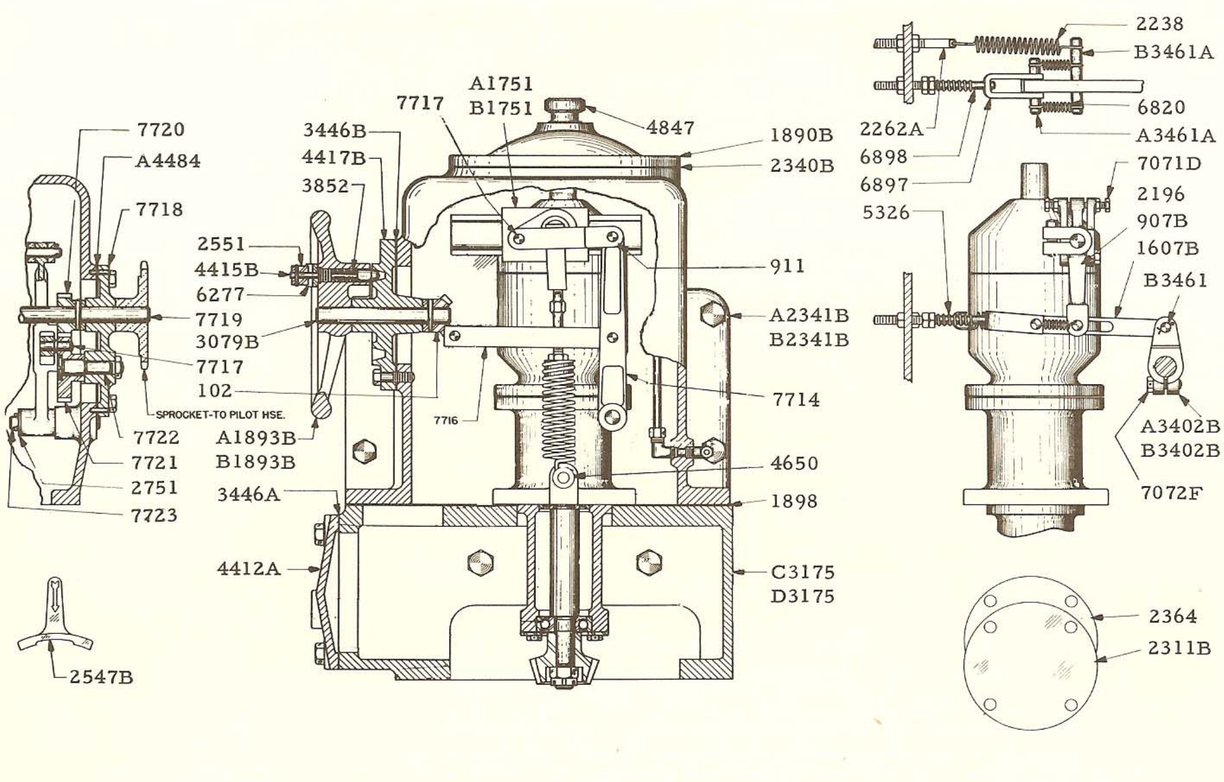
Section 18 —— Camshaft



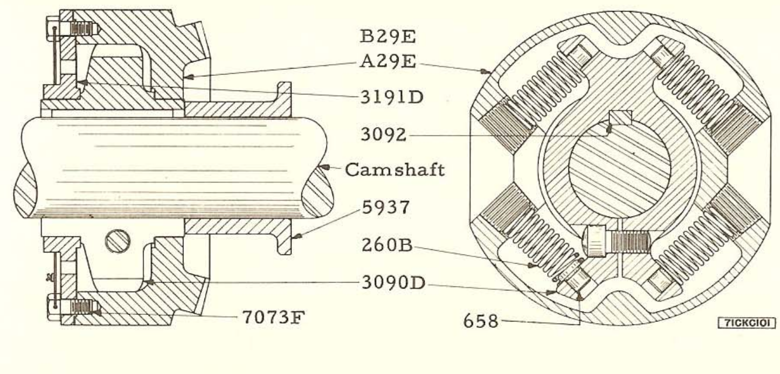
Section 19 —— Woodward Governor



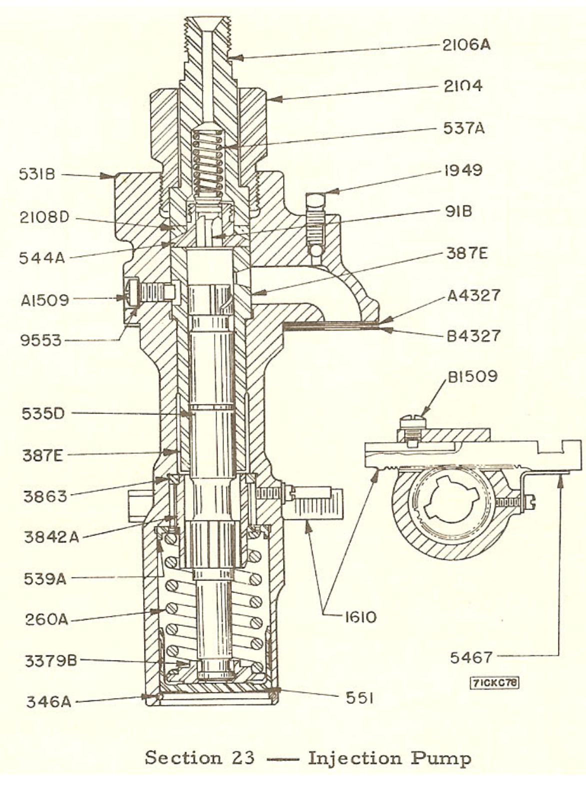
Section 20 —— Pickering Governor



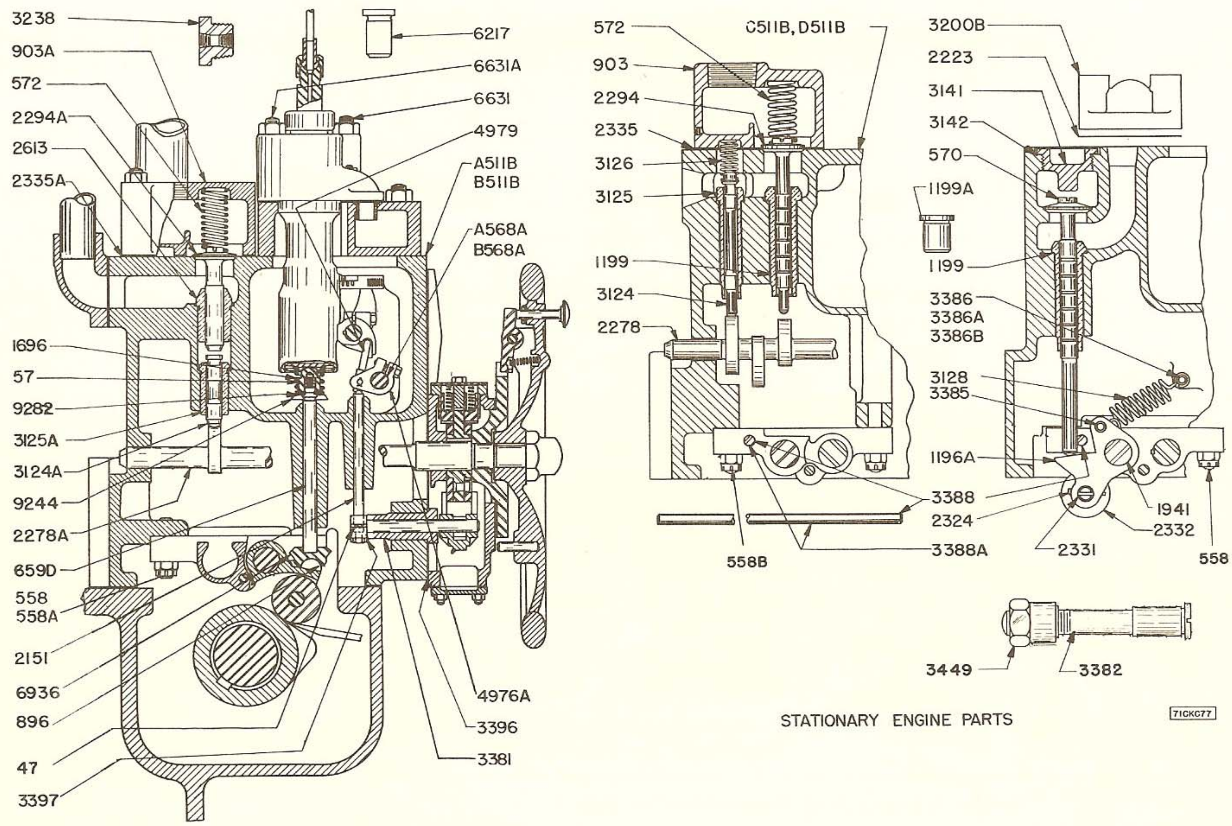
Section 21 —— Governor Speed Control - Marine Engines



