ENTERPRISE
ENGINE & FOUNDRY CO.

INSTRUCTION MANUAL

SAN FRANCISCO
CALIFORNIA

Injector plunger & sleeve for Admiralla Fuel pumps Stamped T24

ENTERPRISE

DIESEL ENGINE

TYPE DMQ-6

ENGINE NUMBER 41065

16" BORE 20" STROKE

1000 HP AT 300 RPM

-0.197" fuel tappet

4021.2 CU. IN PER. CYL DISPLACEMENT

INJECTION SET 5 1/4 INCHES ON FLYWHEEL BEFORE TOP DEAD CENTER

TOTAL WEIGHT OF ENGINE & FLYWHEEL 81,200 POUNDS.

LUBE OIL CAPACITY 70 GAL. MINIMUM IN SYSTEM

FIRING ORDER AHEAD 1-5-3-6-2-4

FIRING ORDER ASTERN 1-4-2-6-3-5

WHEN MAKING INQUIRIES FOR PARTS OR SERVICE STATE ENGINE NUMBER AND TYPE

ENTERPRISE ENGINE & FOUNDRY CO.
600 FLORIDA STREET
SAN FRANCISCO, CALIFORNIA
U.S.A.

D McEVOY

On 1200 H.P. 8 Cyl. 2 engines

8.7" Throttle at 8750 Blower Speed

at 275 R.P.M. at 24 m/m Fuel pump

25 m/m = 103° Load,

Fuel injection set 14.3° before

top center on flywheel.

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LIST OF ILLUSTRATIONS

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PART I

INTRODUCTION AND WORKING PRINCIPLES

The purpose of this booklet is to acquaint the owner and engineer with the operation of his engine. In order to obtain maximum efficiency and continuous trouble-free service, the contents of this booklet should be carefully studied and the instructions, particularly regarding inspection and maintenance, followed carefully.

Enterprise Diesel Engines have proven themselves, and are giving all over the World continuous trouble-free service, even under extremely severe working conditions. The design of the engines was selected after exhaustive research and many years of engine building experience, with the primary view in mind of obtaining maximum simplicity of operation and maintenance, and maximum dependability.

Every engine is carefully and thoroughly tested and inspected before leaving our plant, and only such adjustments should be made by the operator as are indicated in the succeeding pages. It is suggested that the operator establish a certain system of routine inspection suitable to his particular service condition. This will more than pay for itself in lowered maintenance cost and more satisfactory operation.

The matter of cleanliness can hardly be stressed enough. It indicates, in a large measure, the care the engine receives otherwise.

If there is any specific condition that troubles the operator, and for which there seems no explanation in this booklet, we suggest getting in touch with our Service Department, stating the condition in full.

Enterprise Diesel Engines operate on the four stroke cycle principle. They are of the full diesel, vertical, mechanical injection type. The fundamental principles of operation are as follows:

1. Intake Stroke:
   Air is drawn into the cylinder at atmospheric temperature and pressure.

2. Compression Stroke:
   The inlet valve closes when the piston is slightly past bottom dead center. During the upward stroke of the piston the air is compressed to approximately 400 lbs/sq.in. This raises the temperature sufficiently to ignite the fuel. Just before top dead center, the fuel is sprayed into the compressed air through a nozzle, which is designed for the proper distribution and atomization of the fuel.

3. Expansion Stroke:
   During this stroke work is done on the piston by the combustion of the fuel. The heated gasses expand during the downward stroke of the piston until, near bottom dead center, the exhaust valve opens.

4. Exhaust Stroke:
   The exhaust valve remains open during the next upward stroke of the piston, expelling the gasses, until the piston again reaches the top dead center when the exhaust valve closes, the inlet valve opens and the cycle is repeated.

PART II

INSTALLATION

1. General

When installing the engine, special consideration should be given to the following:

(a) Placing the engine on its foundation.

(b) Connecting the water, fuel oil lube oil, exhaust and starting air lines. (Refer to Installation Drawings and Piping Diagrams).

2. Placing of Engine on Its Foundation

When placing the engine on its foundation make sure that the crankshaft is exactly in line with the shafting; and that the engine is evenly supported over its entire length so that there is no distortion of the base.

After the engine has been bolted down, check crankshaft alignment as follows: Measure distance between inside faces of crank webs with crankshaft deflection gage, or, if not available, with inside micrometers. Check this distance at intervals of approximately 90°. Readings should not differ by more than .003". If misalignment is indicated, determine cause and correct. Distortion at the last two cranks only usually indicates crankshaft out of line with shafting.

3. Cooling Water Lines

Installation work for the water system consists of connecting suction and discharge lines, of the raw water pump; also heat exchanger and surge tank, in the circulating water system. The water discharge from the thrust bearing cooling coils must be connected to overboard.

4. Fuel Oil Lines

Connect line from fuel oil supply tank to inlet of first stage filter, which is mounted on the after side of the engine.

Pressure tank should be mounted slightly above the top of the injection pumps.

Connect the transfer pump discharge to the pressure tank with a relief valve in this line whose

discharge is piped back to the suction of the transfer pump. From the outlet of the pressure tank run a line to the inlet of the duplex type filter mounted on the engine cylinder block.

A vent valve is mounted on the top of the pressure tank to expel any air that might accumulate in the tank.

Run a line from nozzle drain header to bilge or waste tanks. The nozzle drain may be returned to the storage tank if top level of storage tank is below injection pump header.

Remove all scale and dirt from pipe lines before starting.

5. Lube Oil Lines.

Lubricating system is complete on the engine when shipped. Installation consists of connecting the scavenge pump discharge to the lube oil service tank and connecting service tank to pressure pump suction.

The lubricating oil pump is of the duplex type. The outer pump (scavenge pump) transfers oil from the engine base to the service tank. The inner pump (pressure pump) takes oil from the service tank, forces it through the filter and oil cooler to the various points to be lubricated. A four-way valve is placed in the line before the oil cooler to isolate same in case of any leaks between lubricating oil and water sections. (See Section on Maintenance). With cooler isolated the oil passes through valve directly to main oil header. Remove all scale and dirt from pipe line before starting.

6. Starting Air System.

Connect the compressors to the tanks. Install a safety valve on each compressor ahead of any valve in the line and a safety valve on each tank. Install a pressure equalizer on each compressor line and run a line from the end of the equalizer fartherest from the compressor back to the unloader pilot on the compressor.

Provide suitable drain at any point in the system where condensate would tend to accumulate.

7. Exhaust System.

In laying out exhaust piping, use as few bends as possible; where bends are necessary they should be of long radius. If more than three bends are used, increase

the entire pipe to the next nominal size. If more than six bends are necessary increase the pipe two nominal sizes.

Installation should be made, so that piping and muffler may be easily disconnected and cleaned.

PART III

INSTRUCTIONS FOR STARTING

1. Before Starting for First Time

When an engine is just installed or has been out of service for a long time, or if extensive work has been done on the engine, the following points should be observed before any attempts are made to start:

Check all bolts and nuts to make sure they are tightened down thoroughly, particularly main bearing, connecting rod, cylinder head and foundation bolts.

Check crankshaft alignment as explained in Part II Installation.

Inspect all connections in lubricating and fuel oil, cooling water and starting air lines.

Bar engine over with relief cocks open, at least three complete turns, to make sure everything is clear.

Remove crankcase side cover next to the flywheel, and bar the engine over until the crank nearest flywheel is at top center position to allow easy access to lubricating oil suction screen inside the crankcase. Inspect lubricating oil suction screen in order to make sure it is not clogged and that no water or grit has accumulated in the crankcase.

Inspect also the lubricating oil service tank which should be at least 1/3 full when starting, with oil in the crankcase covering the suction inlet. If no oil is in the crankcase, the lubricating oil service tank should be at least 3/4 full. Open valves from the service tank and any other valves which are necessary to the flow of the lube oil through the system. If the lubricating and fuel oil filters have not been cleaned recently, clean as directed in the Maintenance Section.

The fuel system should be bled of air. To accomplish this proceed as follows: Open valve in fuel lines. Open vent plugs in filters and allow fuel to escape until all air has been expelled. Then remove vent plugs on fuel pumps, again allowing fuel to escape until there is a smooth flow without air bubbles. Finally bleed injection lines as follows:

Set all injection pumps at full fuel. The operating control interlock keeps the injection pumps in the stop, or no fuel, position when the engine is shut down. Move the control to the ahead or astern operating position. When this is reached the interlock will have cleared and the tension of the governor spring will open the fuel pumps to the full fuel position.

Open the nozzle bleeder valve slightly and prime the pumps by means of the priming shaft on the pump base until a definite resistance is felt, indicating that all the air has been expelled. Do not use too long a wrench nor too great a force on the priming shaft. If, upon attempting to prime a pump, no resistance at all is felt, it is an indication that the fuel tappet is on the peak of the fuel cam. First prime those pumps that are not in this position and then bar the engine over until the tappets are contacting a low point on the cam, thus making it possible to prime the remaining pumps. This condition can readily be seen by observing the timing mark in the window in the fuel pump body.

Inspect adjustment of hydraulic valve lifters as explained in Section "Valve Gear" and clearance of starting air valve as indicated on Engine Instruction Plate. Be sure air valve cap is in upper position when checking clearance. (See Section, "Timing of Air Starting Valve.")

Lubricate fuel pump control and governor linkage making sure all pins and cotter pins are in place.

Open all valves in the water suction and discharge lines and make sure there are no obstructions in the lines.

2. Starting and Stopping

Air pressure of not less than 200 lbs/sq. in. should be available although a warm engine may be started on 100 lbs/sq.in.

1. Move operating control to ahead or astern position.
2. Set fuel control handle at approximately 1/4 fuel.
3. Move operating control in direction to start and release as soon as engine fires or movement of governor linkage is observed.
4. To stop engine move operating control, so indicating pointer is vertical in "Stop" or "Neutral" position.

WARNING!

Never use any other compressed gas but air for starting, and particularly do not use Oxygen under any circumstances as it will result in a violent explosion.

3. Emergency Stopping Procedure

If for any reason the engine cannot be shut off by the above method, it may be stopped by closing the valve between final stage fuel filter and fuel oil header.

PART IV

RUNNING AND INSPECTION

1. Pressures

While running under normal load, at rated speed, pressure gages should read as follows:

Lubricating Oil	30 to 45 lbs/sq.in.
Circulating Water	15 to 20 lbs/sq.in.
Fuel Oil	10 to 15 lbs/sq.in
Starting Air Pressure	150 to 250 lbs/sq.in.
Sea Water Discharge	3 to 15 lbs/sq.in.

2. Temperatures

While running under normal load, at rated speed, temperature should read as follows:

Lubricating Oil From Engine	120° to 160°F.
Circulating Water From Engine	120° to 160°F.
Exhaust Temperatures	750° to 850°F.

3. General Maintenance

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

Thrust bearing should be felt frequently and oil container inspected to make sure of proper lubrication and cooling.

Duplex fuel oil filter between tank and engine should have the valve in such a position as to operate on one section only. The second section should be clean and ready to switch over. One filter should be cleaned about once a week. Where the fuel oil is clean and the filter does not show much dirt, this period may be increased.

Oil level in lubricating oil service tank and fuel oil tank should be watched closely to observe any sudden gain or loss in oil level. Drain valve in fuel tank and lubricating oil service tank should be opened at least once a day to drain out any water or sludge which may accumulate.

If the fuel pumps require adjustment in order to average the exhaust temperatures, care should be taken to see that the difference between any two pumps is not in excess of 2 millimeters on the control rod. If the difference in exhaust cannot be corrected without exceeding this maximum difference, it is an indication of wear or improper adjustment of pumps or nozzles, or holes in injection nozzle, may be plugged.

This condition may also be due to carbon deposits on the thermocouples or improper length of the thermocouples which should have a 4" stem. They should be removed every 3 months and checked. Scrape the stems if necessary.

A daily record should be kept of important pressures, temperatures, and other important conditions. These readings will be found valuable for future reference and occasional crosschecking will give indications of impending trouble if such should arise. Then small corrections can be made early to avoid major corrections later resulting from improper observance of operating conditions.

A sample log sheet is given as a basis for a convenient form.

ENGINE ROOM LOG
M.S. ENTERPRISE

	Date		
	Engineer		
	Time		
Engine RPM			
Aver. MM Fuel Pumps (Max.Diff. -2 M.M.)			
Aver. Exh. Temp. (Max. Range - 50°)			
Lube Oil Pressure			
Circulating Water Pressure			
Fuel Oil Pressure			
Starting Air Pressure			
Lube Oil Temperature			
Water Temp. from Engine (Aver.)			
Feel Side Doors check ( ) if o.k. Note any exceptions.			
Fuel Filters check ( ) if o.k Note if dismantled and cleaned which ones, and condition.			
Lube Filters check ( ) if o.k Note if dismantled and cleaned which ones, and condition.			
Level of lube oil service tank Note how much oil added if any			
Remarks:			

PART V

MAINTENANCE, DESCRIPTION OF PARTS, METHODS OF ASSEMBLY AND DISASSEMBLY

1. LUBRICATING SYSTEM

A. General

The lubricating pump is of the duplex type. The inner pump (scavenge pump) transfers oil from the engine base through a filter to the service tank. The outer pump (pressure pump) takes oil from the service tank and forces it through a filter and oil cooler to the various points to be lubricated. A relief valve mounted on the pressure pump prevents oil pressure from exceeding 35 lbs/sq.in. by allowing excess oil to be by-passed back to the suction side of the pump. A four-way valve is placed in the line to and from the oil cooler. In case of any leaks between lubricating oil and water sections, turn four-way valve so oil flows from filter directly into lube oil header, and replace cooler element at earliest convenience.

A leak between lubricating oil and cooling water sections may be detected by a depletion of lube oil in service tank, in excess of normal lube oil consumption.

Lubricating oil filter, between pump and oil cooler, consists of one large metal edge element. It should be cleaned about every four hours by turning handle one complete turn in a clockwise direction. Turning handle drives a scraper around face of element.

If oil pressure drops as shown on main lubricating oil gauge, it usually indicates that this filter element is being coated. Turning handle as explained above will usually correct this condition.

Never use a wrench on scraper handle. If handle sticks, it is a sign that some foreign substance has become wedged between scraper and element. If this should occur, stop engine at earliest convenience and remove filter element. To do this, remove the four nuts at top of element and element assembly may be lifted out. Clean element, scraper and case. If scraper is bent, straighten and free all moving parts. During re-assembly, be sure all gaskets are in good condition and tighten all bolts firmly to avoid leaks.

Filter should be disassembled and cleaned at

intervals of one to two months, depending upon the conditions of the oil. During normal operation, drain plug in bottom of case should be removed about once a week to drain sludge and foreign particles from the filter.

About once a month crankcase breathers should be removed and washed in a mixture of kerosene and lubricating oil. Inspect and clean inside of crankcase, especially lubricating oil suction screens and reservoir below. Remove oil from crankcase if any water or sludge is present.

B. Lubricating Oil Pump. (See Illustration "Lubricating Oil Pump")

The duplex unit consists of two gear type pumps mounted in the same housing. It is driven by a gear meshing with the idler gear. The main impeller gears of both pumps are splined to the drive shaft which runs in bronze bushings. The idler shaft is held stationary in the housing; the idler gears are bronze bushed and rotate on the stationary idler shaft.

If oil pressure drops as shown on main lubricating oil gauge, first see that there is sufficient oil in the lubricating oil service tank and that the lubricating filter is clean. Make sure that all piping connections are tight and that the lines are free. Make sure air bleeder line from top of relief valve to cover of scavenge pump is clear and that relief valve is seating properly.

If oil pressure is still low, dismantle pump and check clearances (see "Table of Clearances"). Proper side clearance is obtained by means of .006" gasket on each side of pump body. If faces of inside or outside covers have become worn, face off in lathe until all evidences of wear have disappeared. If inner faces of housing have become worn, face off outside until exactly flush with faces of gears. Replace gears and bushings if necessary. Gears are cut in pairs and should not be interchanged, however, any pair of gears may be used in either the pressure or scavenge pump.

Re-assembly

Place drive shaft (17) in housing. Assemble main gear (11) and idler gear (12) of pressure pump. Replace

inside cover (1) and gasket of proper thickness to make end clearance .006" and bolt in place. Check clearance of shaft shoulders "A" and "B" as follows: With drive gear held against thrust bushing (2) shoulder "A" must not protrude beyond face "C" of scavenge pump. Back out drive gear as far as it will go and determine clearance between drive gear and thrust bushing. This should be at least .010" to provide clearance for shoulder "B". Replace main gear (11) and idler gear (12) of scavenge pump. Replace shims (10), thrust collar (5), lock washer, and lock nut, installing sufficient shims to provide .004" to .007" end play in the drive shaft. Replace outside cover (4) and gasket of proper thickness to make end clearance of gears (11) and (12) equal to .006".

C. Relief Valve

The relief valve consists of a bronze plunger operating in a cast iron housing. When the line pressure equals the pressure at which the valve is set, the plunger moves off its seat allowing the excess oil to by-pass to the suction side of the pump. The spring is correctly set at the factory to maintain a pressure of 35 lbs/sq.in. when oil is hot. Under normal conditions, the adjustment should not be changed. If adjustment becomes necessary, proceed as follows: Remove cap, loosen adjusting screw lock nut and adjust as required. One turn of the adjusting screw changes the opening pressure approximately 1-3/4 lbs/sq.in.

2. FUEL INJECTION SYSTEM

A. General Description

A fuel injection pump and nozzle is provided for each cylinder. Pumps are operated from the main camshaft and are connected to a common fuel supply header. Each pump meters the fuel and discharges it through its injection tube to the nozzle in the center of the cylinder head. A full description of pump and nozzle is given below.

B. Maintenance of Fuel System

B-1 Filters

The strainer and filter should be operated on one side only having the non-operating side always clean and ready for use.

For change and maintenance see section "Fuel Filters".

During normal operation, handle on second filter should always be against one or the other stop plate, in its extreme position over one of the other of the elements. This element is then in operation. If engine fires irregularly, indicating that filter is clogged, move handle to other extreme position. This places the other element in operation. Clean the one that has been in use in accordance with instructions in Section "Fuel Filters".

If the filters are in good working order, only rarely should there be any reason for cleaning the nozzles or pumps. The only attention which should normally be given to these units is an occasional drop of engine oil to the pump plunger guide, applied through the window at the lower portion of the pump body.

DO NOT TAKE APART AND WORK ON EITHER PUMP OR NOZZLE UNLESS ABSOLUTELY NECESSARY AND THEN ONLY IF THOROUGHLY FAMILIAR WITH THIS PRECISION EQUIPMENT.

B-2 Nozzles

If engine has been running unevenly and a fuel nozzle is suspected, remove this nozzle and replace it with a spare.

To Remove Nozzle

Disconnect inlet and drain. Remove nozzle retainer. Nozzle assembly may then be pried out.

Before replacing nozzle, remove all carbon or other foreign substance from nozzle seat in head. See that gasket surface is clean and that gasket is clean and in good condition. Tighten hold down nuts evenly and just sufficiently to prevent blow-by.

The nozzle may be tested by connecting it to high pressure fuel line from any pump; operate the pump by means of priming shaft on pump base.

Nozzle can also be tested by means of separate test pump. When pressure as shown on gage of test pump reaches the proper value, the valve in nozzle should snap open and a finely atomized fuel spray should emerge from each of the orifices in the nozzle. These sprays should be symetrical and of equal density. If test pump is operated slowly, valve in nozzle will open and close rapidly, the condition commonly known as chattering. An experienced operator can tell from the sound of this chattering whether the nozzle is in good condition.

Nozzle should be replaced and repaired if it shows excessive dribble or if fuel emerges in a solid stream. Dribble will cause excessive carbon formation, even though nozzle atomizes properly. A solid stream is caused by a sticky stem or by foreign particles within the passages or under the seat.

If nozzle valve opens at a pressure below or above 2200 - 2300 lbs, the spring tension should be adjusted.

For methods of adjustment, disassembly and cleaning of nozzles, see Section "Nozzles".

B-3 Pumps - See Drawings "Fuel Pump" and "Timing of Fuel Pump"

If one of the injection pumps does not function properly, first ascertain if fuel oil is flowing freely to pump. To do this, loosen vent screw (1) on front of pump just above supply connection. Fuel oil should flow freely without showing air bubbles. Allow fuel to flow until all air bubbles disappear. If flow is sluggish it is probably due to clogged filters. In this case clean filters as directed.

Next open nozzle bleeder valve by turning handle on top of nozzle body in center of cylinder head two turns in a counter-clockwise direction. Then, with the control rods on the pumps set at approximately 20 mm., operate the pump a few times by means of priming shaft on pump base in order to bleed all air from injection tubing and passages in nozzle body; then close bleeder valve. If tappet is on cam lobe (as shown by mark "A" on slidable pump plunger being above line on inspection window-see Drawing "Timing of Fuel Pump"), bar engine over until tappet is clear of lobe. If Pump still does not function properly, remove and replace with spare pump.

To Remove Pump

Take off short connection to fuel manifold. Remove lower end of injection tube. Draw out control rod pin; remove hold down nuts. Pump can now be lifted off pump base.

To Adjust Timing - See Illustrations "Timing on Fuel Pump"

Timing is controlled by position of tappet adjusting plug. Before replacing pump make preliminary adjustment by barring engine back one-half turn of the flywheel, or approximately 180 flywheel degrees before firing top dead center. Tappet roller will then be clear of cam lobe. Top of adjusting plug should then be .197" below top surface of pump base. To change adjustment, loosen locknut on plug and screw plug up or down as required. One-half turn of plug changes position approximately .032". After this preliminary adjustment has been made, replace pump and tighten all hold down nuts. Bar over until top center mark on flywheel is as shown on title page. If timing is correct, mark "A" on slidable pump plunger will register with line on inspection window, as shown in Illustration "Timing on Fuel Pump".

C. INJECTION PUMPS

Operation of Injection Pump.

Fuel enters through inlet fittings 23 and 25 into the cavities surrounding the upper end of the barrel and, during the suction stroke of the plunger, is drawn into the cylinder through the inlet port. On the upstroke, the upper edge of the plunger closes the inlet port. Fuel is then delivered through delivery valve 2 to the spray nozzles. When the upper edge of the metering helix uncovers the by-pass port, the flow of fuel through the delivery valve is sharply terminated. During the remainder of the upstroke fuel is by-passed through a central hole in the plunger, through the metering helix and the by-pass port into the lower groove which surrounds the barrel. From here it may return to the inlet fitting.

It is seen from the above that the duration of injection and consequently the amount of fuel injected is determined by the angular position of plunger in the barrel. The quantity of fuel is regulated by rotating the plunger by means of the control sleeve 4 and the control rod 3. The plunger floats on a film of fuel during its entire stroke, and therefore requires only a very small amount of force for accurate and sensitive regulation. This condition is obtained by providing a small helical groove diametrically opposite the metering groove. These grooves distribute a fuel film evenly over the cylinder walls.

PRECAUTIONS TO BE OBSERVED AND SUGGESTED EQUIPMENT FOR REPAIR OF ANY INJECTION UNIT.

Before disassembling any injection unit, cover bench with clean grease-proof paper. See that paper and all tools are perfectly clean. Place a pan, approximately 10" x 15" and about 2" deep about two-thirds filled with filtered kerosene in a convenient position. A pressed steel white enameled surgical pan

is most convenient and is easy to keep clean. If parts are very dirty and a considerable number have to be washed, another pan arranged in the same way is advisable for final rinsing before re-assembly. A squirt can which allows a stream of kerosene to be directed under pressure through fine grooves and holes in various parts will also be found convenient. Hands should be kept clean, especially during re-assembly.

To Dismantle Pump - See Illustration "Fuel Pump"

Clamp pump in vise in inverted position. Press down plunger guide (5) and insert a 5/32" pin about 2" long in hole in flange spigot. Take out spring ring (6) by means of screw driver and pliers. Press plunger guide (5) down again and remove the temporary pin. All parts in lower portion of pump body (7) can then be removed in the following order: plunger guide (5), lower spring plate (8), plunger spring (9), pump plunger (10), regulating sleeve (4), spring ring (11), and upper spring plate (12).

Unscrew delivery nipple holder (13) and take out delivery valve (2) and delivery valve spring (14). Back off locking screw (15) about three turns. Carefully press out pump barrel (16) and delivery valve seat (17), including special gasket (18).

If plunger or pump barrel are found to be damaged, they should both be replaced. Never use a plunger from one barrel in another barrel, as the plunger and barrel are so accurately ground and lapped to fit that they cannot be interchanged. The same applies to the delivery valve and its seat.

Do not use grinding compound or extremely hard tools which may scratch closely fitted parts.

Before re-assembly, all parts should be washed in kerosene and oiled with a light lubricating oil.

