From the collection of John Dulaney.

BLH 600 Series Engine Manual

ENGINE MANUAL

for

600 SERIES DIESEL ENGINES

This manual applies to the following models only

Model 606—606-A and 608-A

Price $2.50 each

BALDWIN-LIMA-HAMILTON CORPORATION
PHILADELPHIA, PENNA.

9-15-50
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FOREWORD

This manual is published by the Baldwin-Lima-Hamilton Corporation and covers the description and maintenance of the 600 Series Diesel engines as installed in Diesel-Electric Locomotives. The 600 series includes six and eight cylinder Diesel engines of both the supercharged type and normally aspirated type.

The information contained herein is written for men who have a fundamental knowledge of internal combustion engines and their repair. Elementary definitions and details of basic shop procedures are therefore frequently omitted. The repair of some equipment on these engines requires a thorough knowledge of such work. If maintenance men experienced with such equipment are not available, consult a service engineer or return the equipment to the factory for repair.

A separate section of this book is devoted to each item listed in the table of contents. Each section has its independent series of page numbers and contains a brief general description of the item followed by specific maintenance information. The end of the sections list specifications summarizing clearances, dimensions, settings and similar facts for servicing the engines.

In order to help maintain maximum availability of Diesel Locomotives with the greatest economy the Baldwin-Lima-Hamilton "Unit Exchange" or the "Repair and Return" service plans are recommended for servicing certain items on the engine, such as Fuel Pumps, Fuel Injectors, Governor, Lubricating Oil Pump, Water Pump and Turbocharger. Under these plans, replacement units are furnished from stocks on hand at various warehouses, or the original equipment is returned after being repaired. Arrangements for this service should be made through the nearest B.L.H. district office.

The recommended schedule for periodic maintenance of various items is published in a separate Maintenance Bulletin. Operating instructions for various types of locomotives and maintenance instructions for many auxiliary items of equipment are published in separate manuals or bulletins.

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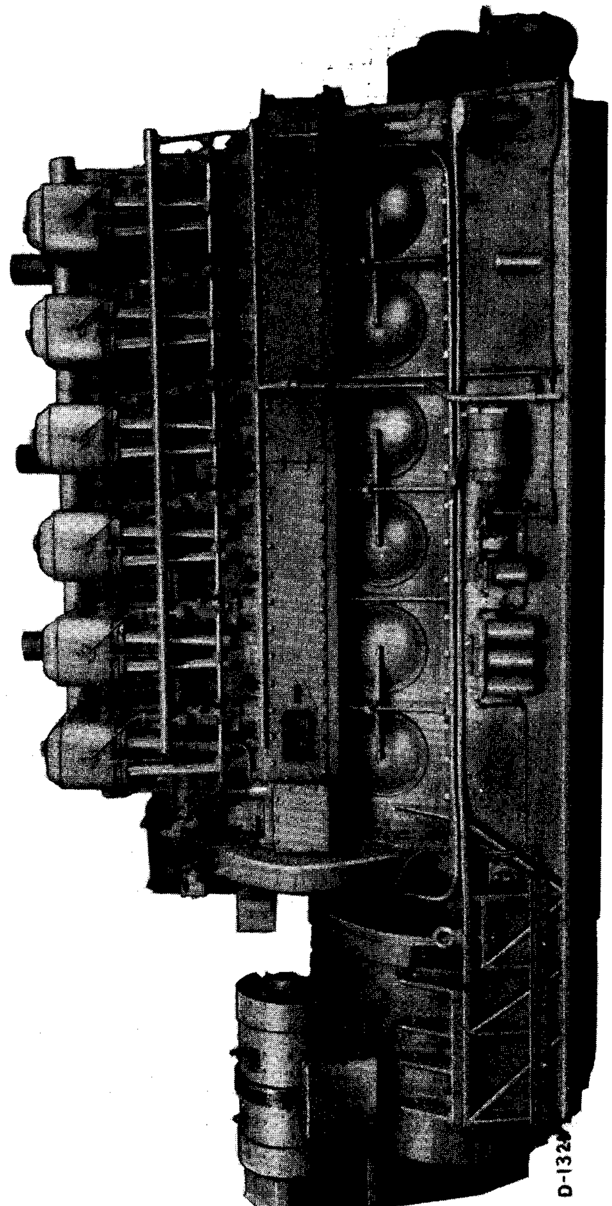
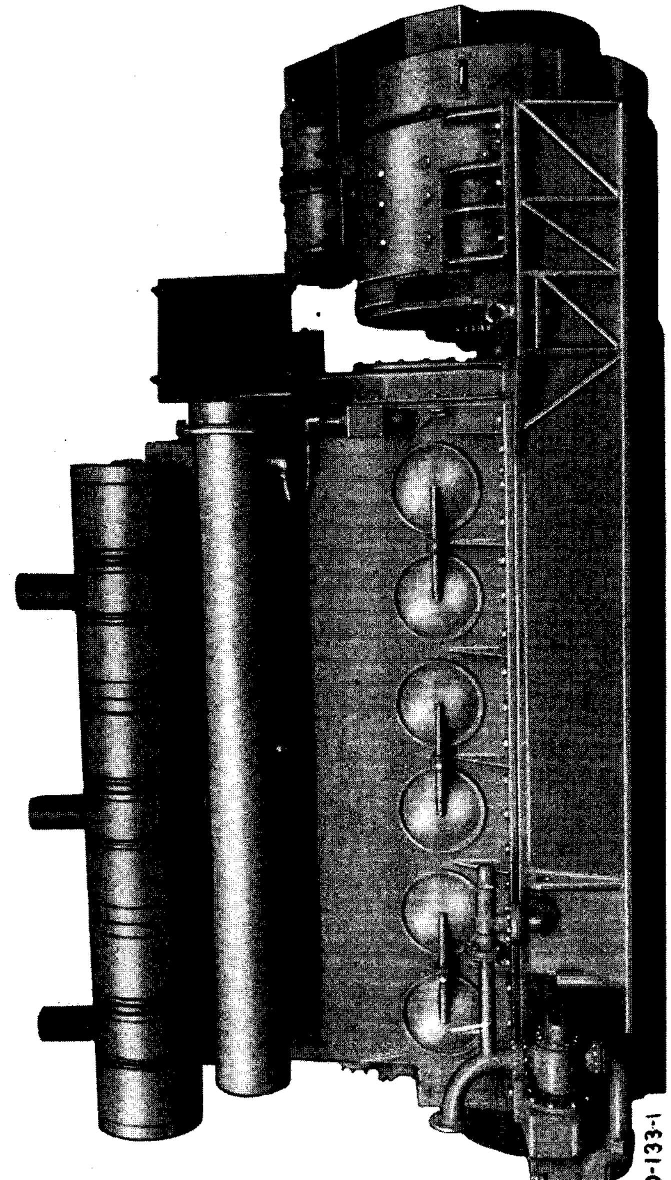
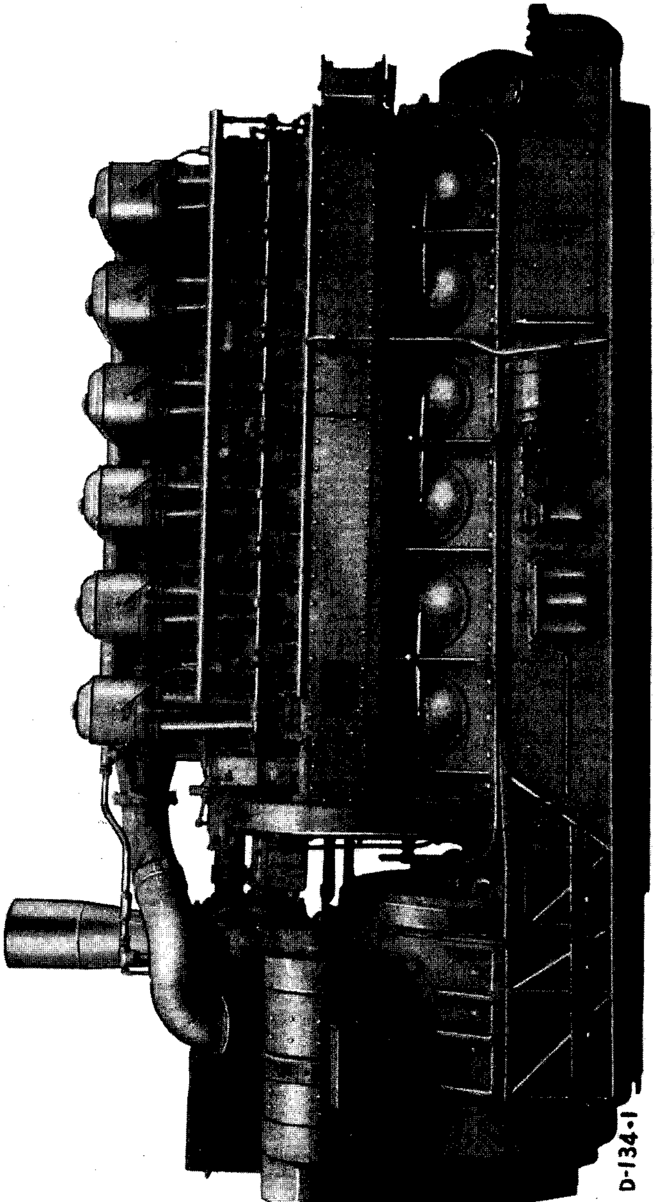


Model 606 Engine (Normally Aspirated)
Figure 1
Valve Gear Side



Model 606 Engine (Normally Aspirated)
Figure 2
Exhaust Side



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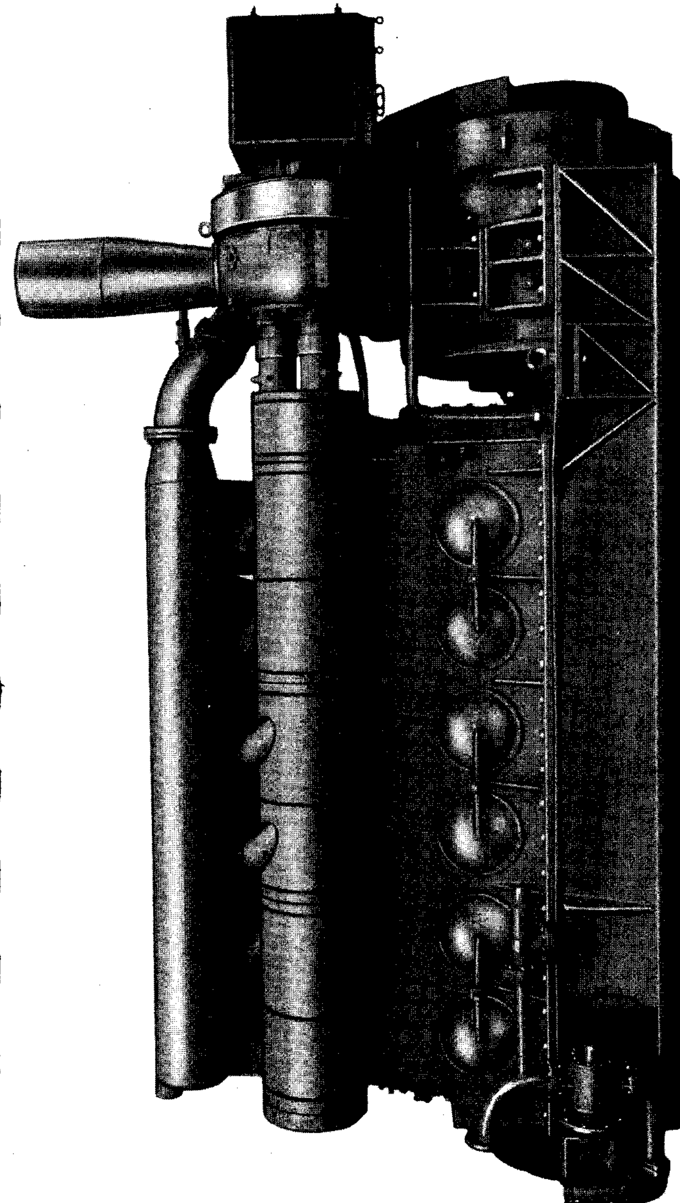
Model 606A Engine
Figure 3
Valve Gear Side



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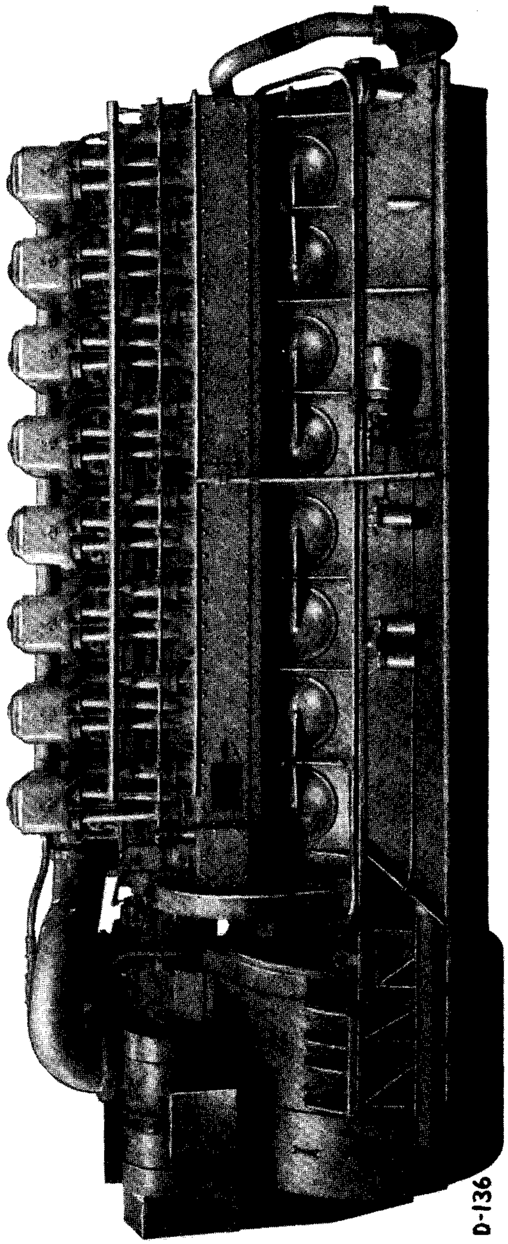
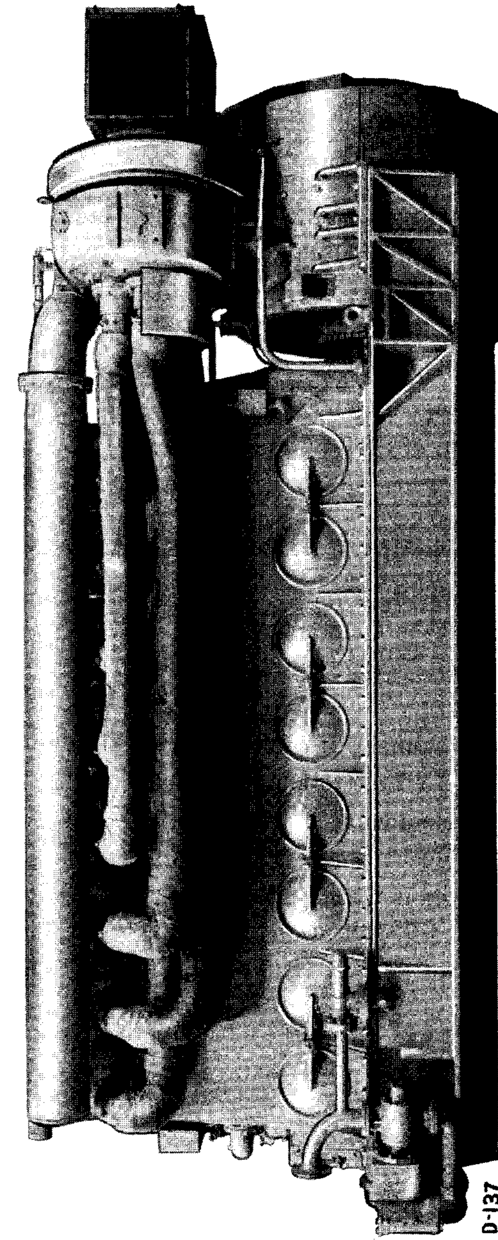
Model 606A Engine
Figure 4
Exhaust Side



Model 608A Engine
Figure 5
Valve Gear Side



Model 608A Engine
Figure 6
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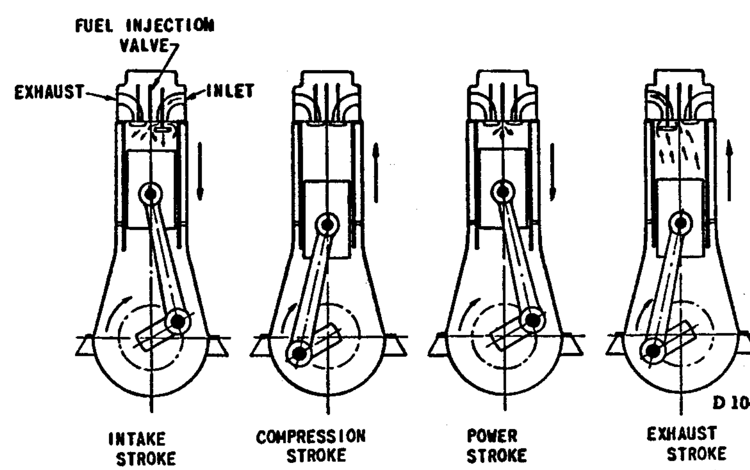
OPERATING DESCRIPTION

The 600 Series Diesel engine is a four-cycle vertical in-line engine built as either a 6 cylinder normally aspirated or a 6 or 8 cylinder supercharged model. Separate fuel injection pumps and injectors are provided for each cylinder. All pumps are engine driven with the exception of the fuel oil supply pump which is motor driven.