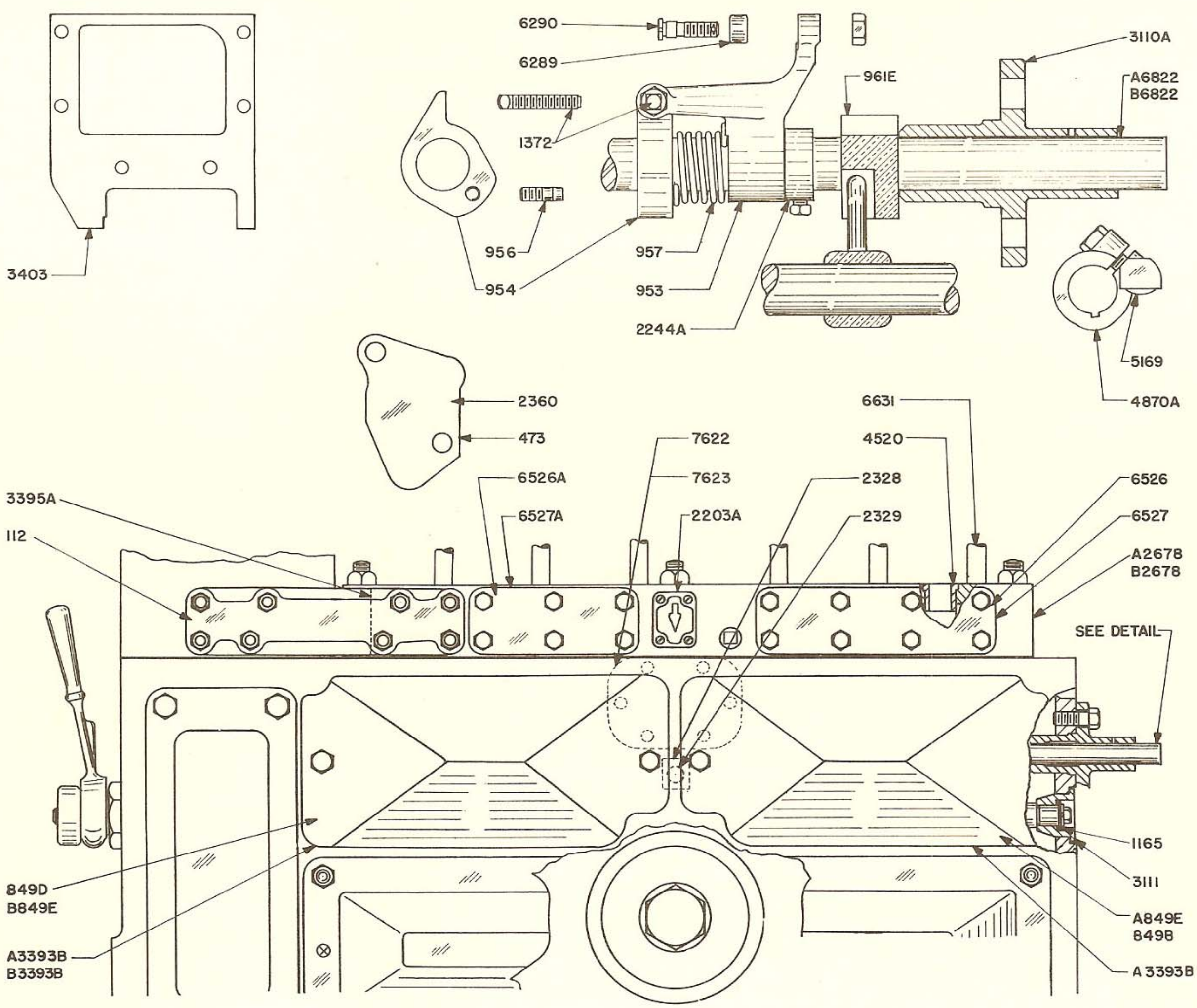
Section 22 —— Governor Drive Gear



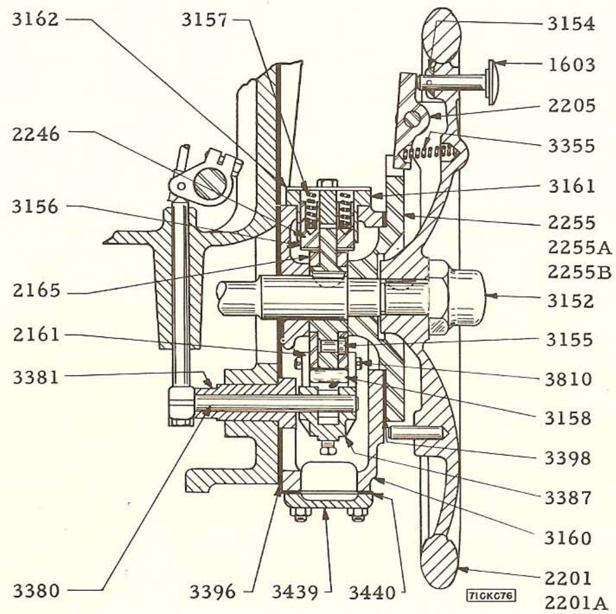
Section 23 —— Injection Pump



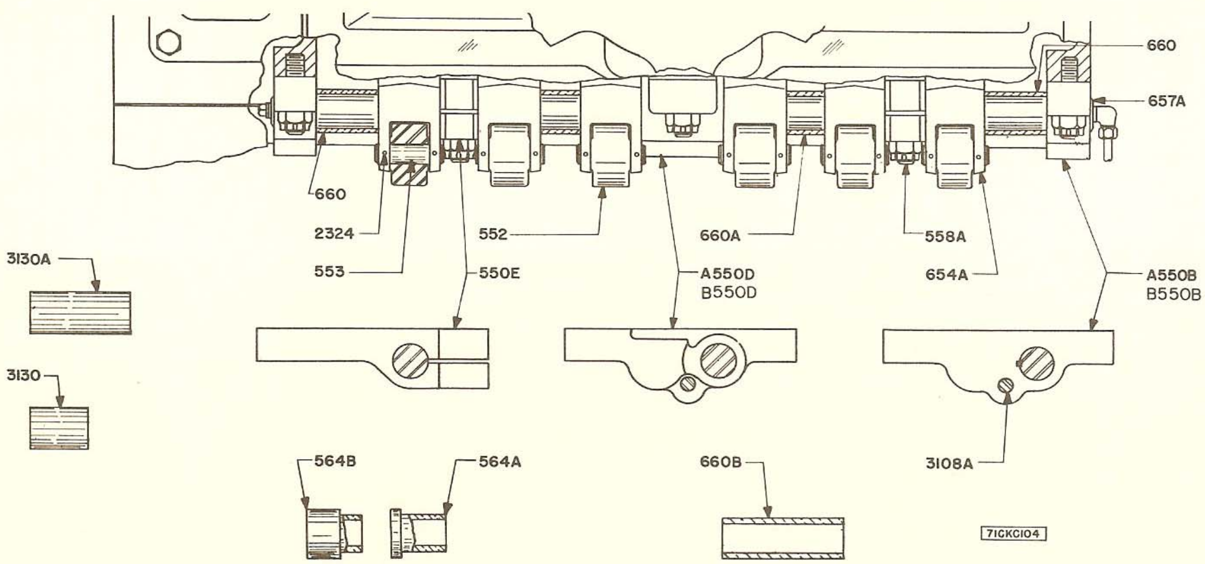
Section 24 — Fuel and Air Valves



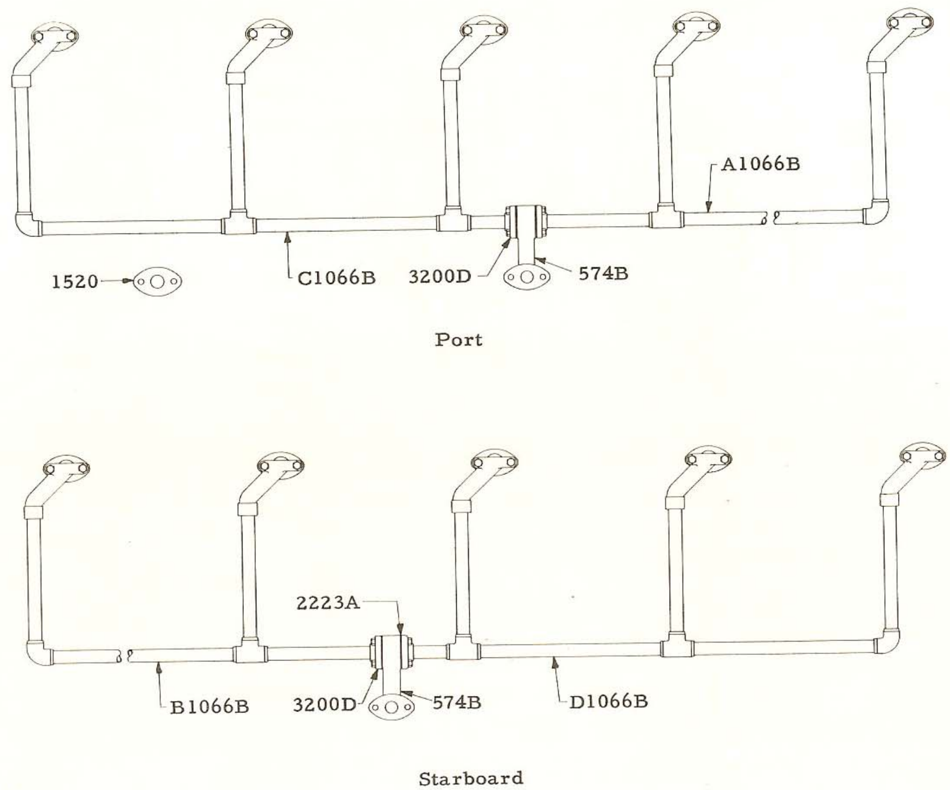
Section 25 —— Fuel Reservoir Base



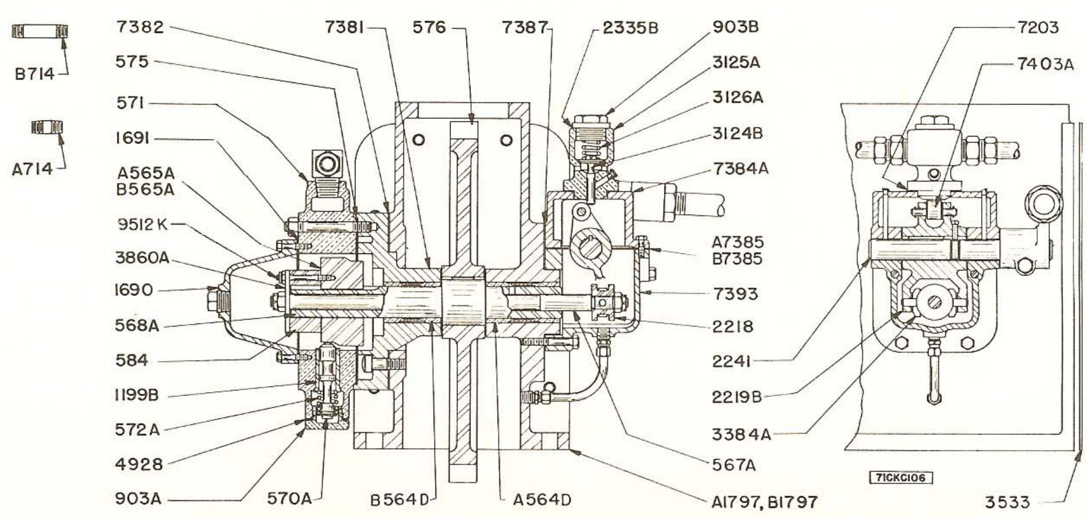
Section 26 —— Control Handwheel



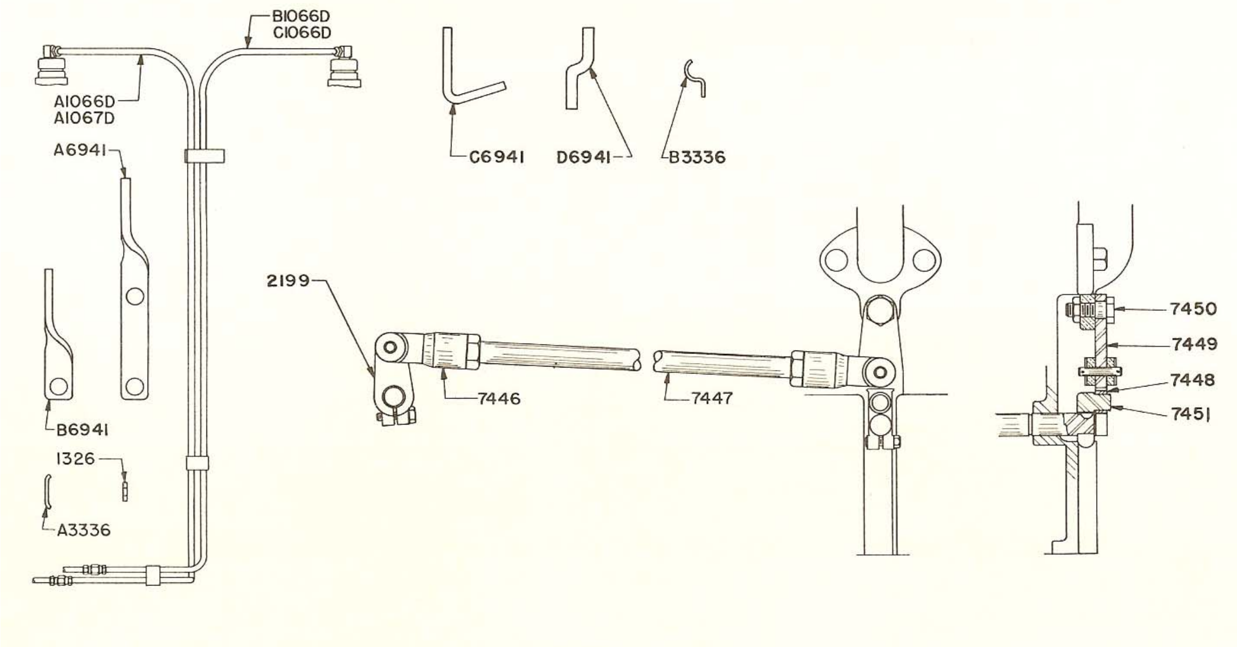
Section 27 —— Injection Pump Rocker Shaft