To Re-assemble Pump

Install parts in reverse order from disassembly, proceeding as follows: Clamp pump body (7) in vise in

upright position. Place pump barrel (16) in body in such a way that positioning groove on largest diameter lines up with locking screw (15). See that ground surfaces of joints are perfectly clean and free from scratches. Locking screw should fit into groove in pump barrel. Avoid binding and distortion of barrel. Test this by moving barrel up and down in body.

Next insert delivery valve seat (17), and special gasket (18). Be sure that lapped face of delivery valve seat makes a perfect joint with top face of barrel. Insert delivery valve (2) and spring (14). Screw delivery nipple holder (13) into body, tightening it sufficiently on gasket to prevent leaks.

Now invert pump body for installation of remaining parts. Position control rod (3) so that punch mark which is in center of rack in a space between the teeth is approximately in center of pump body.

Place regulating sleeve (4) in pump body so that punch marked tooth of sleeve meshes with punch marked space of control rod.

The following parts can now be re-assembled in the order given: upper spring plate (12), spring ring (11), plunger spring (9), pump plunger (10), and lower spring plate (8). When replacing pump plunger, be sure to have mark on lug of plunger in line with marks on regulating sleeve and control rod. (See Illustration "Bottom View").

Insert plunger guide (5) on top of spring, press down, insert temporary pin in hole in flange spigot, press in spring ring (6) and remove temporary pin.

Re-assembly is now complete. For a check, work control rod back and forth. Test freeness of plunger by pushing plunger guide against spring a few times. This can be conveniently done by gripping a hammer handle in the vise and using end of handle as a tappet. Guide should return through force of spring and any sticking of plunger will be readily noticed.

INJECTION PUMP TROUBLES AND REMEDIES

NO DELIVERY OR INSUFFICIENT DELIVERY

Probable Cause	Suggested Remedy
1. Fuel tank empty or valve in line closed.	1. Refill tank with fuel. Check whether air release on tank is operating properly. Check whether transfer pump delivers fuel to tank. Open all valves in line.
2. Fuel inlet pipe clogged or second stage filter element dirty.	2. Clear pipe. Clean filter element.
3. Air lock in pump.	3. Vent pump and nozzle.
4. Pump plunger remains suspended in barrel.	4. Thoroughly clean all parts, particularly plunger and barrel. If either are damaged, replace both with spares.
5. Plunger spring broken.	5. Replace with spare.
6. Delivery valve does not seat properly.	6. Clean delivery valve and seating. If either are damaged, replace both with spares.
7. Delivery valve spring broken.	7. Replace with spare.
8. Leakage back to suction chamber from surfaces between top of barrel and delivery valve seat.	8. Clean faces. Remove burrs and scratches from delivery valve seat and barrel.
9. Worn or defective plunger or barrel.	9. Replace with spare.

INJECTION PUMP TROUBLES AND REMEDIES

(Continued)

CONTROL ROD JAMMED OR BINDING

10.	Dirt causes pump plunger to jam or control rod rack is coated with dirt.	10.	Dismantle and clean.

LEAKAGE OF FUEL

11.	Supply connection leaks.	11.	Install new gasket or replace connection if damaged.
12.	Leakage past spring guide caused by worn plunger or improper seal of barrel in main body.	12.	Replace defective parts with spares.

D. Nozzle - See Illustration "Fuel Nozzle"

The nozzle consists of the nozzle proper, including the body (18), valve (19), nozzle holder (16), and the spray tip (17). Nozzle valve seals injection system from combustion chamber except during time that fuel pump has built up sufficient pressure to overcome spring pressure acting on valve. This pressure is set between 2200 - 2300 lbs/sq.in. and may be adjusted by pressure adjusting screw (11) and locknut (8) at the top of nozzle holder. When nozzle valve opens, fuel is injected into combustion chamber through orifices in spray tip in a finely atomized spray. Injection continues until pump plunger uncovers by-pass port, causing rapid drop of pressure. Nozzle valve then seats quickly to avoid dribble. A small amount of fuel leaks around nozzle valve, thereby lubricating valve stem. This fuel is drained through connection made to leak off nipple nut (6) at top of nozzle holder. The bleeder screw (7) also drains into this connection. Unscrewing bleeder screw allows ball valve to lift off it's seat and fuel will by-pass, thus preventing injection.

An edge filter (2) is provided in fuel inlet stud (3). It consists of stainless steel and bronze discs of approximately .002" spacing. The purpose of this filter is to trap any particles which may be in the line past final fuel filter.

Before doing any work on nozzle see section "Precautions and Suggested Equipment for Repair of any Injection Unit".

To Adjust Nozzle Spring Pressure

Adjustment of spring pressure should only be attempted on test pump with gauge. While pumping fuel through nozzle in regular way, observe gauge and increase or decrease spring pressure to obtain opening pressure between 2200 - 2300 lbs/sq.in. To adjust spring pressure, remove protection cover (9). Loosen locknut (8) and adjust pressure adjusting screw (11) as required. Each quarter turn of adjusting screw changes opening pressure approximately 150 lbs/sq.in.

To Remove or Change Nozzle

Place nozzle holder body (15) in vise on flat portions provided for purpose with nozzle body (16) in upright position. Unscrew nozzle cap nut (16) holding nozzle body to holder body. Use close fitting wrench to prevent damage to nut. Wash nut (16), spray tip (17), nozzle valve body (18), and valve (19) in clean kerosene. Interior of nozzle body should be cleaned out with a small strip of wood soaked in kerosene. Rub valve with a clean, soft (but not fluffy) cloth soaked in kerosene. Do not use grinding compound or extremely hard tools which may scratch closely fitted parts. If the nozzle valve can be rotated freely in its body without friction or "rattle", then it fits correctly in the nozzle. If nozzle body or valve are found to be damaged, they should both be replaced. Never use a valve from one nozzle body in another body, as the valve and body are so accurately ground and lapped to fit that they are not interchangeable.

Re-assembling of Nozzle

Wash nozzle body, valve and spray tip in clean kerosene. Bring valve and body together and see that valve revolves easily. Before replacing nozzle body, valve, and spray tip in holder, be sure lapped sealing surface on nozzle, holder, and spray tip are perfectly clean and free from burrs and scratches. Care should be taken in screwing down nut to tighten just sufficiently for good seal without distorting any part by using excessive force.

To Overhaul and Clean Nozzle Holder

Place nozzle holder body (15) in vise on flat portions provided for purpose with nozzle protection cover (9) in upright position. Remove protection cover. Loosen locknut (8), and unscrew adjacent screw (11). Draw out pressure adjusting spring (13), and spindle (12). Wash all parts in kerosene. Unscrew inlet stud (3). Press out edge filter (2) with 3/16" pin. Clean filter and inside of inlet stud with kerosene.

Re-assembly of Nozzle Holder

When replacing filter, fit should be such that it is just possible to press filter into stud by hand with aid of 3/16" pin. If filter is too loose, replace with a new filter. Be sure seating faces of inlet stud and nozzle holder body are clean and that inlet stud gasket (1) is clean and in good condition. Tighten inlet stud sufficiently to prevent leaks without distorting any part by excessive force.

Replace spindle, spring, and spring cap nut. Adjust nozzle opening pressure according to instructions, page 6-10. Replace protection cover.

INJECTION NOZZLE TROUBLES AND REMEDIES

NOZZLE VALVE STICKING

Probable Cause	Suggested Remedy
1. Dirt in nozzle	1. Remove and clean nozzle
2. Poor lubricating qualities in fuel oil. (Fuel oil above 32° Baume gravity usually has poor lubricating quality).	2. Change to fuel of proper specifications.
3. Nozzle body and valve corroded or eroded due to acid, water, or dirt in fuel oil.	3. Replace nozzle body and valve with spares. Check fuel and filters.

LEAKAGE OF FUEL AROUND NOZZLE HOLDER OR EXCESSIVE LEAK-OFF THROUGH NOZZLE DRAIN

4. Joint between nozzle holder and nozzle not tight.	4. Clean faces. Remove burrs and scratches from nozzle body and holder.
5. Nozzle valve worn and loose in nozzle body.	5. Replace nozzle body and valves with spares. Check fuel and filters.
6. Nozzle valve stuck in closed position or nozzle orifices clogged.	6. Remove and clean nozzle.

E. Fuel Filters

First filter between storage tank and transfer pump is of the metal edge scraper type. To disassemble and clean this filter, proceed as follows: Remove filter case; clean element, scraper and case. If scraper is bent straighten and free all moving parts. During re-assembly, be sure all gaskets are in good condition and tighten all bolts firmly to avoid leaks.

Second filter between tank and injection pump supply header consists of two combination fabric and metal elements with a two-way shut off valve between them. Valve lever should always be against one or the other stop plate during normal operation.

To Clean Element of Duplex Filter

Turn shut off valve lever until it hits stop plate. This lever will then be over the element that is in operation as indicated on lever. Drain the case that has been in use by removing drain plug. Replace plug.

Remove the four clamping ring nuts from the studs, using the special wrench serving also as a handle. Slide off case and clamping ring as a unit. Pull both elements from their slide fits in the head.

Clean the fabric element by placing it upside down in a partially filled container of cleaning fluid. Compress the element and allow it to expand. As it expands, the cleaning fluid will be drawn inside the element, and when again compressed the fluid is forced through the filter cloth. Repeat this operation several times until the dirt on the outside of the cloth is removed. The metal element should be cleaned by washing off with a soft cloth in the cleaning fluid.

Reassemble and place valve lever in position about half way between central position and open position of element just cleaned. Open inclined vent plug on end of filter head until oil flows freely at this point. Then close this plug and open vent plugs on top of filter head. When oil flows from both these plugs, close plugs and move valve lever until it hits stop plate.

F. Fuel Transfer Pump

Fuel transfer pump is of the plunger type; it is directly connected to the camshaft by means of a coupling.

If fuel filters are in working order, the transfer pump should require no attention except an occasional inspection of the stuffing box for leaks. When repacking, use 3/16" square packing about 27" long of a type approved for oil pump plungers.

G. Relief Valves

A relief valve is located in the discharge line of the fuel pump, and is set at 20 lbs. Should the fuel pressure exceed this amount, the relief valve will lift off it's seat, and the excess oil will be by-passed back to the suction side of the pump.

3. AIR STARTING SYSTEM - (See Illustration "Air Starting Valve")

The air starting system consists of a main valve, piston operated, a pilot valve, and the starting valve in each head. The mechnaism is put into operation by moving the operating control into the start position, thus opening the pilot valve.

The function of the pilot valve is to bleed the air off of the upper side of the piston of the main valve. The resultant overbalance of pressure on the lower side of the piston opens the valve, and thereby charges the air manifold. The air starting valves in each head are so constructed that as soon as pressure builds up in the air manifold a piston (1) is forced upward against the rocker arm, which in turn, through the push rod, forces the cam follower against the air starting cam. The pressure on this piston also overbalances the tendency of the air pressure to open the valve. The action of the cam, push rod, and rocker is to force this piston down against the air starting pressure, thus eliminating its closing effect on the valve and allowing the valve to open.

There is also an auxiliary piston (2) in the starting valve which is connected directly to the valve stem (3). It is acted upon by air pressure and aids in opening the valve against cylinder pressure.

If it is desired to turn the engine over slowly by air without starting it, this can be done by cracking the main valve; by means of the set screw on the bottom of the valve body.

Be sure the set screw is fully released before attempting to start the engine.

B. Reverse Mechanism

The air motor is geared to an eccentric shaft which, in turn is strapped to the camshaft to shift it axially. The eccentric at each end of its travel reaches an adjustable bumper stop and remains at the stop due to tension in a spring holding it over center.

The position of the cams in respect to the tappet rollers in the operating position is obviously controlled by the adjustment of the bumpers. The importance of obtaining the proper operating position, therefore, cannot be over-emphasized and should be accomplished as follows:

Tighten the cork packing until considerable resistance is felt. Then operate the reverse eccentric manually and observe when the camshaft is in the extreme after position. By use of feelers, measure the distance between the after face of an inlet cam and the forward face of the adjacent bearing. Then operate the reversing eccentric in the same direction until the eccentric strap strikes the bumpers. The camshaft will be observed to have traveled a short distance forward. Again measure the clearance between the same inlet cam and bearing without maintaining a strain on the eccentric shaft. The clearance now should be .030 - .040 more than that previously measured. If the clearance is not as specified the bumpers should be screwed in or out with a spanner wrench provided for the purpose until this adjustment is correct.

This same procedure should be carried out with the camshaft in the forward position. In this case, the minimum clearance between the forward face of the fuel cam and the after face of the adjacent bearing should be ascertained, and on the final position against the bumper the clearance adjusted to obtain the same as in astern.

The forward bumper controls the clearance when the camshaft is forward and the after bumper controls the clearance when the camshaft is aft.

When the eccentric is on dead center in either direction there should be a minimum of .005" clearance between any one bearing face and the adjacent cam face.

Be sure to tighten the bumper locknuts firmly to prevent change in adjustment when tightening cork compressing screws.

Maintenance

Grease fittings have been provided on the housing to facilitate lubrication of the reversing mechanism. This should be done once a week.

The line oiler to the air motor should be filled with a light oil approximately SAE 10 once a week.

In both cases, if excessive maneuvering is being done, lubrication should be provided more often.

C. Starting and Reverse Control (See Drawing "Starting and Reverse Control")

Starting and reversing is combined in one control. Reversing of the engine is accomplished by moving the control to desired position as indicated on the face of the control mechanism housing. An interlock prevents the starting air from being turned on until the camshaft is in the proper running position. When this position is reached, the interlock will have cleared, permitting the control to be moved into the start position. As soon as the engine fires release the control, which will return to its normal operating position. With engine running the speed is controlled by the fuel control lever (See "Governor and Fuel Control"). To stop engine move control until pointer is vertical between ahead and astern, which is the "Neutral" or "Stop" position of the engine.

Maintenance

Starting and reverse control mechanism should be oiled once a week, through oil holes provided in housing. Should the reversing control mechanism be removed from the engine the following procedure must be strictly followed in the re-installation:

Remove one of the camshaft covers. By means of a wrench on the eccentric shaft extension below the reversing mechanism, set engine camshaft in "Neutral" position which is exactly half way between the ahead and astern position.

Position control so that pointer is exactly vertical in "Neutral" position. Set the indicating pointer on the face of the control mechanism in place and bolt to the engine.

To connect the air motor control linkage to the air motor, set the air motor handle in the center of its off position. Adjust yoke on link until clevis pin can be inserted. Make sure air motor lever is in its original position on shaft.

Remove cover (1) and by means of adjusting screw (2) set fuel rack on pumps at zero.

Starting and reversing mechanism should now be in time.

Before starting make sure all controls are free and all pins and cotter pins are in place.

4. VALVES AND VALVE MECHANISM - See Illustration "Valve Mechanism"

A. Description

Intake and exhaust valves are of alloy steel. Exhaust valve has a deflector on the stem just below the guide.

B. To Remove Valve, Intake and Exhaust

Remove cylinder head as explained in Section "Cylinder Head". Take off rocker shaft stud nuts and remove rocker assembly and hydraulic lifters. Place valve spring tool (furnished with engine) over valve retainer. Clamp tool in place by tightening set screws against cylinder head. Screw down fork by means of handle until retainer is depressed far enough to allow valve keeper wedges to be removed. Valve is now free and can be drawn out. Remove springs and if necessary, replace valve guide.

B-1. To Remove and Install New Valve Spring (Without removing head)

Bar engine until piston in cylinder, on which valve spring is to be changed is at top dead center. Take off rocker shaft stud nuts and remove rocker assembly. Place valve spring tool (furnished with engine) over valve retainer. Clamp tool in place by tightening setscrews against cylinder head. Screw down fork by means of handle until retainer is depressed far enough to allow valve keeper wedges to be removed. If retainer sticks to valve stem a slight tap with a hammer will release this and valve will drop down and come to rest on top of piston which must be at top dead center. Release valve spring tool and remove retainer and valve spring. Install new spring and set retainer on top of spring. Put valve spring tool in position and screw down on fork until valve keeper wedges can be inserted in retainer. Release valve spring tool being sure keepers are correctly located in retainers. Replace rocker arm assembly. Under no circumstances bar engine while valve spring is being replaced.

Air Starting Valve - See Illustration "Air Starting Valve"

To aid in removing the valve, in case it is stuck in the head, jacking screw holes have been provided on each side of the valve cage. To dis-assemble the valve, first unscrew the upper cap. To do this it is necessary to lock the piston by placing a pin through one of the cored slots in the valve cage and into the cored hole in the bronze piston. Next, remove the locknut on top of the valve stem and all parts will then come out. When cleaning always check the drilled air passage in the bronze piston for any obstruction.

The piston rings in both the main and auxiliary pistons are the type that seal on one side only. Care should be taken upon re-assembly that these rings be inserted properly. The rings on the larger piston seal pressure applied on the bottom, whereas the smaller rings seal pressure applied on top as in a normal engine piston. It is essential that the cap be screwed down securely and locked by bending copper gasket over flats of the cap and bronze piston.

C. Inspection and Reseating

Upon inspecting the valves, particularly exhaust valves, the seat surface may have the appearance of pitting due to the fact that small carbon particles may be trapped on the seats and impress themselves upon the metal; this condition has no effect upon operation unless there is an indication of blow-by. In this case valves should be reseated as explained below.

Reseating Valves

Valve may be refaced on standard valve refacing machine or ordinary lathe. Seat should be exactly 45°. If done in lathe by means of cutting tool, be sure to use very fine feed and sharp tool for final cut. If grinding wheel is used, wheel should be dressed for exact trueness before final grinding cut is taken. Remove only sufficient material to eliminate pits and to make seat run exactly true with stem.

Reseating Heads

If guide is worn, a new guide should be installed before refacing. Reface head in drill press if available, otherwise use hand reamer. Use standard 45° reamer and face just sufficiently for trueness and removal of pits. Next, limit width of seat to $11/32" \pm 1/64"$ by means of 75° reamer. After this operation, valve should be replaced in head and face of valve checked with seat by means of blueing.

If proper tools for making these corrections are not available, and it is absolutely necessary that repairs be made, valve may be ground by means of grinding compound in usual manner, however, this will not produce a satisfactory seat; therefore, if such repairs have to be made, heads and valves should be refaced as soon as possible in accordance with the above instructions.

D. Valve Gear - See Illustration "Valve Mechanism".

General Description.

Intake and exhaust valves are operated through rocker arms and push rods which are actuated by cams and tappets. Lower end of push rod rests in the tappet. Top of push rod contacts lifter body which actuates rocker arm through the hydraulic lifter.

Action of the hydraulic lifter: Oil under pressure from the lubricating system is led through a duct drilled in the rocker arm (3) connecting the lubricating hole in the rocker shaft (6) with the annular groove on the outer diameter of the lifter body. A hole (A) connects this groove to the inside of the lifter body. With the cam roller on the base circle of the cam and the valve seated, the light spring (13) lifts the hydraulic plunger (14), so that its upper end contacts the adjusting screw (7), thus eliminating backlash in the valve mechanism. As the plunger moves upward , increasing the volume of the pressure chamber, the check valve (9) is moved off its seat and oil from the supply chamber fills the pressure chamber. As the cam lobe lifts the roller, the lifter body is forced upward, slightly decreasing the volume of the pressure chamber, thereby closing the check valve. Further rotation of the camshaft lifts the valve through the confined column of oil.

During the time the valve is off its seat, a predetermined slight leakage of oil occurs providing for added length in the valve mechanism due to temperature changes. When the roller leaves the receding flank of the cam and contacts the base circle, the oil which fills the pressure chamber is exactly the right amount to eliminate all backlash in the valve mechanism.

While the roller is on the base circle, the force tending to open the valve is that due to the spring (13), and the oil pressure. This is much less than the main valve springs which hold the valve closed. The pressure of the oil in the supply chamber is negligible under normal operation due to the small area of the plunger.

The self-adjustment of the hydraulic lifter is effective immediately upon starting as the supply chamber remains filled from previous operation of the engine.

The upper end of the push rod is lubricated by oil from the hydraulic lifter. Leakage from the lifter body and hydraulic unit escapes through holes above the lifter body lubricating the lower end of the push rod and cam roller. A trough along the outside of the rocker provides lubrication for valve stem and guide.

Maintenance

Under normal operation, the valve gear should require no attention. Since the hydraulic lifters compensate for small amounts of wear in the valve mechanism, it is not necessary to adjust the valves periodically.

If noise develops in the valve mechanism, it is usually due to one of the following causes:

1. Excessive oil pressure
2. Air or air bubbles (foaming oil) in the lifters
3. Insufficient oil supply
4. Improper setting of adjusting screw on top of rocker
5. Plunger or lifter body sticking
6. Ball check valve sticking
7. Worn plunger or cylinder
8. Ball check valve leaking
9. Lifter spring defective

If oil pressure on lifter unit is above 50 lbs/sq.in. cylinder of hydraulic unit may leave its seat in body and prevent plunger from acting, thus causing excessive valve clearance. This may be checked by holding hand on the adjusting screw with the engine running at about 300 RPM. If this causes the roller to leave the top of the valve stem immediately, it is an indication that the lifter unit is not functioning properly. Do not do this for more than 8 or 10 strokes as this will cause roller to leave valve stem even if lifter is operating properly. Next, observe whether

oil flows from leakoff holes in rocker. If there is no oil at this point, ascertain cause immediately and correct. Next, inspect lubricating oil piping for air leaks, especially suction piping to pressure and scavenge pumps. Excessive air in the lubricating oil line will usually be indicated by a fluttering of the oil pressure gage or by a loss of oil pressure.

Next, adjust hydraulic unit as follows: While engine is running at approximately 300 RPM, screw down adjusting screw (7) until valve begins to ride slightly open at all times. This may be observed by pressure on adjusting screw as well as roller being tight at all times. Then back off from this point 1 turn, which is equal to 1/16" oil column in lifter body.

If improper operation is still indicated, remove lifter unit as follows: disconnect rocker shaft lubricating line; remove rocker shaft stud nuts; lift rocker shaft until lifter units will clear push rods; remove lifter units and take off rocker assembly; remove plunger from cylinder; wash thoroughly with kerosene, all parts of the lifter unit and bore of rocker. Be sure hole (A) in lifter body is clear. If plunger or cylinder is found to be worn, or if spring is broken or shows signs of set, renew plunger and cylinder. Never use a plunger from one cylinder in another cylinder as they are tested at factory for proper rate of leak-down. Do not use grinding compound or extremely hard tools which may scratch the surfaces of these accurately fitted parts. Make sure plunger is a free fit but not loose in cylinder. Check unit as follows: Wash thoroughly in kerosene and dry. Hold in vertical position, release spring from counterbore in cylinder and pull plunger out as far as possible retaining alignment in cylinder. Press plunger down and release quickly. If plunger kicks back repeatedly, it indicates that considerable air is retained and unit is in good condition. Usually when plunger is depressed as quickly as possible with index finger, it should kick back almost half its length; if excessive leakage is indicated, it may be at check valve or at plunger. To ascertain where leakage occurs, repeat operation described above with check ball submerged in kerosene. A leaky check ball will be indicated by considerable bubbling.

Re-assembly

Wipe off plunger and inside of cylinder with a clean, soft, (not fluffy) cloth. Replace plunger in cylinder, making sure plunger spring snaps into bore of cylinder; this can be done readily by a slight twisting motion in the direction to wind up the coil of the spring. Assemble lifter in lifter body. Replace unit in rocker arm; see that lifter body is free in rocker arm bore. Replace rocker assembly and tighten stud nuts.

To adjust lifter unit after re-assembly with cylinder dry; Back off adjusting screw about two turns. Bar over until piston is on firing dead center; cam roller is now on base circle of cam. Take up on adjusting screw until plunger rests against bottom of cylinder; at this time roller on rocker contacts top of valve stem and valve end of rocker cannot be raised. Next, back off adjusting screw one complete turn (1/16"). Valve mechanism is now in proper adjustment. After a lifter unit has been removed and replaced, the valve gear will clatter when the engine is started as some time is needed to expel the air from the lifter cylinder, however, if lifter unit is in good condition this noise should cease in about 5 to 15 minutes. If valve noise persists, check adjustment with the engine running at approximately 300 RPM, as explained on preceeding page.

After engine has been idle for a period of time, or after having been tested a long period of time elapses before installation, the zero lash units may stick. This will make them slow to seat when engine is first started causing noisy valve action. If this still persists after a short time proceed as follows: With engine running at about 300 RPM back the adjustment off until the rocker has a slight clearance, then tighten adjustment nut slightly which should eliminate the noise. The same noisy action may appear at maximum speed, if so, it can be corrected by the proceedure outlined above.

E. Tappets and Guides - See Illustration "Valve Mechanism"

Description

Intake and exhaust rollers have bronze bushings for bearings. The fuel tappet roller has needle bearings. The roller pin is serrated on one end to keep it from turning. Lubrication for both tappet in guide and tappet roller is from the auxiliary force feed header mounted under the camshaft bearings. Individual lines connect to each tappet cluster. Ducts distribute oil inside cluster to tappets. Oil flows to the inside of tappet to lubricate the push rod end.