In a four-cycle engine, there are four strokes of the piston, (two revolutions of the crankshaft), to complete one cycle of events. The piston moves downward on the intake stroke drawing in fresh air through the valves in cylinder head. On the following upward stroke of the piston, this air is compressed, the valves in the cylinder head being closed. Shortly before the piston reaches upper dead center, fuel is injected into this highly compressed air causing it to burn. The resulting expansion of gases forces the piston downward for the power stroke. On the following upward stroke, the burnt gases are expelled through the exhaust valves. The cycle is then repeated.

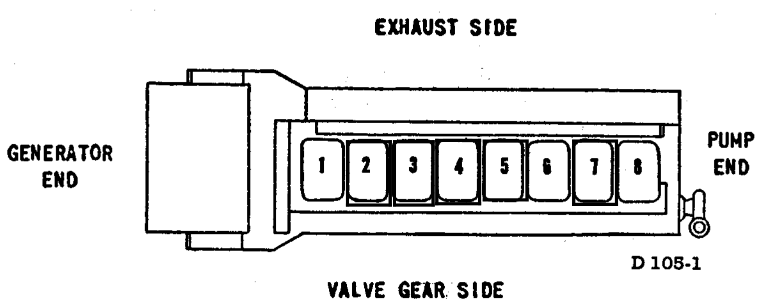


Operating Diagram

Figure 7

The turbocharged engine permits a higher output of power than a normally aspirated engine. The energy of the exhaust gas is used to drive a gas turbine which is directly coupled to a centrifugal blower. This blower supplies air to the engine cylinders, at a pressure above atmospheric. This air scavenges the hot gases from the cylinder and provides a charge of air of higher density and pressure. This increased amount of fresh air permits combustion of a greater quantity of fuel and consequently a higher output of power.

Figure 8 illustrates the engine arrangement as referred to in the following pages. The lubricating oil pump, water pump, strainers and filters are located at pump end of engine. The main generator, exciter and auxiliary generator are located at generator end. The direction of rotation is counterclockwise when viewed from the generator end.



Engine Arrangement Diagram

Figure 8

GENERAL DATA

SUPERCHARGED

	8 Cylinder	6 Cylinde
H. P. for traction..........	1600	1200
Model	608A	606A
B. H. P.	1750	1315
R. P. M. at rated power....	625	625
R. P. M. at idle...........	315	315
No. of cylinders..........	8	6
Bore inches	12¾	12¾
Stroke inches	15½	15½
Firing order	1-4-7-6-8-5-2-3	1-2-4-6-5-3
B. M. E. P.—P. S. I........	140	140
Weights—Lbs. (dry)		
Engine-Generator Unit ...	55,500	45,100
Main Generator	15,580	12,180
Auxiliary Generator	920	920

NORMALLY ASPIRATED

	6 Cylinder
H. P. for traction..........	800
Model	606
B. H. P.	875
R. P. M. at rated power....	625
R. P. M. at idle...........	315
No. of cylinders..........	6
Bore inches	12¾
Stroke inches	15½
Firing order	1-2-4-6-5-3
B. M. E. P.—P. S. I........	93.5
Weights—Lbs. (dry)	
Engine-Generator Unit ...	44,100
Main Generator	12,180
Auxiliary Generator	920

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OPERATING ROUTINE

STARTING THE ENGINE FOR THE FIRST TIME OR AFTER A LONG PERIOD OF SHUT-DOWN

a. Fill fuel tank with suitable fuel oil. For recommended fuel oil refer to B. L. H. specification MBG-102.

b. Fill cooling system with clean soft water. Refer to "Engine Cooling System." If atmospheric temperature is below freezing, use suitable anti-freeze solution in the water or place locomotive in heated building before filling cooling system. Great care must be exercised to prevent freezing of the water if anti-freeze is not used.

c. Fill crankcase and camshaft trough to proper level with new lubricating oil. For recommended lubricating oil refer to B.L.H. specification MBG-101.

d. Check the condition of lubrication of all accessories and apply lubricant as required.

e. Clean and recharge the air intake filter unit.

f. Pour new lubricating oil on all valve stems. If engine has been idle for a long period, use oil mixed with kerosene for initial lubrication of valve stems.

g. If engine has been idle for a long period, remove the casings of fuel and lubricating oil strainers for complete cleaning of the elements, renew the cartridges in the fuel oil filter and lubricating oil filter.

h. Run the fuel oil supply pump to prime the system. Open the vent on the fuel oil filter.

i. Remove crankcase covers and check the cylinder bores, and if dry, apply new oil into each cylinder when the piston is at the top position.

j. Bar the engine over several complete revolutions. This will also prime the fuel pumps and injectors.

k. Start the engine and operate at idling speed for ten minutes. Shut the engine down and check all bearings and pistons for lubrication and temperature.

l. If conditions are satisfactory, operate the engine under light load for a half an hour. Shut down and inspect again before putting the engine into normal service. Pay close attention to all pressure and temperature gauges while engine is running.

OPERATING ROUTINE AFTER A PARTIAL OR COMPLETE OVERHAUL

a. When starting the engine after having installed new parts, such as pistons, piston rings, piston pins, cylinder liners, or bearings, check the condition of lubrication thoroughly as outlined in the preceding paragraph, and the same procedure for starting should be followed. The following operating and inspection procedure is recommended.

b. Operate the engine at idling speed for ten minutes and check the temperature and lubrication of all pistons and bearings or other newly installed parts.

c. If conditions are satisfactory, operate the engine under light load for half an hour. Shut the engine down and repeat the above inspection.

d. Operate the engine under normal load for an hour. Shut the engine down and again repeat the inspection.

e. The above "run-in" and inspection procedure should be executed carefully before the locomotive is returned to normal service.

OPERATING DIFFICULTIES AND CAUSES

ENGINE DOES NOT TURN WHEN START BUTTON IS PRESSED

a. Battery switch is open or loose battery connections.
b. Weak battery.
c. Bar or tool left in a place to block the engine from turning.
d. Engine stop switch open (if installed).
e. Multiple unit switch (if installed) is not in correct position.
f. Starting contactors do not close. Check electrical system.
g. Emergency engine stop switch closed (if installed).

ENGINE TURNS BUT DOES NOT FIRE OR DOES NOT CONTINUE TO RUN AFTER RELEASING START BUTTON

a. Emergency fuel shut-off valve has been tripped.
b. Fuel tank empty.
c. Fuel supply pump not operating properly.
d. Clogged fuel strainer or filter.
e. Fuel system not primed properly.
f. Lubricating oil pressure too low to keep the shut-down switch from operating.
g. Engine overspeed stop has been tripped.
h. Engine shut-down cylinder or solenoid valve not functioning properly.
i. Insufficient oil in governor casing.

IRREGULAR OPERATION

a. Governor not functioning properly because of lack of oil or faulty adjustment.
b. Leak in the fuel suction piping causing air binding of the injectors.
c. Air or water in the fuel system.
d. Sticking or leaking injector valves or fuel injection pump plunger.
e. Sticking or leaking intake or exhaust valves.
f. Broken springs in injectors or fuel pumps.

g. Broken exhaust or intake valve springs.
h. Dirty or clogged fuel filter or strainer.
i. Insufficient fuel supply pressure because of dirty or faulty adjustment of relief valves or improper functioning of supply pump.
j. Unsuitable fuel oil.
k. Clogged air intake filter.

ENGINE OVERHEATS

a. Insufficient water supply in the system.
b. Dirt or scale deposited in the radiators.
c. Leak in water pump suction line.
d. Water pump not functioning properly.
e. Restrictions in water lines.
f. Engine overloaded.
g. Radiator fans not functioning properly.
h. Shutter control not functioning properly.

EXCESSIVE EXHAUST TEMPERATURE

a. Engine overloaded.
b. Late fuel injection.
c. Fuel injectors or injection pumps not functioning properly.
d. Faulty valve timing.
e. Unsuitable fuel oil.
f. Turbocharger not functioning properly.

ENGINE KNOCKS

a. Too early fuel injection.
b. Fuel injectors not functioning properly.
c. Cylinder head stud nuts not drawn up sufficiently.
d. Loose bearing bolts.
e. Exhaust header bolts not drawn up sufficiently.
f. Worn bearings.
g. Worn cylinder liners.
h. Unsuitable fuel oil.

ENGINE SMOKES

a. Engine overloaded or distribution of load between cylinders not equalized.

b Fuel injectors or injection pumps not functioning properly.
c. Late fuel injection.
d. Improper valve timing.
e. Clogged air intake filter.
f. Leaking exhaust or intake valves.
g. Clogged oil drain holes in wiper ring grooves.
h. Wiper rings not installed properly on piston.
i. Stuck or worn piston rings.
j. Unsuitable fuel oil.
k. Unsuitable lubricating oil.

LUBRICATING OIL PRESSURE TOO LOW

a. Insufficient lubricating oil in the sump.
b. Lubricating oil suction strainer clogged.
c. Pressure relief valve leaking, set too low, or spring broken in valve.
d. Lubricating oil pump not functioning properly.
e. Leak in lubricating oil system.
f. Heat exchanger clogged.
g. Lubricating oil filter clogged.

LUBRICATING OIL PRESSURE TOO HIGH

a. Pressure relief valve stuck or set for too high a pressure.
b. Restriction in lubricating oil piping inside the engine.
c. Lubricating oil too heavy.
d. Lubricating oil temperature below standard operating conditions.

ENGINE STOPS

a. Fuel tank empty or broken supply line.
b. Emergency fuel shut-off valve has been closed.
c. Engine overspeed stop tripped.
d. Lubricating oil pressure has become too low and the shut-down has operated.

e. Fuel filter or strainer clogged.
f. Air or water in fuel lines.
g. Failure of fuel supply pump.
h. Governor not functioning properly.

EXCESSIVE LUBRICATING OIL CONSUMPTION

a. Unsuitable lubricating oil.
b. Piston wiper rings worn excessively or stuck in grooves.
c. Drain holes in piston ring grooves clogged.
d. Piston wiper rings installed upside down.
e. Oil level too high in the crankcase.
f. Cylinder liners are worn excessively.

TURBOCHARGER OVERHEATS

a. Engine exhaust temperature too high.
b. Insufficient supply of cooling water.
c. Clogged circulating passages.
d. Turbo water jacket has excessive scale deposits.
e. Air intake filter clogged or not functioning properly.
f. Leaks in air intake header.
g. Low turbocharger discharge pressure.

INCORRECT TURBOCHARGER LUBRICATING OIL PRESSURE

a. Engine lubricating oil filter clogged.
b. Incorrect lubricating oil.
c. Obstructions in internal passages.
d. Pressure gauge not functioning properly.

TURBOCHARGER VIBRATES

a. Worn bearings.
b. Uneven deposit on impeller.
c. Impeller shaft or turbine wheel damaged.
b. Thrust collar retaining nut loose.
e. Turbocharger holding down bolts loose.

DIESEL ENGINE MAINTENANCE

GENERAL INFORMATION

Baldwin-Lima-Hamilton Diesel engines are built to rigid standards and are designed to give low-cost service under continued hard use. The heavier the schedule, the more important maintenance becomes.

ACCURATE RECORDS

General observations should be recorded concerning the operation under varying conditions, excessive wear of moving parts and necessary replacements. Prompt recognition and correction of faulty performance is important.

REGULAR INSPECTION

Inspections should be scheduled at regular intervals and rigid adherence to recommended overhaul periods is absolutely necessary. Recommendations in this Manual are for average operating conditions. Unusual conditions may necessitate changes, but the importance of systematic follow-up cannot be over-emphasized.

CLEANLINESS IS OF UTMOST IMPORTANCE

When working on the engine:

a. Clean all parts thoroughly.

b. Remove all dirt, scale and rust.

c. Be careful not to damage the machined surfaces of any piece.

d. Make sure no lint gets on the journals or bearings as it will cut and score the lining.

e. Keep water where it belongs, do not allow it to get into fuel oil and lubricating equipment.

f. Water causes most damage to fuel pumps, cuts valve seats and scores plungers.

HANDLE WORK IN AN ORDERLY MANNER

a. Always follow a definite routine taking care not to miss a single step.

b. Parts of assemblies and sub-assemblies must be kept together to prevent loss and to insure reassembly in the same group. Few items are interchangeable, therefore this is very important.

SAFETY TO WORKERS

Repairmen must learn to be cautious in the handling of heavy parts as well as in the removing and reassembly of working units. The loss of a finger or even a hand may result from carelessness in any one of a dozen operations. Keep tools and parts up out of the way to prevent tripping over them.

ENGINE

The engine includes a number of group assemblies which are designed to work together at the highest possible efficiency. Thus it is possible to check the operation of several assemblies at one time and still follow a logical procedure which will insure the complete inspection and necessary adjustments required for proper maintenance.

The main assemblies of the engine are the Bedplate, Frame, Pistons, Connecting Rods, Cylinder Heads and Camshaft.

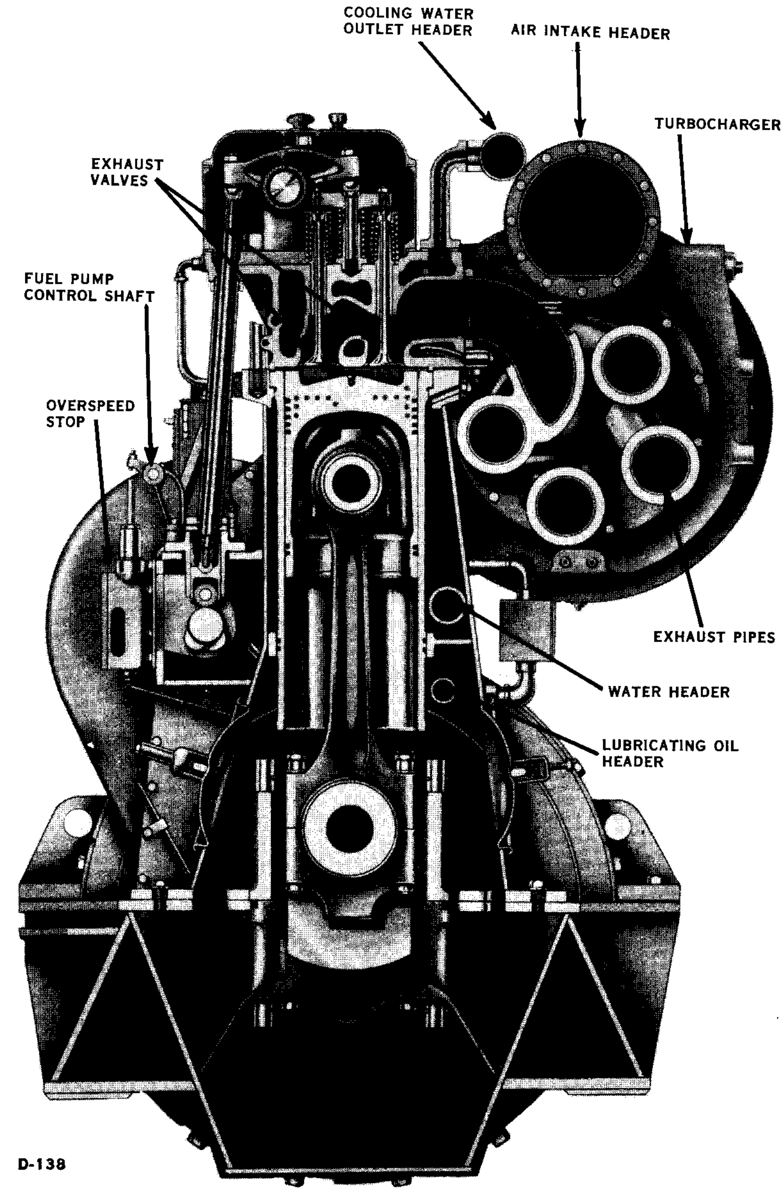
The Lubricating Oil, Fuel Oil and Engine Cooling Systems are described separately. It will be noted that the description and maintenance procedures recommended for the mechanically operated devices in these systems are described in their proper sections. Each of the main assemblies include several important sub-assemblies which are covered in logical order.

Following an overhaul the engine should be load tested. This offers an opportunity to observe the performance of the engine and take immediate action to make adjustments or correct operating difficulties before the engine is returned to normal service. Load testing must be done only by personnel who are carefully trained and have a thorough understanding of the inter-relation between electrical and mechanical portions of the engine-generator unit.

All nuts and bolts on the engine should be periodically tightened and a tightening procedure should be established as part of the regular maintenance program. The most accurate method of tightening is by means of a torque wrench and the following are the torque values to which the various nuts and bolts should be tightened.

TORQUE READINGS

Main bearing bolts	500 ft. lbs.
Main frame bolts	800 ft. lbs.
Outside frame bolts	500 ft. lbs.
Generator mounting bolts	500 ft. lbs.
Cylinder head nuts	1200 ft. lbs.
Generator coupling bolts	800 ft. lbs.
Spring sprocket to crankshaft bolts	270 ft. lbs.
3/8" nuts and bolts	20 ft. lbs.
1/2" nuts and bolts	50 ft. lbs.
5/8" nuts and bolts	100 ft. lbs.
3/4" nuts and bolts	170 ft. lbs.