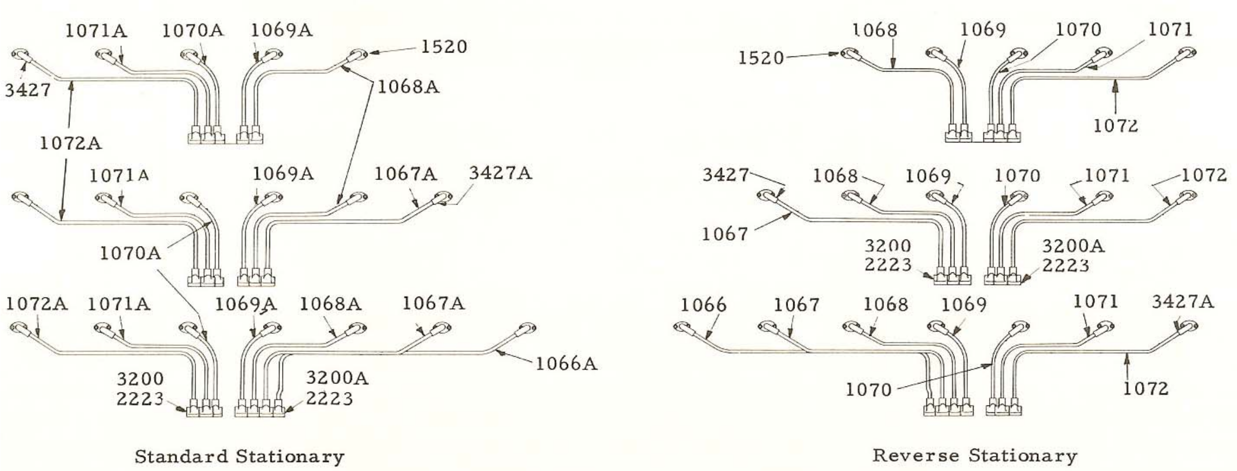
Section 28 —— Air Start Header - Marine Engines



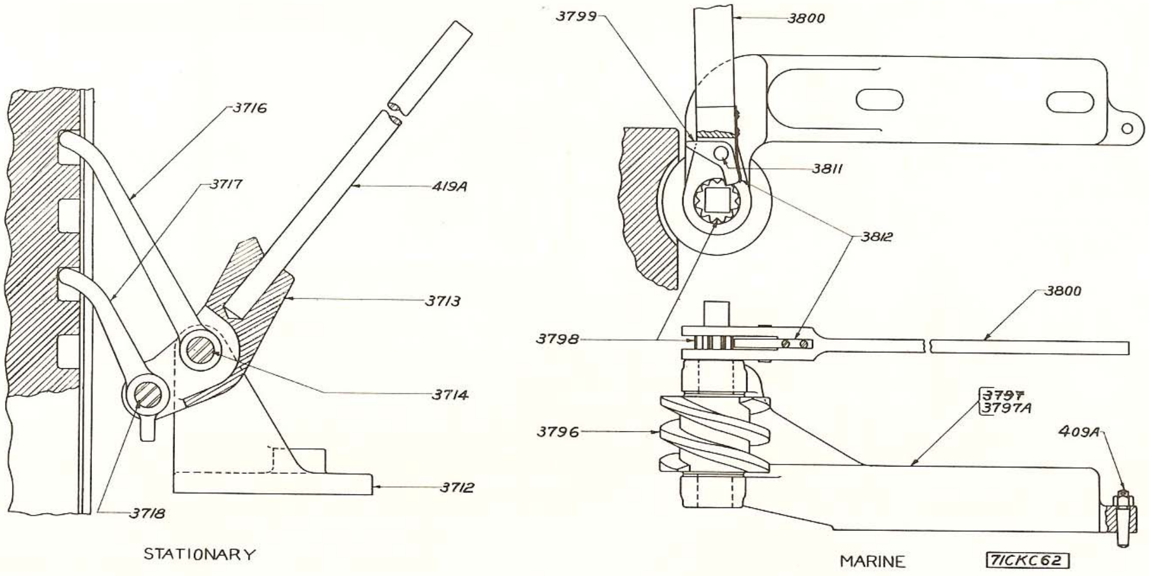
Section 29 —— Air Distributor - Marine Engines



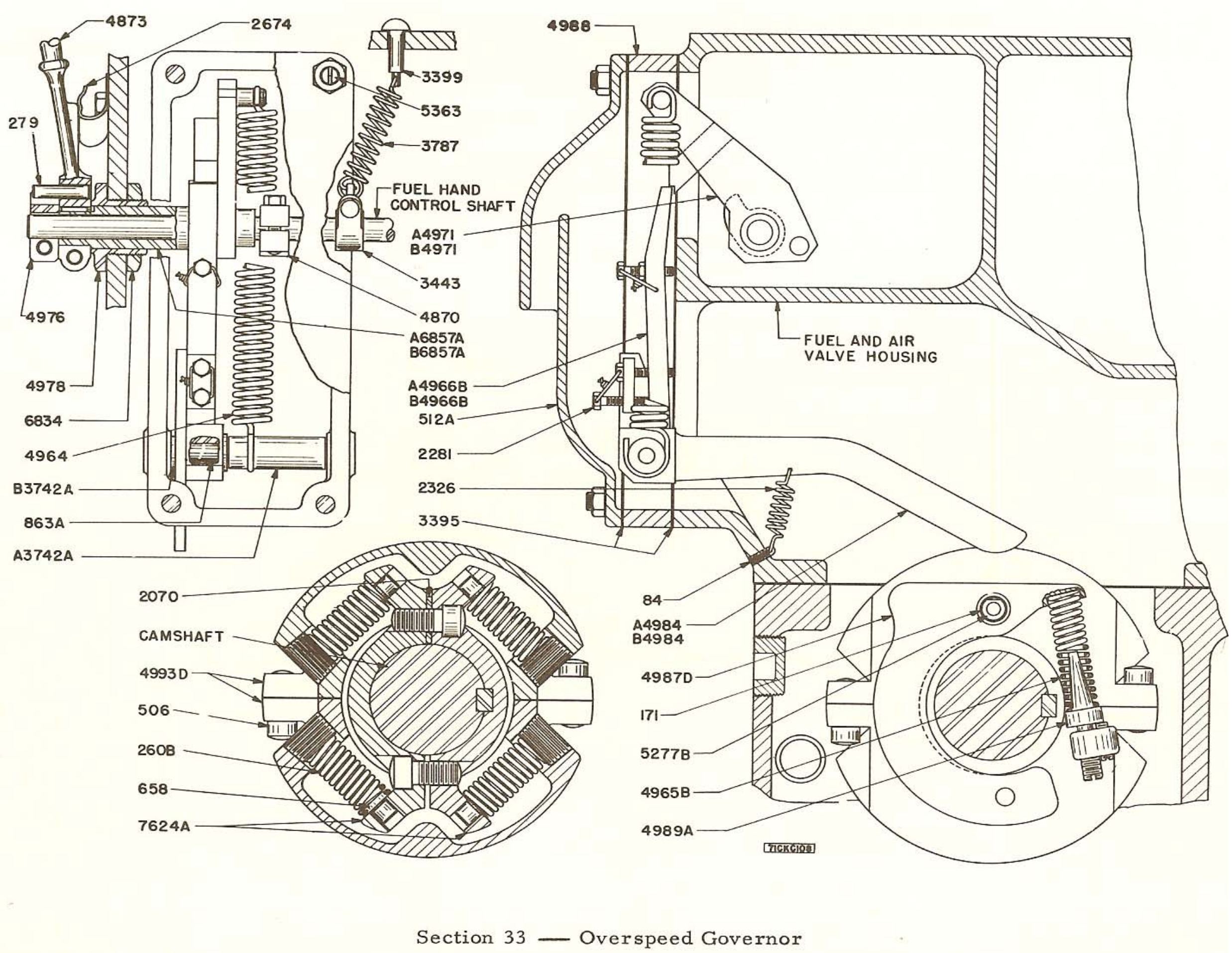
Section 30 —— Air Distributor Piping - Marine Engines



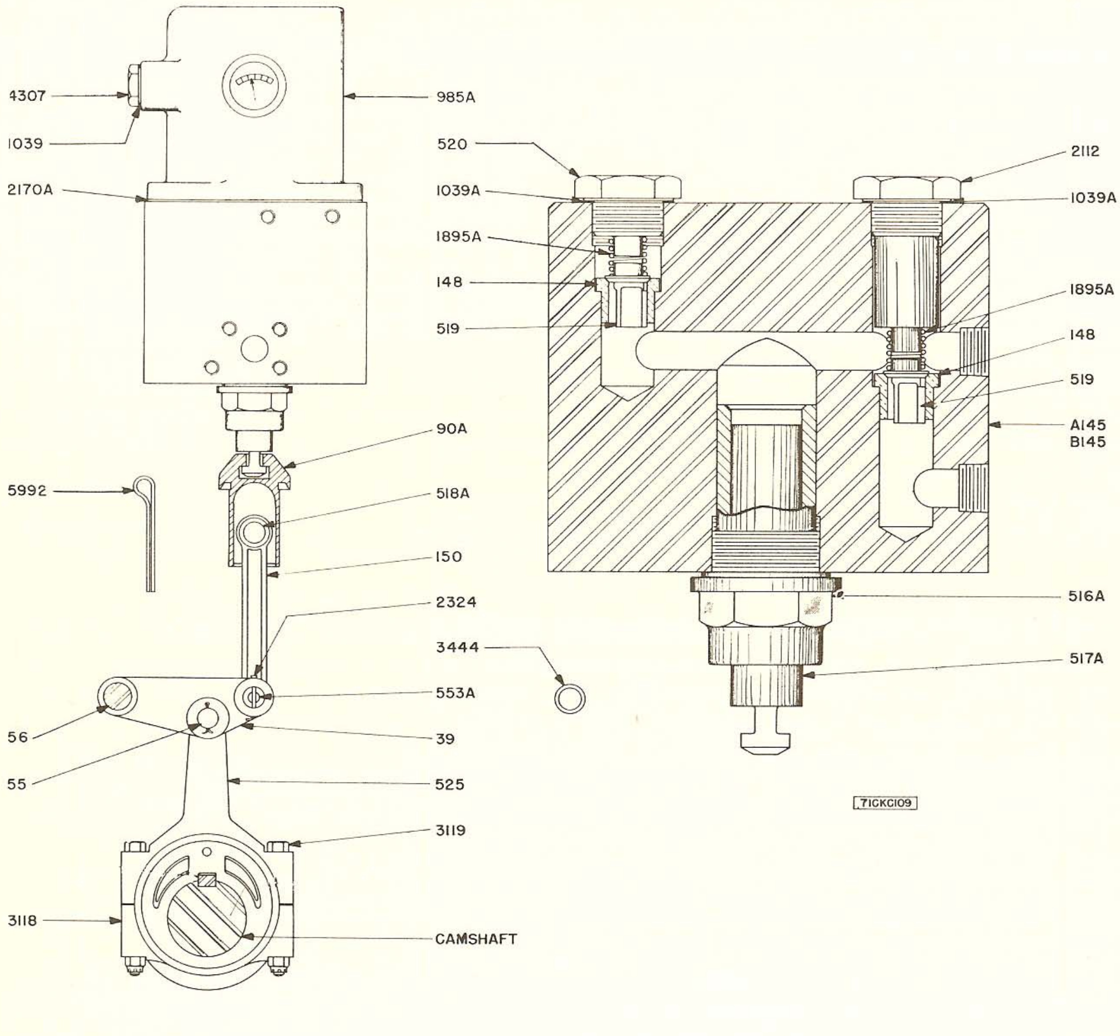
Section 31 —— Air Start Pipes - Stationary Engines