The fuel tappet guides are individual for each cylinder and are integral with the fuel pump base. The fuel tappets are also lubricated from the auxiliary force feed header.

Maintenance

About once a month, camshaft covers should be removed and tappets and rollers inspected. Tappet clearances in guides should be checked with feelers. Tappets should be raised by pry bar and rollers and needle bearings checked for freeness on pins and in slot. The fuel tappet should return readily through force of fuel pump spring.

Recommended clearances are given in Table of Clearances and should be closely adhered to.

Assembly and Disassembly

The inlet, exhaust and air tappets are included in one cluster, which can be readily removed by disconnecting all oil lines and removing the nuts holding it to the crankcase. Before removing, place small pins in the holes provided in the exhaust and inlet guides to support the tappets as they are drawn away from the cams. Upon reassembly, be certain that the dowels that mate with the slot in crankcase have not fallen out. If the dowels are to be replaced or returned to their reamed hole in the cluster, be certain the flats line up exactly and that they fit well into the slot in the crankcase before tightening the hold-down nuts.

To remove fuel pump tappet, first disconnect lines to fuel pump and remove it. Then disconnect lube oil lines and draw out tappet and guide. Again tappet may be supported by pin placed into hole provided in the guide.

F. Timing of Air Starting Valves - See Illustration "Air Starting Valve"

When adjusting the clearance for proper air starting valve timing, it is essential that the valve is in the extreme up position. To accomplish this most conveniently proceed as follows: Close the globe valve in the starting air line. Open the main valve wide by means of the jack-screw underneath. Then crack the globe valve just sufficient to maintain 25 - 35# pressure in the manifold. This pressure will hold the valves up but is not enough to turn the engine over. Now by pushing down on the push rod end of the rocker arm until the tappet roller contacts the cam, the clearance can be measured between the rocker roller and the top of the air valve. The recommended amount of clearance is stamped on the engine name plate.

It is very important when checking clearance, to be certain that the air valve is in its normally closed position. If there is any doubt, bar the engine over until the inlet valve is open on the cylinder whose air valve is being adjusted.

CAUTION! Every time before attempting to bar the engine over, be certain that the globe valve in the starting air line is closed.

5. WATER JACKET AND COOLING SYSTEM

A. Jacket Water System

Water from the circulating pump flows from the manifold through each separate cylinder compartment, thence through drilled holes in the top of the cylinder head and out through elbows on the head to the water cooled exhaust manifold. Discharge from the forward end of the manifold is piped through the heat exchanger into the pump suction.

Vent connections are provided at the forward and after ends of the outlet manifold which are connected to the surge tank with a globe valve in each branch. Piping to the surge tank is on a continuous rise to avoid air pockets. There is a line from the surge tank outlet to the suction of the pump. If any valve is placed in this line, keep it wide open during operation.

Under normal operation, the vent valves should be open about 1/8 turn.

Temperature of circulating water entering heat exchanger should never exceed normal operating temperature. If excessive temperature is indicated, drop all load immediately and determine cause. If temperature does not decline after 2 or 3 minutes, stop engine. If pressure is low as indicated by gage, it is usually a sign that air is present in the pump. Venting the top of the pump or the top of the suction will usually correct this. If engine runs too hot with pressure normal or too high, water jackets and heat exchanger should be cleaned as explained later.

A-1. Raw Water System

Water from the ciruclating pump flows from the pump through the heat exchanger, lube oil cooler and overboard.

B. Pumps

Pumps are of the centrifugal type and should require no attention under normal operation. If leakage occurs, tighten packing gland, being very careful to avoid excessive pressure on the shaft causing it to run hot. If the shafts run hot and the pumps persist in leaking, remove gland and repack.

C. Maintenance

When draining circulating water system be sure to remove the plug at the lowest point in the line.

Engine water jackets should be inspected periodically by removing water manifold covers and inside screens. Clean out all loose scale and sediment. If hard scale is present an approved scale solvent should be circulated through the system for a period of two or three hours in a direction opposite to that of normal flow. System should then be drained and clean water should be circulated for an additional two or three hours to remove all traces of the solution and sediment. Avoid the use of any corrosive substance, such as muriatic acid.

After removal of any major part of the cooling system, such as a cylinder head, check after re-assembly by filling the engine with water and subjecting it to a pressure of 50 lbs/sq.in.

Clean out raw water side of oil cooler in same manner..

Take off bonnets and remove tube bundle from heat exchanger. Clean out in the same manner as engine water jackets.

6. CYLINDER HEAD

To Remove Head

Drain water from engine. Loosen flanges which connect exhaust manifold and intake air elbow to head. Next remove rocker shaft assembly and hydraulic lifters. Disconnect fuel injection tube from pump. Disconnect nozzle drain fitting on outside of head. Remove nozzle as follows: Disconnect inlet and drain; remove nozzle retainer and pry out nozzle. Replace nozzle holder retainer and use for lifting eye-bolt. Next unscrew all holding down nuts and head is ready to be lifted off. If head adheres to gasket, take strain on tackle and jar head with lead hammer.

Use new gaskets when re-assembling an engine. An old cylinder head gasket may appear to be in good condition, but after re-assembling the head and starting the engine the gasket may prove defective, necessitating the complete removal of the cylinder head and installing a new gasket.

With the head off, inside of combustion chamber and top of piston should be cleaned if excessive carbon is found. Piston should then be lowered to bottom dead center position and upper part of bore cleaned. Cylinder walls should be given a coating of clean lubricating oil before re-asembly.

Thoroughly clean off top of block and face of cylinder head to present a clean surface for the new head gasket.

When replacing head, screw hold down nuts hand tight. Next, insert capscrews holding exhaust manifold and air intake elbow to head and screw them hand tight. Then tighten hold down nuts with socket wrench furnished for the purpose. Tighten capscrews holding manifold and intake elbow.

7. RELIEF VALVE

A relief valve is mounted on each cylinder head near the fuel nozzle. An indicator cock is connected to relief valve body.

To release compression in cylinder, open indicator cock, or turn knurled handwheel on relief valve in clockwise direction until it lifts valve off its seat.

Relief valve is set at factory to release at 900 lbs/sq.in. pressure. If it should pop continually while engine is running, it is usually and indication that the maximum cylinder pressure is too high. This is caused by overloading of the engine or by too much fuel being injected into the cylinder.

If the operator has satisfied himself that the popping is not due to either of these causes, the relief valve should be removed and tested by hydro-static pressure. Valve should release when pressure reaches 900 lbs/sq.in. To increase release pressure, loosen locknut and screw down on adjusting nut. When making this adjustment care should be taken not to screw down on the adjusting nut until spring is compressed solid. If it is necessary to do this in order to prevent valve opening before pressure reaches 900 lbs/sq.in. it is an indication that the spring has become too weak and should be replaced.

8. CONNECTING ROD AND BEARING -See Illustration "Cross Section"

Connecting rod is a solid steel forging bored out at top to receive connecting rod bushing. Rod is drilled through to allow oil under pressure from crankshaft to reach this bushing.

Connecting rod bearings are steel cast boxes separate from the connecting rods. They are provided with bronze shells lined with Bermax. Shims are provided for clearance adjustment. (See Table of Clearances).

Compression shims between connecting rod and bearing allow adjustment of compression pressure if necessary. Normal clearance between top of piston and top of block with piston on top dead center should be .900-.885. When actual clearance agrees with recommended value, compression pressure should be 460 lbs/sq.in. to 610 lbs/sq.in. at rated speed. If pressure is much below this value, compression is being lost, and gaskets, valves, rings, etc., should be checked.

About once every six months one connecting rod bearing should be removed and inspected.

To Remove a Connecting Rod Bearing

Tighten setscrews holding connecting rod bolts in position and then remove nuts. Raise piston to top dead center position and insert piston holding fixture in hole near bottom of cylinder liner in order to hold piston and connecting rod in top center position when bearing is removed.

When re-assembling, remove all burrs especially from around hole in cylinder liner and from the bottom of the piston skirt.

To Check Alignment of Connecting Rod and Bearing

With bearing assembled, remove connecting rod nuts after tightening setscrews. Bar engine over carefully to various positions and check alignment between foot of rod and top of bearing with feelers at forward and after faces of bearing. If misalignment of more than .002" is found, check clearance of piston in liner and of piston pin in piston and bushing. Replace any worn parts. Recheck alignment and correct top surface of upper half of bearing to obtain correct alignment if necessary.

9. PISTON - See Illustration "Cross-Section"

Pistons are especially selected for heavy duty service. Rings used are: two sealing rings at the top, three compression rings, and two oil regulator and wiper rings, one of which is below the piston pin.

Piston pin bearings are bronze alloy bushings pressed into the connecting rods. Four holes around the circumference provide full pressure lubrication from crankshaft oil ducts and hollow connecting rods.

Piston pins of carburized and hardened alloy steel are full floating, prevented from end-wise movement by aluminum plugs in the pistons.

About once every six months to one year, one or more pistons should be removed and inspected.

To Remove Piston

Remove cylinder head as outlined on page 10-1. Then bar engine until piston is at top dead center. Disconnect connecting rod bearing as follows: Tighten setscrews holding connecting rod bolts in place and remove nuts.

Insert eye bolt in top of piston. Be sure threads in tapped hole are clean so that eye bolt may be inserted at least 5/8". Piston and connecting rod may now be lifted with chain tackle. Make sure the holes in connecting rod foot are clear of the connecting rod bolts; otherwise there is danger of straining the piston with the tackle if the edges of the holes should catch in the bolt threads. Be careful to guide lower end of connecting rod through liner to prevent marring of liner bore.

To Remove Rings (See Illustration "Piston Ring Arrangement"

Insert a screw driver in ring gap. Spread ring and insert four 1/32" x 1/2" steel strips about 8" long between ring and piston equally spaced around circumference. Slide ring off carefully. Rings above piston pin should be removed over top of piston. Remove lower oil ring over bottom. As each ring is removed, attach tag so that when re-assembling ring will be in same position in its proper groove.

Clean thoroughly all rings, grooves, and drain holes.

Check ring gap clearance as follows: Insert ring in liner and slide it down squarely, measuring gap at various levels in liner. Gap clearance should be determined at smallest diameter of bore traversed by ring. See Piston Illustration and Table of Clearances, for correct gap clearances.

If gap clearance exceeds by 1/16", or more, the recommended clearance given in the illustration and table, then the bore of the liner should be measured with inside micrometers. If bore at any point is worn more than .040" on the diameter, liner should be replaced. Liner wear is usually limited to last few inches of ring travel near the top, and if rings show excessive gap clearance near the bottom, it usually indicates ring wear. When replacing rings, fit gap clearance to amount given in illustration and table. Check gap clearance as outlined above.

To Remove Piston Pin

Withdraw each of the two aluminum plugs as follows: Place a washer 2" outside diameter, 9/16" inside diameter and 1" long over a 1/2" standard capscrew about 5" long. Insert capscrew in tapped hole in piston plug and withdraw plug using washer as a ram. The pin is a wringing fit in the piston and should push out easily with little force from either side.

Bushing end of connecting rod should be washed in kerosene and then blown out thoroughly with compressed air.

Correct clearances of piston pin in piston and bushing are given in Table of Clearances.

When installing new pin, scrape out all carbon and burrs from bore in piston. Make sure pin has proper clearance in both piston and bushing.

To Replace Bushing in Connecting Rod

A heavy press is necessary. If this is not available, bushing should be split by sawing with a hacksaw from the inside. This will relieve the pressure and bushing can then be readily driven out. To insert new bushing, remove all burrs and clean connecting rod thoroughly. Place entire connecting rod in a pan of oil heated to 350° - 450° F. Remove connecting rod and place on substantial support. Insert bushing with one of the oil holes in line with drilled hole in rod---drive in. This operation should be done quickly, as bushing will heat up and expand rapidly. Make sure bushing protrudes the same amount on both sides.

To Re-Assemble Piston in Liner

Assemble piston and rod, taking care to return them to their original relative positions. Aluminum plugs are marked and are not interchangeable. They should be from .003" to .008" below the diameter of the piston when checked with a long scale held against the surface of the piston skirt. Check with feelers, being certain to hold the scale parallel to the axis of the piston. Hang piston on chain tackle and install rings in proper positions. Cover cylinder walls with a coating of clean cylinder oil. Lower piston carefully into liner, using ring guide. With crankpin on top dead center and connecting rod bearing in place, let piston down slowly on bearing and bolts. Be sure proper number of shims are in place and that surfaces are clean. After assembly has been completed and before cylinder head has been replaced, measure distance from top of piston to top of cylinder block. (See Table of Clearances).

If any new wearing parts have been installed, engine should be run for at least eight hours at about half speed and at a light load. During this time it should be stopped frequently to ascertain any undue heating of piston or pin.

10. MAIN BEARING

Main bearings are of the precision type. The cast steel caps are line bored with the engine base to insure accurate alignment. Upper and lower shells are identical; they are bronze back lined with bearing metal. No shims are used; accurate location of parts is accomplished by steel locking rings in cap, holding also upper shell to cap.

To Remove Main Bearing

Take off cap. Insert the tool provided into oil hole in crankshaft. Shell may now be rolled out by barring engine over carefully until shell is free. Remove one bearing at a time, inspect and clean it and replace before disturbing other bearings. Oil groove in shell is offset. When installing shells, make sure the grooves are staggered to prevent formation of a ridge in crankshaft journal by wear.

Alignment and Clearances

A careful check of alignment and clearances should be made about once every two months for the first six months and thereafter about once every six months.

Test Alignment as Follows:

Measure distance between inside faces of crank webs with crankshaft deflection gage, or if not available, with inside micrometers. Check this distance at intervals of approximately 90°. Readings should not differ by more than .003". Refer to form in back, "Crankshaft Deflection."

If misalignment is indicated, it may be due either to uneven wear in the bearing shells or to distortion of the engine bed.

If uneven wear is indicated, replace the shells which are worn. Do not scrape shells or base or attempt to rebabbitt shells. If engine bed distortion is indicated, check and correct as specified in "Installation, Part II".

11. LINER

Liners are of the water contact type. They are inserted in cylinder block and located at top and bottom surfaces. Material is a special alloy cast iron having a hardness of 200 to 240 Brinell. The cylinder head holds the liner firmly through the gasket; the latter also seals the combustion chamber and circulating water passages. Two rubber rings seal the liner at the bottom. To facilitate installation, these rings are placed in grooves machined in the block. There is a cored chamber between the two grooves; a drain hole at the bottom of this chamber on each cylinder center prevents water from reaching the crankcase and also gives indication of any leak.

See Table of Clearances for piston skirt clearance.

To Remove Liner

Remove cylinder head and piston in accordance with instructions given in Sections "Cylinder Head" and "Piston". Withdraw liner by means of plates and puller bolt supplied for the purpose.

Before replacing liner, install new sealing rings. A coating of a good grade of grease for rubber lubrication should be placed on rings and on those portions of liner which fit into rings and into bore at top of cylinder block. It is essential that liners be replaced in their original cylinders and that each liner be re-assembled in its original position relative to the cylinder block.

12. CAMS, CAMSHAFT AND CAMSHAFT BEARINGS

Cams are nickel alloy steel carburized, hardened and ground. Each cam is securely fastened on the camshaft by key and two setscrews. Each setscrew is kept from turning by a plug formed by Cerro-Base. To melt out, heat with a small blow torch. Be careful not to heat cam to point where it discolors, as this will reduce hardness of surface. Cerro-Base should be used in re-assembly. If it is not available solder may be used.

Bearings should be checked by means of feelers about once every six months. If wear is indicated above allowable, replace shells. Do not attempt to scrape or rebabbitt.

Camshaft bearings are of the precision type. The cast steel caps are line bored with crankcase to insure accurate alignment. Upper and lower shells are not alike; so care must be taken upon re-assembly. The upper shell has a drilled oil hole. The shells are steel backed, lined with Bermax. No shims are used; accurate location of parts is accomplished by steel locking rings in cap which also hold the upper shell to cap.

13. GOVERNOR AND FUEL CONTROL

Description - (See Illustration "Governor and Fuel Control")

The governor is of the centrifugal flyball type, working against accurately loaded springs, the tensions of which can be regulated by adjusting screws. Lubrication of the internal mechanism is provided by a pressure oil line from the engine lubricating system. The speed of the engine is controlled by the fuel control handle in conjunction with the governor. Moving the fuel control handle in the direction to increase engine speed actuates the governor which in turn rotates the fuel control rack in the direction to increase the fuel setting.

When the engine is running at any speed and a load is applied, the governor will increase the fuel setting within limits of stops, to maintain the engine speed at which the fuel control handle is set.

Maintenance - (See Drawing "Governor and Fuel Control")

The fuel mechanism is accurately adjusted at the factory and unless parts have been removed from the engine during shipment or during installation, no care should be necessary beyond oiling the linkage pins and shaft bearings.

14. TIMING GEARS (See Illustration "Gear Set")

Timing gears have accurately cut helical teeth. Gear teeth are lubricated by streams of oil directed in such a manner that all gears will have an abundance of oil at all times. About once every six months covers on gear case should be removed and gears inspected and backlash tested between all gears. Test radial and thrust clearance of idler bushing. If backlash between any pair of gears exceeds value given in the Table of Clearances by .006" or more, adjust as described below provided the backlash is not caused by excessive wear of the teeth. In this case, replace the worn gear.

Accessories on the front of the engine are flange mounted. When installing these accessories, proceed as follows: Position flange of housing or mounting bracket so that the gears have the correct backlash, and slightly tighten bolts. Check by turning accessory gear back and forth by hand. Bar engine to several positions and check backlash. Adjust if necessary then tighten flange securely and make final ckeck for proper clearance.

To Remove Gear Case

Take off all accessories, disconnect all lines to gear case, remove pin in eccentric shifter strap, which allows reversing mechanism to be removed, and unbolt gear case from cylinder block and base.

To Remove Idler Gear

Take off idler thrust plate and shims. Gear may now be withdrawn. Install new bushings if radial clearance exceeds .010". When installing new bushings, remove all burrs from bore of gear. When re-assembling gear on idler stub shaft, adjust thrust clearance to .003" by use of proper number of shims.

If the idler only is to be removed, be certain to mark the mating teeth on crankshaft, idler and camshaft gear before disassembly. This will eliminate the necessity of going through the engine timing procedure as stated below when re-assembling.

To Replace Crankshaft Gear

The gear is a shrink fit on the crankshaft. To remove gear, split it by drilling a series of holes from top of keyway. Insert 3/4" studs about 24" long in tapped holes and withdraw gear. When installing a new gear, first fit a new key. Key should be a driving fit on the sides only in both crankshaft and gear; allow.005" - .010" clearance top or bottom. Remove all burrs from crankshaft.

Insert studs in tapped holes in gear. Place gear in a pan of oil heated to 350° - 450° F. Gear may now be placed in position on crankshaft.

To Remove Camshaft Ring Gear

Take out bolts holding ring gear to hub; ring gear may now be removed from hub.

To Replace Camshaft Gear Hub

Remove camshaft nut and washer. Insert 1/2" studs about 6" long in tapped holes in hub. For a puller, use a 3/4" x 1-1/4" bar about 10" long with two holes 9/16" in diameter and at 8-1/8" centers. When replacing hub a new key should be fitted. In assembling a new ring gear and hub, position so that four slotted holes in hub are centered over the respective drilled holes in ring gear. Clamp gear and hub, but do not drill and ream the remaining two holes in ring gear until after camshaft has been timed, as these are locating holes. Replace gear assembly on camshaft, install washer and nut.

To Time The Engine

Remove idler gear according to instructions given above. Bar engine until mark "1-6" on circumference of flywheel is exactly under the center of the flywheel pointer. Position camshaft so that gear keyway is exactly vertically upward. (See Illustration "Gear Set"). Replace idler gear. Loosen camshaft ring gear on hub and adjust position of camshaft until top surfaces on intake and exhaust rollers on #6 cylinder are exactly on the same level, with the piston on top center, indicating that intake valve is about to open and exhaust valve is closed. (See Timing Diagram). The timing is now correct; ream locating holes in ring gear with 9/16" reamer and insert bolts.

Camshaft may be timed by means of No. 1 fuel injection pump if operator is certain that timing of this pump is correct. When using this method proceed as follows: Remove idler gear. Bar engine until mark "1-6" on circumference of flywheel is exactly under center of flywheel pointer. Position camshaft so that gear keyway is exactly vertically upward. Replace idler gear. Next bar engine until mark "1-6" on circumference of flywheel is * ahead of center of flywheel pointer. Adjust camshaft until mark "A" on slidable pump plunger registers with line on inspection window. Clamp gear to hub. Bar engine a few degrees in direction of normal rotation and make sure fuel cam continues to raise pump plunger. When adjustment is satisfactory, ream locating holes in ring gear with a 9/16" reamer and insert bolts.

* See injection setting on title page.

PART VI

TABLE OF CLEARANCES

VALVES

Exhaust Valve Clearance in Guide - - - .0055" - .007"
Replace Guide if clearance exceeds .020"-.025"

Inlet Valve Clearance in Guide - - - - .0035" - .005"
Replace Guide if clearance exceeds .020"-.025"

Air Starting Valve Clearance in Cage - 1/64"

Main Piston in Cage - - - - - - - - - - .002" - .004"
Replace Piston if clearance exceeds .015"

Auxiliary Piston in Main Piston - - - .002" - .004"
Replace Worn Parts if clearance exceeds .015"

ROCKER ARM

Radial Clearance on Shaft - - - - - - - .002" - .004"
Replace rocker arm bushings if clearance exceeds .010"

Roller Pin in Rocker - - - - - - - - - - .000" - Press Fit
Replace rocker arm or use oversize pin if clearance exceed .002"

Pin in Roller - - - - - - - - - - - - - .0015" - .0035"
Replace pin and roller if clearance exceeds .010"

TAPPETS

Tappet in Guide - - - - - - - - - - - - .002" - .004"
Replace with new Tappet Guide Liner if clearance exceeds .015" - .020"

Roller Pin in Tappet - - - - - - - - - .000" - .0015" Press Fit

Roller in Forks of Tappet - - - - - - .006" - .008"

TABLE OF CLEARANCES

(Continued)

obsolete

CONNECTING ROD BEARINGS

Clearance on Crankshaft - - - - - - - - .008" - .011"
Adjust with shims if clearance exceeds .018"

Side Clearance - - - - - - - - - - - - - .005" - .010"
Rebabbitt if clearance exceeds .018"

Top of Piston to Top of Cylinder Block .682"- .692"
Adjust by means of compression shims between foot of connecting rod and bearing.

MAIN BEARING

Clearance on Crankshaft - - - - - - - - .008" - .011"
Adjust with shims if clearance exceeds .015". Rebabbitt shells if one or more bearings varies more than .010" from original bridge gage reading. See pages 18-1 and 18-2.

Thrust bearing is adjacent to flywheel.
Thrust Clearance - - - - - - - - - - - - .012" - .015"
Rebabbitt if clearance exceeds .020"

PISTON

Piston in Liner (Skirt clearance) - - .014" - .016"
Replace liner if diameter of bore at any point exceeds 16.040".

Piston Pin

In Piston - - - - - - - - - - - - - Light Driving Fit @ 70° F.

Replace pin if clearance exceeds .002"

Piston Pin
In connecting Rod Bushing - - - .0065" - .0075"
Replace bushing if clearance exceeds .015"

PART VII

ENGINE TROUBLES AND SUGGESTED REMEDIES

ENGINE FAILS TO TURN OVER WHEN OPERATING CONTROL IS MOVED INTO START POSITION

Probable Cause	Suggested Remedy
1. Air Starting Equipment out of order, which may be:	
a. Insufficient air pressure.	a. Pump up pressure to 200 to 250 p.s.i.
b. Valves closed in air supply.	b. Open all valves.
c. Air valves improperly timed.	c. Adjust timing.
d. Air Starting valve stuck or leaking.	d. Release pressure in cylinder by means of the relief valve. Remove air valve and clean.
e. Air not being bled from top of Air Starting Valve.	e. Check pilot valve and line to pilot valve for obstruction.