Cross Section of Series 600 Engine

Figure 9

NOTES

BEDPLATE, CRANKSHAFT, MAIN BEARINGS

BEDPLATE

DESCRIPTION

The bedplate is a welded steel structure, extending the length of the engine with extensions for supporting the main generator. It forms the lower supporting structure for the engine and functions as a reservoir for the engine lubricating oil.

The bedplate contains heavy transverse webs having integral main bearing saddles to support the main bearings and maintain proper crankshaft alignment. Fitted steel caps hold the bearing shells in place. The bearing caps are secured to the bedplate by internal through bolts.

MAINTENANCE

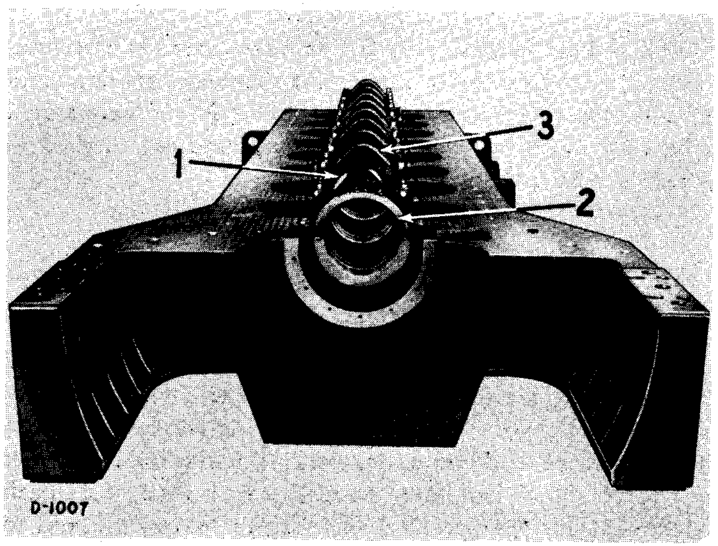
CLEANING

If any work is done on the engine that would allow dirt or metal chips to get into the crankcase, the interior of bedplate must be cleaned before the engine is run again. Use a suitable solvent and wipe dry with lintless rags. *Do not use waste!* The bedplate should be flushed out each time the oil is changed. Dirt and foreign matter allowed to accumulate in the crankcase will shorten the life of the bearings and may even cause them to fail.

PAINTING INSTRUCTIONS

The interior of the engine is painted at the factory with a B.L.H. approved grade of crankcase sealer. The spaces so painted include the inside of the bedplate, frame but not water passages or liner, cam trough, and chain drive housing. If these spaces are repainted after an engine overhaul, the surfaces should be thoroughly cleaned with a caustic solution to remove old paint, sludge, and oil from the surface of the metal. Failure to do this may cause the paint to peel off and clog up the lubricating oil lines and filters. Machined surfaces such as the bearing bores, also flanges or surfaces that receive gaskets or seals, should not be painted.

The external surface of the engine (after cleaning) should receive a good coat of primer followed by a coat of enamel. The fuel pump racks, control shaft springs, name plates, shaft pulleys, etc., and all other surfaces that are not to be painted should be covered with masking tape. In regard to the generator, protect all internal parts and all external wiring that does not have a metallic sheathing.



Engine Bedplate

Figure 1

1. Thrust Bearing Cap **2. Thrust Bearing Flange** **3. Main Bearing Cap**

CRANKSHAFT

DESCRIPTION

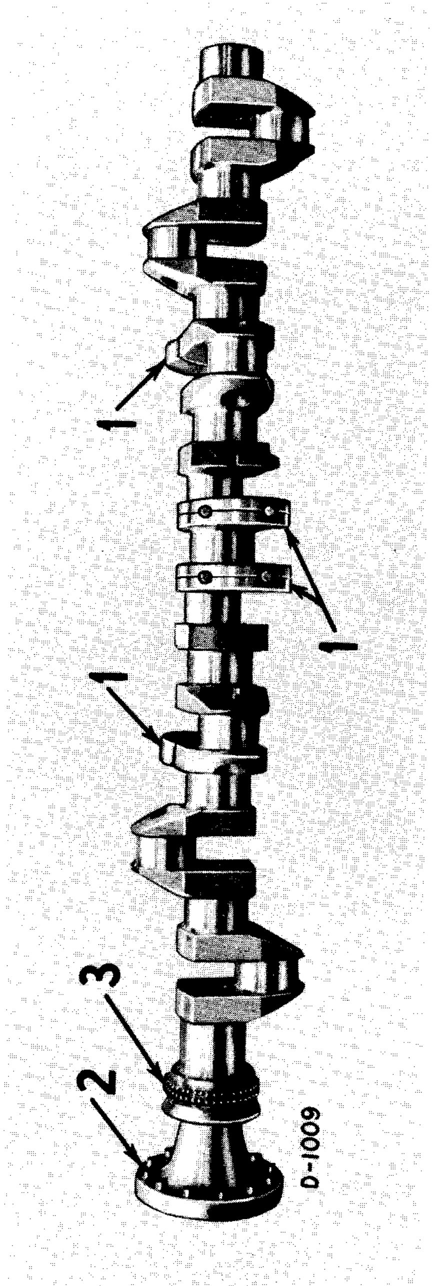
The crankshaft is a heat-treated solid steel forging. Drilled passages in the journals and crankwebs provide for pressure lubrication of the bearings. A coupling flange for bolting the crankshaft to the generator is forged integral with the shaft. The crankshaft is dynamically balanced and is provided with counterweights. All main bearings may be removed for inspection or replacement without disturbing the counterweights. However, if a counterweight is removed care must be taken to replace counterweight in the same location and exact position from which it was removed. The bolts securing the counterweight to crankshaft should be tightened with a torque wrench to 650 ft. lbs. *Caution:* Be sure to lock bolts in place after tightening by tack welding them, with stainless steel welding rod, to the counterweight.

MAINTENANCE

INSPECTION OF SHAFT

When any main or connecting rod bearings are removed, the crankshaft journals should be inspected. If any scratches, rough spots, or surface nicks are found they should be reconditioned with a fine oil stone. Do not use file or emery cloth. The stoning action should be applied in a direction around the journal and not across it.

The journals should also be closely checked for cracks. Under no circumstances should the engine be run if there is a crack in the shaft.



Engine Crankshaft

Figure 2

1. Counterweights 2. Coupling Bushings
3. Sprocket for Camshaft Drive Chain

REMOVING THE MAIN GENERATOR

If the generator must be removed from engine, the procedure is as follows:

a. On a supercharged engine remove the turbocharger and its air, water and lubricating oil piping which would interfere with the removal of the generator.

b. Disconnect the coupling between the air compressor and the generator.

c. Remove the generator coupling bolts, washers and barring ring. Then remove the generator coupling bushings from the flange by pulling them into a short length (approximately 3″) of 2″ std. pipe by using a 1½″—12 Am. Std. thread bolt and several washers.

d. Remove the bolts, nuts and dowels, which secure the generator to the engine bedplate and disconnect the generator leads.

e. Support the generator weight by slings and slide it toward the air compressor until it clears the spigot or centering disc on the end of the crankshaft flange. The generator may then be lifted from the locomotive.

ALIGNING THE MAIN GENERATOR TO ENGINE

Whenever a main generator is to be mounted, align the generator with engine as outlined below:

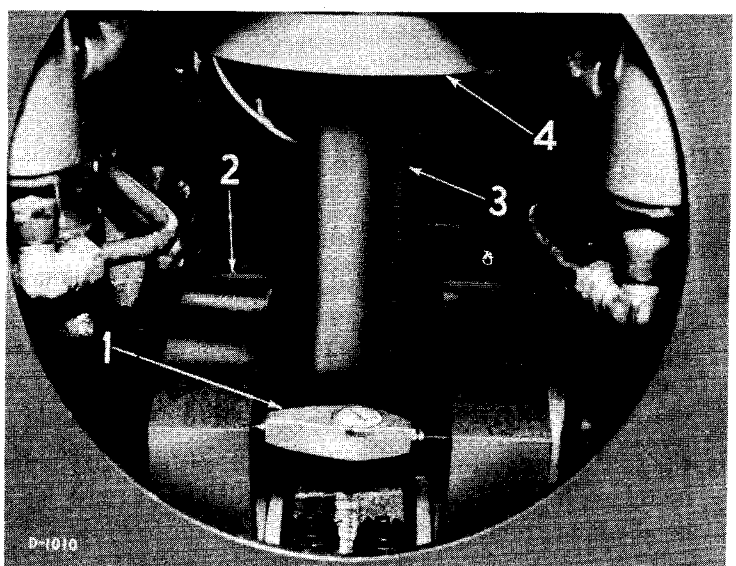
a. Inspect the joining faces of the generator armature shaft and the crankshaft. Remove any burrs or rough spots. Inspect the threads in the coupling bolt holes in generator shaft also threads on the bolts and make sure that the coupling bolts all turn freely in the holes.

b. Place the generator on the bedplate with 0.270″ shims underneath each mounting flange. All shims must be in good condition and free of burrs.

c. By the use of slings and a hoist move the generator up to the crankshaft and alter its position until the spigot or centering disc on the end of the crankshaft flange fits into the recess on the end of the generator shaft. Let the weight of the generator then settle on the engine bedplate. Line up the holes in crankshaft and generator shaft and install the generator coupling bushings, bolts, and lock washers. Before installing coupling bushings apply a suitable lubricant to the outside of each bushing.

d. Check camshaft drive chain and water pump drive chain to be sure that there is sufficient slack in the chains then install the bolts and nuts securing the generator to the bedplate. These bolts, also the generator coupling bolts, must be tight before starting to check alignment of generator.

e. Check the generator to crankshaft alignment by measuring the distortion of #1 crank of the crankshaft as it is rotated through one revolution. The distortion is determined by inserting a distortion gauge between the webs of the crankshaft, on the exhaust side of engine, at #1 cylinder. Be careful to place the gauge in a position as shown in Figure 3 with its axis parallel to the center line of the crankshaft. The gauge should be located as near the same position as



Measuring Deflection Between Crank Webs

Figure 3

1. Distortion Gauge **2. Crankshaft Web**
3. Connecting Rod **4. Piston**

possible for all measurements. Spin the gauge a few times to make sure that it is seating properly. A change in the gauge reading after spinning indicates that it was not properly seated in the crank webs. After any error due to reseating has been removed, bar the engine over until #1 crankpin is at bottom dead center position and set the dial of the distortion gauge to zero.

f. Bar engine over, from the valve gear side, through one revolution and record the readings at four positions 90° apart. For correct alignment the difference between the top and bottom dead center positions should not exceed 0.0005″ and the difference between the front and rear positions of the crank should not differ by more than 0.001″.

g. If the difference between the top and bottom dead center positions is greater than 0.0005″, remove mounting bolts and change amount of shims under the generator mounting flanges. Remove shims if the reading is plus, and add shims if the reading is minus, at the rate of approximately 0.005″ change in shim thickness for 0.001″ distortion.

h. After the generator has been correctly shimmed, another check should be made with the distortion gauge. If the difference between the top and bottom dead center positions is within the allowed limit, but the difference between the opposite horizontal positions of the crank is not within the allowed limit, loosen the mounting bolts and move the commutator end of the generator in the direction in which the crankpin is pointing when the gauge reading is the least. This corrects the misalignment in the horizontal plane.

i. All of the above checking is accomplished without using air pressure in the cylinder, therefore, it is necessary to make a final check on at least three cylinders (first, center and last) for proper alignment using air pressure as described under "Main Bearing Alignment." The generator coupling bolts and flange mounting bolts must be tight when the final distortion check is made.

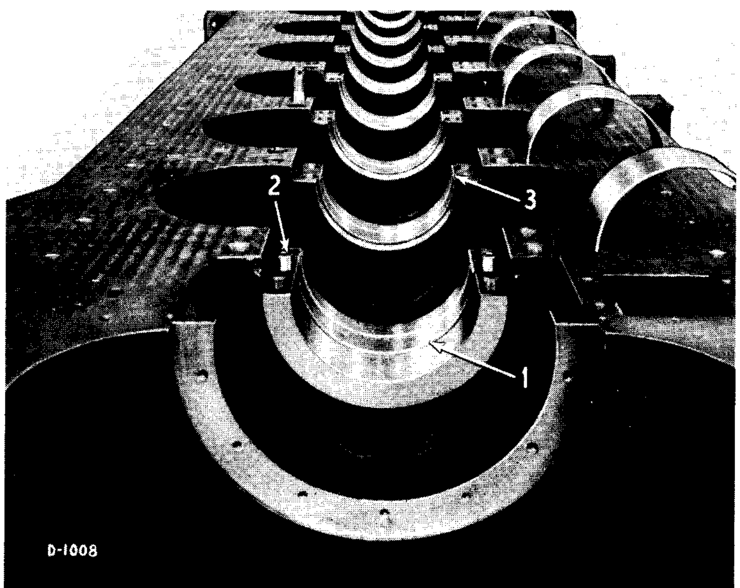
j. When the generator alignment is correct, the generator mounting flanges should be doweled to the bedplate. Drill and ream new dowel holes if necessary. If the original generator, shims and dowels are reinstalled, it may not be necessary to change the shim thickness or shift the generator, but this fact *does not* eliminate the necessity for checking alignment.

k. If the engine-generator unit complete has been removed from locomotive, check the alignment using air pressure in the cylinder after the unit is reinstalled in locomotive.

MAIN BEARINGS

DESCRIPTION

The main bearings are precision type with crush or press fit provided to insure good back contact and do not require shims between the shells or under the caps. These shells are not adjustable to take up for wear and must be renewed when the shell is worn below the low limit of thickness, or



Main Bearing

Figure 4

1. Main Bearing Shell **2. Dowel for Thrust Bearing Cap** **3. Locking Lip**

the clearance between the shaft and the shell is beyond the recommended limit (see Bearing Specifications). A bronze flange is attached to each side of the thrust bearing cap to serve as a thrust bearing. When a thrust flange is worn excessively it may be renewed.

Each bearing consists of two shells, the lower shell resting in the bearing saddle and the upper shell held in place by the bearing cap. The shells are located by a locking lip on each shell which fits into nesting slots in both the cap and saddle. The bearing thickness is held to close tolerances to insure proper running clearances and the bearings *should never be scraped.* Each shell is marked with a number to indicate its location and care must be taken to replace all shells in the correct position. The bearing caps are stamped with the bearing number on the shoulder of the cap and should be placed with the numbers on the valve gear side of the engine. The thrust bearing cap is stamped with a zero and the main bearing caps are numbered from the generator end.

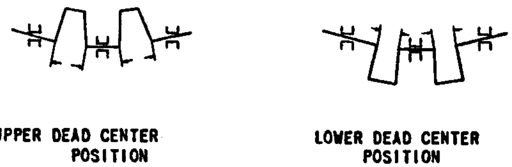
MAINTENANCE

MAIN BEARING ALIGNMENT

Proper alignment of bearings is important and should be checked at regular intervals. A method of checking the misalignment of the main bearings is by measuring the distortion of the crankshaft in one revolution of travel. It is suggested that the misalignment of all cranks be measured. Record all measurements in tabular form as outlined in Figure 5. This data may be used as a basis of comparison with subsequent checks to determine the presence of wear or condition of the bearings.

An increase in misalignment is only an indication of an undesirable condition and further checking is necessary to determine its cause although it usually warrants the removal and inspection of the main bearings. The procedure for checking alignment of main bearings is as follows:

a. Starting with #1 cylinder connect a pipe tee fitting and an air hose to the cylinder head indicator connection. Provide a pressure gauge at one outlet of the tee and a valve in the air hose line, refer to Figure 6.



EFFECT OF MISALIGNMENT OF MAIN BEARING

STRAIN GAUGE READINGS								
CYLINDER NUMBER	1	2	3	4	5	6	7	8
A - CRANKPIN IN BOTTOM POSITION WITH AIR	0	0	0	0	0	0	0	0
B - CRANKPIN IN BOTTOM POSITION • AIR RELEASED								
C - CRANKPIN IN FRONT POSITION (CAMSHAFT SIDE)								
D - CRANKPIN IN TOP POSITION WITHOUT AIR								
E - CRANKPIN IN TOP POSITION WITH AIR								
F - CRANKPIN IN REAR POSITION (MANIFOLD SIDE)								
G - DIFFERENCE FRONT AND REAR (C MINUS F)								

D 1003

Checking Alignment of Main Bearings

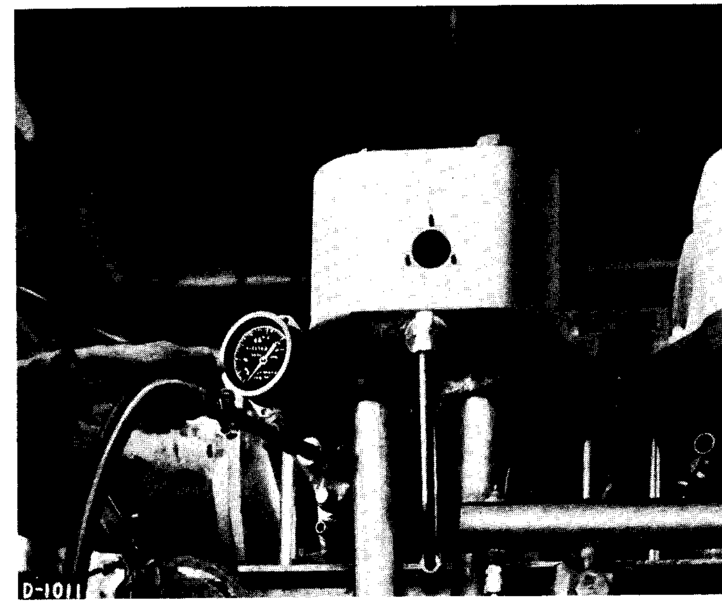
Figure 5

b. Loosen the valve tappets, remove the rocker arm fulcrum bracket stud nuts, and lift off the rocker arm assembly. This is to prevent the valves from opening during a complete revolution of the #1 crank. (For setting valve clearances when replacing rocker arm assembly see Section 7.)

c. Bar the engine over until the #1 crank is in its bottom dead center position. A bevel protractor held against the crank webs will give a sufficiently accurate setting.

d. Admit air to #1 cylinder and regulate the pressure to approximately 100 p.s.i. This will force the crankshaft to a firm seat in the bearings adjacent to the cylinder.

e. Place the distortion gauge between the webs of the crankshaft, on the exhaust side of engine, at cylinder #1 as described in item "e" Page 106, and set dial to zero with air pressure in the cylinder. This is reading "A" on chart.