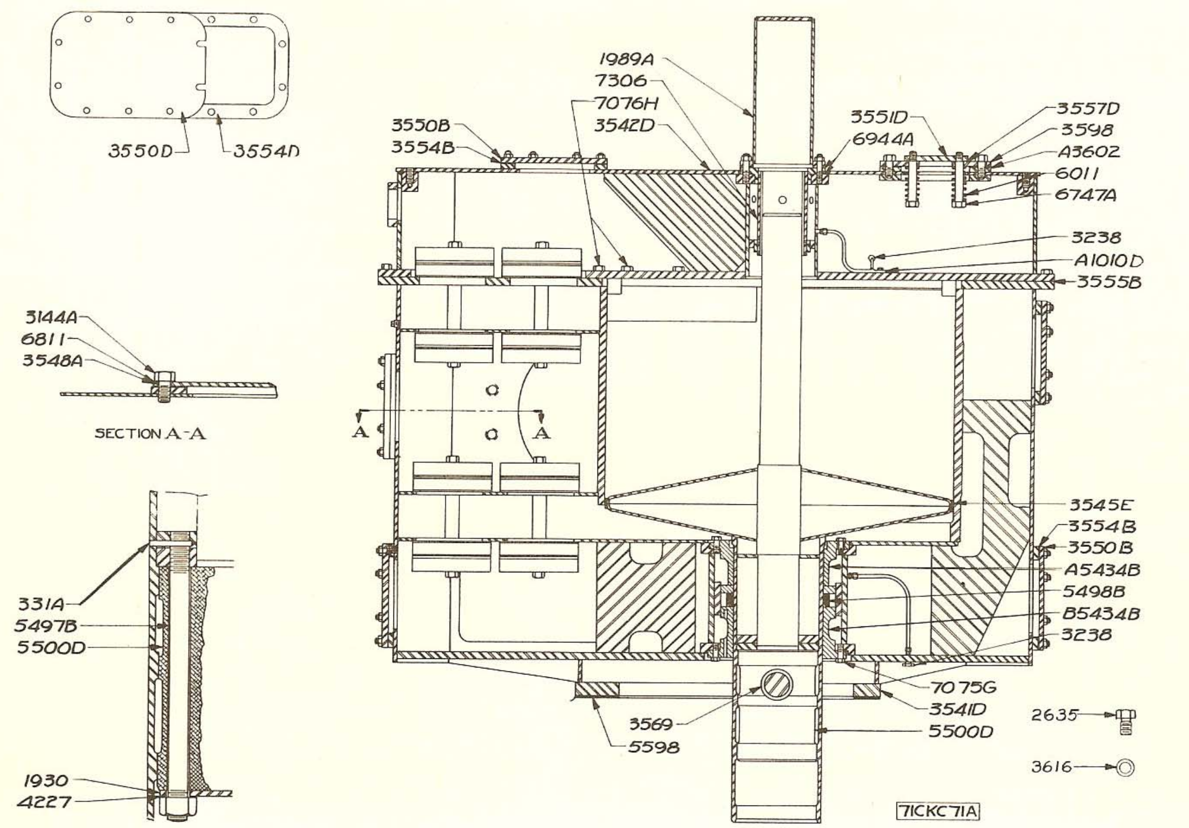
Section 32 — Flywheel Barring Device and Turning Worm