ENGINE TURNS OVER ON AIR BUT WILL NOT START

2. No fuel is being delivered, because of:	
a. No fuel in tank or valve closed.	a. Refill tank and open all valves.
b. Fuel inlet pipe clogged or filter dirty.	b. Clean pipe and filter
c. Air in fuel line.	c. Vent system of air.
d. Water in fuel.	d. Drain all water from fuel system and refill with clean oil.
e. Fuel control linkage sticking in "off" position.	e. Free linkage

ENGINE TURNS OVER ON AIR BUT WILL NOT START (Continued)

Probable Cause	Suggested Remedy
4. Injection pump timing improperly set.	4. Adjust timing
5. Lack of compression due to -	5. - -
(a) Valves sticking.	(a) Free valves and deposit oil on stems.
(b) Valves riding open.	(b) Adjust hydraulic lifters.
(c) Valves not seating properly.	(c) Reseat valves.
(d) Leaky head gaskets.	(d) Replace gaskets.
(e) Incorrect clearance between top of piston and top of cylinder block.	(e) Adjust clearance by adding shims between connecting rod and bearing. Check clearance of connecting rod bearings and piston pin bushings.
(f) Stuck piston rings.	(f) Clean rings, ring grooves and oil drains.
(g) Rings or cylinder liners worn.	(g) Replace rings. Use oversize rings if necessary. If liners are scored or worn more than .040" replace liners.
(h) Cracked piston	(h) Replace piston

ENGINE STOPS OR SLOWS DOWN WHEN RUNNING

Probable Cause	Suggested Remedy
6. Fuel tank running dry.	6. Check whether transfer pump delivers fuel to tank. Check whether air release on tank is operating properly.
7. Water in fuel.	7. Drain all water from fuel system. Refill with clean oil.
8. Exhaust manifold becomes clogged.	8. Clear manifold and ascertain cause of excessive accumulation.
9. Piston seizing. Actual seizure accompanied by high-pitched squeaking noise.	9. Stop engine immediately at first sign of a tight piston. Check cooling and lubrication. Inspect piston and liner. Replace if necessary.

ENGINE FIRES IRREGULARLY

10. Lack of proper fuel delivery due to --	
(a) Fuel inlet pipe clogged or second stage filter element dirty.	(a) Clear pipe. Clean filter.
(b) Fuel tank running dry.	(b) Check whether transfer pump delivers fuel to tank. Check whether air release on tank is operating properly.
(c) Air in fuel line.	(c) Vent filter, supply header, injection pumps and nozzles.
(d) Water in fuel.	(d) Drain all water from fuel system. Refill with clean oil.

ENGINE FIRES IRREGULARLY

Probable Cause	Suggested Remedy
11. One or more cylinders misfires or fires irregularly due to -	11. - - -
(a) Fuel nozzle bleeder valve open.	(a) Close bleeder valve.
(b) Fuel nozzle stuck, clogged, damaged or worn.	(b) Replace with spare and check.
(c) Leaky joints in injection tubing.	(c) Clean joint faces and tighten joints.
(d) Fuel pump control lever improperly set.	(d) Adjust fuel pump control lever until pyrometer reading for this cylinder coincides within 20°F. to readings on other cylinders. If, when this condition is satisfied, control rod reading on pump differs by more than 2 mm. from that of other cylinders, check cause and correct.
(e) Fuel pump timing	(e) Adjust timing.
(f) Fuel pump dirty, damaged or worn.	(f) Replace with spare and check.
12. Lack of compression in one or more cylinders,	12. See Item 5.

SMOKY EXHAUST - BLACK SMOKE CAUSED BY EXCESSIVE FUEL

13. Intake louvres or elbows clogged.	13. Remove and clean.
14. Injection nozzle not closing tightly or not atomizing properly.	14. Replace with spare and check.

SMOKY EXHAUST - BLACK SMOKE CAUSED BY EXCESSIVE FUEL

	Probable Cause		Suggested Remedy
15.	Fuel pump improperly timed.	15.	Adjust timing.
16.	Engine overloaded.	16.	Check load. Reduce if necessary.
17.	One or more injection pumps delivering too much fuel per stroke.	17.	Adjust fuel pump control lever until pyrometer reading for this cylinder coincides within 20°F. to readings on other cylinders. If, when this condition is satisfied, control rod reading on pump differs by more than 2 mm. from that of other cylinders, check cause and correct.

SMOKY EXHAUST - BLUE SMOKE - LUBRICATING OIL IN EXHAUST

18.	Piston rings stuck or drain holes clogged.	18.	Clean rings, grooves and oil drains.
19.	Rings or cylinder liners worn.	19.	Replace rings. Use oversize rings if necessary. If liners are scored or worn more than .040" replace liners.

ENGINE KNOCKS

20.	Fuel pump timing improperly set.	20.	Adjust timing.
21.	Nozzle sticking open.	21.	Replace with spare and check.
22.	Type of fuel not suitable.	22.	Check fuel with specifications.
23.	Piston too loose in liner.	23.	To check: Cut out cylinder in question by opening bleeder valve. If knock disappears, check piston skirt clearance. Install new liner, or piston, if necessary.

ENGINE KNOCKS (Continued)

	Probable Cause	Suggested Remedy
24.	Loose piston pin or piston pin bushing worn or burned out.	24. To check: Place piston on bottom dead center. Check with pry bar on piston. Replace piston pin or piston pin bushing, if necessary.
25.	Connecting rod bearing burned out or badly worn.	25. Check clearance with pry bar. Replace shells, if necessary.
26.	Main bearings burned out or badly worn.	26. Remove cap and inspect. Replace shells if necessary.

INSUFFICIENT LUBRICATING OIL PRESSURE AS SHOWN ON MAIN LUBRICATING OIL GAUGE

27.	Insufficient oil in service tank due to -	27. --
	(a) Lubricating oil screens in base clogged or suction connection from base covered with sludge.	(a) Clean screens and suction connection.
	(b) Piping connections loose.	(b) Tighten connections.
	(c) Scavenging pump defective.	(c) Check clearances.
28.	Lubricating oil filter clogged	28. Clean filter
29.	Clogging of oil line.	29. Clear line.
30.	Relief valve sticking, not seating properly or improperly adjusted.	30. Free valve, reseat and adjust if necessary.

INSUFFICIENT LUBRICATING OIL PRESSURE AS SHOWN ON MAIN LUBRICATING OIL GAUGE - Continued -

	Probable Cause	Suggested Remedy
31.	Loose or worn bearings.	31. Adjust bearing clearances. Replace if necessary.
32.	Pressure piping connections loose.	32. Tighten connections.
33.	Pressure Pump defective.	33. Check clearances.

EXCESSIVE LUBRICATING OIL PRESSURE AS SHOWN ON MAIN LUBRICATING OIL GAUGE

34.	Relief valve stuck or adjustment incorrect.	34. Free valve and adjust if necessary.

INSUFFICIENT JACKET WATER PRESSURE AS SHOWN ON MAIN WATER PRESSURE GAUGE

35.	Air in jacket water pump.	35. Open vents on pump or on top of suction. Inspect circulating water piping for air leaks.

JACKET WATER PRESSURE SUFFICIENT BUT TEMPERATURE EXCESSIVE

36.	Insufficient water supply due to --	
	(a) Sea suction clogged or valves closed.	(a) Clear suction and open valves.
	(b) Loose connections.	(b) Tighten.
	(c) Air in water pump.	(c) Open vents on pump or on top of suction.
	(d) Overboard discharge clogged.	(d) Clear discharge.
	(e) Temperature control valve not properly set.	(e) Reset to obtain correct temperature.

JACKET WATER PRESSURE SUFFICIENT BUT TEMPERATURE EXCESSIVE

Probable Cause	Suggested Remedy
37. Engine water passages clogged, or coated with scale.	37. Clean out engine with approved solvent.

MISCELLANEOUS TROUBLES

38. Lubricating oil temperature too high due to oil cooler passages clogged or coated with scale.	38. Clean oil cooler.
39. Engine speed fluctuates or fuel control shaft changes position constantly due to --	
(a) Governor linkage or fuel control shaft stuck.	(a) Free governor linkage and fuel control shaft.
(b) Fuel pump control rod stuck.	(b) Replace pump with spare.
(c) Governor linkage worn.	(c) Replace worn parts.

MISCELLANEOUS TROUBLES - Continued.

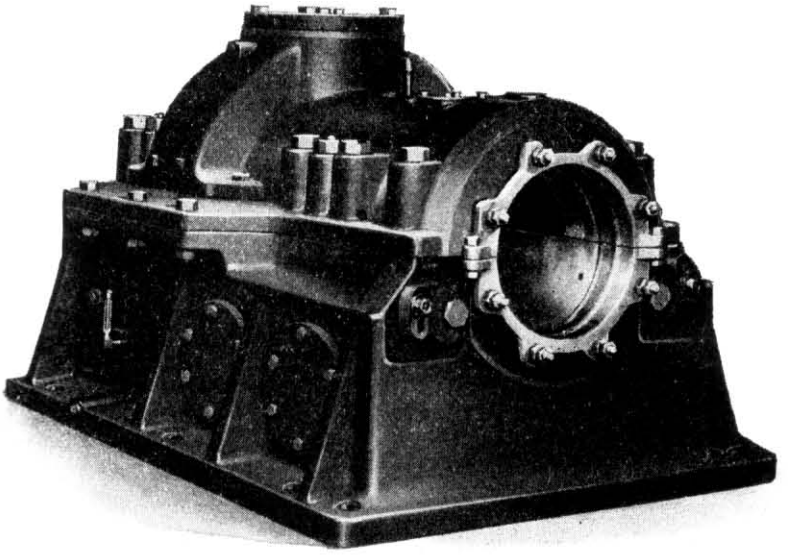
	Probable Cause	Suggested Remedy
40.	Excessive smoke from crankcase breathers due to --	
	(a) Stuck piston rings.	(a) Clean rings, ring grooves, and oil drains.
	(b) Rings or cylinder liners worn.	(b) Replace rings. Use oversize rings if necessary. If liners are worn more than .040", replace liners.
	(c) Cracked piston.	(c) Replace piston.

7108

INSTRUCTIONS

for

Installing and Operating



Style GH

(Horizontal Two-Shoe Adjustable Type)

KINGSBURY THRUST BEARINGS

STYLE GHS-19 THRUST BEARING
for towboat

Enterprise Engine & Foundry Co.
San Francisco, Calif.

4316-28 TACKAWANNA STREET FRANKFORD, PHILADELPHIA, PA.

Cable Address "ALKING," Philadelphia

SEATTLE	TULSA	ST. PAUL	BOSTON
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DENVER	HOUSTON	DETROIT	NEW ORLEANS

5-17-34-1000

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(1) GENERAL DESCRIPTION:

The standard Style GH bearing includes two pairs of thrust shoes (two shoes for ahead and two for astern thrust) individually adjustable fore and aft by jack screws, and a journal bearing, all mounted in one housing with suitable end closures. There is only one thrust collar, usually forged integral with shaft.

Lubrication is automatic, being accomplished by an oil scraper riding on top of collar, distributing oil to collar surfaces and journal bearing.

(2) BEARING SURFACES:

Great care is taken to make thrust collar surfaces flat and smooth, and square with shaft. Marks left by final machining or grinding are removed by lapping.

The journal bearing portion of shaft is finished to size and lapped smooth.

Shoes have steel bodies and are faced with genuine hard babbitt. The bearing surfaces are machined and then scraped to an accurate surface plate. The radial edges are rounded slightly.

The journal bearing is bored smooth to allow a running clearance of .002", plus .001" per inch of shaft diameter. The bearing surface is grooved on both sides for nearly its full length to provide oil supply channels. No other grooves or channels should be provided.

As packed for shipment from the factory the bearing surfaces are carefully protected against bruises, scratches and corrosion. They are slushed with a neutral water-proof coating, and no wood or other damp packing material is allowed to touch them. Damage may occur in re-shipment or storage, unless the same precautions are observed. Hence, careful final inspection is needed, to be sure all surfaces are in good condition when bearing is installed.

Any bruises on the babbitted faces of the shoes or journal bearing should be removed with a scraper. Slight bruises or rusting of shaft journal or collar surfaces may be removed with a fine oil stone. If deep rusting occurs, refinishing may be necessary. Never use a coarse-grained stone, or scraper, or file on shaft journal or collar surfaces.

(3) CLEANING:

All parts of bearing, housing and any oil piping should be thoroughly cleaned before assembling. Remove all anti-rust coatings with gasoline or kerosene. Use rags or cloth for cleaning, as waste leaves lint, which clings to minute burrs and may cause trouble in the bearing. Hand holes are usually provided in lower half of housing to facilitate cleaning. Bearings are cleaned before shipment and should be protected from dirt while awaiting installation. Nevertheless, a final inspection, and clean-out if necessary, should be made, before bearing is run for the first time.

(4) INSTALLATION NOTES:

The journal bearing and shaft must be brought into close alignment for satisfactory operation. Strong, rigid foundations are essential. The most accurate alignment will be disturbed if the seating is so weak as to be distorted by thrust or radial loads.

(5) END PLAY:

To allow for oil films between thrust bearing surfaces, and for expansion by heat, it is strictly necessary to provide end play.

A satisfactory rule for total end play is to allow .001" per inch of collar diameter. If this end play is much reduced, say by 50% or so, there will be a needless increase in friction and heating; very little is to be gained, however, by adding to the above allowance.

Using the jack screws, adjust for end play as follows: Keeping thrust collar in desired fore and aft position, set up firmly on forward-end jack screws so ahead shoes will bear equally against collar. Lock the screws. Next set up on after-end jack screws, using a "feeler" gauge, with thickness equal to end play, back of the pivotal support of each shoe. Lock the jack screws and remove the "feelers."

(6) GRADE OF OIL:

For average installation of propeller thrust bearings, a heavy turbine or engine oil should be used. For any given bearing, oil should be chosen with due regard to viscosity. If it is too light, the lubricating film may be dangerously thin. If it is too heavy, the friction is needlessly high. Specific advice as to minimum proper viscosity for any definite installation is regularly marked on bearing nameplate. As a rule the viscosity should be about 200 seconds Saybolt at operating temperature of the oil bath.

The oil must be clean and free from grit and other injurious substances. Fine grit has a scouring action and may gradually wear down the bearing surfaces. Poor oil may cause corrosion.

Oil of good quality does not "wear out" by use in these bearings, but lasts indefinitely if not contaminated.

(7) OIL LEVEL:

It is vitally important to maintain the oil at a suitable level. Oil level plates are attached to both sides of housing, with "High" and "Low" oil levels noted.

Fill housing with oil to "High" mark when not running. A slight draw down of oil level will be noted when bearing is running. Occasionally oil should be added to make up for leakage and evaporation. Be sure the make up oil is clean. The air vent holes provided should be kept open. Oil gauge may be placed on either side of housing.

(8) COOLING:

Most of these GH propeller thrust bearings run air-cooled. That is, the heat of friction is carried off readily by the surrounding air and foundation.

For large, high-speed bearings water-cooling coils may be provided in the oil reservoir in housing, or oil may be circulated thru bearing from an external oil supply system. The rate of circulation (water or oil) must be regulated so as to give oil bath a satisfactory temperature.

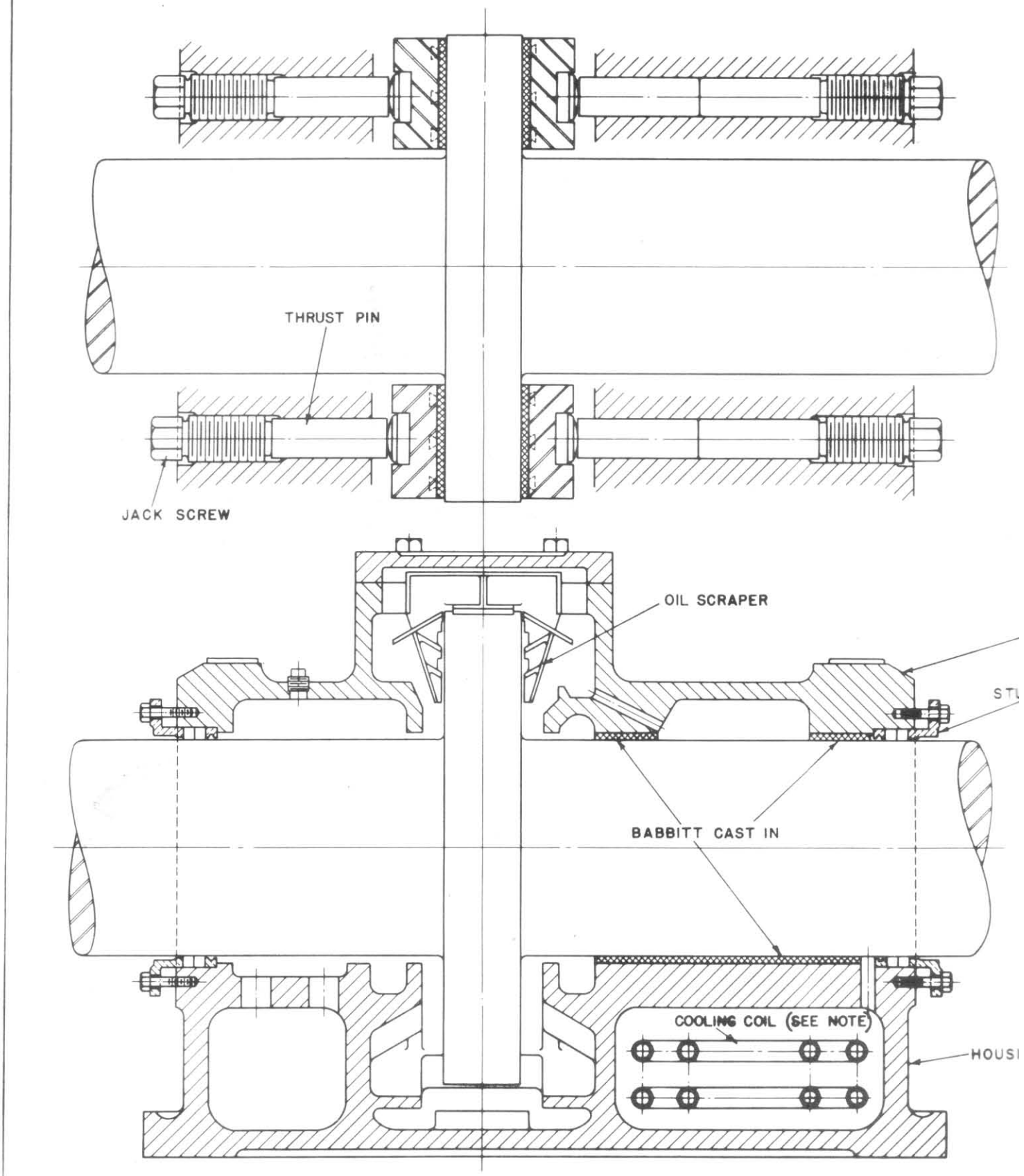
(9) OPERATION:

In normal operation, the only attention required by the bearing is as follows:—Keep oil at proper oil level; in water-cooled and oil-cooled bearings, guard against interruptions of circulation; make sure that oil added is clean; do not take up hard on stuffing box glands, as unnecessary heating of the shaft will occur.

(10) REPAIRS AND SERVICE:

The attached print shows the bearing construction and lists the principal parts by name. It will serve as a guide for ordering spare or repair parts. In all correspondence give the order number marked on the nameplate attached to side of housing.

Prompt service is available from our home office in Philadelphia, Penna., and from the branch offices listed at the foot of the front page.

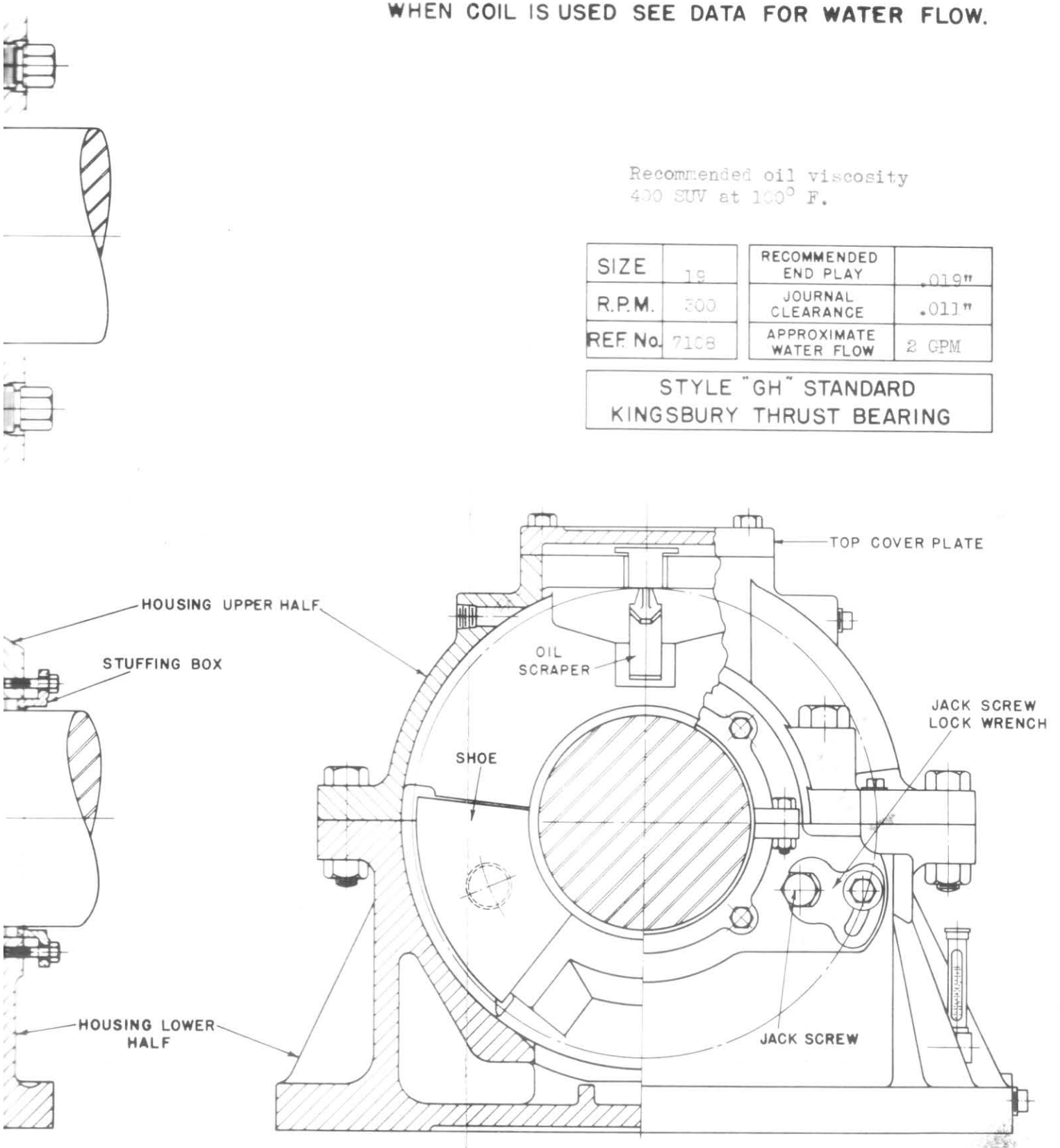

THRUST PIN
JACK SCREW
OIL SCRAPER
BABBITT CAST IN
COOLING COIL (SEE NOTE)

NOTE:- BEARING IS FREQUENTLY FURNISHED WITH A COOLING COIL WHEN COIL IS USED SEE DATA FOR WATER FLOW.