Air Connection to Cylinder for Checking Bearing Alignment

Figure 6

f. Release air pressure and record reading. This is reading "B" on chart.

g. Bar engine over, from valve gear side, until crank webs are parallel with top of bedplate which would be 90° of rotation from bottom dead center and record reading. This is reading "C" on chart.

h. Bar engine over in same direction until crank is at top dead center. Check this position with a bevel protractor. Record the reading which in this case is reading "D" on the chart.

i. At this point it is advisable to place two steel or wooden blocks between the barring ring and the bedplate to prevent the crankshaft from rotating when air pressure is applied to the cylinder. Make sure that the reading "D" is not changed in the process of blocking the shaft.

j. Admit air to the cylinder (100 p.s.i.) and record the reading as shown on the chart as "E". Release the air pressure and unblock the crankshaft.

k. Continue barring engine in same direction until crank webs are again parallel with the top of the bedplate but on the opposite side from step (g). Record the reading as shown on the chart as "F".

l. The difference between the top and bottom positions with air, measurement "E", should not be more than +0.003". The difference between the front and rear positions should not be more than 0.0015", refer to "G" on chart. As the engine bearings wear, the measurement "E" will increase and a set of readings for all cranks might show one or two readings in excess of 0.003". This does not mean definitely that the bearings are defective but does warrant an inspection of the main bearings.

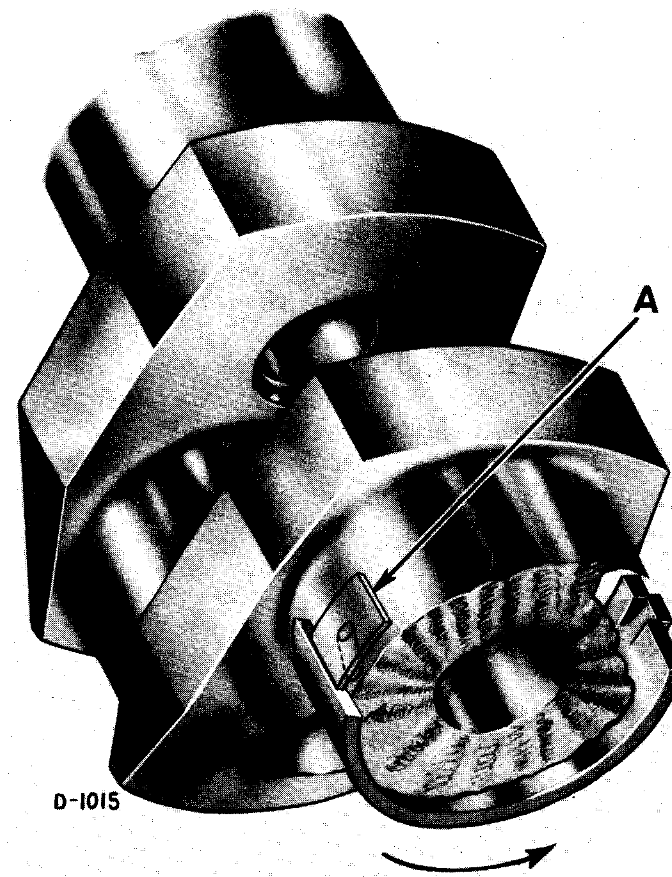
MAIN BEARING REMOVAL

a. Remove the lubricating oil supply line to the main bearing cap.

b. Remove the top nuts of the main bearing cap bolts and let the bolts drop into the crankcase.

c. Knock the cap loose with a lead hammer and lift it out through the crankcase opening. Remove the upper bearing shell. It is recommended that the chain housing be removed to facilitate removal and installation of the thrust bearing cap.

d. Bar the engine over, from valve gear side, until the oil hole in the crankshaft journal shows up and insert the main bearing removing tool "A" Figure 7 (use right hand or left hand tool as required B.L.H. Pt. No. 600-70-034 R.H. or 600-70-035 L.H.). *Warning*: Do not use any other tool or substitute as this will damage the bearing saddle and probably the shell and journal. Continue barring the engine over from the valve gear side until the lower shell is rolled out. For the lower shell in the center main bearing this procedure is varied by using the center main bearing removing tool (B.L.H. Pt. No. 600-70-036) and inserting it in the hole in the crankshaft journal. When removing more than one lower shell at a time, remove only every other one so that the crankshaft is never without proper support. *Do not attempt to turn crankshaft from the exhaust side of engine when removing a bearing shell.*



Method of Removing Bottom Shell

Figure 7

INSPECTION OF MAIN BEARINGS

Examine each shell for cracks, pitting, or foreign particles embedded in the bearing metal also check for evidence of bearing moving in cap. If there is any doubt about the condition of a shell, it should not be used again. With a ball end type of micrometer measure the thickness of each shell at various points to determine the amount of wear and whether it is wearing evenly. If it is not wearing evenly, check the crankshaft distortion by the method listed in this section. If the distortion is greater than the permissible 0.003″, check the chain and belt tensions on the crankshaft, and the generator and air compressor alignment. The specifications at the end of this section give the original and minimum shell thicknesses. A bearing shell that is worn close to its minimum thickness point or one that is wearing unevenly should be replaced. The main journals should be inspected at this time according to the crankshaft maintenance instructions on page 103. It is good practice at this time to check the lubricating oil strainers and filters for the presence of bearing metal. In case any bearing metal is found, all bearings (Main and Crank) will have to be inspected and the oil passages and crankcase flushed out. The above procedure should be followed if any bearing metal is found during routine filter and strainer cleanings. The frequency of main bearing inspection can be found on the maintenance schedule. When making a sampling inspection of main bearings, the condition of the center main bearing will usually indicate the condition of the other main bearings.

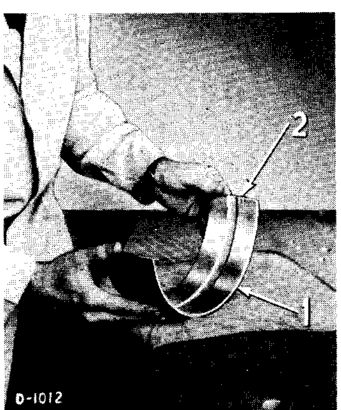


Figure 8

Examine Bearing Surface of each Shell

1. Shell **2. Locking Lip**

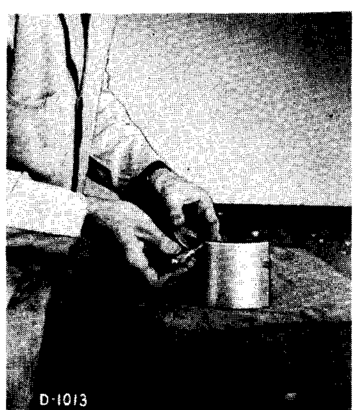


Figure 9

Measure Shell Thickness with a Ball End Type Micrometer

REPLACEMENT OF MAIN BEARINGS

a. Roll in the lower shells by hand if possible and only resort to using the bearing removing tool when necessary. Care must be taken to roll shell in the correct direction and to the correct position so that shell locking lip is not damaged.

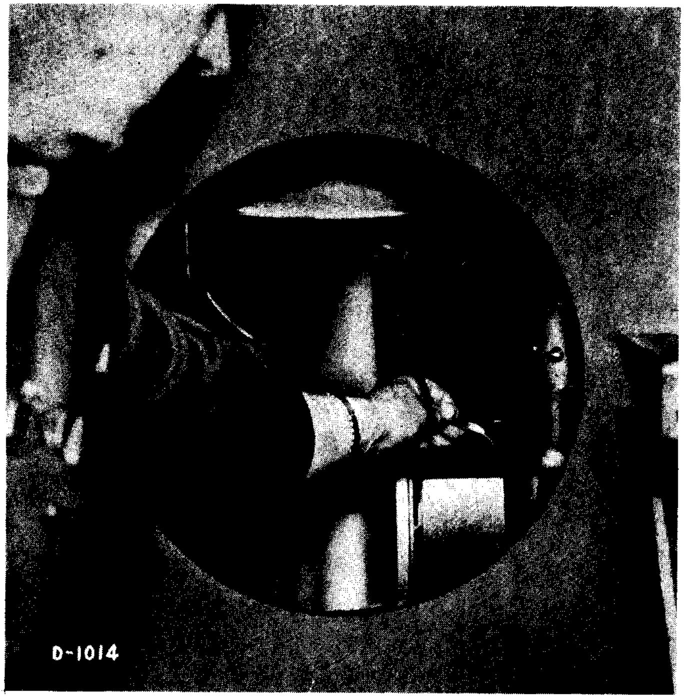
b. Replace the original bearing shells that are still usable on the same journals from which they originally came and in the same position. Do not put shells in backwards, see page 108 for details. Lubricate journals before replacing shells. If bearings have been in service for a long period it is not advisable to install new bearings in one or two cylinders and use original worn bearings in the other cylinders.

c. Replace the top shells in the proper bearing caps, then apply cap and shell assemblies. Use a lead hammer to force the cap down tight but be careful not to cock it in doing so.

d. Replace the nuts on the main bearing cap bolts and draw them up so that the cap is tightened down evenly. The nuts should be given a final tightening with a torque wrench to 500 ft. lbs. (B.L.H. Pt. No. for complete torque wrench set is 600-70-017.) The right and left hand wrench Pt. Nos. are 600-70-015 and 600-70-014 respectively.

e. Install the lubricating oil supply lines to the bearing caps.

f. Check the bearing clearances by inserting long bearing feelers between the crankshaft and the top shell at both ends of the bearing. Be sure that feelers are clean otherwise the bearing may be damaged. The clearances will be equal to the thickness of the largest feeler that can be easily inserted plus 0.001″. Feelers should also be inserted between the shaft and shell at the parting line to be sure that the shells are not pinched in during installation. The bearing cap bolts must be drawn up tight when measuring bearing clearances. The clearances are listed in the specifications at the end of this section.



Check Clearance with Feeler Gauge

Figure 10

g. It is not possible to get a feeler gauge between the crankshaft and the shell on the thrust bearing. In this case the bearing clearance must be determined by measuring the thickness of each shell with a ball end type of micrometer as described under "Inspection of Main Bearing."

Do not use lead wire or strips to check bearing clearances as they may distort the bearing lining and cause a bearing failure.

h. Check the main bearing alignment according to the method outlined on pages 109 to 112 for all cranks. The distortion for any crank should not exceed 0.003".

As outlined above the bearing clearances should all be within the specified limits and the distortion less than

0.003" before an engine is run after a bearing overhaul. The lubricating oil pressure should be closely watched when an engine is run after an overhaul.

SPECIFICATIONS

BEDPLATE

Main and thrust bearing bore diameter....	10.000"-10.001"
Length of thrust bearing saddle.........	6.997"- 6.998"
Width of recess in bearing saddles for bearing caps	13.624"-13.625"

CRANKSHAFT	New	Limit
Main and thrust journal diameter..	9.585"-9.586"	
Crankpin journal diameter.......	8.836"-8.837"	
Thrust bearing journal length.....	8.250"-8.252"	
*Out-of-roundness of journals and crankpins	0.0005"	.003"
Non-parallelism of journals and crankpins	0.0005"	
Squareness of flange face on a 21" diameter circle to center line of crankshaft	0.001"	

*If the crankshaft journals and crankpins are found to be out-of-round greater than .003" the crankshaft should be removed from engine and reconditioned as required. Standard undersize bearings may be obtained for use with a reconditioned shaft.

MAIN BEARINGS (Copper Lead)	New	Limit
Main and thrust bearing running clearance	0.006"-0.010"	0.014"
Main bearing shell thickness......	0.203"-0.204"	0.200"
Thrust bearing end clearance.....	0.008"-0.014"	0.030"
Thrust bearing flange thickness....	0.620"-0.622"	
Thrust bearing cap length including thrust flanges	8.237"-8.242"	

NOTES

FRAME

The frame is mounted on the bedplate and is a welded steel structure forming the upper part of the crankcase and the water jacket chamber. Bored seats are provided for supporting the cylinder liner. The water header is welded integral with the frame. A camshaft housing is welded to the side of the frame. Openings are provided for access to the crankcase and crankshaft bearings. Oil-tight covers close these openings. The frame is bolted to the bedplate along the outside flange and by four load carrying bolts inside at each main bearing.

MAINTENANCE

At any time that liners are removed from the frame, the water jackets should be thoroughly cleaned of scale and rust. Inspect the top liner seat of the frame for any evidence of cracks resulting from head pressure on the liner. Any pitting marks or rough spots on liner seats of the frame should be reconditioned as outlined in liner section of this manual. Also check the cylinder head studs for evidence of cracks.

If the frame has been removed from bedplate or a new frame is to be installed on a bedplate the following procedure should be followed:

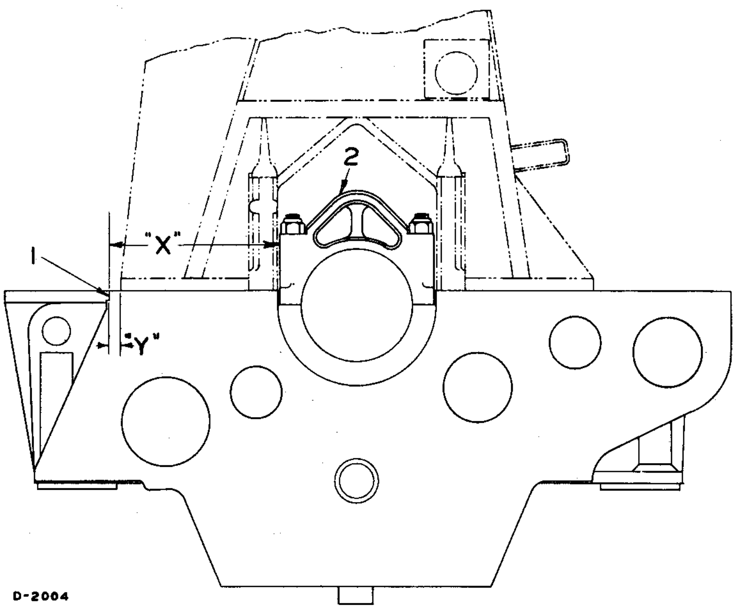
a. Clean top of bedplate thoroughly and apply a new gasket. Permatex may be used to hold gasket in place.

b. Measure distance "X" (Figure #1) which is the dimension from the machined surface on side of main bearing cap to machined edge on valve gear side of bedplate.

c. Lower frame on bedplate and align pump end of frame with pump end of bedplate.

d. After frame has been lowered on bedplate check dimension "Y" at center line of the first and last cylinders. This dimension must be the same at both of these locations and equal dimension "Y" Figure #1 ("Y"="X"—14 3/16"). Move frame as required to obtain correct location.

e. Tighten frame bolts by means of a torque wrench to the torque values as listed on page 24 of this manual.



Installing Frame on Bedplate

Figure 1

1. Machined Edge on Bedplate **2. Main Bearing Cap**

CYLINDER LINER

The cylinder liners are made of alloy cast iron and are fitted into the upper section of the frame. A copper gasket at the top and rubber rings at the bottom seal the liner in the frame to form a water jacket. The liner bores are chrome-plated to reduce wear and lengthen the life of the liner.

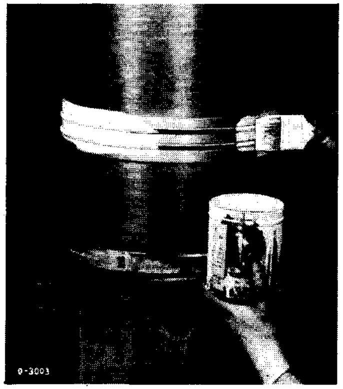
MAINTENANCE

A liner should not be removed except for replacement or cleaning of water jacket or for reconditioning of liner seating joint in frame.

Before removing a liner, mark top of liner and frame so that liner may be reassembled correctly. Drain water from frame jacket and rig up a trough of canvas or heavy paper inside of crankcase to catch any dirt that may fall when removing liner. Liner removing fixture B.L.H. Pt. No. 60-70-030 may be used for removing liner, refer to Figure 3.