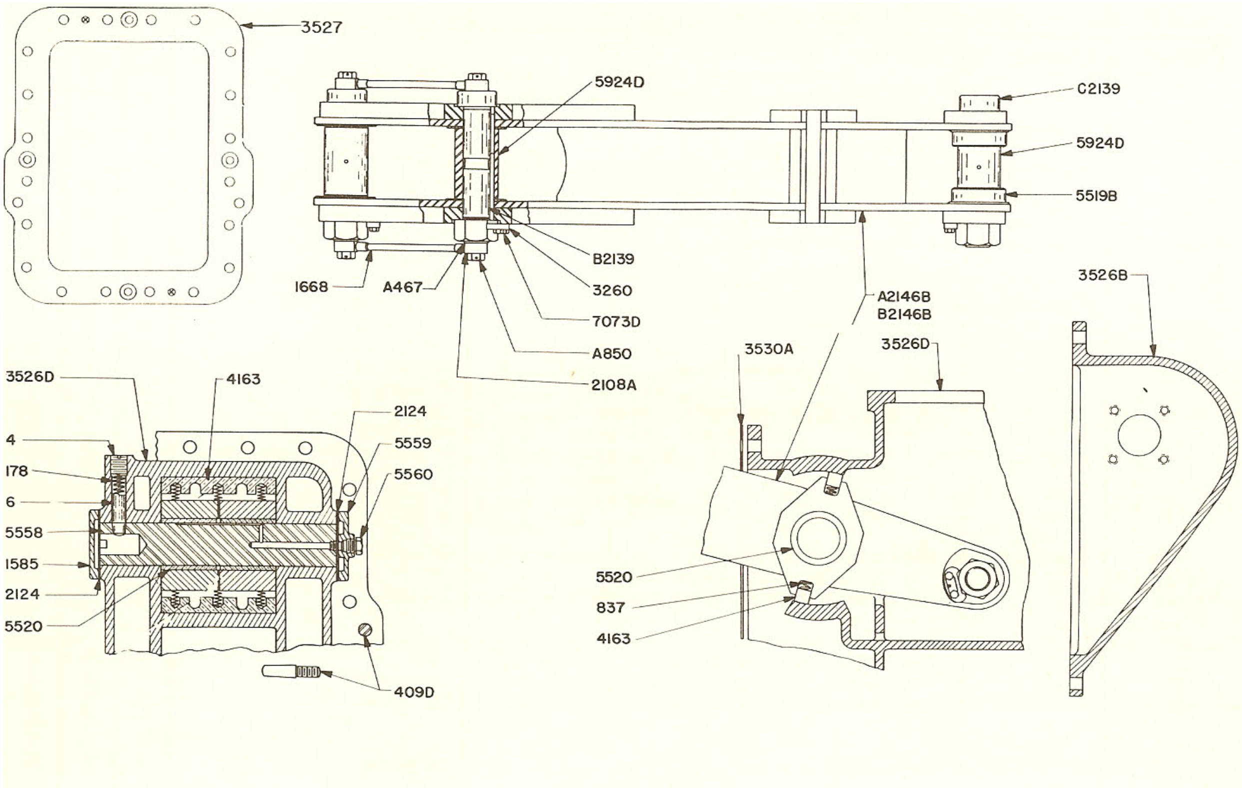
Section 33 — Overspeed Governor



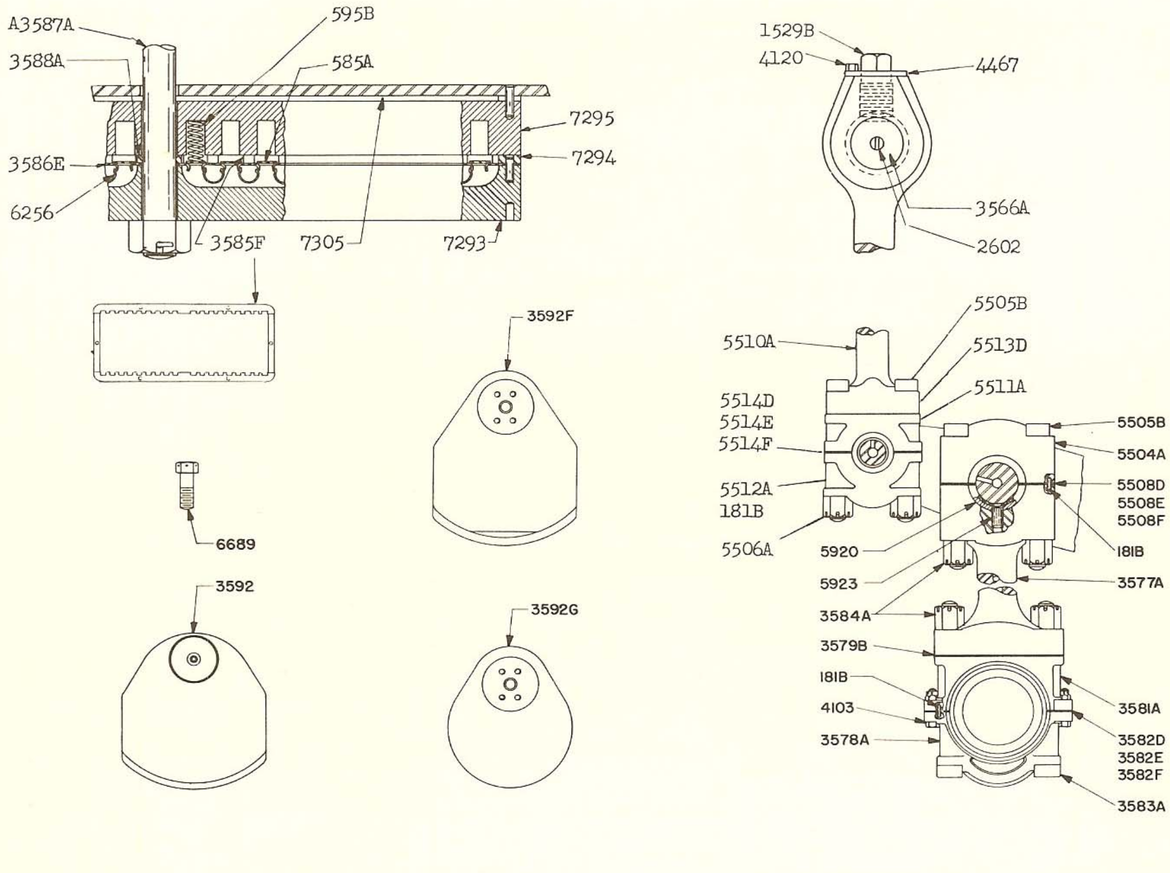
Section 34 — Auxiliary Fuel Pump



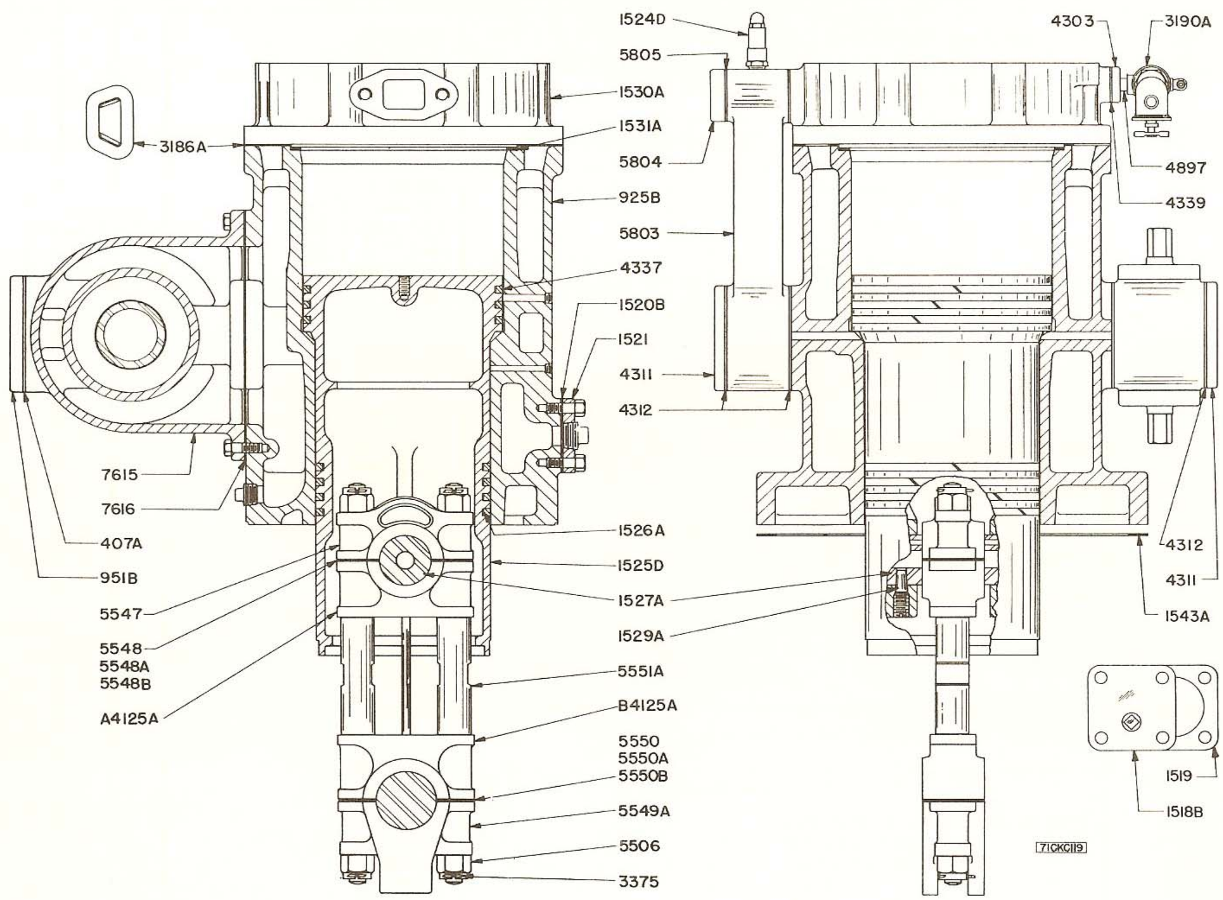
Section 35 — Scavenge Pump Cylinder



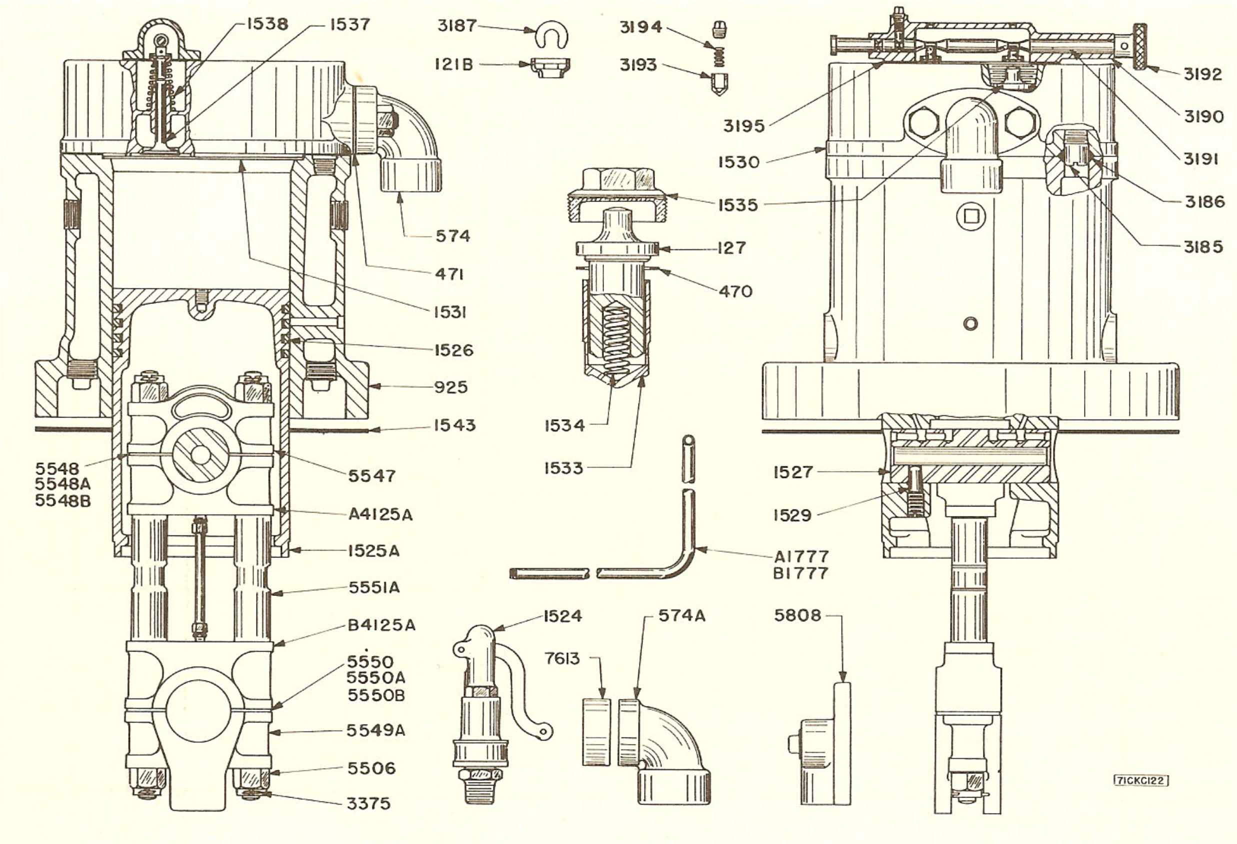
Section 36 — Scavenge Pump Rocker



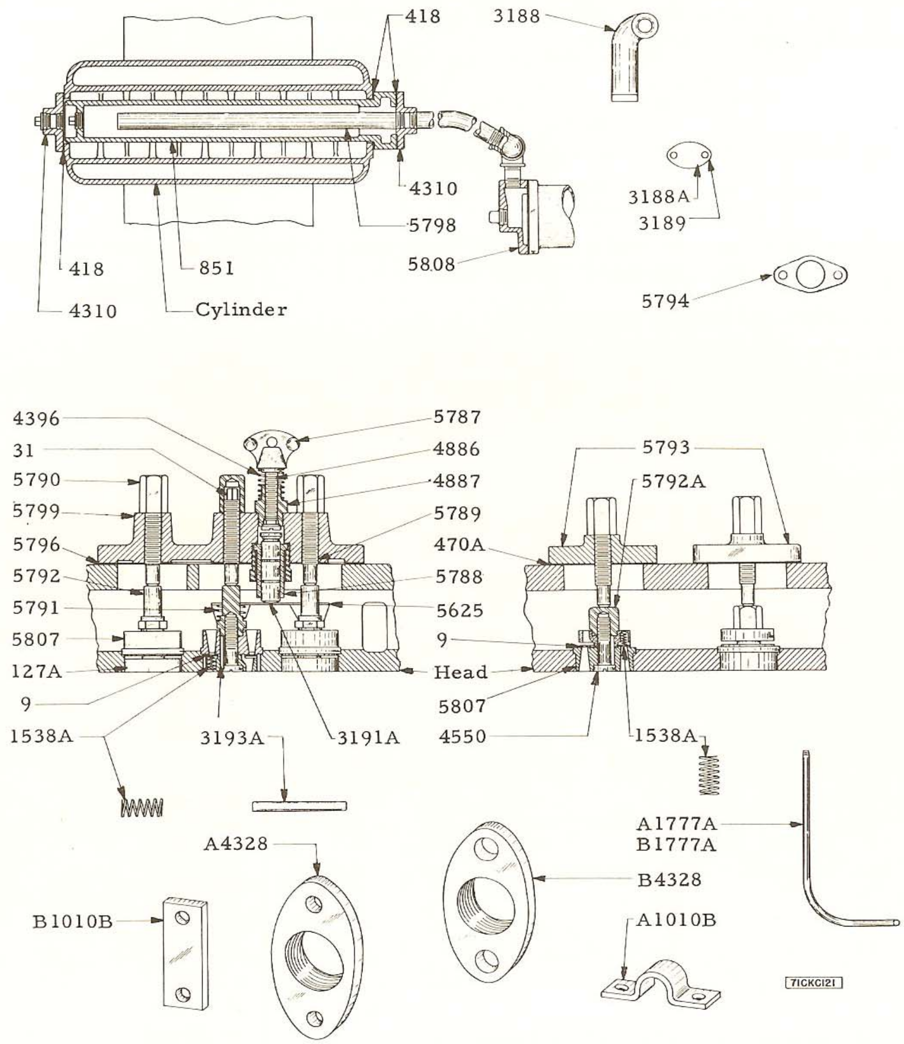
Section 37 —— Scavenge Pump Air Valve, Connecting Rod and Piston Link