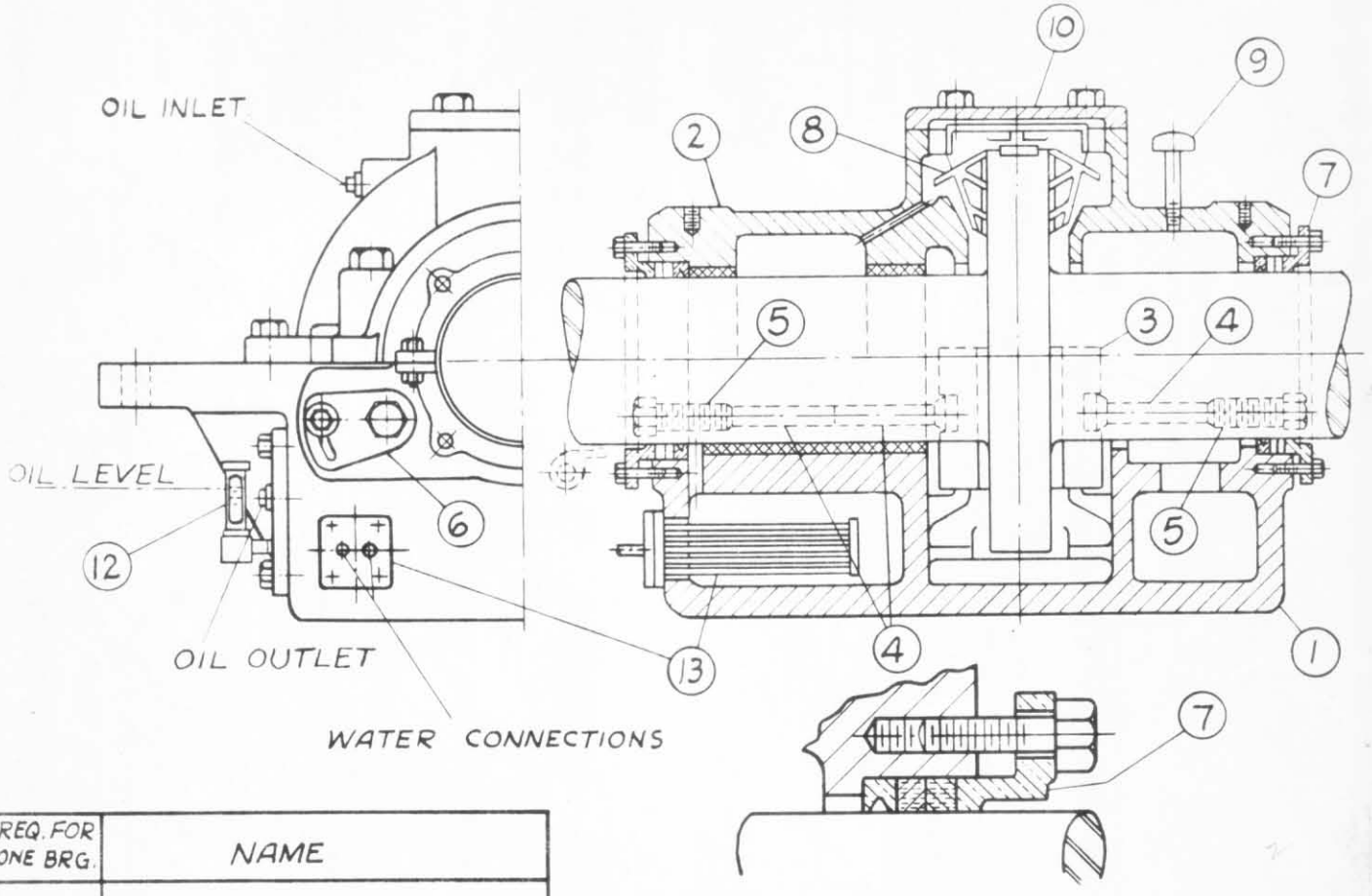
Recommended oil viscosity
400 SUV at 100° F.

SIZE	19	RECOMMENDED END PLAY	.019"
R.P.M.	300	JOURNAL CLEARANCE	.011"
REF. No.	7108	APPROXIMATE WATER FLOW	2 GPM

STYLE "GH" STANDARD
KINGSBURY THRUST BEARING



DATE:- 4-13-37. No.262465



ITEM	REQ. FOR ONE BRG.	NAME
1	1	HOUSING LOWER HALF
2	1	HOUSING UPPER HALF
3	4	SHOE ASSEMBLY
4	6	THRUST PIN
5	4	JACK SCREW
6	4	LOCK WRENCH
7	2	STUFFING BOX ASSEMBLY
8	1	OIL SCRAPER
9	3	AIR VENT
10	1	TOP COVER
11	2	SIDE COVER
12	1	OIL GAUGE
13	1	OIL COOLER

FOR MOUNTING DIMENSIONS
SEE DWG. #462685.

DR:- R.H.
DATE:- 7-1-40.

SPECIAL 19" GHS BEARING

PART LIST | KINGSBURY MACHINE WORKS, INC. | NL-2510-LD

PART IX

ENGINE DRIVEN AUXILIARIES

AIR COMPRESSOR (See Illustration "Compressor Drive")

Description

The two stage air compressor, mounted on a bracket located over thrust bearing, is "V" belt driven from the flywheel. The drive is so designed, as to permit replacement of the "V" belts without disturbing flywheel or shafting. The compressor is air cooled and is equipped with an automatic unloader pilot.

Maintenance

Occasionally check "V" belts for proper tension. Slippage will rapidly ruin the belt. Do not use any belt dressing. Adjustment is made by loosening lower lock nut and then turning upper lock nut to move compressor up or down until belts have proper tension. Check alignment between compressor sheave and main engine flywheel, after belt adjustment.

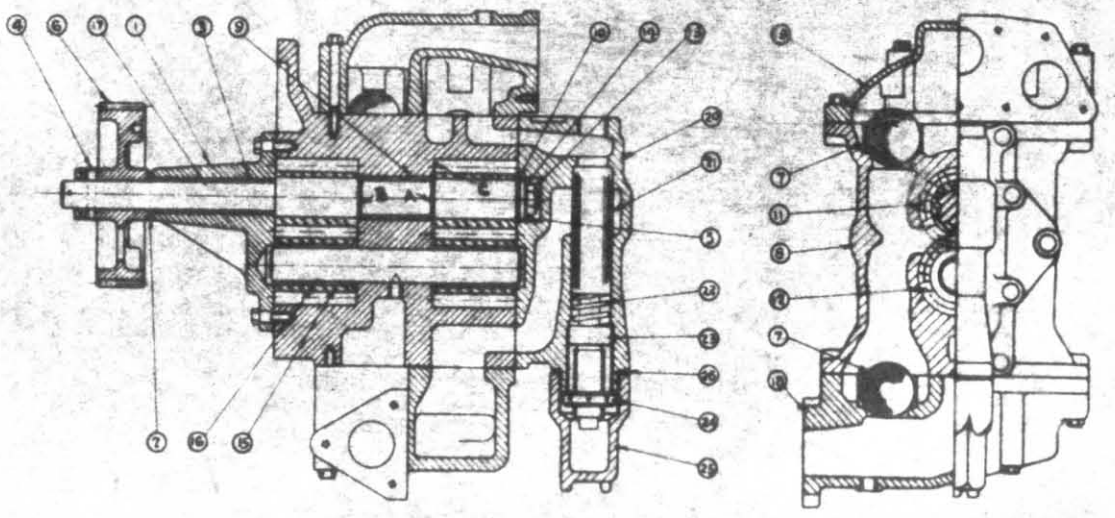
Lubricate idler puller bearings with a good grade of grease.

Lubrication is the only attention that the compressor will normally require. The oil level in the crankcase must be maintained between high and low marks on bayonet gauge. Use the same lubricating oil as used in the main engine. Watch condition of lubricating oil and when same becomes dirty or worn out, clean crankcase and refill with new oil. The time for this varies with operating conditions.

The valves are the vital part of the compressor and are not to be tampered with except that a two months inspection for an excessive accumulation of foreigh matter or any broken parts is recommended. If valves are clogged with foreign matter, remove and wash in kerosene. Thoroughly dry all parts before re-assembling. When disassembling, note the relation of the various parts to each other, so that the relationship can be maintained upon re-assembly.

If the unloader system does not function, do not tamper immediately with the pilot, but check thoroughly for other sources of trouble. If the trouble is diagnosed as being in the pilot, usually a throough cleaning is all that is necessary.

1 INSIDE COVER
2 THRUST BUSHING
3 BUSHING
4 TAPER PIN
5 [illegible] COLLAR
6 DRIVE GEAR
7 VALVE
8 HOUSING
9 BUSHING
10 SHIMS
11 MAIN GEAR
12 IDLER GEAR
13 LOCKNUT
14 LOCKWASHER
15 BUSHING
16 IDLER SHAFT
17 MAIN DRIVE SHAFT
18 SUCTION VALVE CAGE
19 DISCHARGE VALVE CAGE
20 RELIEF VALVE BODY
21 PLUNGER
22 SPRING
23 STEM
24 LOCKNUT
25 CAP
26 GASKET

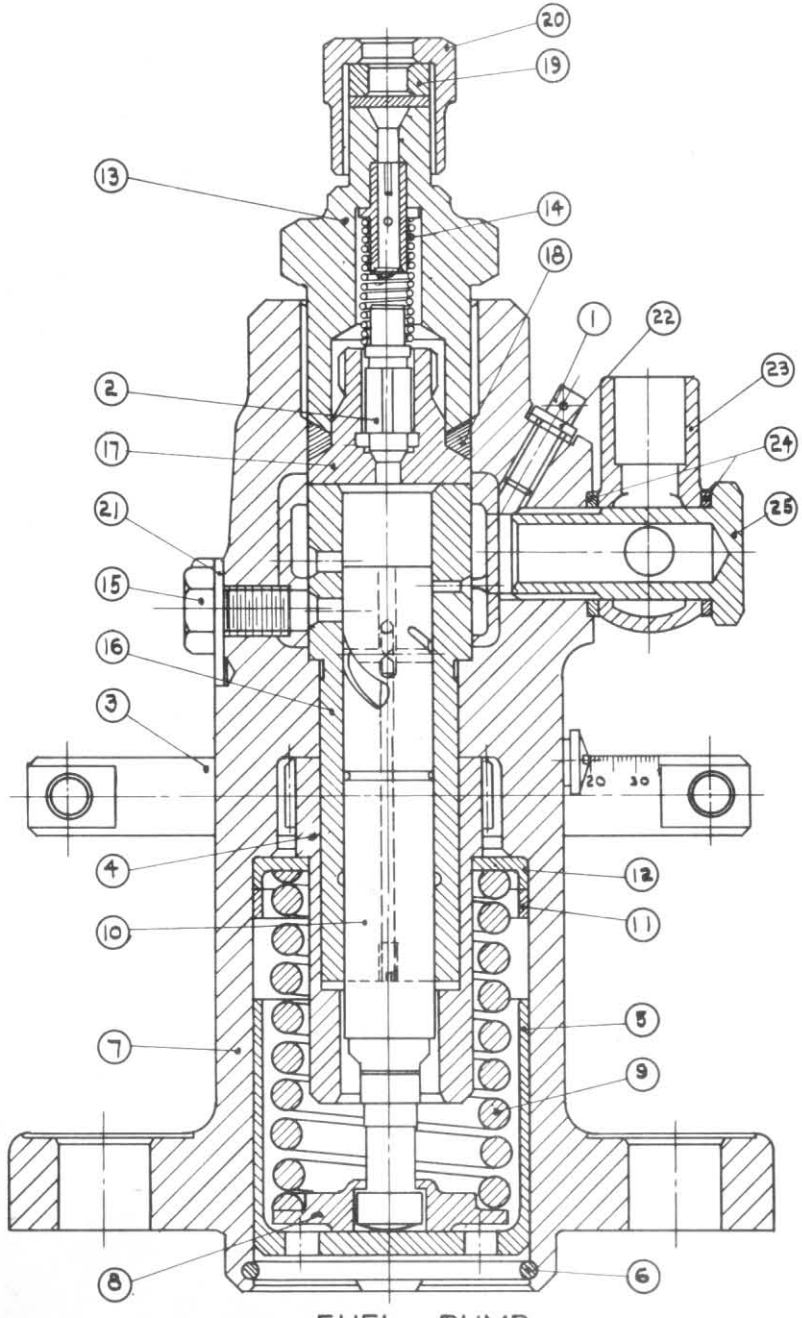


ALLOW .004 .007 END PLAY IN MAIN SHAFT

GASKETS TO CLEAR GEARS ALL AROUND

LUBRICATING
OIL PUMP

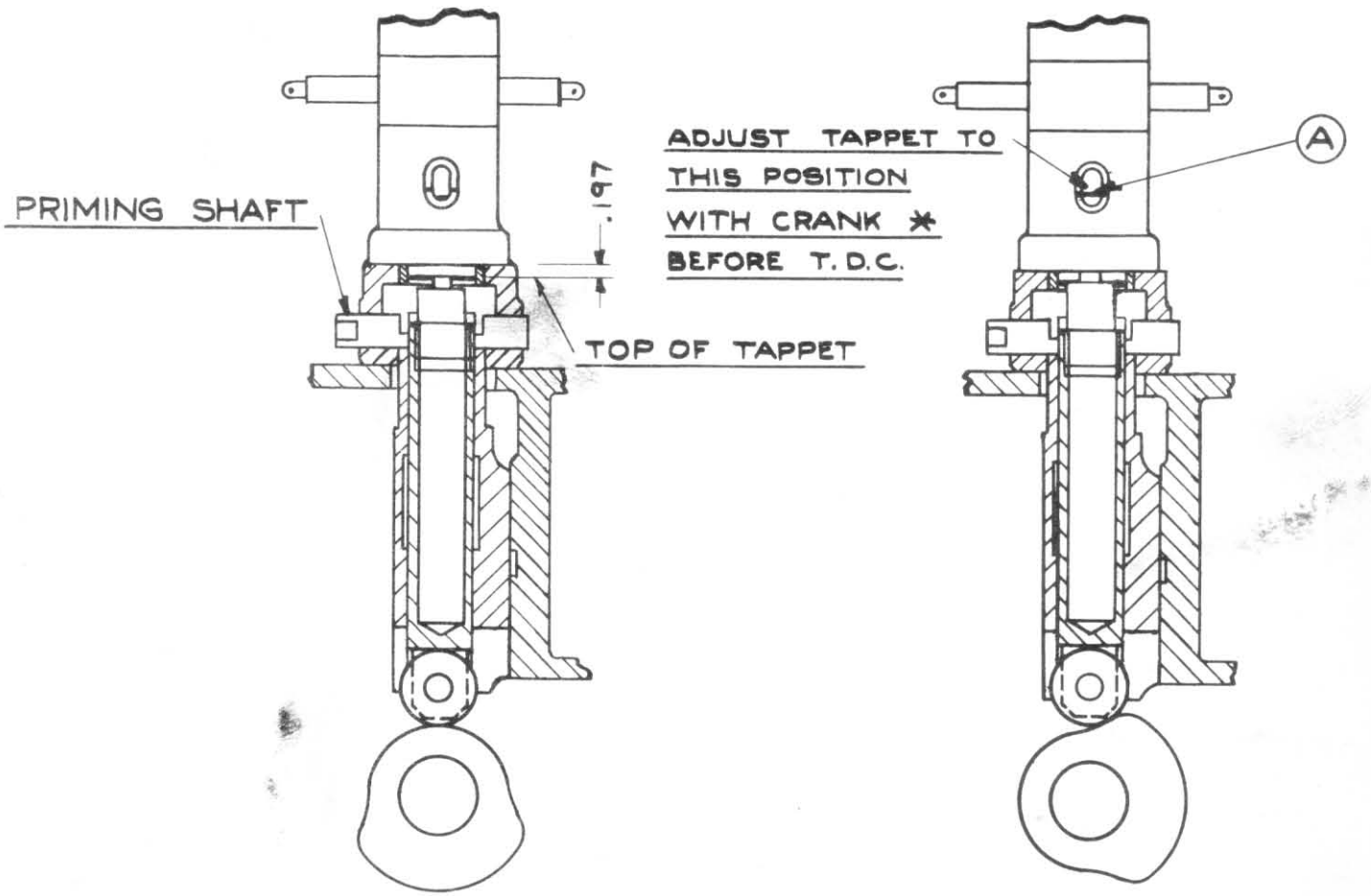
1. VENT SCREW
2. DELIVERY VALVE
3. CONTROL ROD
4. REGULATING SLEEVE
5. PLUNGER GUIDE
6. SPRING RING
7. PUMP BODY
8. LOWER SPRING PLATE
9. PLUNGER SPRING
10. PUMP PLUNGER
11. SPRING RING
12. UPPER SPRING PLATE
13. DELIVERY VALVE HOLDER
14. DELIVERY VALVE SPRING
15. BARREL SET SCREW
16. PUMP BARREL
17. DELIVERY VALVE SEAT
18. SPECIAL GASKET
19. WASHER, NIPPLE NUT
20. DELIVERY NIPPLE NUT
21. BARREL SET SCREW LOCKWASHER
22. VENT SCREW GASKET
23. FUEL INLET UNION
24. GASKET
25. RETAINING SCREW



FUEL PUMP

INITIAL ADJUSTMENT

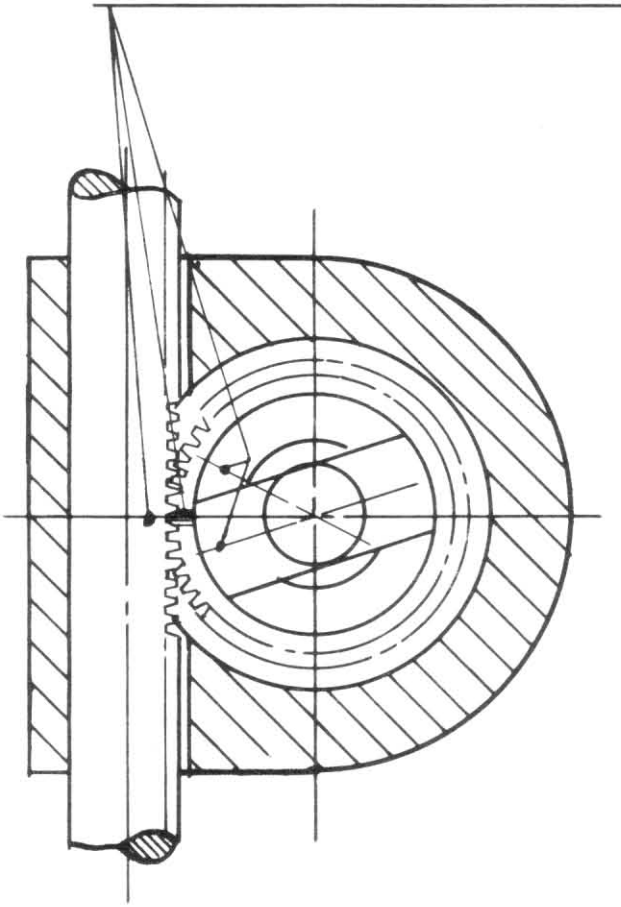
FINAL ADJUSTMENT



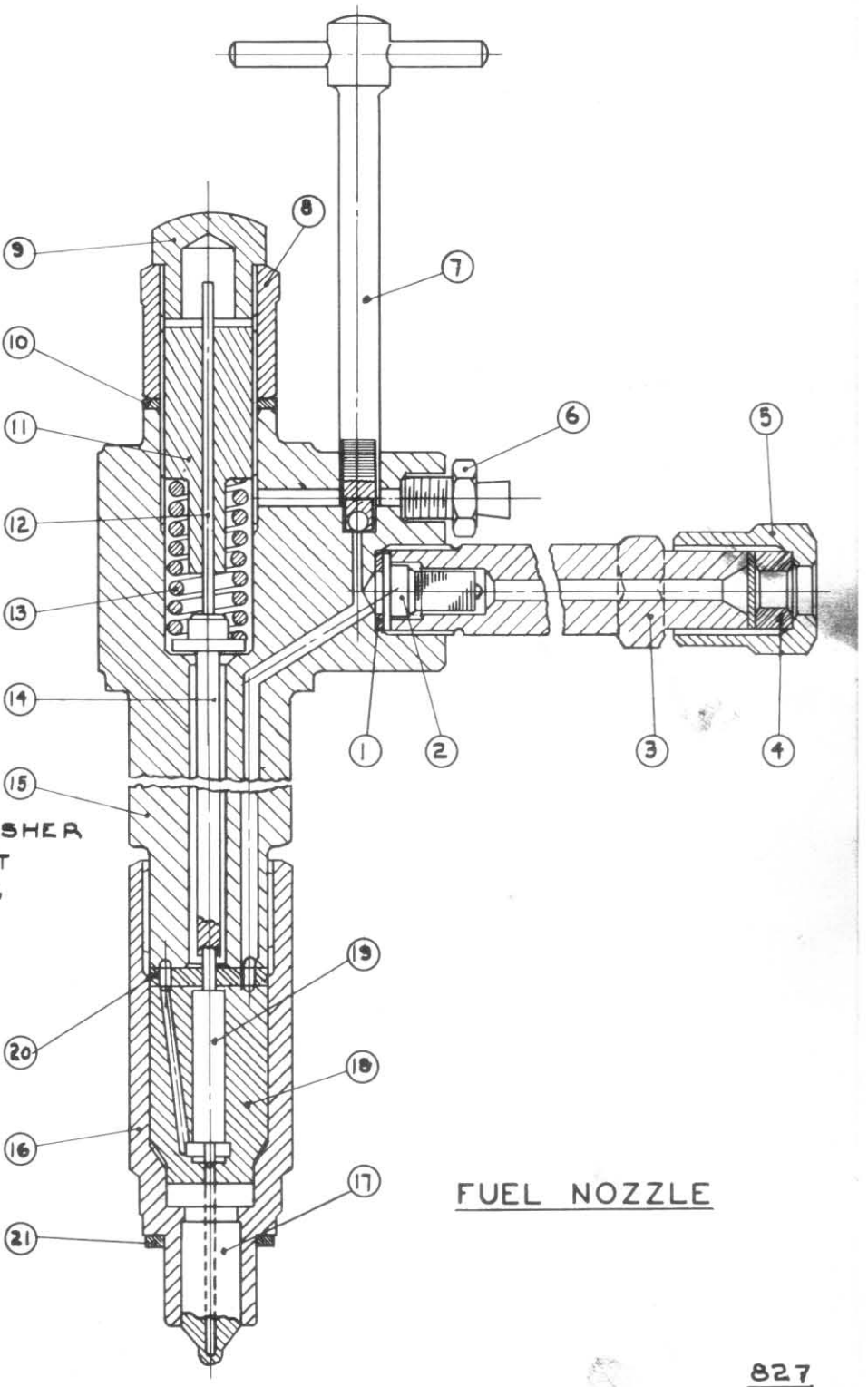
IF THE ADJUSTING MARK "A" ON THE SLIDING PLUNGER GUIDE DISAPPEARS AT THE UPPER EDGE OF THE INSPECTION WINDOW, MECHANICAL DAMAGE WILL OCCUR TO PLUNGER AND DELIVERY VALVE.