After liner is removed from frame, clean the outside of liner of scale and dirt deposits, also clean water jacket space in frame. If liner seat in frame shows any pitting marks or rough spots, it should be reconditioned by scraping and coarse lapping as required. If the liner has been in service for a long period a shoulder may have developed in the upper end of the liner bore. This shoulder must be removed before reinstalling liner.

Clean Outside of Liner
Figure 1

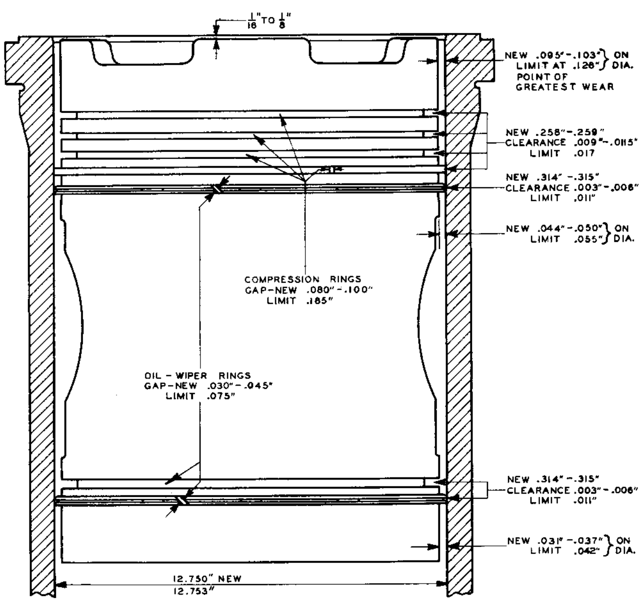


Paint over Rubber Rings
Figure 2

Bar piston to top position of stroke and remove connecting rod bolts. Insert an eye bolt in tapped hole in piston top, attach hoist and pull piston and rod assembly. When hoisting piston, care must be exercised to prevent end of rod from touching and scratching liner bore.

Set each piston with rod on blocks preferably in a vertical position. Care should be taken to keep all parts for each piston and rod assembly together to facilitate reassembly.

Remove piston rings. Remove piston pin end plugs. Support connecting rod so piston pin can be pushed out, after which rod is removed from the piston. Clean all piston and connecting rod parts. Remove carbon from ring grooves. Clean oil passage through center of connecting rod, also clean the oil holes and connecting grooves in piston pin bushing. Make sure oil drain holes in piston oil wiper ring grooves are clean. Use an air jet for cleaning oil holes and grooves. Use a cleaning solvent to slush out the oil passages in the piston pin and cooling coils in piston.



Piston and Piston Ring Clearances

Figure 2

SPECIFICATIONS

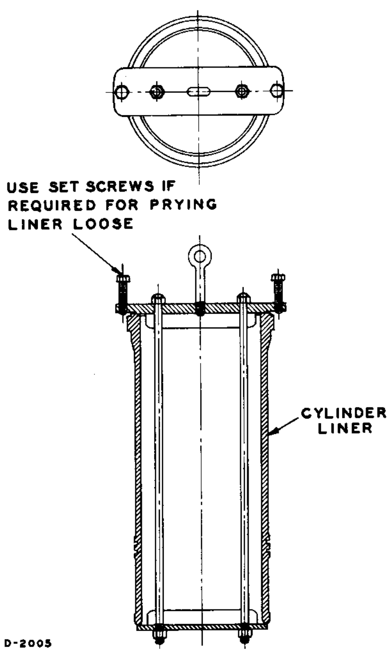
LINER BORE	New	Limit
Diameter	12.750"-12.753"	12.778"
Out-of-round	Not more than .0015"	.004"
Taper	Not more than .002" (in length of liner)	.004"

The limit of 12.778" listed above is the recommended wear limit measured at the point of greatest liner wear. If other wear factors such as condition of valves, rings and pistons, which also affect compression pressures, are held within satisfactory limits it may be possible to operate an engine with liners worn in excess of this limit. However, if liners are worn, it is necessary to make frequent checks on compression pressures in order to assure good combustion. Satisfactory combustion will result if compression pressures can be maintained at 450 p.s.i. or higher.

After checking seat in frame, liner with gaskets may be installed. Both sides of gasket are to be coated with white lead and oil (free of grit or any other foreign matter). Never re-use old copper or rubber gaskets.

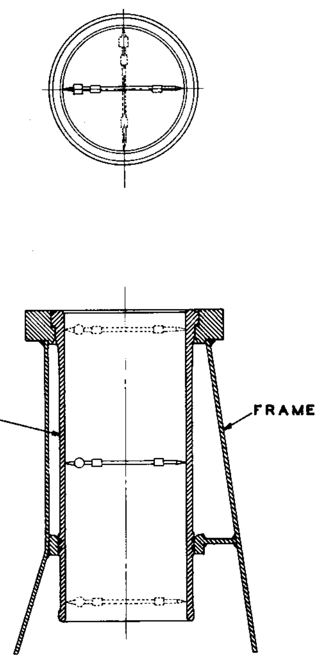
Adjust rubber seal rings evenly around the liner. This prevents pinching of the rings and distortion of liner. Paint over the rings with white lead and oil as an extra precaution against leaking.

After liner is in place, determine the bore at the top, center and bottom in planes parallel to and right angle to centerline of crankshaft, refer to Figure 4. The out-of-roundness should not exceed limits as specified at end of this section. The water passages in the frame should be subjected to a hydrostatic test at a pressure of 60 p.s.i. after replacing any liners.



Liner Removal Fixture

Figure 3



Method of Checking for Roundness of Liner

Figure 4

SPECIFICATIONS

LINER BORE	New	Limit
Diameter	12.750"-12.753"	12.778"
Out-of-round	Not more than .0015"	.004"
Taper	Not more than .002" (in length of liner)	.004"

The limit of 12.778" listed above is the recommended wear limit measured at the point of greatest liner wear. If other wear factors such as condition of valves, rings and pistons, which also affect compression pressures, are held within satisfactory limits it may be possible to operate an engine with liners worn in excess of this limit. However, if liners are worn, it is necessary to make frequent checks on compression pressures in order to assure good combustion. Satisfactory combustion will result if compression pressures can be maintained at 450 p.s.i. or higher.

NOTES

PISTON AND CONNECTING ROD

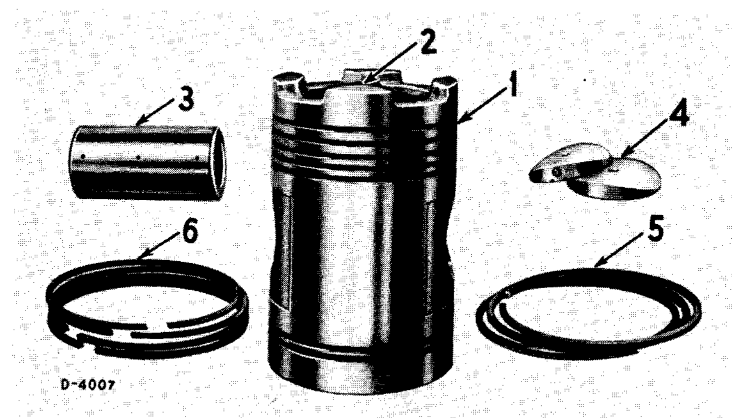
The pistons are aluminum alloy castings with a steel cooling coil cast into the crown. Each piston is equipped with four compression rings and three oil wiper rings. One oil wiper ring is located above the piston pin and two below the piston pin.

The piston pin is of the full floating type. Plugs fitted into the piston limit the end-wise movement of the piston pin.

The connecting rod is a drop forging, drilled its length for piston pin lubrication and piston cooling oil. The connecting rod cap is a steel forging bolted to the rod with four bolts. Each crank pin bearing consists of two precision type shells. The shells are located by a locking lip on each shell which fits into nesting slots in both the cap and rod. The piston pin bearing is a solid bronze bushing pressed into the eye end of connecting rod.

MAINTENANCE

After removing cylinder heads but before removing pistons, clean upper end of liner bore if carbon deposits are excessive. Cover top of piston to prevent any carbon or grinding particles from entering between piston and liner.



Piston Assembly

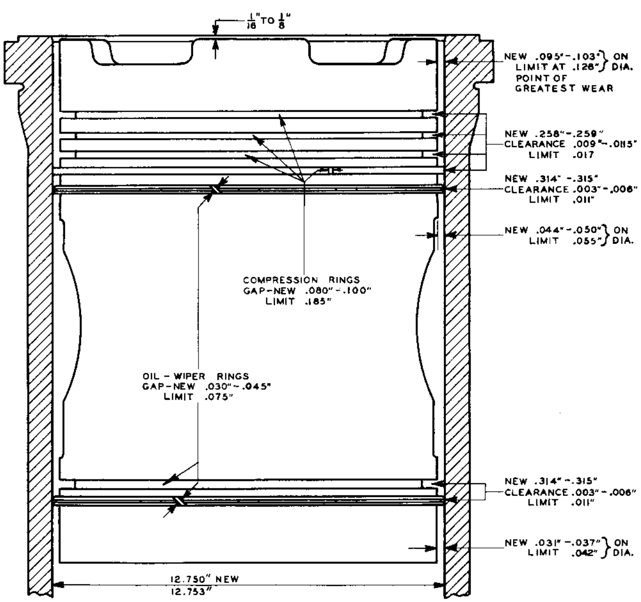
Figure 1

1. Piston
2. Tapped Hole for Lifting
3. Piston Pin
4. Piston Pin End Plugs
5. Oil Wiper Rings
6. Compression Rings

Bar piston to top position of stroke and remove connecting rod bolts. Insert an eye bolt in tapped hole in piston top, attach hoist and pull piston and rod assembly. When hoisting piston, care must be exercised to prevent end of rod from touching and scratching liner bore.

Set each piston with rod on blocks preferably in a vertical position. Care should be taken to keep all parts for each piston and rod assembly together to facilitate reassembly.

Remove piston rings. Remove piston pin end plugs. Support connecting rod so piston pin can be pushed out, after which rod is removed from the piston. Clean all piston and connecting rod parts. Remove carbon from ring grooves. Clean oil passage through center of connecting rod, also clean the oil holes and connecting grooves in piston pin bushing. Make sure oil drain holes in piston oil wiper ring grooves are clean. Use an air jet for cleaning oil holes and grooves. Use a cleaning solvent to slush out the oil passages in the piston pin and cooling coils in piston.



Piston and Piston Ring Clearances

Figure 2

Inspect piston skirt, if any rough spots are found they should be removed by using fine emery cloth and oil. Be sure to wash off all grit after using emery. Check piston diameter and clearances in liner at top and bottom. Check clearance of rings in grooves. If clearances of rings are not within limits specified in Figure #2 the grooves should be refinished and oversize width rings installed. The end gap clearance should be checked when ring is inserted in a true horizontal plane in cylinder near the bottom.

Inspect piston pins and bushings for wear. The clearance for pin in bushing should be not less than .005″ or more than .008″ on diameter. Check also clearance of pin in bores of piston. This clearance should not exceed .002″. Installing the piston pin requires considerable care. The pin must not be forced. Tap pin gently with a soft hammer and rotate until it can be pushed into place by hand.

The piston pin end plugs are fitted in the piston counterbores with an interference fit of 0.001″ to 0.0025″. Plugs may be placed in a can of dry ice for approximately ½ hour

Installing Piston

Figure 3

1. Piston Ring Guide

prior to insertion into piston counter-bores. Plugs must be reinstalled in the places from which they were removed. After insertion, plugs should be held against shoulder of counter-bore, until plugs are tight. Do not file outside diameter of plugs to facilitate application to piston.

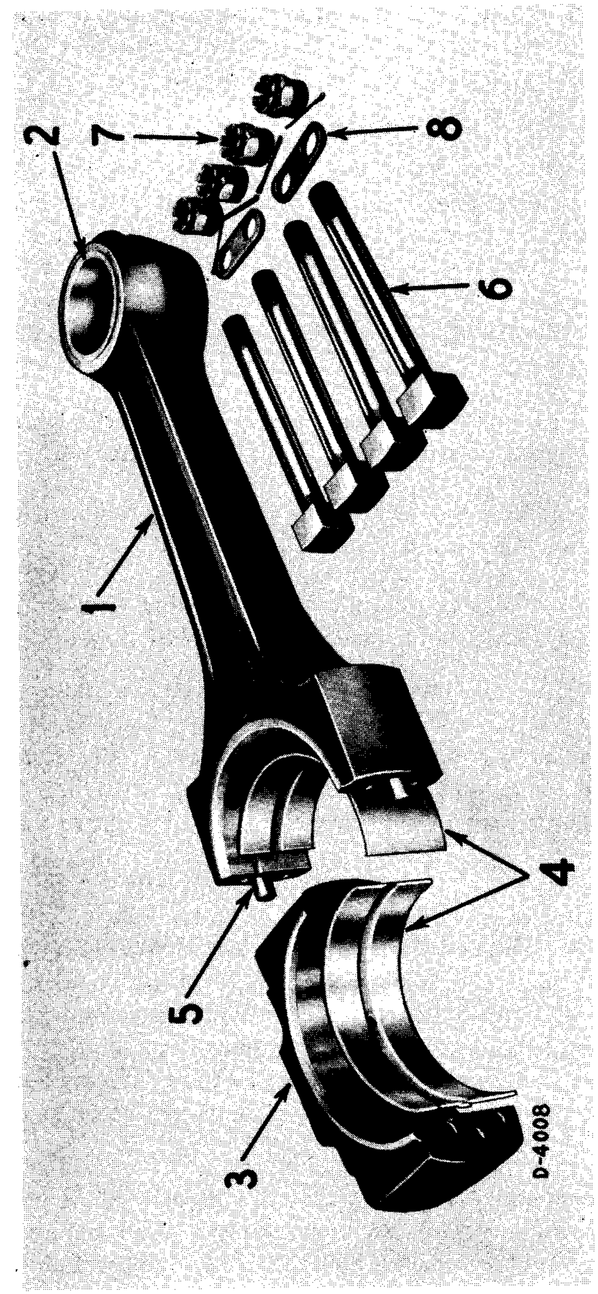
The measurement of pistons for wear or roundness must be done with the plugs in place.

When replacing piston in cylinder, place piston ring guide (B.L.H. Pt. No. 600-70-103) on top of cylinder liner, apply a liberal amount of new lubricating oil to the piston skirt and rings, then lower piston slowly into cylinder taking care that rings are not damaged.

The crankpin bearings are precision type with crush or press fit provided to insure good back contact and do not require shims between the shells. These shells are not adjustable to take up for wear and must be renewed when the shell is worn below the low limit of thickness or the clearance between the shaft and the shell is beyond the recommended limits. (See Bearing Specifications listed at the end of this section.)

The crankpin bearing shells should be carefully inspected. If there is any doubt about the condition of a shell, it should not be used again. With a ball end type micrometer measure the thickness of each shell at various points to determine the amount of wear. A bearing shell that is worn close to its minimum thickness should be replaced. If any rough spots or scratches are found on crankpins, they should be reconditioned with a fine oil stone. Do not use file or emery cloth. The crankpin bearing clearance should be checked, when the rod and piston are assembled in the engine, by inserting long bearing feelers between the crankpin and the top of the shell at both ends of bearing. The connecting rod bolts must be drawn up tight when checking clearances.

If new shells are to be installed, a careful inspection should be made to be sure that the locking lips on shells are in the correct position and the shells fit properly into the connecting rod foot and cap. Also check that the bearing has the proper clearance. Push the top and bottom shells firmly into the connecting rod foot and cap. Do not file or scrape joint



Connecting Rod Assembly
Figure 4

1. Connecting Rod
2. Piston Pin Bushing
3. Connecting Rod Cap
4. Crank Pin Bearing Shells
5. Dowel Pin
6. Connecting Rod Bolts
7. Connecting Rod Bolt Nut
8. Connecting Rod Washer

faces or shells. When the crankpin bearing is finally assembled the two shells will be forced to a firm seat around the entire peripheral area when the bolts are drawn up.

Connecting rod bolts should be carefully inspected. If any defects, such as cracks or evidence of stretching are revealed, bolts should be replaced. Connecting rod bolts which are known to have been abused or overtightened must be replaced. In the event a piston seizure should occur, it is advisable to replace all the rod bolts in that particular cylinder. Filing or grinding of connecting rod bolts must not be permitted under any circumstances.

Each time a piston and rod assembly is removed the liner should be inspected and measured. (See liner instructions.)

When reassembling the piston and connecting rod in the engine, the following routine should be followed:

a. All wearing surfaces of piston, liner, piston-pins, crankpins and bearings should be covered liberally with new lubricating oil.

b. Connecting rod bolts should be reassembled in the same place as originally located. Bolts, nuts and connecting rods are marked for ease of reassembly. Washer, "8" Figure 4, must be installed with the chamfered edge adjacent to the machined radius on the connecting rod.

c. Tighten bolts evenly, drawing up on each bolt only a fraction of a turn each time. Do not sledge. When drawn up properly the total stretch of each bolt should be .010"-.011" measured from end to end of bolt. Measurements must be taken before and after tightening at exactly the same points and as close as possible to the center of the bolt. If a torque wrench is used, tighten the bolts to a torque value of 500 ft. lbs.

d. After pistons and connecting rods are assembled in engine and bolts drawn up, bar engine over a few turns and check that crankpin bearings move freely on the crankpins.

When starting, observe operating routine recommended on pages 16 and 17.