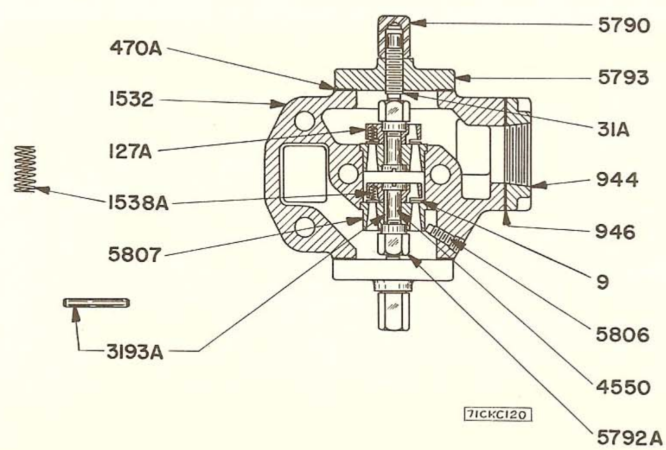
Section 38 — Two Stage Air Compressor



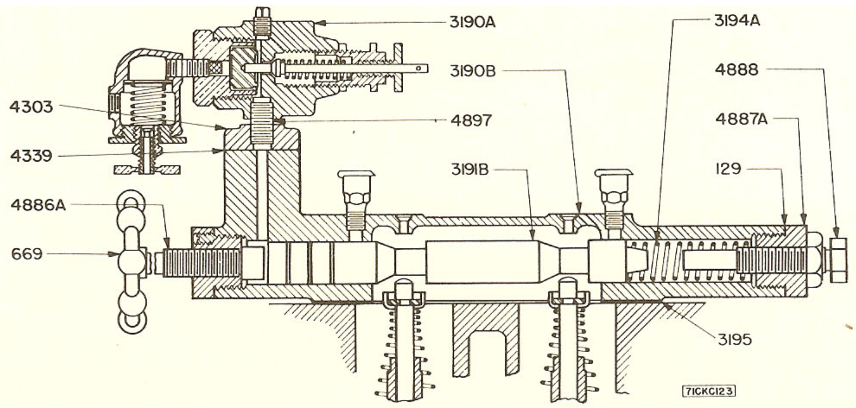
Section 39 —— Single Stage Air Compressor



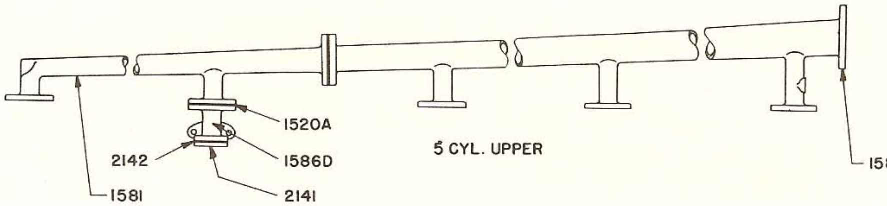
Section 40 — Air Compressor Unloader



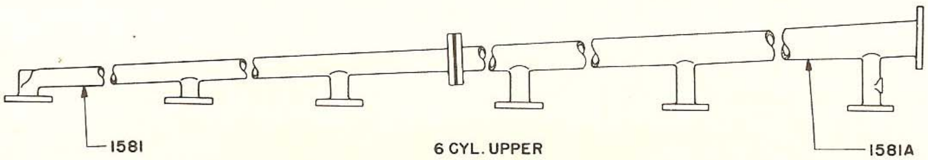
Section 41 — Air Compressor Cylinder High Stage Valve



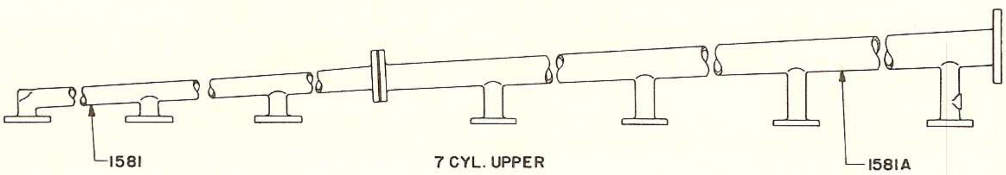
Section 42 —— Air Compressor Hand Unloader