* SEE INJECTION SETTING ON TITLE PAGE

ASSEMBLE PUMP ACCORDING TO THESE MARKS



FUEL PUMP-BOTTOM VIEW SHOWING LOCATING MARKS 829

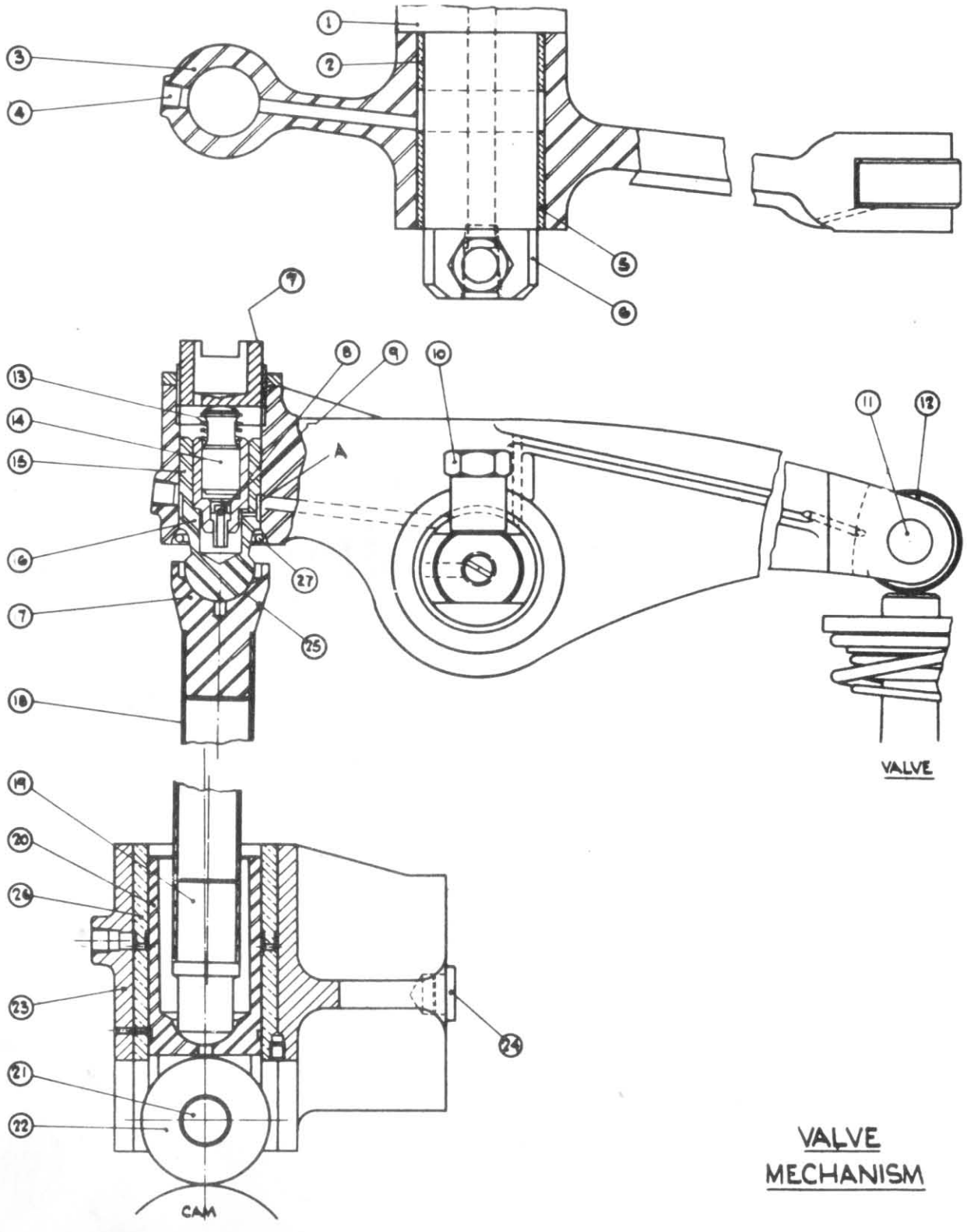


1. COPPER GASKET
2. FILTER
3. INLET NIPPLE
4. HIGH PRESSURE LINE WASHER
5. HIGH PRESSURE LINE NUT
6. LEAKAGE RETURN FITTING
7. BLEEDER VALVE
8. LOCK NUT
9. CAP
10. COPPER GASKET
11. ADJUSTING SCREW
12. FEELER PIN
13. SPRING
14. PRESSURE PIN
15. HOLDER BODY
16. ASSEMBLY NUT
17. SPRAY TIP
18. NOZZLE VALVE BODY
19. NOZZLE VALVE
20. STOP PLATE
21. COPPER GASKET

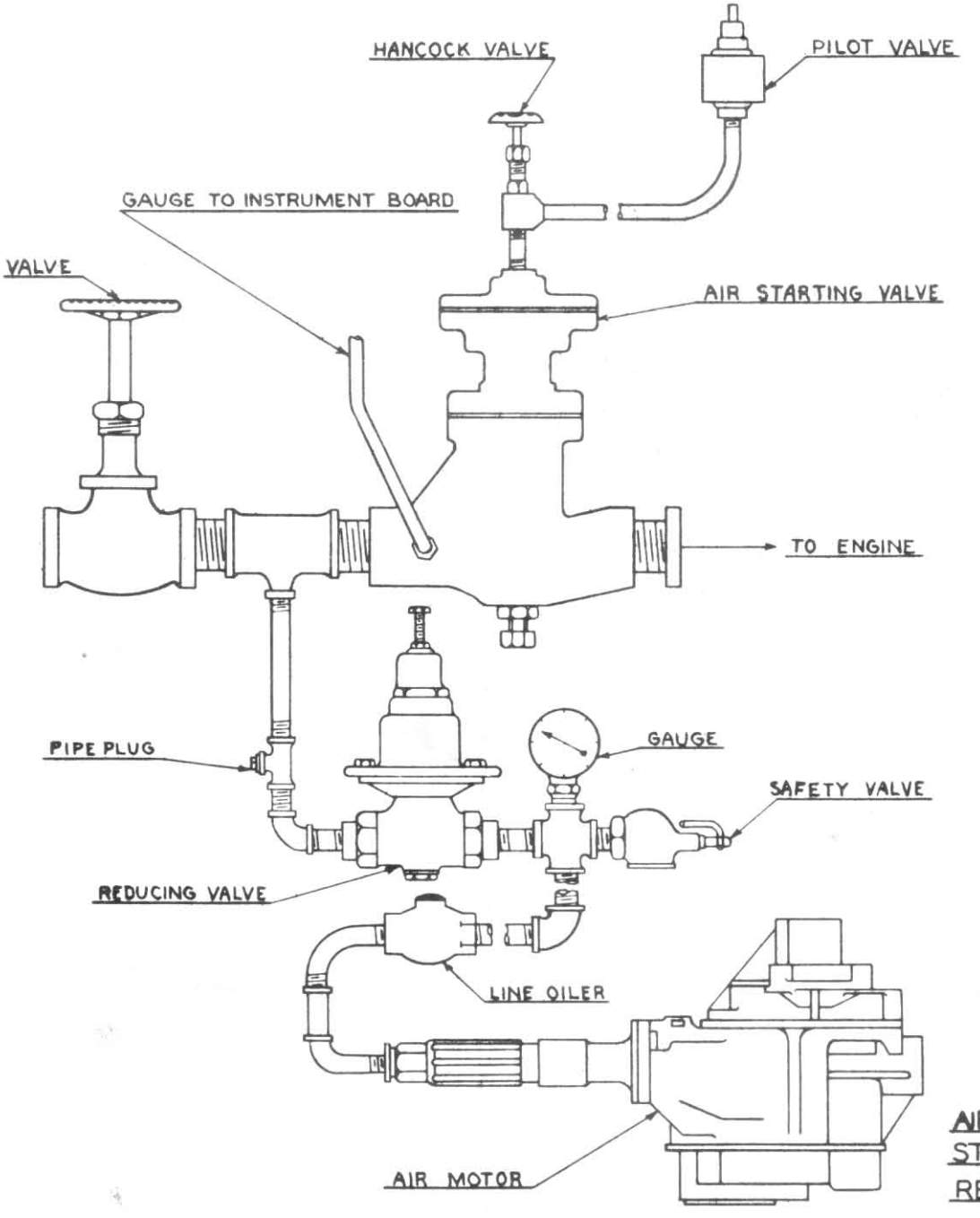
FUEL NOZZLE

827

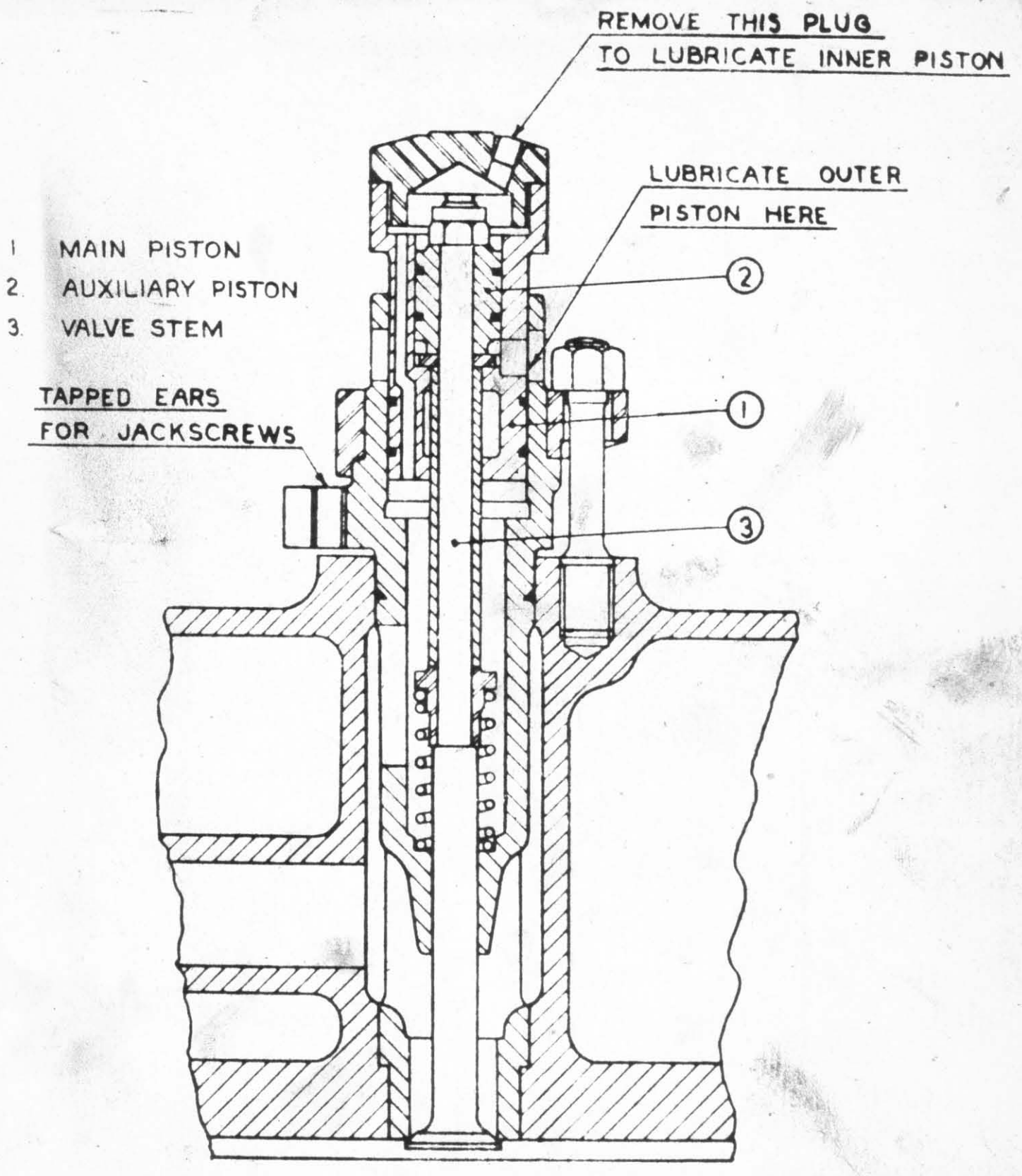
1 AIR ROCKER
2 BUSHING
3 ROCKER
4 PIPE PLUG
5 BUSHING
6 ROCKER SHAFT
7 ADJUSTING SCREW
8 BALL RETAINER
9 CHECK VALVE
10 ROCKER SHAFT STUD NUT
11 ROLLER PIN
12 ROLLER
13 PLUNGER SPRING
14 HYDRAULIC PLUNGER
15 CYLINDER
16 LIFTER BODY
17 PUSH ROD END-UPPER
18 PUSH ROD
19 PUSH ROD END-LOWER
20 TAPPET
21 ROLLER PIN
22 ROLLER
23 TAPPET GUIDE
24 DOWEL
25 BALL SEAT
26 TAPPET GUIDE LINER
27 SNAP RING



VALVE MECHANISM

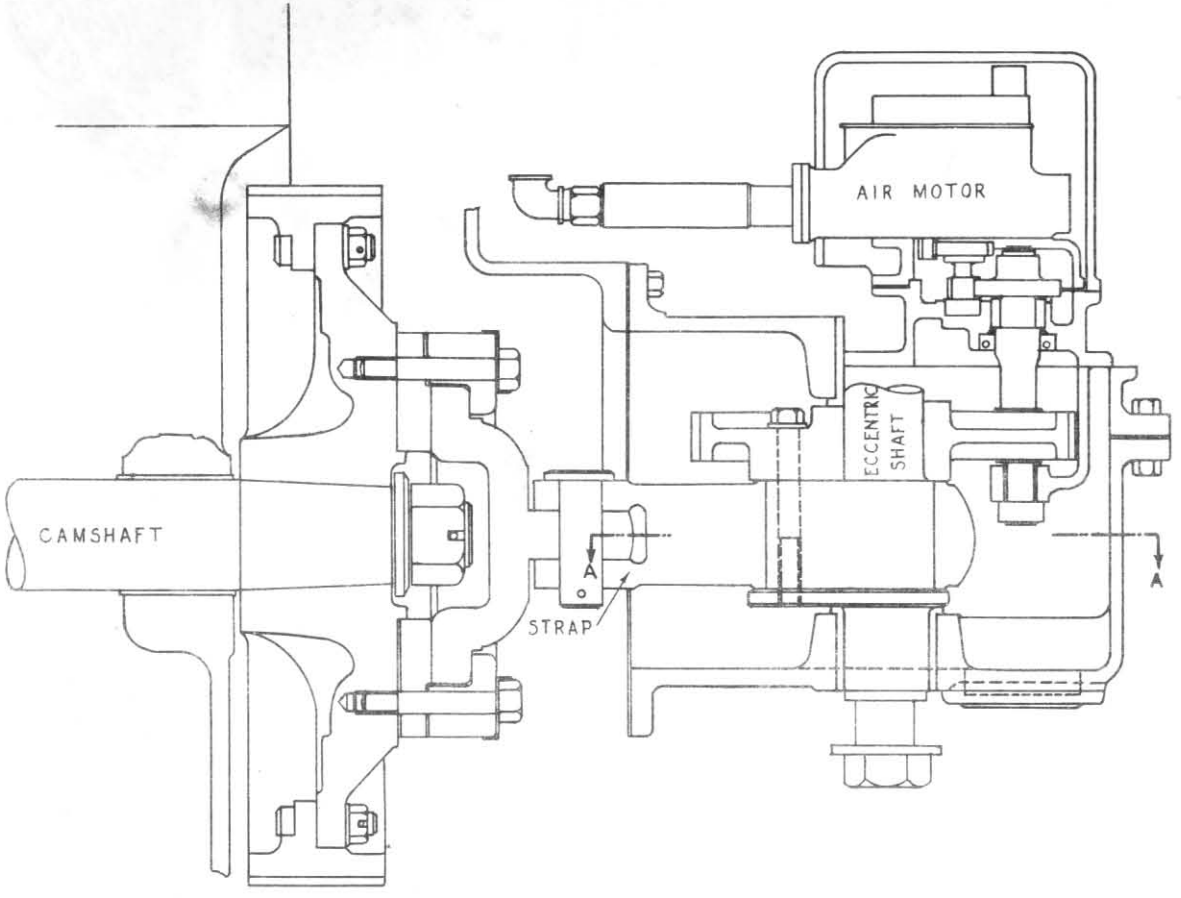


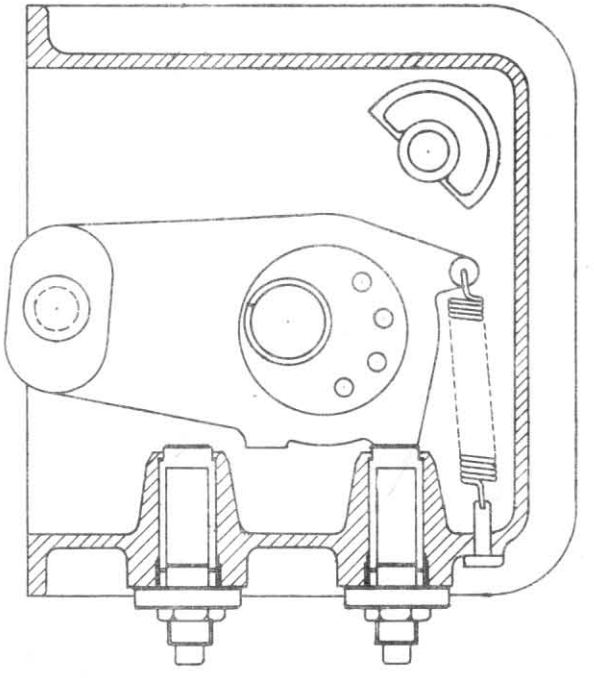
AIR SYSTEM
STARTING &
REVERSING
838-A



AIR STARTING VALVE

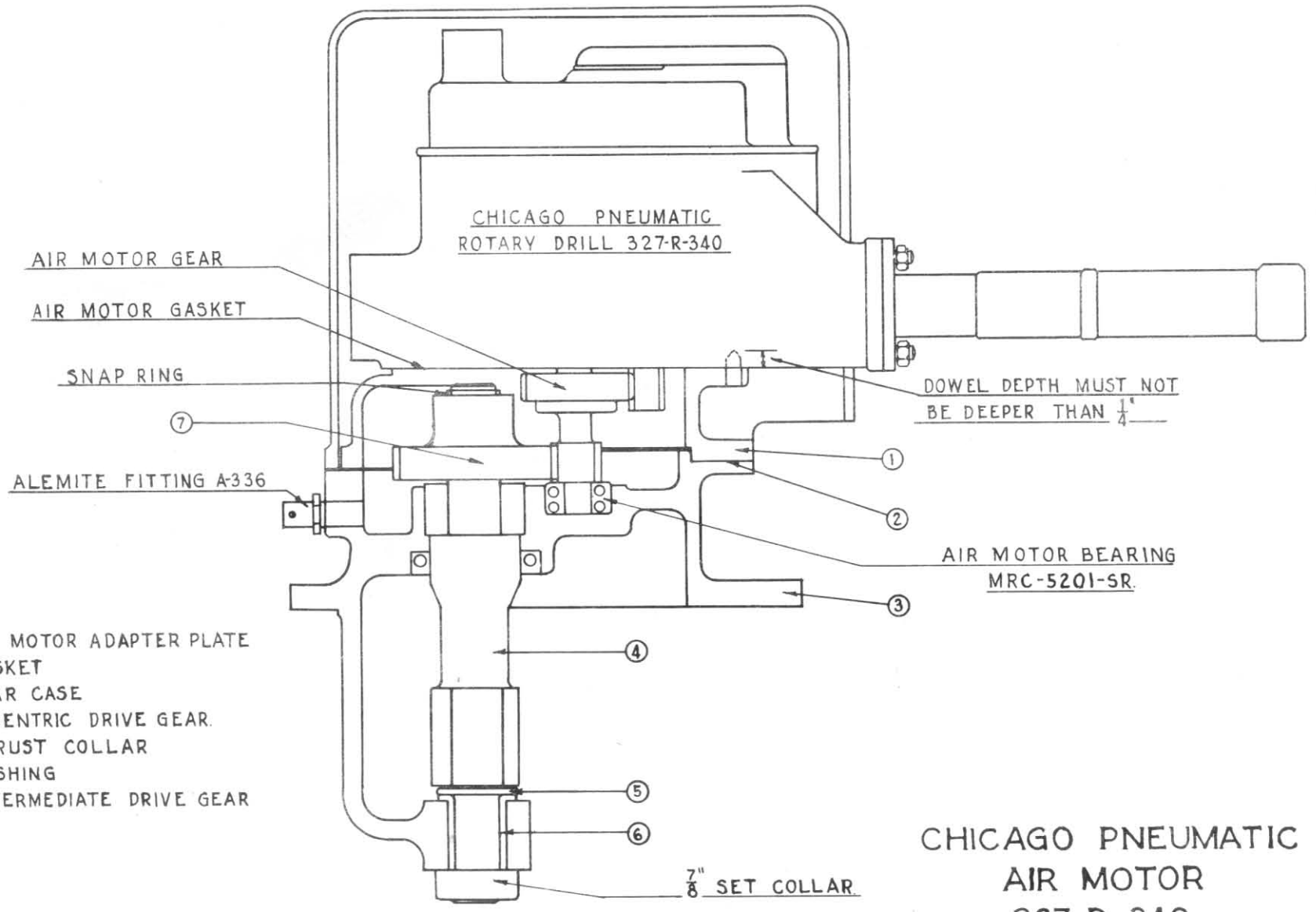
839





SECTION A-A

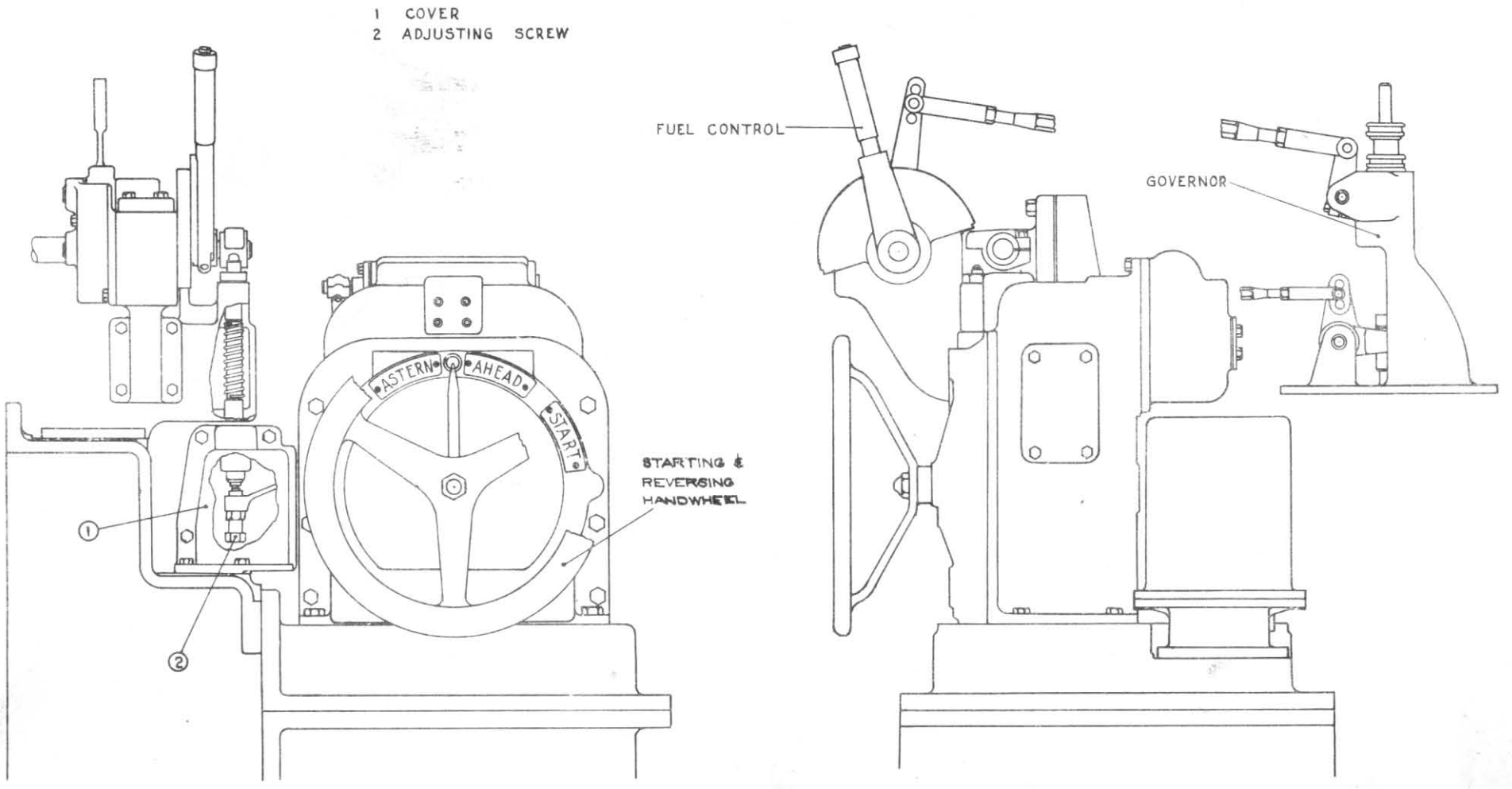
REVERSING MECHANISM



1 AIR MOTOR ADAPTER PLATE
2 GASKET
3 GEAR CASE
4 ECCENTRIC DRIVE GEAR.
5 THRUST COLLAR
6 BUSHING
7 INTERMEDIATE DRIVE GEAR