SPECIFICATIONS

PISTON

	New	Limit
Diameter at top	12.655"-12.650"	
Diameter just below upper wiper ring	12.706"-12.703"	
Diameter at bottom	12.719"-12.716"	12.710"
Diameter of piston pin bore	5.1245"-5.125"	

PISTON PIN

	New	Limit
Diameter	5.123"-5.1235"	5.120"
Bearing Clearance	.005" to .008"	.010"
Clearance of pin in piston	Must not exceed .002"	

CONNECTING ROD

PISTON PIN BUSHING

	New	Limit
Interference, bushing to rod	.001" - .002"	
Bore diameter after pressing in rod	5.1295"-5.1305"	5.134"

CRANKPIN BEARING (Copper Lead)

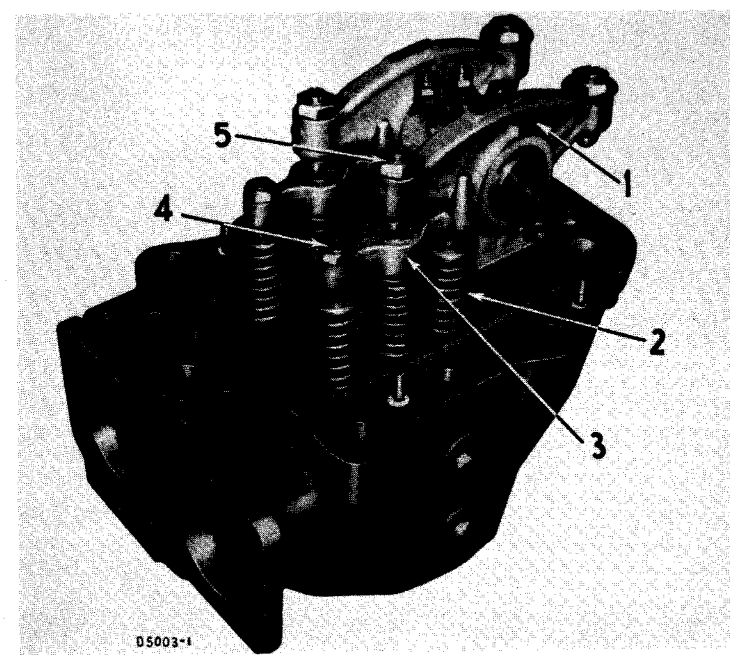
Diameter crankpin journals	8.836"-8.837"	
Rod bore for crankpin bearing shell	9.250"-9.251"	
Bearing Shell thickness	.203"- .204"	.200"
Clearance bearing to crankpin	.005"- .009"	.014"

NOTES

CYLINDER HEAD

The cylinder heads are made of alloy cast iron and are attached to the frame by alloy steel studs. Each head is provided with two air intake valves and two exhaust valves. Fuel injector and indicator valve openings are also provided in each head. Aluminum covers enclose the valve gear mechanism. Removable jumpers carry cooling water from the frame into the head.

The air intake and exhaust valves are alloy steel, mounted in removable valve guides. A valve bridge under each of the rocker arms actuate the valves. The rocker arms are mounted on brackets attached to cylinder head and are actuated from the camshaft by means of cam followers and push rods. The push rods are enclosed in tubular casings. Valves, rocker arms and push rods are lubricated from the engine pressure system.



Cylinder Head
Figure 1

1. Rocker Arm
2. Valve Spring
3. Valve Bridge
4. Valve Bridge Adjusting Screw & Lock-Nut
5. Tappet Adjusting Screw & Lock-Nut

MAINTENANCE

The following procedure should be followed in removing cylinder heads:

a. Remove cylinder head cover lid.

b. Disconnect and remove fuel injection pipe.

c. Remove cylinder head cover.

d. Drain the water jacket so that water level in engine is well below the cylinder heads. Remove all water connections. Remove exhaust header and air intake header bolts.

e. Remove rocker arms and supporting bracket from cylinder head as a unit. Push rods can then be lifted out through the openings in cylinder head. Remove push rod casings by removing bottom and top flange bolts. Flanges can then be slipped up and down on tube so that tube can be lifted slightly and pulled out at the bottom.

f. Disconnect lubricating oil pipe on front of cylinder head.

g. Disconnect and remove fuel drain piping. Remove fuel injection valve from head.

h. The cylinder head can now be lifted off after removing cylinder head stud nuts. Immediately after removing head, cover cylinder opening to prevent dirt from entering.

i. Completely dismantle rocker arms and valves.

After all parts are completely disassembled they should be thoroughly cleaned. All parts should be checked for wear and defects.

Rocker arm bearings should be checked for clearance. If clearance is not within specifications as listed at end of this section, bushings should be replaced.

VALVES

Before grinding valves, the valve stems and valve stem guides should be inspected for scoring or excessive clearance. If replacement of guides is deemed necessary this should be done *before* valve grinding. Slight scoring of valve stems can be stoned smooth. Inspection of valves and valve seats will determine whether valve seat grinding is necessary.

Improper seating or excessive wear should be corrected by grinding. If the seats on the exhaust valve and cylinder head show pitting marks, these should not be removed by grinding unless seats show excessive wear or valves are not seating properly. Such pitting marks may appear after a relatively short operating period, but usually will not develop further after prolonged operation. Valve seats which show excessive wear should be reconditioned with a valve seat grinder.

Inspect valve springs for defects such as fine cracks or reduced free length. Springs must not show any set after being compressed with coils touching. Free length should be as specified at end of this section. Replace any springs which appear defective or have taken a permanent set.

When reassembling valves in cylinder head, care should be taken not to interchange exhaust and intake valves. Cover valve stems with new lubricating oil when inserting in valve guide bushings. Height of outer valve springs in place should be 4½ inches.

INSTALLING CYLINDER HEADS

a. Make sure that the liner seats properly all around in the frame. Check the side clearance of liner in frame at the top using feeler gauges inserted between the shoulder section of liner and the bore at top of frame. At no place should this clearance be less than .005″.

b. Apply a new cylinder head gasket of the proper thickness. Gasket should be inspected carefully to make sure it is free from defects.

c. Inspect the guide section (commonly termed "Spigot") on bottom face of cylinder head. This spigot surface must be free from indentations and dirt.

d. Inspect the threads of cylinder head studs and nuts carefully and make sure that all nuts turn freely on the studs. If the threads are damaged, recondition same with die or tap. Apply graphite mixed with lubricating oil to the threads on studs and nuts at final assembly.

e. Place cylinder head on engine and check that spigot registers in cylinder liner on top of gasket. Care should be taken that cylinder head is seating free and level.

f. Partly tighten the header bolts. Hand tighten the cylinder head nuts using a short open end wrench. The nuts should be tightened a fraction of a turn at a time, drawing up on every second nut in rotation so as to tighten head down evenly.

g. Check space between top of frame and head at four opposite places. If the clearance at the four points is not uniform within a 1/32", loosen the head nuts and retighten so that the head goes down evenly.

h. The cylinder head nuts should then be tightened to 1200 ft. lb. torque by means of a torque wrench. A torque wrench kit (B.L.H. Pt. No. 600-70-017) has been especially designed for this purpose. The tightening should be done in three steps, 400, 800 and 1200 ft. lb. torque and in the sequence described in paragraph "f" above. Complete tightening of header bolts.

i. When tightening the nuts do not jerk the torque wrench handle, but apply a steady pull.

j. Reassemble push rod casings and insert push rods. Assemble rocker arms to cylinder head. Adjust valve tappet clearance as outlined in paragraphs "a" to "e" inclusive of Engine Timing Section. Each valve bridge has one adjustable tappet screw. This must be set to give same clearance as other end of bridge with solid tappet.

k. Install fuel injector and connect all fuel and lubricating oil piping.

l. Reassemble the water jumper connections and reconnect water piping.

m. Cover all valve gear with a liberal supply of lubricating oil.

n. Before assembling cylinder head cover lid, operate the engine for several minutes and check that oil flows to all valve gear bearings.

o. After the assembly is completed it is advisable to operate the engine for at least four hours until engine is thoroughly warmed up (150° F. cooling water temperature) preferably under load, and then again tighten the cylinder head nuts as outlined above. In order to thoroughly warm up the engine, it may be worked for a day or two before retightening the cylinder head nuts. *Use a torque wrench only for this final tightening.*

The torque wrench, when not used, should be kept in the box so as to protect same from damage.

Do not attempt to stop a blowing cylinder head by means of tightening one or two cylinder head nuts only. If a leak occurs, remove the head and check the seating condition of cylinder head. Also replace the gasket. Retighten the nuts by means of a torque wrench as outlined above.

SPECIFICATIONS

VALVE BUSHINGS	New	Limit
Inside Diameter	.875″-.876″	
Bushing to head—interference	.0005″-.00015″	

VALVES		
Diameter of stem	.868″-.867″	
Clearance—stem to bushing	.007″-.009″	.013″
Valve seat angle	45°	
Diameter of head	4 3/16″	
Lift	.938″	

VALVE SPRINGS, OUTER		
Free length	5 1/4″	
Length—valve closed	4 1/2″-131 lbs.	
Length—valve open	3 9/16″-295 lbs.	

VALVE SPRINGS, INNER		
Free length	4 7/16″	
Length—valve closed	3 1/2″-43.6 lbs.	
Length—valve open	2 9/16″-87.2 lbs.	

VALVE BRIDGE SPRING		
Free Length	5 1/4″	
Length—valves closed	4 3/8″-153 lbs.	
Length—valves open	3 7/16″-317 lbs.	

ROCKER ARM		
Bushing to rocker arm—interference	.001″-.004″	
Inside diameter of bushing—after pressing in rocker arm	2.998″-2.999″	
Diameter of shaft	2.996″-2.995″	
Clearance—bushing to shaft	.002″-.004″	.006″

VALVE AND CYLINDER HEAD GRINDING SPECIFICATIONS		
Thickness of valve head at outer edge	3/32″	3/64″
Depth of seat in cylinder head	5/16″	9/16″*
Width of valve seat	1/4″	

*Using a new valve. Limit is 33/64″ using a remachined valve.

CAMSHAFT AND CAMSHAFT DRIVE

The camshaft is made up in two sections bolted together at the center. Each section is removable from the valve gear side of engine. The cams are integral with the shaft. The camshaft is supported in precision type bearing shells mounted in the fuel pump supporting bracket. A thrust bearing is provided for the camshaft at the generator end of engine. The camshaft is hollow drilled to provide for pressure lubrication of all camshaft bearings.

The camshaft is driven from the crankshaft by means of a roller chain and sprockets located at the generator end of engine. An idler sprocket is used for maintaining chain tension. Lubrication is provided by a pressure spray nozzle directed at the chain.

MAINTENANCE

The camshaft bearings should be checked for clearance with a feeler gauge. Also check camshaft thrust bearing clearance.

A camshaft bearing may be replaced by removing bearing cap and lower shell and rotating upper shell around shaft. New bearing shells are applied in the reverse order. Since the camshaft bearings are readily accessible, it should not be necessary to remove the camshaft except if its condition requires replacement.

If either or both halves of the camshaft require removal, the following procedure is necessary:

a. Remove chain drive housing, chain and camshaft sprocket. Also remove camshaft thrust bearing bracket.

b. Remove cylinder head top covers, rocker arms and brackets, push rods and push rod casings.

c. Remove governor and overspeed stop.

d. Support camshaft on wooden blocks resting on bottom of camshaft trough and remove bearing caps and shells. Remove camshaft follower brackets.

e. Disconnect camshaft joint at center of engine. Either half of camshaft can then be moved toward end of engine and lifted out through front opening of camshaft casing.

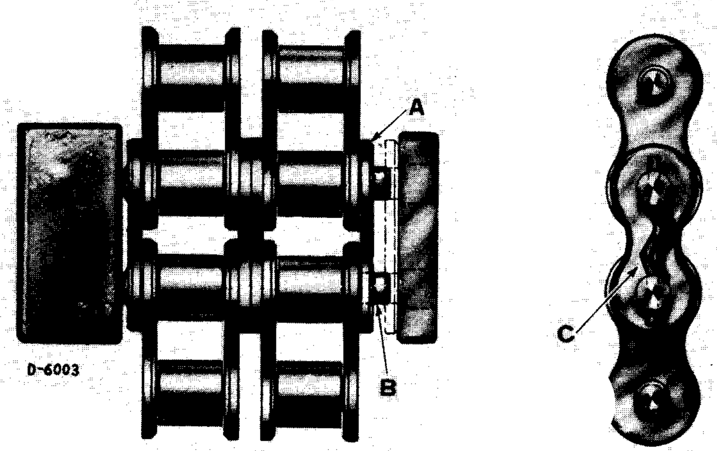
CHAIN DRIVE

The camshaft chain drive should be inspected periodically for wear and tension adjustment. In order to check the tension, remove inspection opening cover plate on chain casing and apply strong hand pressure to center of longest chain span. The total movement or slack should be approximately ¾". It is not necessary to remove chain drive casing to check chain tension.

Chain tension is adjusted by the idler sprocket. After loosening the adjusting screw locking flange located on the valve gear side of bedplate, the adjusting screw can be turned until the chain slack is taken up. Tighten the locking flange and recheck tension. Repeat if necessary until chain is properly adjusted. The locking flange must be drawn up tight after final adjustment is made.

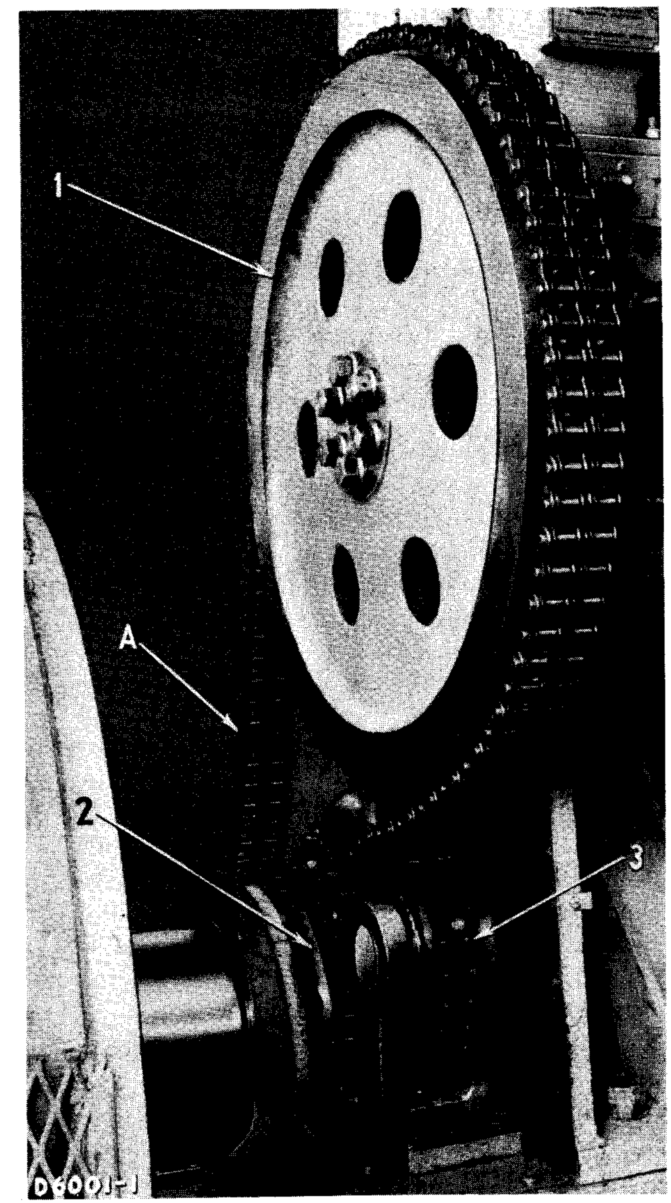
After chain tension has been readjusted, the engine should be barred over at least two revolutions in direction of normal rotation to make sure that tension is not greater than desired at any position of sprockets.

After the full range of idler sprocket adjustment has been utilized, a new chain should be installed. Do not use an offset or half link in the chain.



Removable Link in Camshaft Drive Chain

Figure 1



Camshaft Chain Drive

Figure 2

1. Camshaft Sprocket **2. Crankshaft Sprocket** **3. Adjustable Idler Sprocket**

When a new chain is installed, it should be installed with the proper slack at point "A", see Figure 2. The chain may stretch during the first few days of operation, therefore, the tension in a new chain must be checked after approximately 150 hours operation, and the chain adjusted as required. This also applies to the chain in a new engine.

The chain furnished with the engine has a removable link, see Figure 1. The link side plate "A" should fit very tightly on the pins "B", and it will be necessary, when assembling the link, to drive the side plate in place by using a heavy steel plate, as illustrated in Figure 1. The side plate "A" is secured in place by means of a heavy lockwire "C" or by special alloy steel cotter pins. Secure the lock wire by crimping. After the lockwire is in place, tap lightly on ends of link pins "B" in order to obtain proper clearance for end plate.

Lubrication of the chain should be checked, whenever the inspection cover on chain casing is removed, to be sure that oil is sprayed properly on the chain. Remove and clean nozzle if spray is not sufficient. It is advisable to check the engine timing as described in the next section after making any adjustments to the chain.