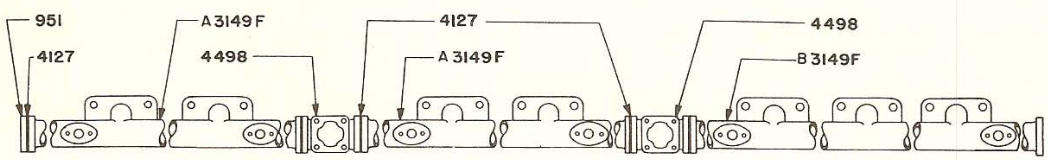
5 CYL. UPPER



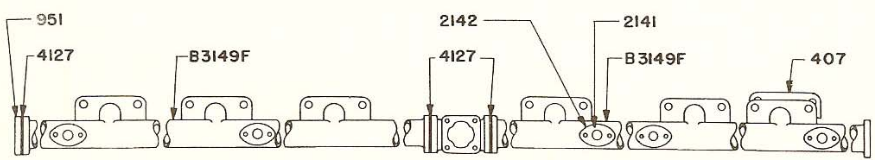
6 CYL. UPPER



7 CYL. UPPER

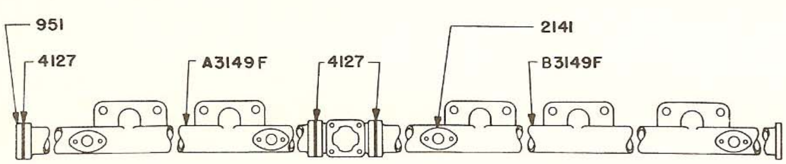


7 CYL. LOWER

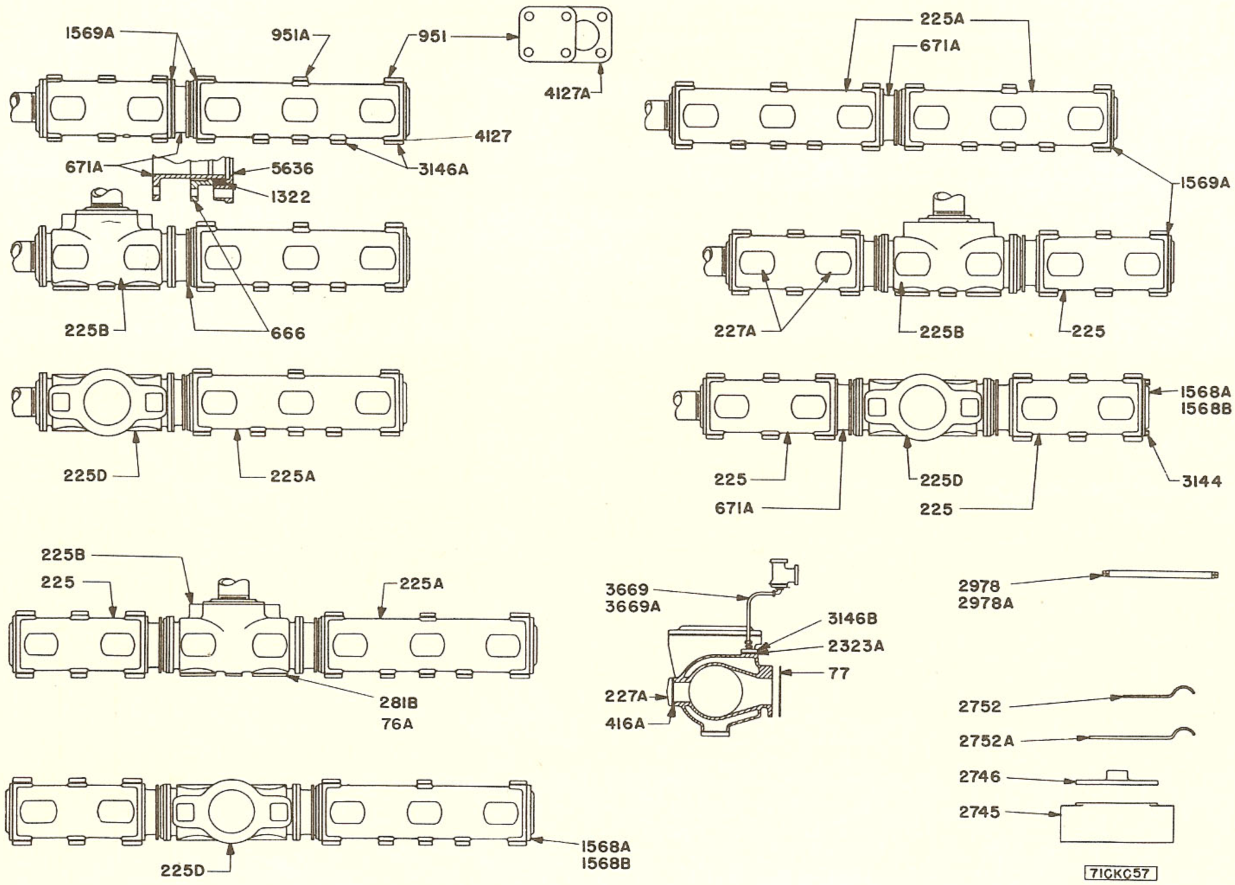


6 CYL. LOWER

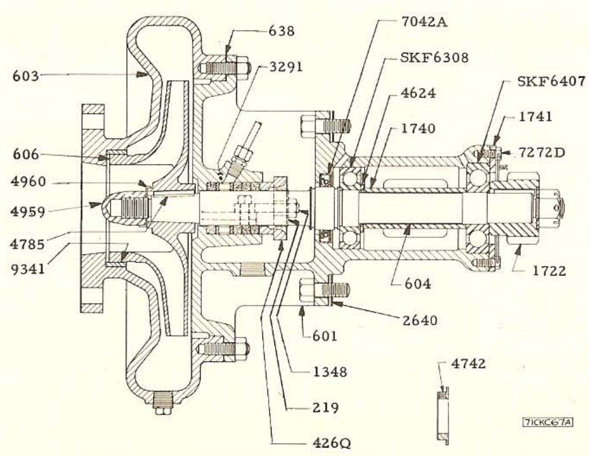
71CKC56-2



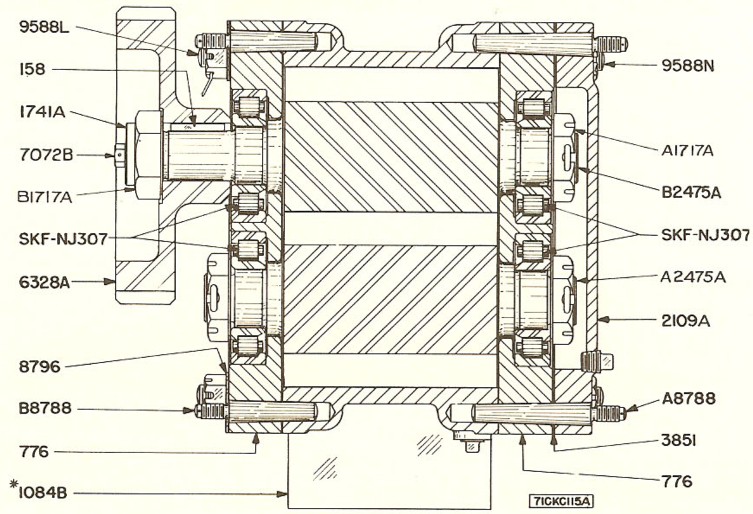
5 CYL. LOWER



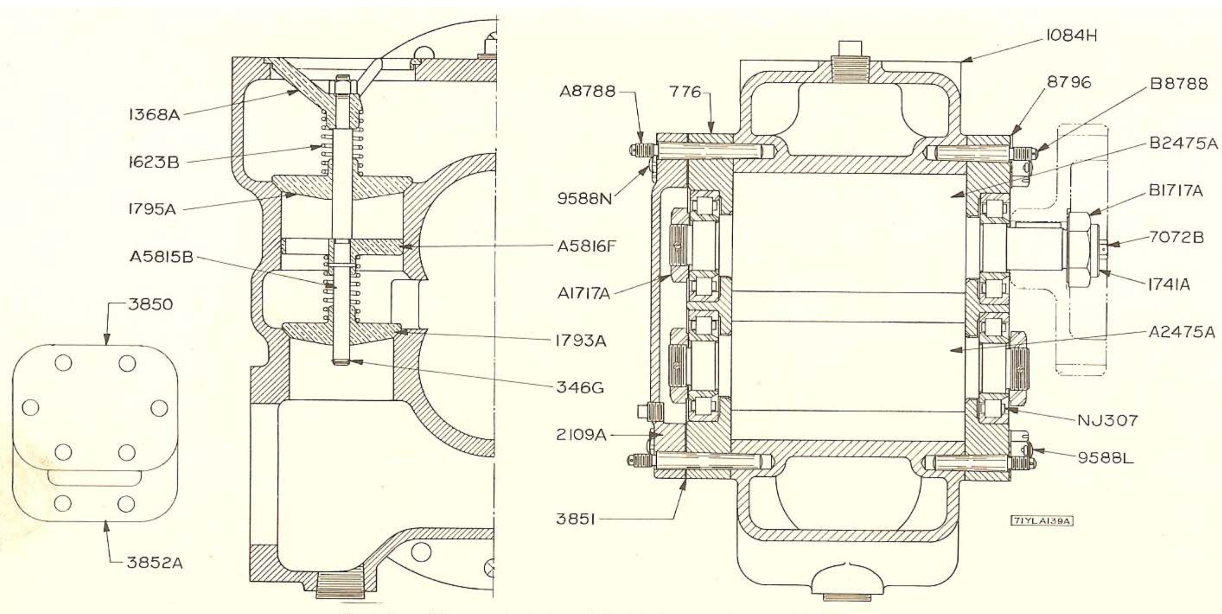
Section 44 —— Exhaust Manifold



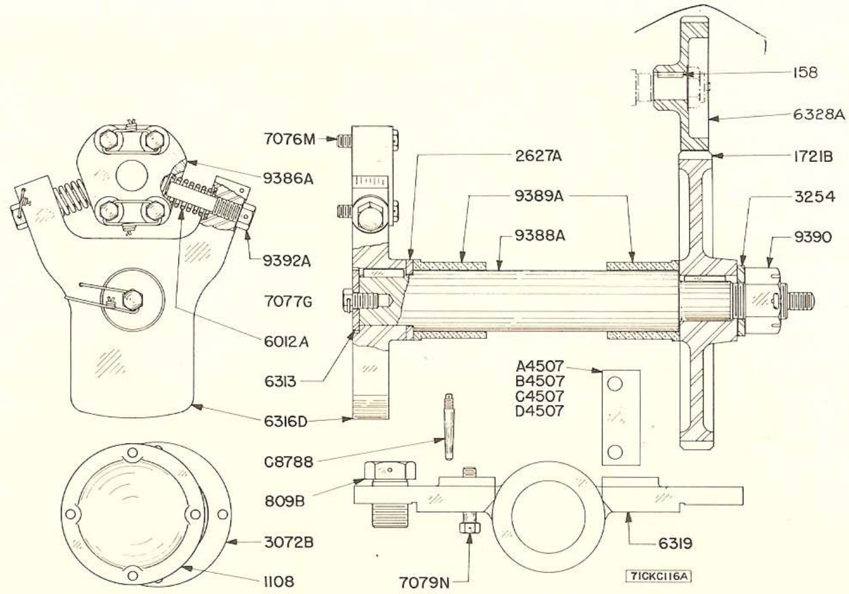
Section 45 —— Centrifugal Water Pump



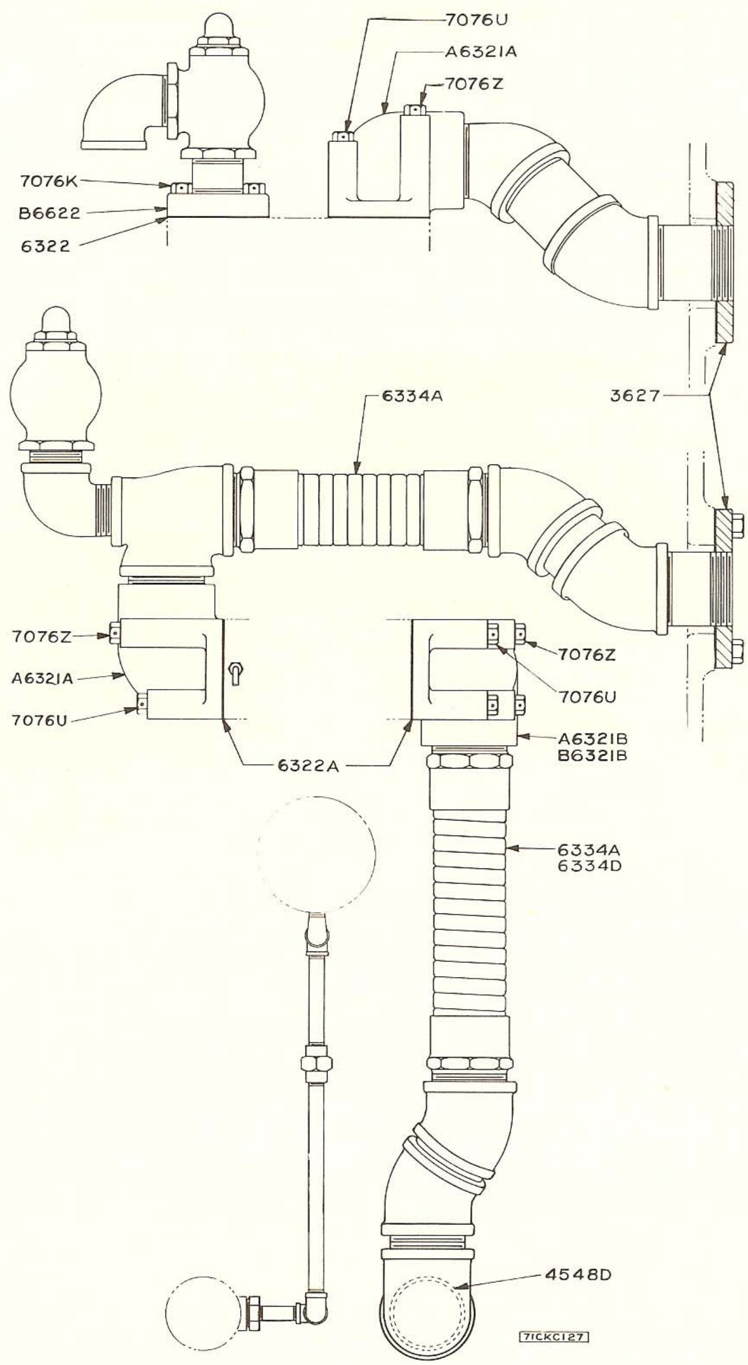
Section 46 —— Built-in Non-Reversible Lubricating Oil Pump



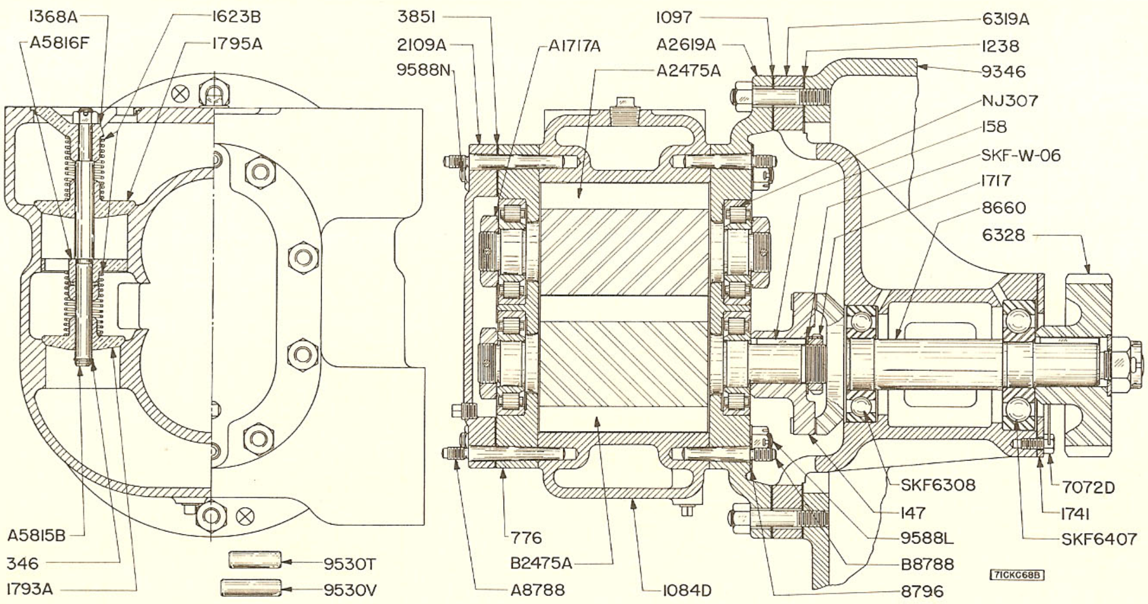
Section 47 —— Reversible Lubricating Oil Pump



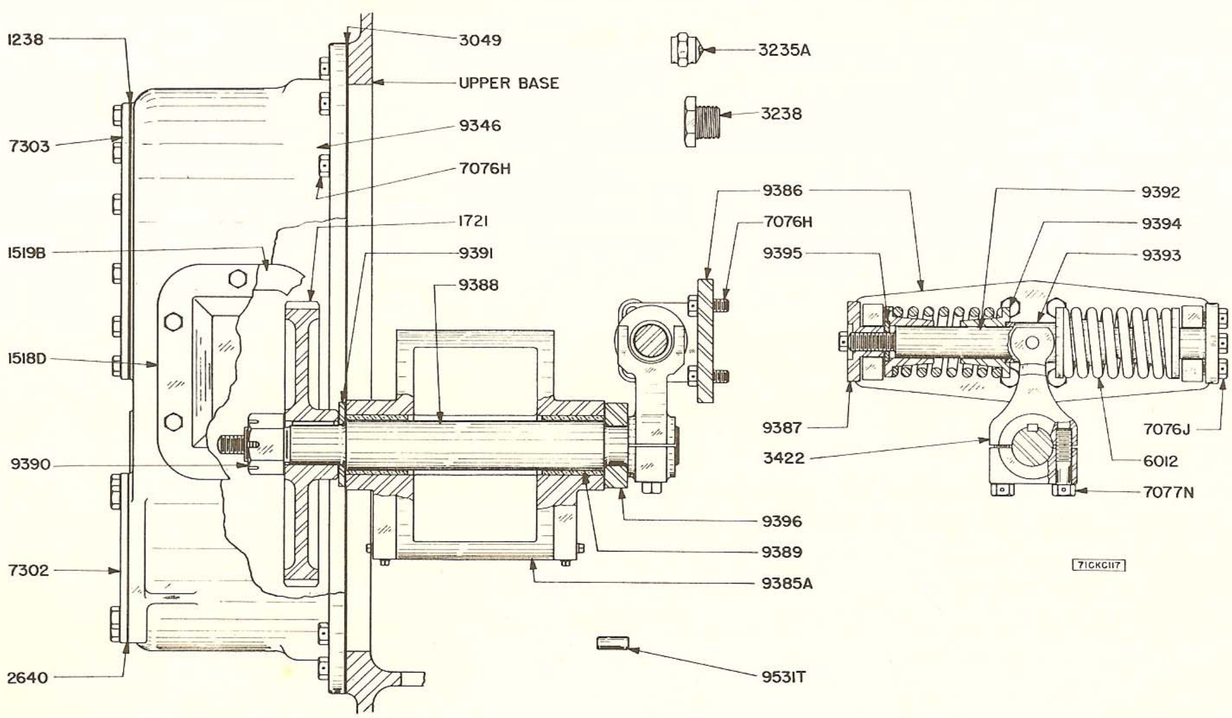
Section 48 —— Built-in Lubricating Oil Pump Drive