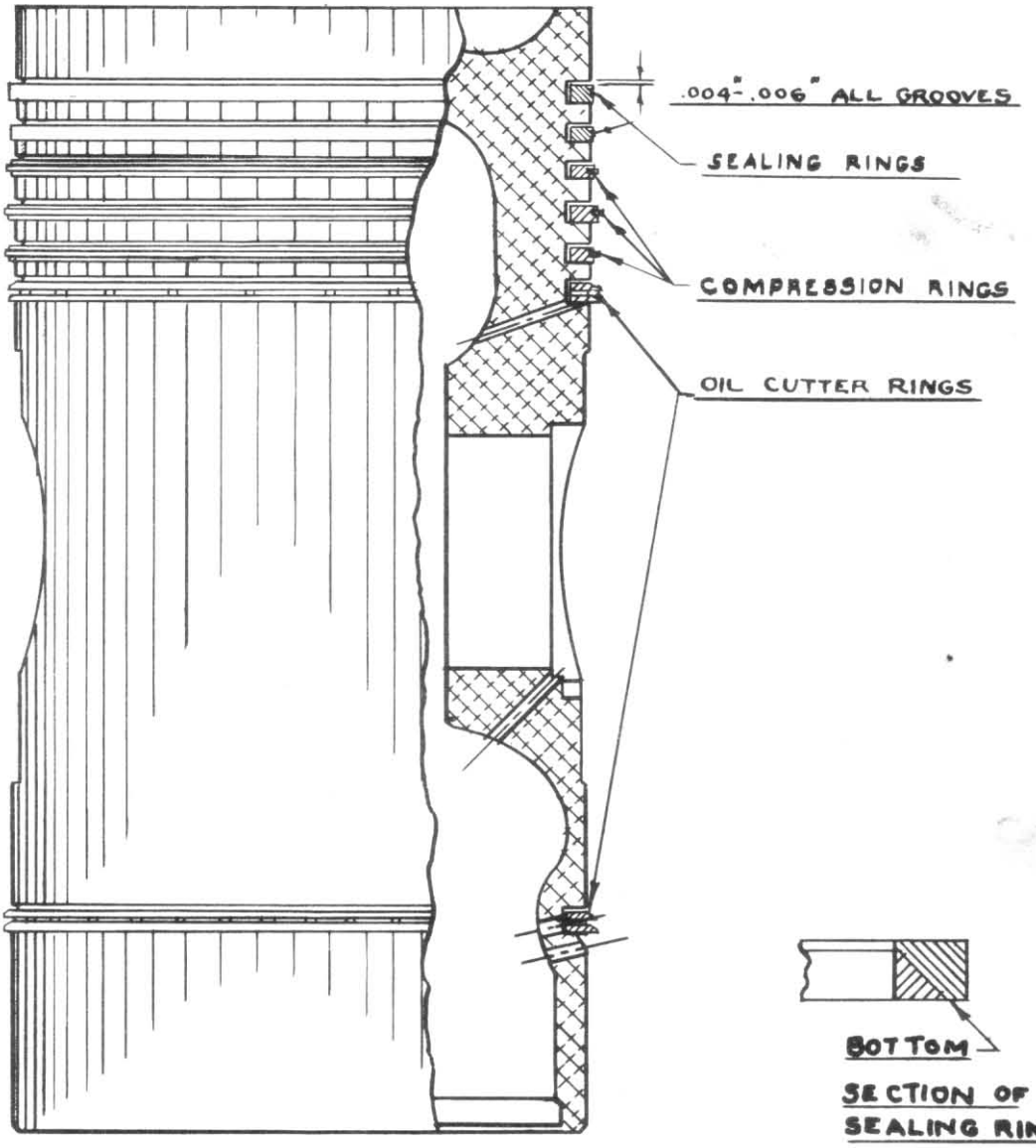
CHICAGO PNEUMATIC AIR MOTOR 327-R-340

892



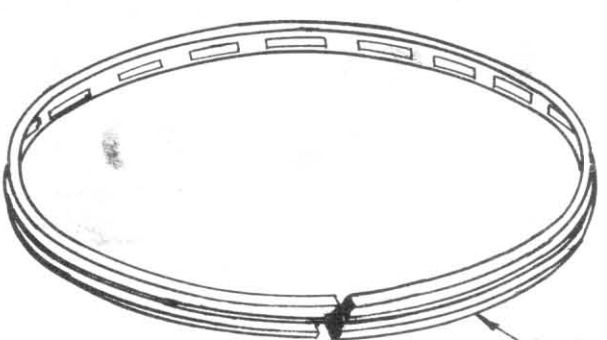
STARTING & REVERSING CONTROLS

895-A



SECTION OF SEALING RING

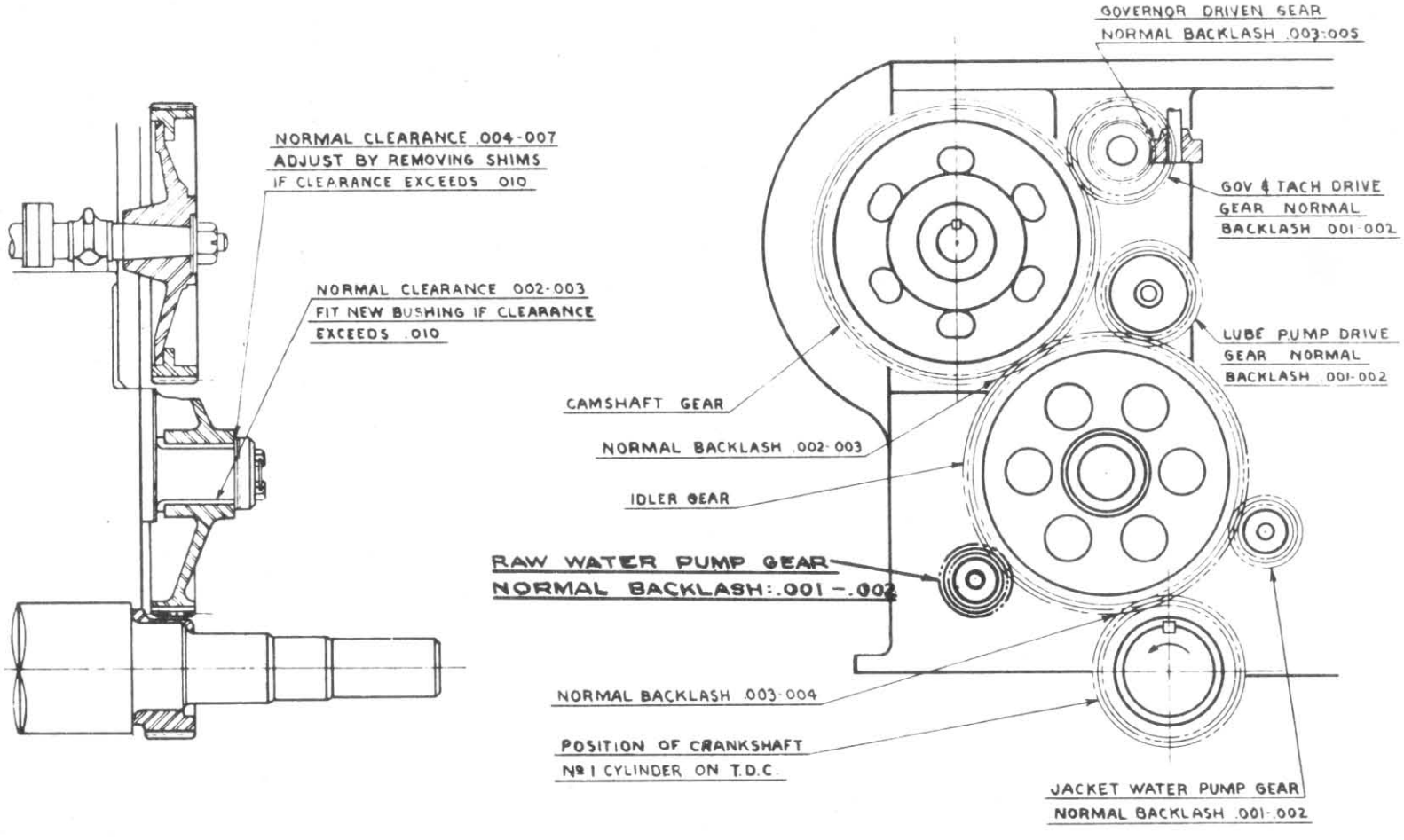
SEE "TABLE OF CLEARANCES" FOR PISTON RING CLEARANCES



THIS FACE MUST BE TOWARD BOTTOM OF PISTON AT ASSEMBLY

OIL WIPER RING

PISTON RING INSTALLATION


NORMAL CLEARANCE .004-007
ADJUST BY REMOVING SHIMS
IF CLEARANCE EXCEEDS .010
NORMAL CLEARANCE .002-003
FIT NEW BUSHING IF CLEARANCE
EXCEEDS .010
GOVERNOR DRIVEN GEAR
NORMAL BACKLASH .003-.005
GOV & TACH DRIVE
GEAR NORMAL
BACKLASH .001-.002
LUBE PUMP DRIVE
GEAR NORMAL
BACKLASH .001-.002
CAMSHAFT GEAR
NORMAL BACKLASH .002-.003
IDLER GEAR
RAW WATER PUMP GEAR
NORMAL BACKLASH: .001 - .002
NORMAL BACKLASH .003-.004
POSITION OF CRANKSHAFT
№1 CYLINDER ON T.D.C.
JACKET WATER PUMP GEAR
NORMAL BACKLASH .001-.002

GEAR SET

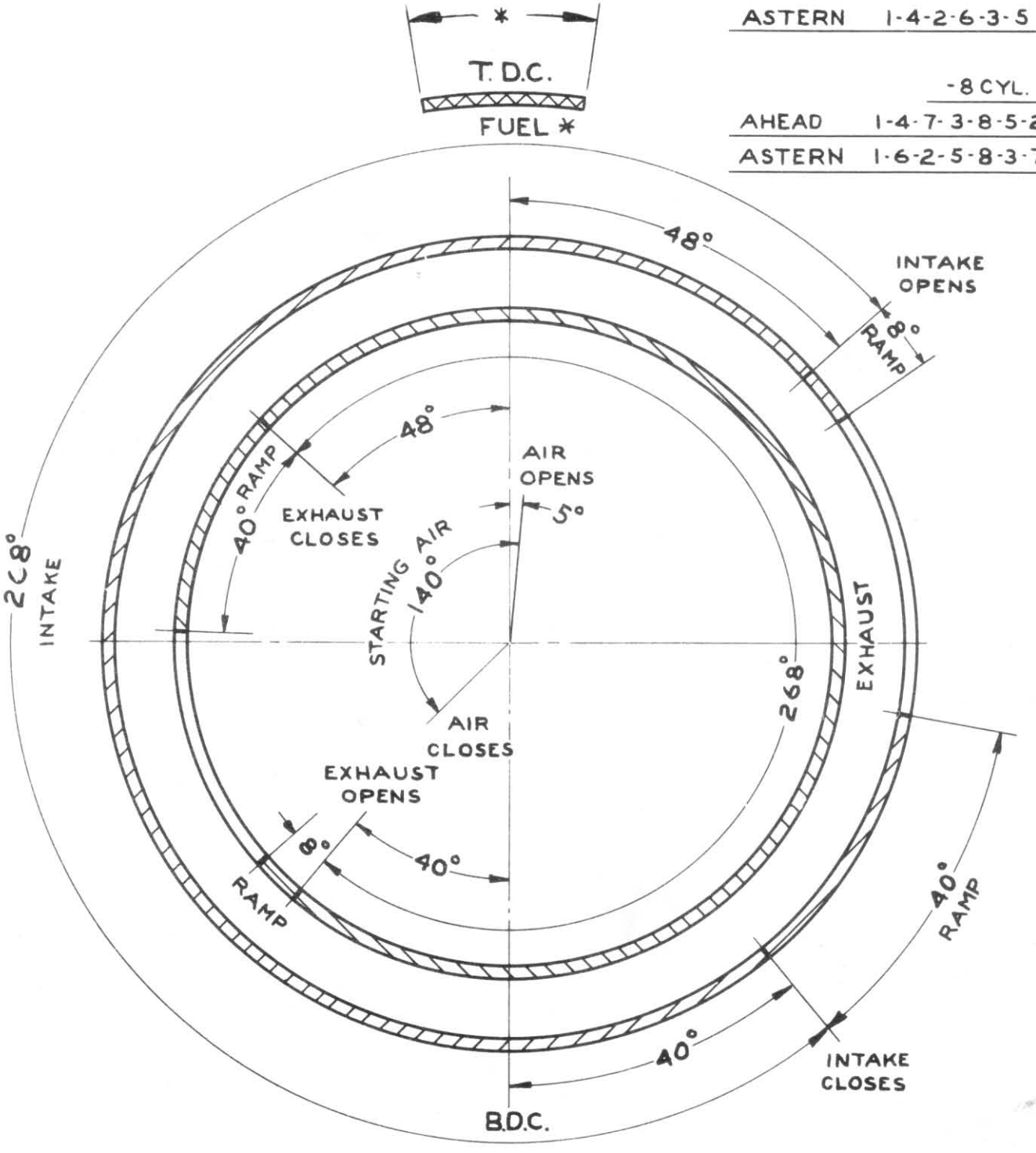
ON 48" DIA. FLYWHEEL, 1° = .4189" & 1" = 2.387°

Donna Jean - Fuel starts 14.3° before T.D.C. Fires at 6° B.T.D.C.

VALVE CLEARANCES	
INTAKE =	0
EXHAUST =	0
AIR STARTING =	.033"

FIRING ORDER - 6 CYL.	
AHEAD	1-5-3-6-2-4
ASTERN	1-4-2-6-3-5

	- 8 CYL.
AHEAD	1-4-7-3-8-5-2-6
ASTERN	1-6-2-5-8-3-7-4



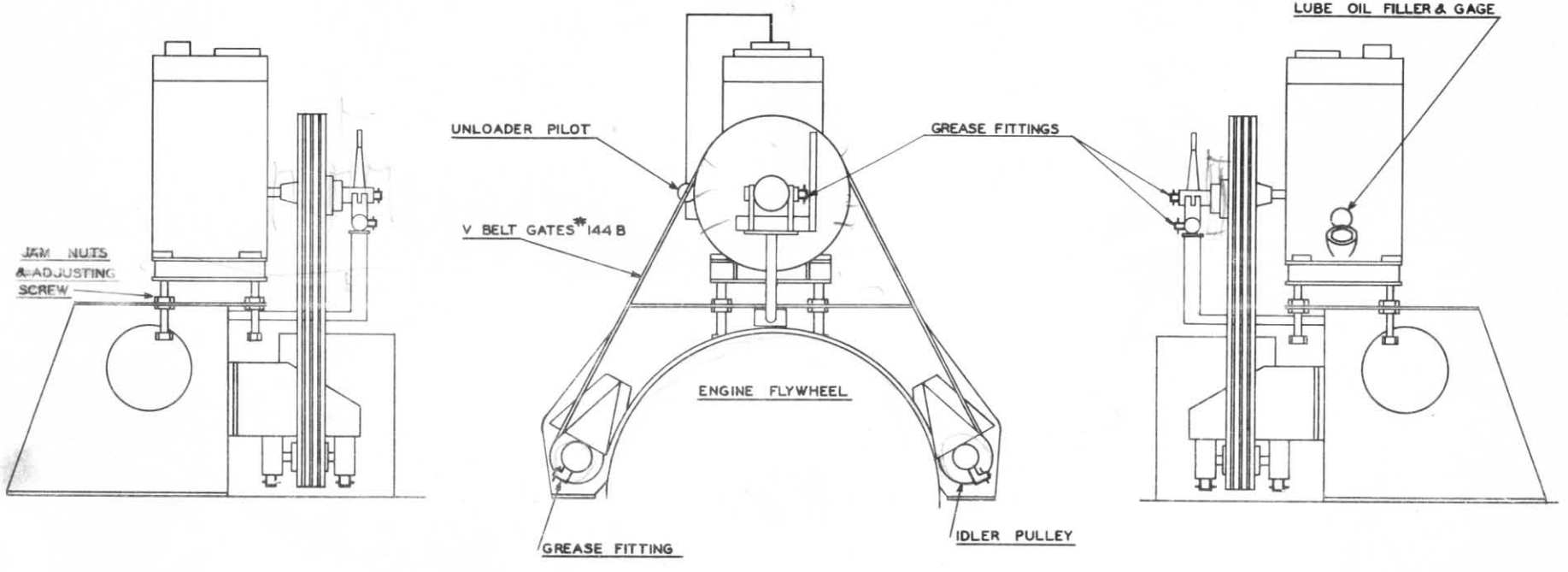
TIMING DIAGRAM

SUPERCHARGED 'Q'

* SEE TITLE PAGE

ENTERPRISE ENGINE COMPANY SAN FRANCISCO

D-1015



COMPRESSOR DRIVE

889

During normal operation, valves should be so set, as to have only one filter in operation. When the time for a change of elements is at hand the other filter may be cut in, and elements changed without shutting down the engine.

If the filters are in good working order, only rarely should there be any reason for cleaning the nozzles or pumps. The only attention which should normally be given to these units is an occasional drop of engine oil to the pump plunger guide, applied through the window at the lower portion of the pump body.

DO NOT TAKE APART AND WORK ON EITHER PUMP OR NOZZLE UNLESS ABSOLUTELY NECESSARY AND THEN ONLY IF THOROUGHLY FAMILIAR WITH THIS PRECISION EQUIPMENT.

B-2 Nozzles

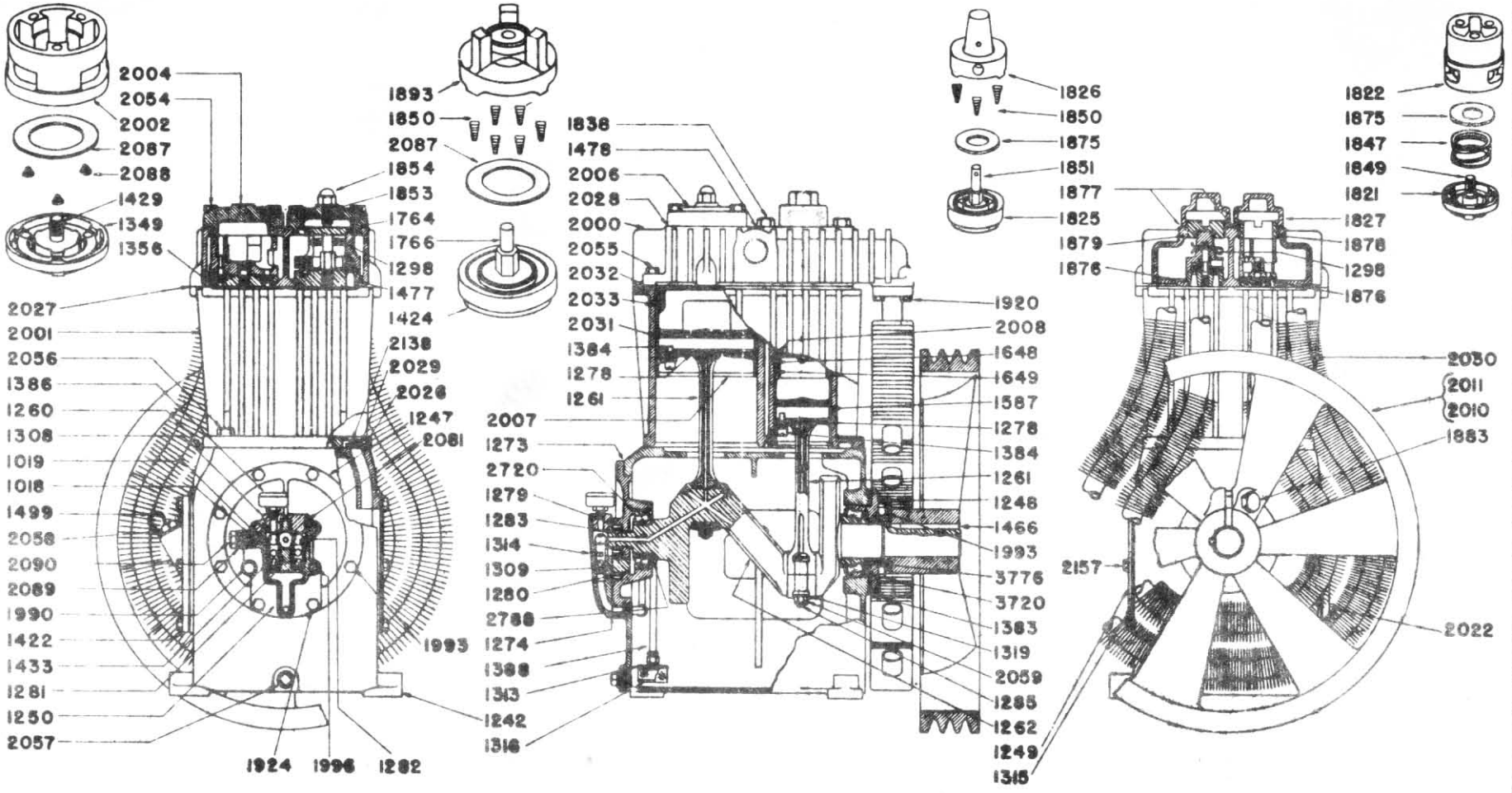
If engine has been running unevenly and a fuel nozzle is suspected, remove this nozzle and replace it with a spare.

To Remove Nozzle

Disconnect inlet and drain. Remove nozzle retainer. Nozzle assembly may then be pried out.

Before replacing nozzle, remove all carbon or other foreign substance from nozzle seat in head. See that gasket surface is clean and that gasket is clean and in good condition. Tighten hold down nuts evenly and just sufficiently to prevent blow-by.

The nozzle may be tested by connecting it to high pressure fuel line from any pump; operate the pump by means of priming shaft on pump base.



QUINCY MODEL 340 SIZE 5½&3X3½ TWO STAGE AIR COMPRESSOR

QUINCY COMPRESSOR CO., QUINCY, ILL.

SA-779

BROWN, BOVERI & COMPANY,
LIMITED,
BADEN (Switzerland)

BADEN, 1st June, 1937.

Re:- Reblading of exhaust gas turbine wheels.

The removal of old blades must be done with the greatest care. It is advantageous for easy removal of the blades first to wash the blade fixing parts with paraffin as otherwise scalings originating from combustion and corrosion will cause the blades to stick tightly in the sockets. The actual driving out of the blades must be carried out gently, as rough handling may cause the hollow rim sections left between the slots of the blade sockets to be deformed and to bend over, and even cracks in the material may result thereby.

It is therefore advisable to bed the rim of the wheel in the immediate vicinity of the slot from which the blade is to be removed. With a flat driving tool, specially provided for this work, which is placed on the part of the blade root visible from the outside, the blade is then driven out. The edge of the riveting is hereby sheared off.

The fitting of the new blades must be done with great care too. To ease this work, it is advisable to clean the slots in the rim with fine emery paper wrapped round a file. The edges of the blade shoulders must be carefully faced, so that the faces of contact between each pair of blades touch evenly all over (see fig. 1).

In case of laced blades, a lacing wire section should be inserted after riveting 4 to 5 blades, i.e. the number for one lacing segment. The last 4 to 5 blades after being fitted in the slots have to be hammered back to such an extent, that the lacing wire can be inserted. The whole segment will then with light blows of the hammer be redriven in the slots, after which the lacing wire should be soldered. Due to the high working temperature and the corrosive action of the exhaust gases, the soldering job can be carried out with pure silver; Borax to be used as a flux.

The replace blading material as furnished, corresponds exactly with the blading originally fitted in the turbine as regards the design of the fixation. The riveting of the blades has, therefore, to be carried out according to sketch No. 2, see drawing No. TF 678276 e and should be proceeded with alternately on both sides. In order to avoid losses due to ventilation, the protruding rivet-head parts should, if at all possible, be turned down flush with the head of the wheel. When replacing single blades, all other blades of the same segment, laced with one wire section, should be removed. The undamaged blades can be used again; they should be fixed by light caulking at the side where the original riveting material has been punched off (see sketch No. 3).

When replacing single blades please always remove the diametrical opposite blades too in order to keep the balance of the wheel.

After a complete reblading job, the wheel must be rebalanced statically.

BROWN, BOVERI & COMPANY,
LIMITED

Erection Department 1.

Drawing No. TF 678276 e.

GENERAL DESCRIPTION OF PRESSURE-CHARGING SET

The pressure-charging set consists of a centrifugal blower driven by an exhaust gas turbine, the two forming a compact unit.

a) Turbo-blower.

The turbo-blower is of the single-stage, single-flow type.

Casing. The blower casing consists of two main castings, namely the barrel with the tangential air discharge branch, and the outer end cover with the air suction opening. Both parts are cast in a light metal-alloy.

Rotor. The rotor is designed for clockwise rotation when seen from the turbine end. It consists of a common rigid shaft of forged open-hearth steel for blower and turbine, on to which the blower impeller is fitted. The latter consists of a hub and a covering disc, between which the blades are riveted. The complete impeller is of a high tensile alloy-steel. It is accurately balanced before leaving our works, both statically and dynamically, and subjected to a severe over-speed test, in order to reveal any defects or weakness in the material, which would otherwise remain hidden.

Bearings and Lubrication. The rotor is carried at both extremities by bearings of the ball type. One of the bearings is a combined supporting and thrust bearing for fixing the axial position of the shaft, whereas the other bearing is elastically mounted, so as to allow free heat expansion of the shaft.

The bearings are lubricated by oil under pressure, supplied by spiral oil pumps driven off the ends of the main shaft. (For vertical sets only one oil pump is incorporated in the design.)

Diffuser. In order to ensure that the kinetic energy of the air leaving the impeller is converted into pressure under as favourable conditions as possible, a bladed diffuser, having fixed blades, surrounds the impeller, and is fitted into the blower casing.

Glands. Labyrinth glands of pure sheet nickel, which can if necessary be readily renewed, are provided throughout. There are, therefore, no rubbing parts in the set, which minimizes the wear and tear.

b) Turbine.

The turbine casing again consists of two essential parts, namely the cooled barrel in cast iron, with exhaust connection, and the uncooled inlet casing in welded steel*) with exhaust gas inlet branches. Both parts are bolted together, and centred by keys. The barrel is on the opposite side again solidly bolted to the blower casing.

---

*) or cast steel

Heat insulation. Moderate surface temperatures are obtained throughout the turbine. For this purpose, the barrel is provided with a water-cooled jacket. Heat-radiation from the inlet casing is prevented by a water-cooled shield, which also carries the bearing at the turbine end. A water-cooled diaphragm is provided between the turbine and the blower.

Nozzle ring. The nozzle ring is centred in the inlet casing and consists of two rings in cast iron, into which the blades of heat resisting steel are casted.

Rotor. The turbine disc forms one piece with the shaft. The special profiled blades of heat resisting steel are rivetted in the disc. They can withstand a high exhaust gas temperature, the max. of which is stated under the technical data.

Glands. Labyrinth glands with compressed-air seal are provided where the shaft traverses the turbine casing, thus preventing leakage of exhaust gases.

ERECTION

General.

The pressure-charging set can be fitted directly on a bracket fixed to the Diesel engine.