SPECIFICATIONS

CAMSHAFT

	New	Limit
Journal diameter	3.4955″-3.4965″	
Bearing shell thickness	.0855″-.0860″	
Bearing clearance	.003″ - .006″	.010″
Thrust bearing clearance (lateral).	.006″ - .010″	.025″

CAMSHAFT DRIVE IDLER

Bushing to idler—interference.....	.002″ - .004″
Diameter of shaft...............	1.999″ -1.998″
Clearance	.004″ - .006″

ENGINE TIMING

For intervals at which the engine timing should be checked consult your maintenance charts. The camshaft drive chain will increase slightly in length due to stretch and wear which will cause the valve timing to become gradually late. Therefore the timing must be adjusted to compensate for the increased length in the chain. In a new engine or after a new chain has been installed the timing should be checked after about 10,000 miles.

The engine timing is controlled by three cams which operate the fuel injection pump, intake and exhaust valves. The cams for all cylinders are made integral with the camshaft and located in exact positions relative to each other. Therefore, it is only necessary to inspect and adjust the opening position of the valves on No. 1 cylinder. However, the valve tappet clearance for all valves should be set according to the method outlined in paragraphs "a" to "e" below. The tappet clearances must be adjusted to comply with clearances specified at the end of this section.

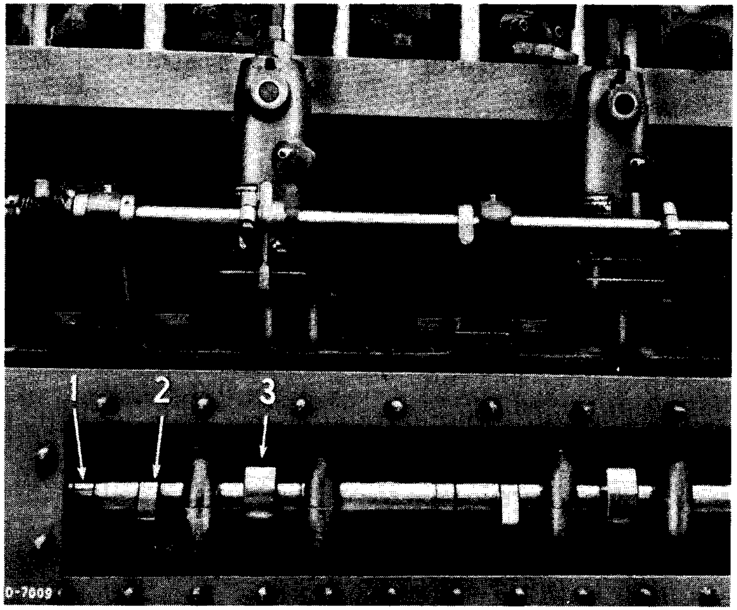
Before inspecting and adjusting the timing it is important to check, and correct if necessary, the camshaft drive chain tension. This operation is described in the preceding section.

The timing of valves may be inspected and adjusted as follows:

a. Bar the engine over so that the exhaust valves on No. 1 cylinder are closed (cam roller on low portion of the cam). The piston must be on the expansion stroke when inspecting the exhaust valve opening position.

b. With a feeler gauge of correct thickness as specified at end of this section, check the valve tappet clearance "1" and "2" under each end of valve actuating bridge "3." See Figure 2. The clearance should be 0.025″ at points "1" and "2."

c. If the above checking indicates an adjustment is necessary, loosen lock nut and back out adjustable tappet screw "4" in one end of bridge approximately ⅛ inch. Opposite end of bridge has solid non-adjustable tappet pin "5."



Camshaft

Figure 1

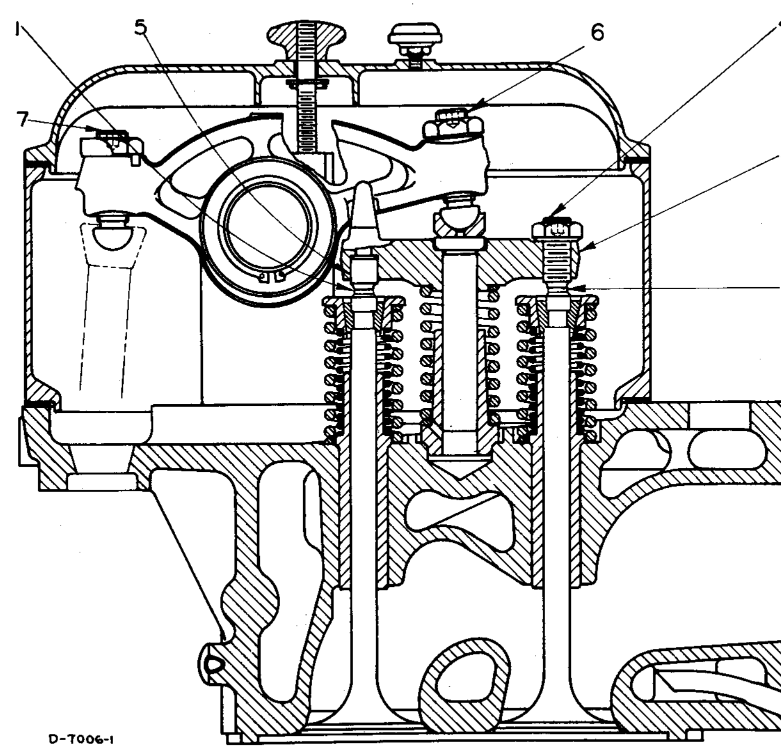
1. Inlet Cam
2. Exhaust Cam
3. Fuel Cam

d. Adjust screw "6" up or down to obtain correct clearance between valve stem and solid tappet pin "5" on bridge. Do not change screw "7" as long as lockplate is securely crimped in place.

e. The adjustable tappet screw "4" in bridge should then be adjusted to give same clearance between valve stem as opposite end of bridge. Lock tappet screw.

f. Bar engine over slowly in direction of normal rotation until valve bridge pressure pins just touch the valve stems. This is the actual opening position of the valves.

g. Ascertain from markings on the generator fan or by means of a bevel protractor on side of crank cheek of No. 1 cylinder, whether or not the timing of the valve is correct. The timing should not be more than one degree earlier or one degree later than specified. If the bedplate is not level, the protractor reading should be corrected accordingly.



Valve Tappet Adjustment

FIGURE 2

h. In the event the valve timing is not within proper limits, it may be corrected by changing the angular relation between the camshaft and the camshaft chain sprocket. Bar engine over to the position at which the valve should begin to open. Block the crankshaft in this position. Remove the lockwire and loosen camshaft sprocket bolts sufficiently to permit angular movement of the camshaft with respect to the sprocket.

If the timing is to be advanced, turn the camshaft in the same direction as normal rotation of engine until bridge tappets just touch valve stems. In the event the timing is to be retarded, the camshaft is turned in the opposite direction until bridge tappets are clear of valve stems and then turned the same direction as for late timing until touching.

i. After adjustment is made, retighten sprocket bolts. Bar engine over through one cycle or two revolutions in direction of normal rotation and recheck the timing of same valve.

j. Inspect the opening of air intake valves of the same cylinder. This will serve as a check on the timing adjustment of the exhaust valves.

k. If the timing of valves is satisfactory install the camshaft sprocket bolt lockwire.

ALTERNATE METHOD OF CHECKING AND ADJUSTING ENGINE VALVE TIMING

This method of adjusting timing is more accurate, than the method described above, and should be used if possible.

a. Remove from cylinder #1 the cylinder head cover lid, fuel injection pipe, rocker arms, and supporting bracket, push rods and push rod casings.

b. Bar engine over so that the cam roller, on the cam being checked, is on the low portion (base circle) of the cam. The piston must be on the expansion stroke when inspecting the exhaust valve opening position.

c. Remove the roller guide assembly for the adjacent valve in the same cylinder, and place it upside down on top of the roller guide for the cam being checked. See Figure 3.

d. Place a dial indicator on the top of the cam follower bracket so that the point rests on a smooth level portion of the cam follower. Adjust dial indicator to "Zero" reading.

e. Bar engine over slowly in direction of normal rotation. Do not jar or jolt bar as this may cause an error in the reading. When the dial indicator reads .020″ the cam follower has completed the movement up the cam ramp and this is the actual opening position of the valve. The reason .020″ is used on the cam follower and .025″ at the valves is because the rocker arm has a ratio of 4 to 5.

f. Ascertain from markings on the generator fan or by means of a bevel protractor on side of crank cheek of No. 1 cylinder, whether or not the timing of the valve is correct. The timing should not be more than one degree earlier or one degree later than specified. If the bedplate is not level, the protractor reading should be corrected accordingly.

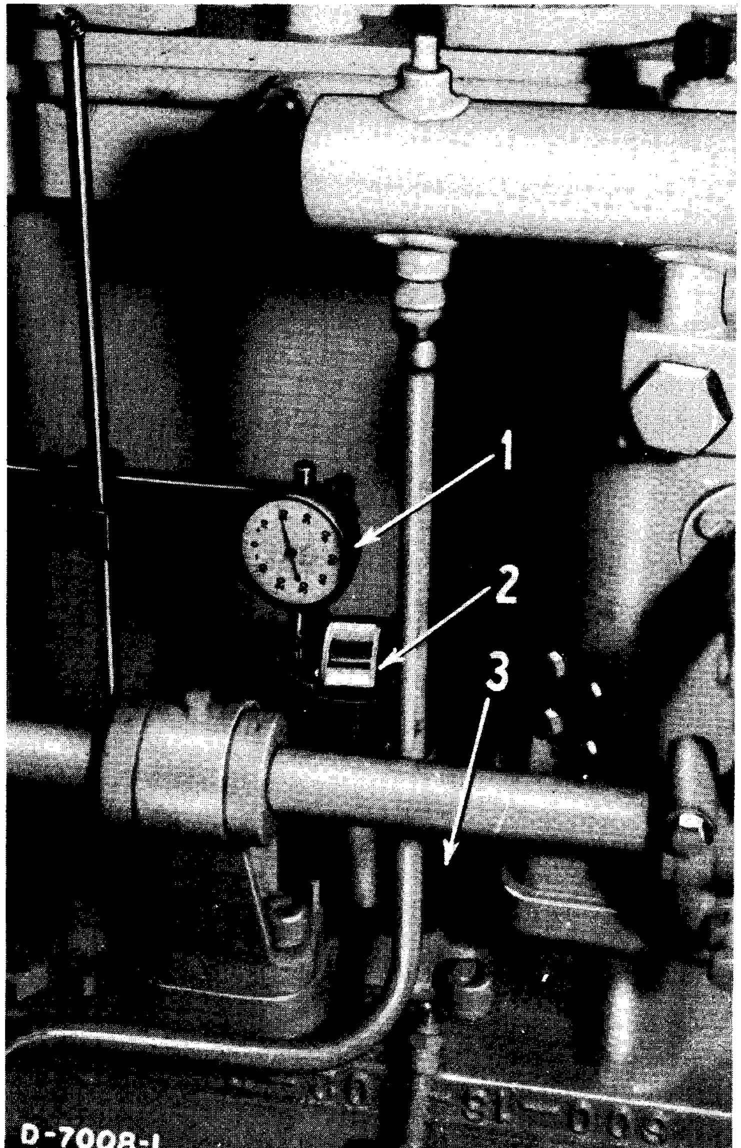
g. In the event the timing is not within the proper limits it may be corrected by changing the angular relation between the camshaft and the camshaft chain sprocket as follows:

Rotate crankshaft one and one half revolutions and locate the dial indicator on the cam follower as described above. Continue to bar engine over slowly and stop when the crankshaft is in correct angular position (valve opening). If the dial indicator does not read .020″, remove lockwire and loosen the camshaft sprocket bolts sufficiently to permit angular movement of the camshaft with respect to the sprocket, then remove two bolts diametrically opposite each other and insert two longer bolts. With a bar, move the camshaft in the proper direction until the dial indicator reads .020″. (.001″ on the dial indicator corresponds to 1° on the crankshaft).

h. After adjustment is made retighten sprocket bolts. Bar engine over one and one half revolutions and recheck timing of same valve as described above.

i. If timing of valves is satisfactory remove the two long bolts and replace original bolts. Tighten all bolts and install camshaft bolt lockwire.

j. Reassemble push rods, push rod tubes, rocker arms and fuel injection pipe.



Checking Valve Timing

Figure 3

1. Dial Indicator **2. Roller Guide Assembly**
3. Cam Follower Bracket

If time does not permit removal of push rods and other parts necessary to make engine valve timing adjustment in accordance with the above method, checking and adjustment may be made by mounting the dial indicator on the push rod end of the rocker arm to determine the .020″ lift on cam. Then proceed to check and make adjustments as outlined under the above method.

FUEL INJECTION PUMP TIMING

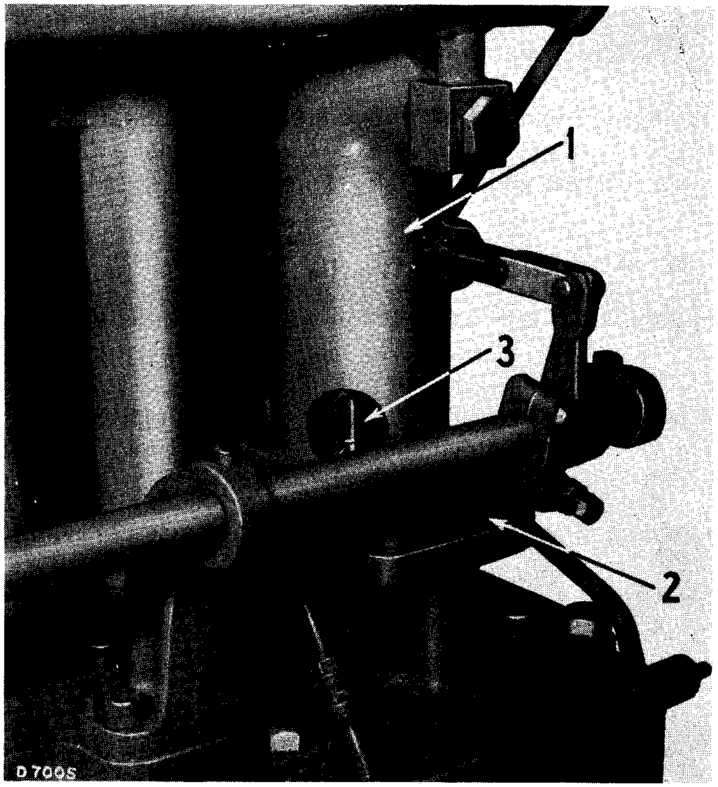
The timing of the fuel injection pumps is adjusted carefully at the factory and it should seldom be necessary to make any changes for normal operating conditions. However, it is necessary to check the timing after the replacement of pump plunger and cylinder or a complete pump assembly.

Before inspecting or adjusting the timing of any fuel pumps, it is important to make sure that the camshaft drive chain is in proper adjustment. If the adjustment of the camshaft drive chain or resetting of the valve timing is required, this work must be done before the fuel pump timing is adjusted.

If the angular relation between the camshaft and camshaft sprocket is altered, the fuel injection pump timing must be checked and corrected if necessary. The pump for each cylinder must be checked.

The timing of the injection pump is checked by barring engine over in direction of normal rotation until the line "A" inscribed on fuel pump plunger guide "B" is in line with marks "C" on each side of inspection window in fuel pump body, refer to Figure 5. This is the point of port closure in the pump and the crank of the cylinder corresponding to the fuel pump being checked, should be at the angle specified at the end of this section.

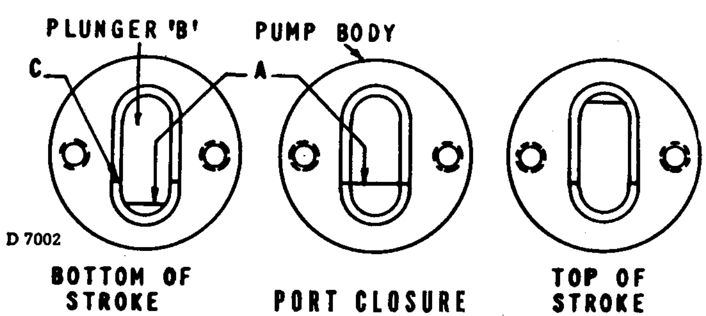
If the angle is not as specified, it can be corrected by adding or removing shims under the fuel injection pump body. This raises or lowers the position of pump cylinder in relation to the plunger and thus alters the beginning of actual injection for the individual pump. Adding shims retards injection and removing shims advances injection. The timing of each pump should be adjusted separately in the proper sequence



Fuel Injection Pump

FIGURE 4

1. Fuel Injection Pump **2. Shims for Timing**
3. Inspection Window



Fuel Injection Pump Inspection Window

FIGURE 5

of firing order. Approximately .015″ shim thickness corresponds to 1° on the crankshaft. The mark "A" in all pumps should be visible through the window port in pump body for both top and bottom of plunger travel.

When a complete new pump, or plunger and cylinder assembly is to be installed, first bar engine over slowly until mark "A" on the pump on which the replacement is to be made, aligns exactly with the marks "C" on window port of pump body. Make replacements without changing position of camshaft. After new parts have been installed, the mark "A" should align exactly with marks "C". If not, change the thickness of shims under fuel pump body as required.

SPECIFICATIONS

	Hesselman Pistons*	
TIMING		
INLET VALVE	Supercharged	Normally Aspirated
Opens .... °B.U.D.C.	81	32
Closes .... °A.L.D.C.	39	48
EXHAUST VALVE		
Opens .... °B.L.D.C.	56	52
Closes .... °A.U.D.C.	79	28
INJECTION PUMP		
Port closes .... °B.U.D.C.	21	32

*This type of piston has a depressed center portion but with a raised cone in the center of this depression.