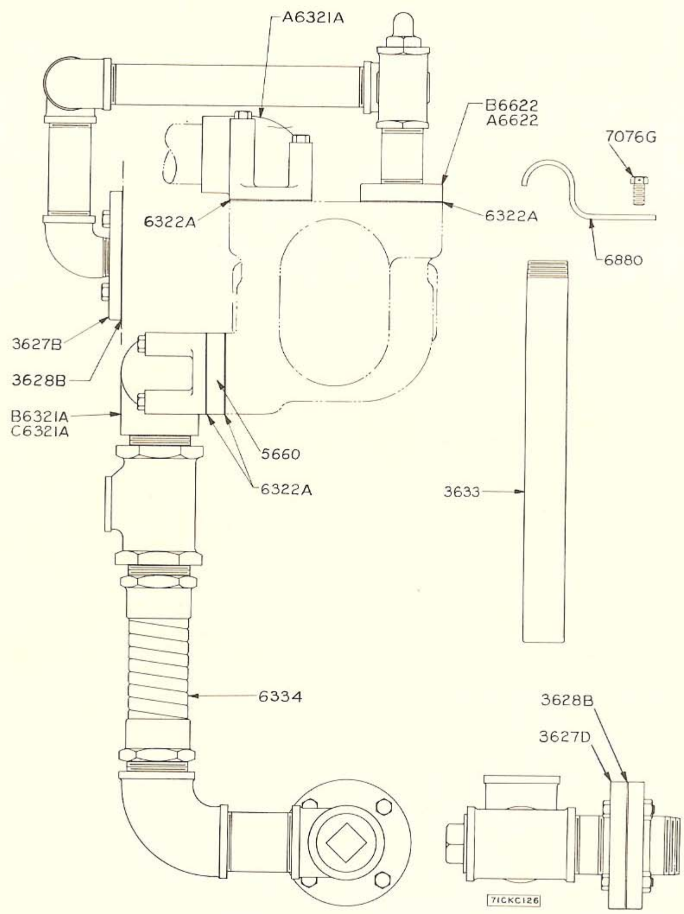
Section 49 — Built-in Lubricating Oil Pump Piping



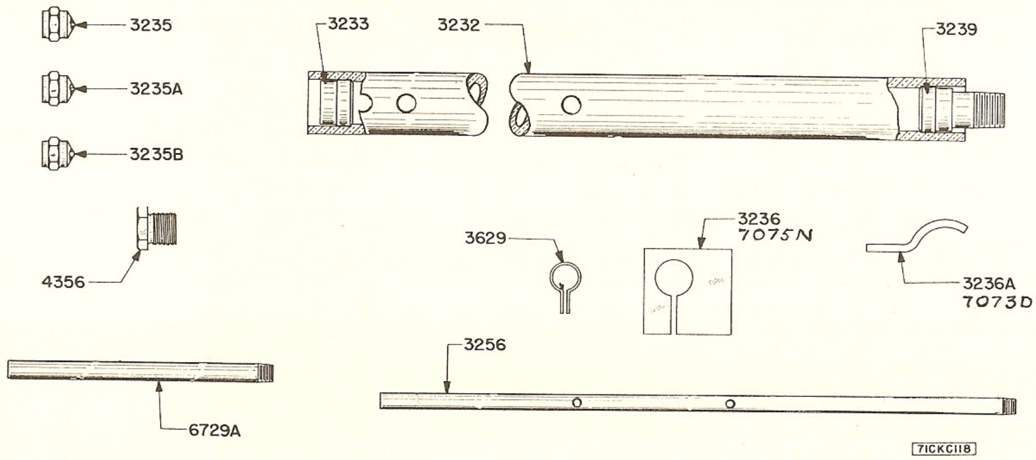
Section 50 — Reversible Lubricating Oil Pump



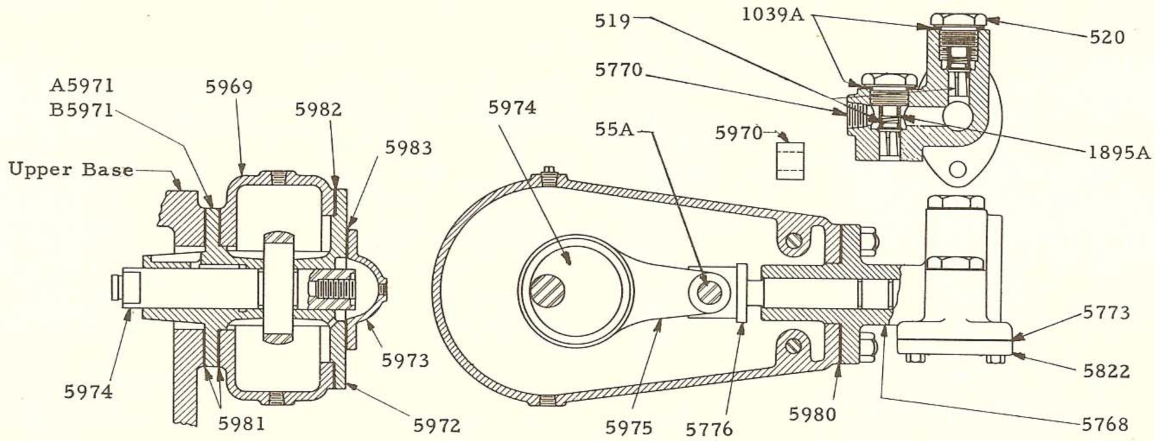
Section 51 — Reversible Lubricating Oil Pump Drive



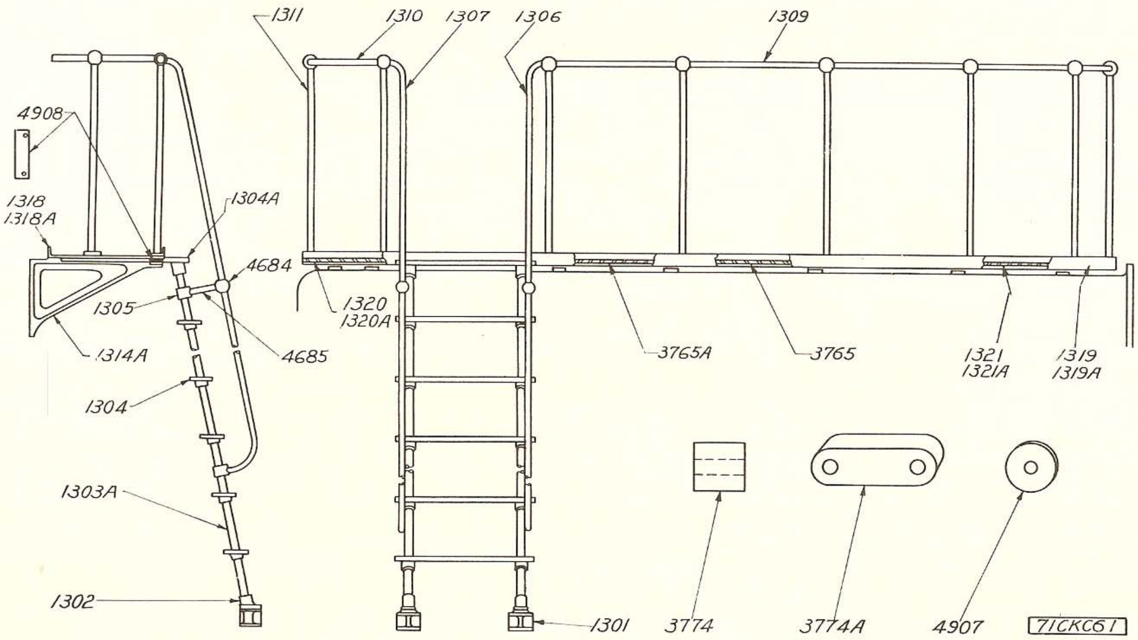
Section 52 — Reversible Lubricating Oil Pump Piping



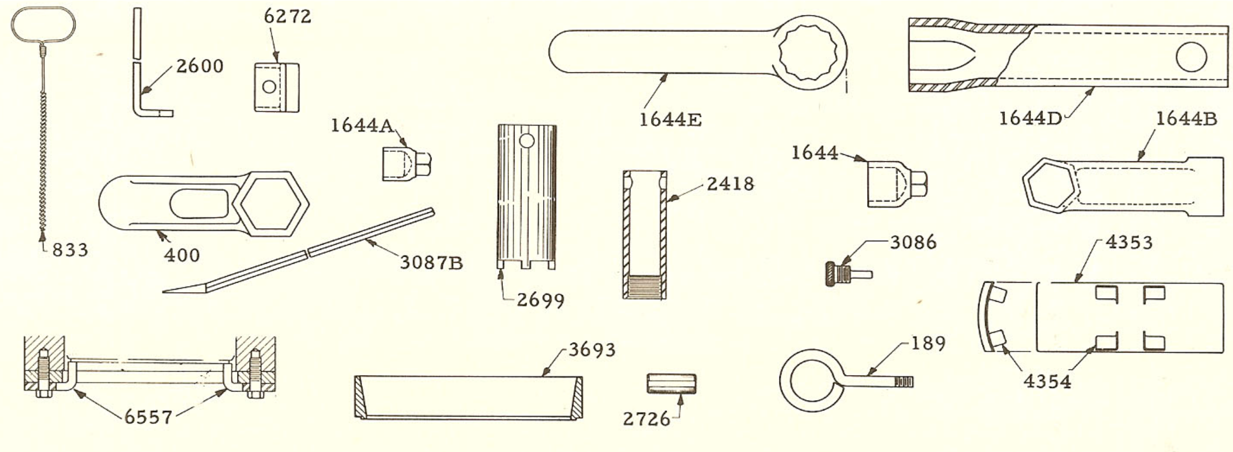
Section 53 — Lubricating Oil Piping



Section 54 — Transfer Pump



Section 55 — Platform and Stairs



Section 57 —— Gauges and Tools