During erection of the pressure-charging set it is advisable to test by hand through the air suction opening whether the shaft turns easily:-

1) After fixing the turbine casing in its definite position.
2) After fitting each pipe line.

The bolts and nuts of the exhaust gas turbine are to be fitted with graphite applied dry. The thread of these nuts have been eased up to prevent gripping at the high working temperatures.

All external forces on the pressure-charging set are to be avoided, otherwise deformation of the turbine housing, resulting in possible stripping of the turbine blades in the nozzle ring, would follow. Expansion pieces or joints should be provided at suitable points in the exhaust gas and air lines, so that all heat expansion in the piping is compensated. The expansion pieces should be fitted slightly extended. On no account should any heavy piping be directly supported by the pressure-charging set.

Care must be taken that no waste, dust, paper, water, etc. can enter the suction pipe of the blower. The suction noise of the blower can be muffled by fitting a suction air line with intern felt lagging or a silencer direct on the suction opening. Such a silencer should be based on the idea of deflecting the air stream and deadening the noise on a felt lining.

The gaskets for the exhaust gas piping should be made with asbestos, those for the air piping and the cooling water with varnished paper or rubber.

C L E A R A N C E S

Blowerset VT 301.

During the revision and reassembling of the exhaust turbo charger care must be taken that the following clearances are maintained; the set being cold:-

Ball Bearings:

a) between bearing cover and outer ring, on diameter		0,03 mm = .0012"
b) between rollers and rings on diameter	min.	0,03 mm = .0012"
	max. abt.	0,10 mm = .0039"
c) axial	abt.	0,3 mm = .012"

Turbine Wheel:

radial (on radius)	0,5 mm = .02"
axial, between disc and nozzle ring	3 mm = .118"

Blower Impeller:

between the impeller and diffuser (on radius)	0,20 mm = .0787"
between balancing ring and intermediate cover (on radius)	0,20 mm = .0787"

Shaft:

sheet nickel glands (on radius)	0,2 mm = .0787"
aluminium glands (on radius)	0,15 mm = .0059"

SETTING TO WORK

After the pressure-charging set has been laid up for some time, the blower shaft must be turned by hand a couple of revolutions or so before starting the machine. Further, if possible, the cooling water circulation should be put in service. In each case, this circulation is to be controlled immediately after starting the motor. Fill up the lubricating oil sump, before starting the diesel engine, up to the mark on the level.

The lubricating oil should possess the following properties:-

1. Specific weight : 0,85 to 0,92 at 15° C
2. Viscosity at 50 °C : about 3,5 to 5° (Engler) 125 - 180 SSO (SAE 20)
3. Flash point of the vapours not lower than 170 °C (120 - 185 - 85°F)
4. Entirely free from acid and water.
5. Must be totally soluble in petrol having a specific weight of 0,695 to 0,705 at 15° C.
6. Must be completely free from vegetable and animal oils.
7. Must have no tendency to saponify or decompose.

Each 500 running hours the quantity of lubricant should be checked. In case of renewal of the lubricant (after approx. 1000 running hours) the old lubricating oil must be completely removed and the bearing chamber cleaned. The new oil must be strained before refilling of the oil sumps. Dirt in the lubricant is extraordinary dangerous as it increases the wear and tear of the bearing rapidly.

A direct jet of oil between the balls destroys the high speed bearing in a comparatively short time due to increased friction and higher service temperature. The high speed bearing should be lubricated by oil vapour, oil deflecting discs directly before the bearing preventing the penetration of oil between the balls.

DISMANTLING

Drawing V 692770.

\+ Item of dismantling tools: drawing V 693357

1. Drain off the lubricating oil and cooling water.
2. Remove blower-side lubricating oil pump (28) and withdraw the bearing cover (29b).
3. Withdraw turbine-side oil pump casing (18).
4. Disconnect bearing fixation flange (6).
5. Loosen at both shaftend ring nut (8) with the tool (1, 2 and 4 +)
6. Remove with the tool (11 and 12 +) the inner sleeve (7) with bearing (1).
7. Withdraw the blower suction casing (29).
8. Fit the guide plate (10 +) on the turbine side, screw the extension (5 +) with plug (8 +) on the turbine side, and extension (5 +) with plug (7 +) on the blower side.
9. Disconnect diaphragm (33) and press it off its seat.
10. Withdraw rotor as far as possible.
11. Sling rotor with wire rope (15 +).
12. Loosen extension on the turbine side. Remove rotor from the set. (Be carefull with nickel sheet glands and turbine blades in laying down the rotor.)
13. Withdraw the turbine side bearing with the tool (11 and 12 +).
14. Disconnect the nozzle ring stud bolts (43) and nuts (42), press the ring off its seat and remove it.

R E V I S I O N

The blower set should be completely dismantled at least once a year. The following must be inspected:-

1) R o t o r .

a) Impeller.

Do they fit firmly on the shaft ?

Are there any signs of contact on the outer periphery or on the inlet ring ?

Any signs of damaged rivet heads ?

b) Balance Piston.

Fit on the shaft or impeller.

Signs of contact.

c) Ring nuts.

Fixing of same.

Are the locking plates in order ?

d) Shaft.

Are there any signs of contact caused by the packing rings ?

Pitted running surfaces should be refaced.

Is tachometer drive in order ?

e) Impulse Wheel.

What is the condition of the blading ?

Are any blades broken or bent ?

Are the inlet edges still sharp ?

Have the blades become badly worn ?

Has the wheel been touching ?

Are there any signs that foreign matter has passed through ?

2) Nozzle ring.

Has the ring a firm fit and has it warped ?

Are the guards for the nuts in order ?

Are there any signs of contact with the tips of the impulse wheel blades ?

Is there any foreign matter lodged between the nozzle plates ?

Have any plates worked loose, been burnt, cracket or bent ?
What clearances are available between blade tips and nozzle ring ?

3) Bearings.

a) Roller Bearing.

Condition of balls and races.

Is there any discolouration due to overheating ?

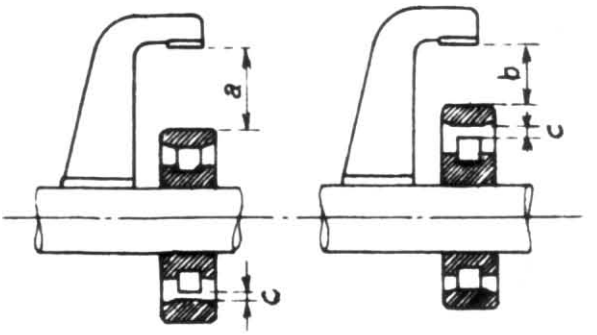
Are any defects visible (rough or broken out parts on balls or races generally are signs of fatigue)

Have any foreign bodies been rolled in the running surfaces ?

Wear of races and cages. Have the clearances increased abnormally

Do the bearings receive too much or too little lubricating oil ?

Has the turbine-side bearing still a tight fit between the flexible sleeves ?



In order to measure the clearance, the ball bearing must first be cleaned with petrol to remove all traces of oil, the clearance can then be measured as shown in this sketch.

clearance $c = a - b$

b) Condition of lubricating oil.

The oil collectors should be examined to see if any impurities have entered the oil, and if any, what kind ? (Fine metal particles ?)

Defective bearings (showing fatigue, too much clearance, defective cages, ... a.s.o.) should be replaced immediately.

To enable BBC to investigate the cause of bearing trouble and to make proposals for a possible improvement in the running of the set B.B.C. would be pleased to receive all replaced bearings, with a report about the occurrencies which have led to their destruction. If possible the approximate number of revolutions made by the shaft during the running period of the bearing should be included in the report.

4) Turbine Gland.

a) Has any dirt entered?

Is the sealing air inlet clean and right?

Is the clearance by wear or corrosion (exhaust gases) excessive ?

b) Blower gland.

Is the clearance excessive?

Are the rings damaged?

5) Diffuser.

Position and condition?

Do they still suit the impellers?

Are the diffusers correctly fitted with reference to the direction of rotation of the impellers?

Have they become dirty?

6) Cylinder.

a) Blower.

Are there any signs of leakage or large accumulations of dirt caused by oil or dust?

Are all measuring points free from leaks?

Are there any air losses?

b) Turbine.

Leakages, signs of dirt caused by oil or carbon?

Is the lagging still in good condition?

Are the cooling water spaces free from scale?

c) Watercooled diaphragm.

Is the cooling water space free from scale?

It is good practice to note all things observed during a revision of the set in a "Revision book". The necessary cleaning intervals might be fixed definitly based on this "Revision data".

R E A S S E M B L I N G

All parts to be cleaned thoroughly. The cooling water spaces to be handled in the same way as those from the main-engine. In case that muriatic acid must be used the cleaning medium may not be left too long a time in the water spaces because of the slight thickness of the castings. After the use of acid the spaces should be thoroughly washed with a soda solution.

The reassembling takes place the opposite way round as mentioned unter "Dismantling". The rotor is to be handled with utmost care when moved in, to keep the nickle-sheet glands from being damaged. The bearings to be greased with vaseline. All bolts and nuts exposed to high temperatures are to be fitted with graphite on the thread. All stud bolts and nuts to be locked.

Both oil sumps to be filled to the mark on the level with fresh, well strained turbine oil (see special lubr. oil prescriptions).

Before finishing the job always check the easy running of the shaft.

Replacing of nickel sheet glands: see special instructions

Replacing of turbine blades : " " "

Replacing of bearings:- The turbine side bearing to be replaced with shrunk on elastic sleeve. The blower side bearing to be shrunk on the inner sleeve by heating the bearing in hot oil to 125°C (260°F). The bearing with sleeve to be passed on the shaft together.

When replacing the nozzle ring the true centering and the clearances of the turbine disc are to be checked.

The bearings are the only parts of the charging set which must be replaced in rather short intervals.
Normally the running period of a bearing will be about two years for a daily service of 12 hours. It should be considered, however, that the life of roller bearings generally varies quite considerably. The bearing manufacturer definites the mean running period for a bearing as that period which will be exceeded by 90 % of all bearings without trouble, 10 % of all bearings will consequently have to be replaced earlier, whilst the life of a large portion of bearings will considerably exceed the "normal" running period.

SPARE PARTS

When ordering spare parts, it is absolutely necessary to quote the works and order numbers of the charging set for which they are required.

The works number is given on page 1 and on the rating plate of the blower.

The following spare parts should be in stock, if used, they should be replaced:-

1/5 set of turbine blades

1 ball bearing for blower side

1 ball bearing for turbine side on elastic sleeve

1 set of gland strips and bushes

1 oil pump spindle with bushing and drive

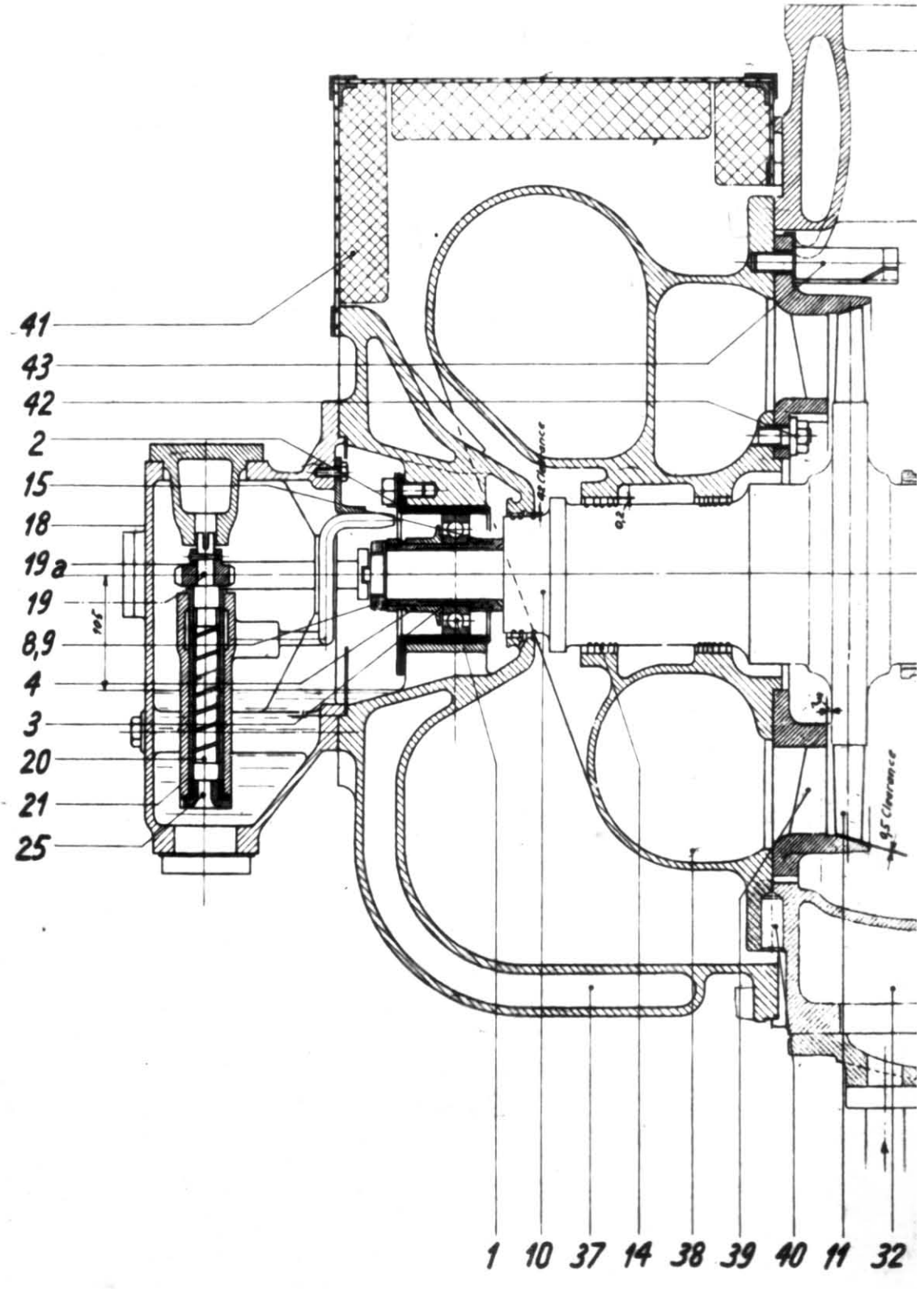
1/10 set of bolts, nuts, screws and guards.

LIST OF THE PARTS OF THE PRESSURE CHARGING SET

Drawing V 692770

1	Main ball-bearing
2	Outer elastic sleeve
3	Inner elastic sleeve
4	Distancing bush
5	Bearing bush
6	Bearing fixation flange
7	Inner blower side bearing sleeve
8	Ring nut
9	Locking plate
10	Shaft
11	Turbine blades
12	Impeller
13	Ring nut
14	Nickel sheet glands
15	Distance bush
16	Balancing ring
17	Nickel sheet glands
18	Oil pump casing
19	Shaft with worm
19a	Worm wheel
20	Turbine side oil pump spindle
21	Turbine side oil pump sleeve
22	Shaft with worm
22a	Worm wheel
23	Blower side oil pump spindle
24	Blower side oil pump sleeve
25	Mouth piece
26	Ball bearing for auxiliary shaft
27	Level
28	
29	Blower suction casing
29a	Gland bush
29b	Blower-side bearing cover
30	Blower casing
31	Diffuser
32	Turbine casing
33	Water-cooled diaphragm
34	Gland ring
35	Radiation guard
36	Rubber packing
37	Bearing bracket
38	Turbine inlet
39	Nozzle ring
40	Centering key
41	Wire gauze
42	Nozzle ring nuts
43	Nozzle ring stud bolts
44	Bracket with roller for the removal of the rotor

All bolts, nuts and screws to be locked.



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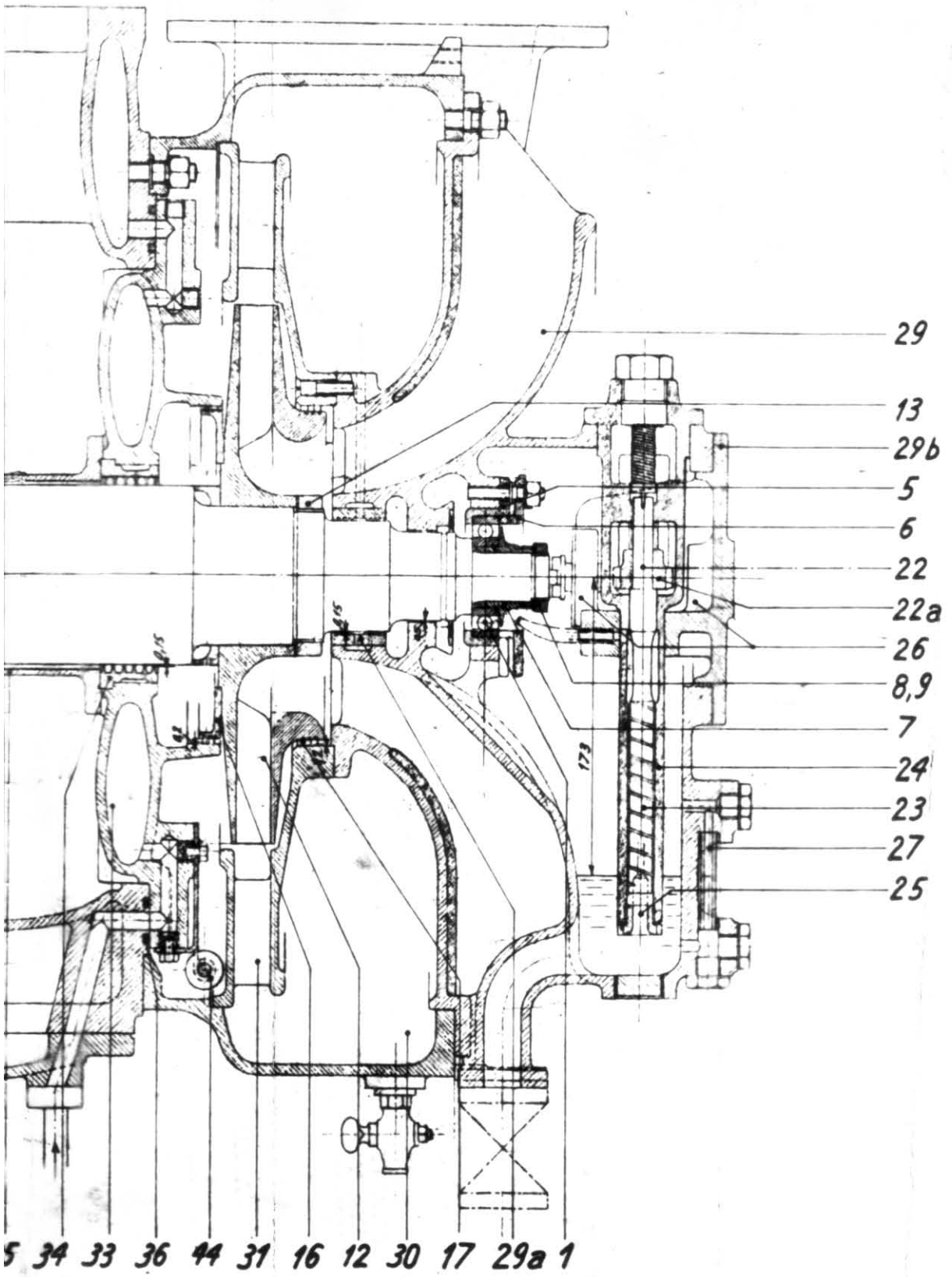
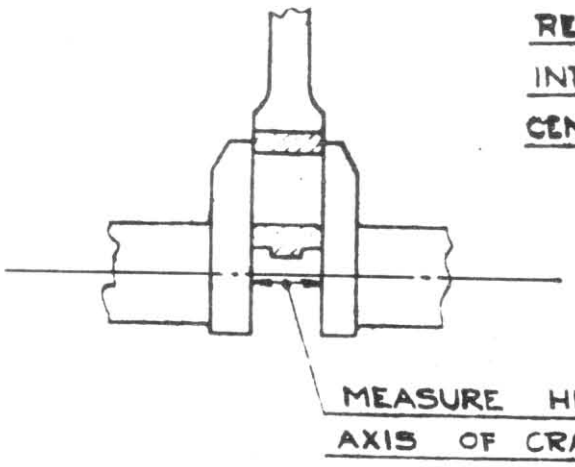


1007855/4 VTG 301	Maßstab		
Sectional drawing	1:2		
BROWN BOVERI Plandr. v. V692770	V 692770		

READINGS TO BE TAKEN AFTER FINAL INSTALLATION, BEFORE FINAL TESTS



READINGS ARE IN THOUSANDTHS WITH INDICATOR SET ZERO AT TOP DEAD CENTER OF PISTON - NOTE WHETHER + OR −.

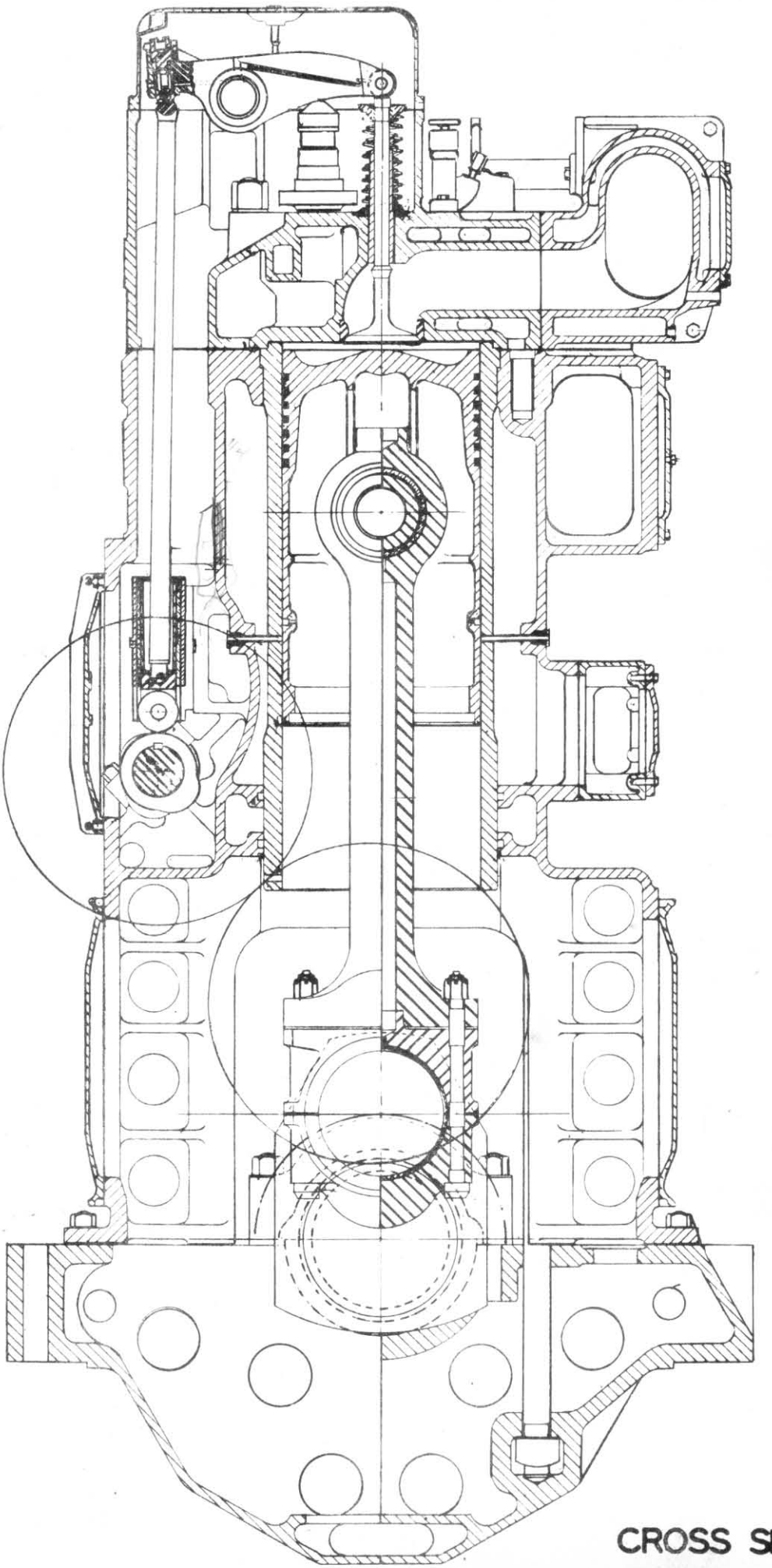
POSITION WHEN VIEWED FROM TIMING GEAR END

CYLINDER Nº.

	1	2	3	4	5	6	7	8
TOP								
RIGHT								
BOTTOM								
LEFT								

CRANKSHAFT DEFLECTION

573-A



CROSS SECTION
DQ ENGINE

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