(Tolerance on all above ratings— ± 1° of crank angle)

VALVE TAPPET CLEARANCES (Cold engine at 70° F.)

Exhaust valves .... .027″-.029″

Intake valves .... .006″-.008″

VALVE TAPPET CLEARANCES (Hot engine at 155° F.)

Exhaust valves .... .033″

Intake valves .... .013″

For timing purposes only, the tappet clearance should be set at: .025″ if checked at valves.

The above temperatures apply to the water temperature with the engine shut down.

GOVERNOR

The governor is of the Woodward Hydraulic relay type and is driven from the engine camshaft by a set of bevel gears. The purpose of the governor is to regulate the speed of the engine in accordance with the position of the throttle located in the locomotive cab. The governor regulates the engine speed by setting the fuel control shaft (regulating shaft) for the required rate of fuel injection.

The governor is controlled by an actuator which is connected to the governor speed control shaft lever by an adjustable linkage. For each position of the throttle lever, there is a corresponding position of the speed control shaft. At any speed setting, the governor functions to maintain the engine speed which corresponds to that setting.

OPERATION OF GOVERNOR

The governor speed control shaft "A" which is connected, through the governor actuator, to engine speed control in the cab and carries a gear "B" which engages a gear rack on the flyball seat "C." The speed of the engine is changed by turning the shaft "A" which in turn changes the compression of the flyball spring "D." Refer to Figure 1. When engine is running at a steady speed, the force exerted by this spring is balanced by the centrifugal force of flyballs "E" and then the center shoulder on the pilot valve "F" covers the ports in pilot valve bushing "G." The gear at the bottom end of this bushing, together with the gear "H" (not shown) form a pump which supplies oil under pressure to the pilot valve and also to the top side of the power piston "J." The spring loaded piston valve "K" relieves the excess oil and thus maintains a constant pressure in the system.

When the load on the engine increases, the engine will slow down momentarily thus reducing the speed and centrifugal force of the governor flyballs. The spring will then force the guide rod "L" and the pilot valves "F" downward. This will uncover the ports in pilot valve bushing "G" thus admitting oil under pressure to the bottom of the power piston "J" and cause it to move upward. This motion is transmitted through link "M" and lever "N" to the terminal shaft, which latter is connected by means of a linkage to the engine fuel injection pump control shaft. When the load increases, the governor will increase the fuel discharge from injection pumps in order to maintain the engine speed.

When the load on the engine decreases, the engine will speed up momentarily thus increasing the speed and centrifugal force of governor flyballs. This will cause the spring to compress and also to move the pilot valve "F" upward. As the ports in bushing "G" are uncovered, the oil under the power piston "J" is permitted to drain out, and the oil pressure which is always maintained on top side of this piston will force it downward in direction of reduced fuel discharge from the injection pumps.

In order to keep the governor from hunting, a compensating dashpot system is used. The actuating piston "P" of the dashpot is connected to the terminal shaft "O" through lever "Q" and links "R" and "S." This piston, therefore, follows exactly each movement of the power piston "J." The receiving side of the dashpot contains a plunger "T" and a spring to keep the plunger in proper position. An oil passage connects the two dashpot chambers.

Referring to the first case of an engine load increase, the pilot valve moves downward and the power piston upward. By following through the motion of the levers and the terminal shaft, the actuating dashpot piston will move downward, pushing the plunger in receiving side of dashpot upward, which restores pilot valve to center and stops the power piston at the required new position. It is now necessary to keep the pilot valve centered until the engine speed picks up and the flyballs are vertical again. To accomplish this, the needle valve "U" under the receiving dashpot is adjusted in a position which will permit the oil to leak out and the plunger to return to center at the same rate the flyballs return to vertical position. Thus the pilot valve and all other parts except the power piston and dashpot actuating plunger will have returned to original positions.

The compensation adjustments as originally set may not be satisfactory after the engine has been put in operation. Although the governor may appear to perform satisfactorily when the engine is operating without load or at constant load, it may be out of adjustment and respond improperly to load changes. It is, therefore, advisable to check the governor

compensation adjustment in accordance with the following instructions. This adjustment can satisfactorily be made only after the governor oil and engine oil have reached their normal operating temperatures, and while the engine is operating without load.

a. Loosen the nut holding the compensation adjusting pointer "V" and set the pointer at its extreme downward position. This moves the lever "W" toward the front of governor and reduces the stroke of dashpot piston "P" relative to the stroke of the power piston "J."

b. Remove the plug "X" and open the compensating needle valve "U" two or three turns with a screw driver.

c. Start the engine and allow it hunt or surge for about thirty seconds to bleed any trapped air from governor oil passages.

d. Gradually close the needle valve "U" until hunting stops or until it is only about ⅛ turn open.

e. If this does not stop the hunting, open the needle valve about one turn and raise the compensation adjusting pointer "V" about two graduations.

f. Close the needle valve gradually again as under (d).

g. Repeat procedure until hunting stops.

h. It is desirable to have as little compensation as possible. Closing the needle valve more than is necessary will make the governor slow to return to normal speed after a load change. Excessive dashpot travel, indicated by the compensation adjusting pointer being too far toward maximum position, will cause an excessive speed change when the load changes.

MAINTENANCE

Use only the best grade of mineral lubricating oil in governor casing. The oil must not contain additives which are used to free up rings, remove carbon, etc., unless a non-foaming additive is also present in the oil. The oil should not foam or sludge excessively when agitated, or form gummy deposits when heated. Oils which have a tendency to foam cause erratic operation of governor. The oil should have a viscosity equivalent to S.A.E. 20 or 30 depending on the temperature conditions. It is important that the oil poured into the governor is *new* and *clean,* because if any dirt enters the governor casing it may upset the proper operation of governor. The can and funnel used for filling governor must be washed thoroughly in kerosene immediately before filling. The funnel should be provided with a fine mesh screen. The oil level in governor should be checked daily and must not be permitted to go lower than the center of the sight glass.

When changing oil in governor the casing should be drained and washed out with a mixture of clean kerosene and clean oil. Use new clean oil only for final flushing. Re-fill with new clean oil of proper viscosity. If cover on governor is removed for inspection, care must be taken to keep any dirt from entering the governor.

When starting engine after changing the oil in governor, it may take several minutes operation before governor is primed and starts to function properly. During this priming period it may be necessary to operate fuel pump control shaft manually by means of small lever or wrench. If the governor continues to hunt it may be necessary to open the compensating needle valve, one or two turns, for a few seconds to facilitate removal of air from the dashpot, after which the needle valve must be returned to its previous setting.

If it becomes necessary to add oil to the governor more often than weekly and if there is no indication of an external oil leak, the drive shaft oil seal at the base of governor may be allowing oil to leak from the governor into the engine camshaft housing. If this occurs, check condition of the oil seal at base of governor.

For any maintenance work which requires disassembly of the governor or its components consult your Maintenance Bulletins, or have a factory service man do the work.

SPECIFICATIONS

	New	Limit
GOVERNOR		
Governor speed at 625 R.P.M. engine speed	1250 R.P.M.	
GOVERNOR DRIVE SHAFT		
Bushing to housing interference	.0005″- .0015″	
Shaft diameter	1.373″ -1.3725″	
Clearance	.002″ - .0035″	.005″
Backlash for drive gears	.002″ - .004″	.006″

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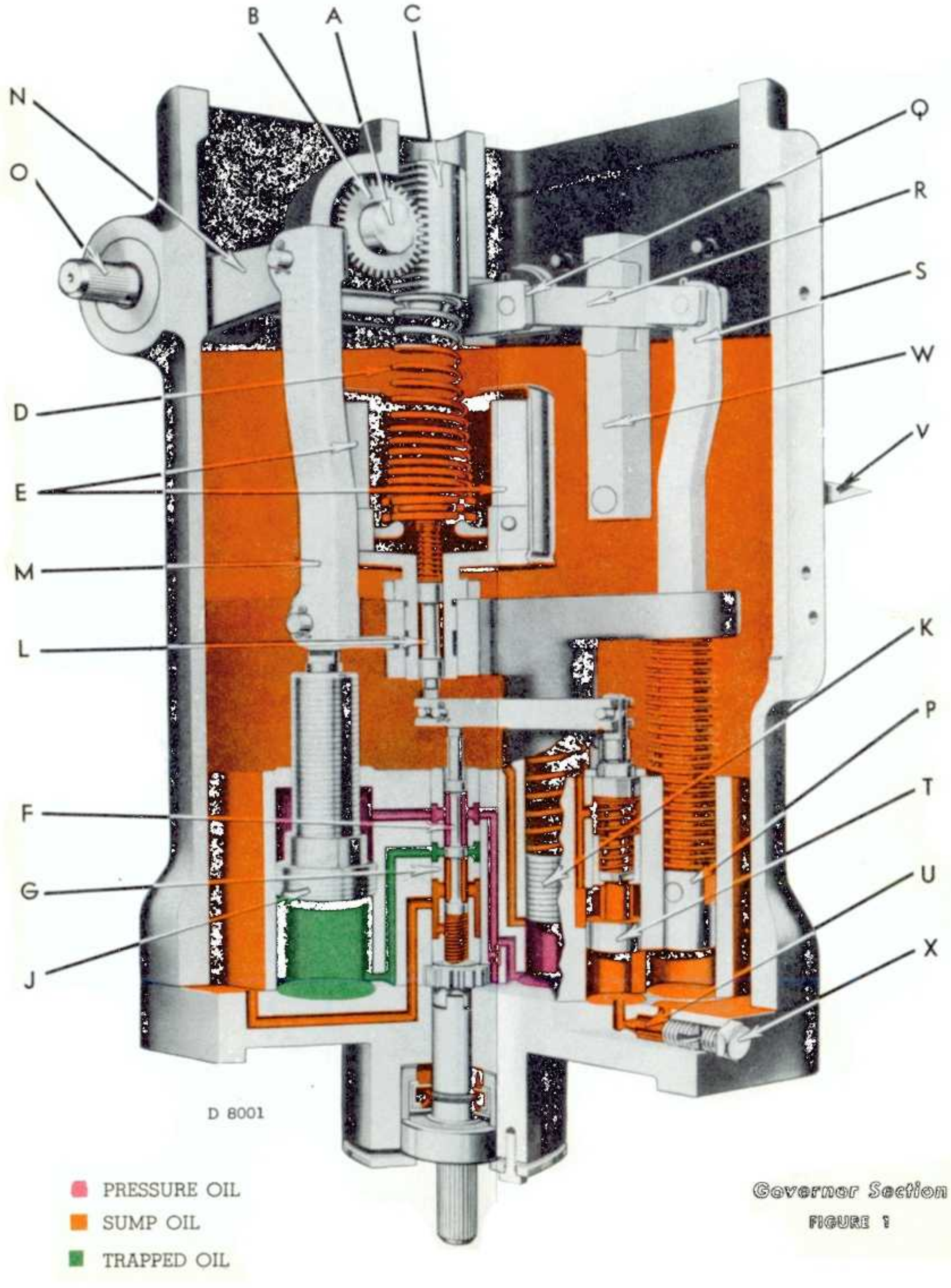


Governor Section

FIGURE 1

PNEUMATIC THROTTLE CONTROL, GOVERNOR ACTUATOR AND OVERSPEED STOP

The pneumatically operated throttle located in the locomotive cab controls the governor actuator which controls the diesel engine governor. The tension on a spring in the throttle valve cylinder is controlled by a cam on the throttle handle. Air from the control air reservoir enters the valve cylinder until a pressure is built up in the cylinder, piping and actuator to balance the force exerted by the spring. This causes a movement of the actuator directly proportionate to any movement of the throttle handle. The full speed position is set by a limiting stop in the actuator.

ADJUSTING AND CHECKING OF THROTTLE VALVE AND GOVERNOR ACTUATOR

a. Install a 0-100 psi air pressure gauge in the tee connection adjacent to the actuator so that the throttle air line pressure may be observed. Refer to Figure 1.

b. Move the throttle handle to first notch "power on" position and check the pressure on the gauge. In this position the engine will operate at idling speed and the governor actuator arm should not move. The gauge should indicate the following readings at the actuator:

14—16 PSI air line pressure on Switchers, and All-Service locomotives using the D-1 controlair throttle valve.

8—10 PSI air line pressure on All-Service locomotives, Transfer locomotives and Road locomotives using the CE-100 control throttle.

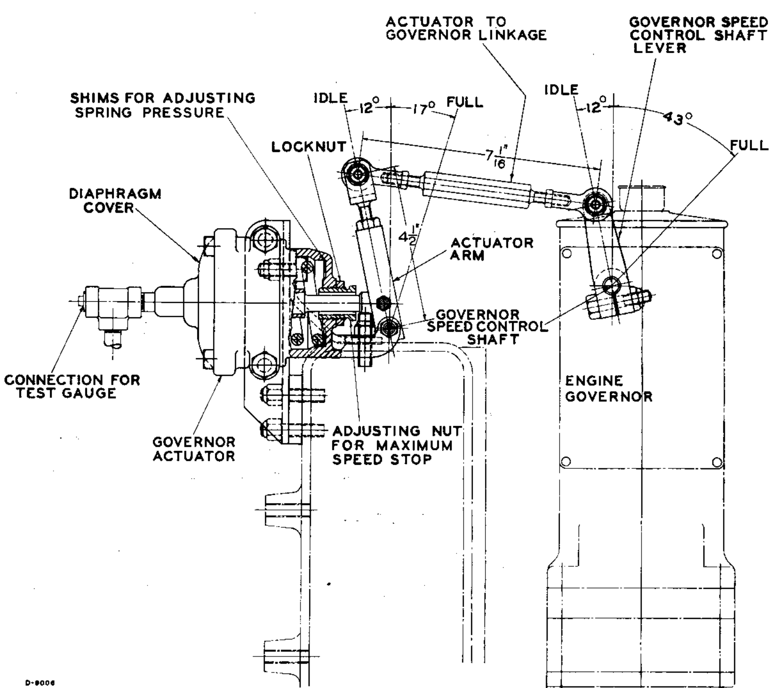
c. Move throttle to the "full speed" position and check the pressure on the gauge. This position of the throttle corresponds to full travel of the actuator arm and the engine should operate at full speed. The gauge should indicate the following readings at the actuator:

53—55 PSI air line pressure on Switchers, and All-Service locomotives using the D-1 controlair throttle valve.

60—65 PSI air line pressure on All-Service locomotives, Transfer locomotives and Road locomotives using the CE-100 control throttle.

d. If the above conditions do not exist an adjustment is provided on the controlair valve to obtain the correct pressure. The adjusting screw at the top of throttle controls the pressure at both the "full speed" position and the "power on" position of the throttle. If the pressures under steps "b" and "c" are not correct, adjust the set screw at the top of throttle accordingly.

e. After adjustment has been made under step "d," there should be no pressure indicated when the throttle is at the "power off" position. In this position the engine will operate at idling speed. If there is a pressure indicated at this position adjust nuts at the bottom of the throttle to show no pressure at the gauge.



Governor Actuator and Linkage

Figure 1

f. Loosen the locknut on the actuator and back off the maximum speed adjusting stop screw, refer to Figure 1. Move throttle slowly out of first notch and check gauge pressure which corresponds to the initial movement of governor actuator. This initial movement (engine speed starts to increase above idling speed), should occur at approximately one (1) pound more than the pressure at first notch position of throttle given under step "b." This means that initial movement of actuator arm should be as follows:

17 PSI air line pressure on Switchers, and All-Service locomotives using the D-1 controlair throttle valve.

11 PSI air line pressure on All-Service locomotives, Transfer locomotives and Road locomotives using the CE-100 control throttle.

g. If initial movement of actuator is not correct, remove actuator diaphragm cover and internal spring assembly. Then adjust shimming of actuator spring until initial movement occurs at the proper throttle line pressure as shown under step "f." Add shims to increase pressure and remove shims to decrease pressure in order to obtain initial movement.

h. Governor actuators must not be interchanged between engines without insuring that the actuators are the same part number. Reference should be made to the parts book applicable to the particular locomotive for the proper part number.

ENGINE SPEED ADJUSTMENT

The linkage between the actuator arm and the governor speed control shaft lever is initially set at 7-1/16" center-to-center distance for the idling position of the actuator arm, refer to Figure 1.

The adjustable vertical arm on the actuator is initially set at a length of 4½" from the center of the pivot point to the center of the bolt hole at the end of the arm. Slight adjustment of this arm may be necessary to obtain the required full engine speed.

At the engine idling position (no movement of actuator arm), both the actuator arm and the governor speed control lever should be parallel and form an angle of approximately 12° counter-clockwise from the vertical. At this position, the red dot should appear at the index hole of the governor face plate.

The hole in the center of overspeed stop cover makes available a convenient means of determining the speed of the engine. Insert the tip of a hand tachometer through this hole and hold it against the end of the overspeed stop shaft. The reading obtained is the overspeed stop shaft speed and must be divided by two (2) to obtain the engine speed. To adjust the engine speed the following procedure should be followed.

a. Start engine with throttle handle in the "power off" position and check the engine speed. If the speed is not 315 RPM the linkage between governor speed control lever and actuator arm should be adjusted. Lengthening linkage increases speed and shortening linkage decreases speed. In order to change the length of this linkage it is necessary to disconnect one end of the link and turn the spherical rod end as required to obtain the correct idling speed.

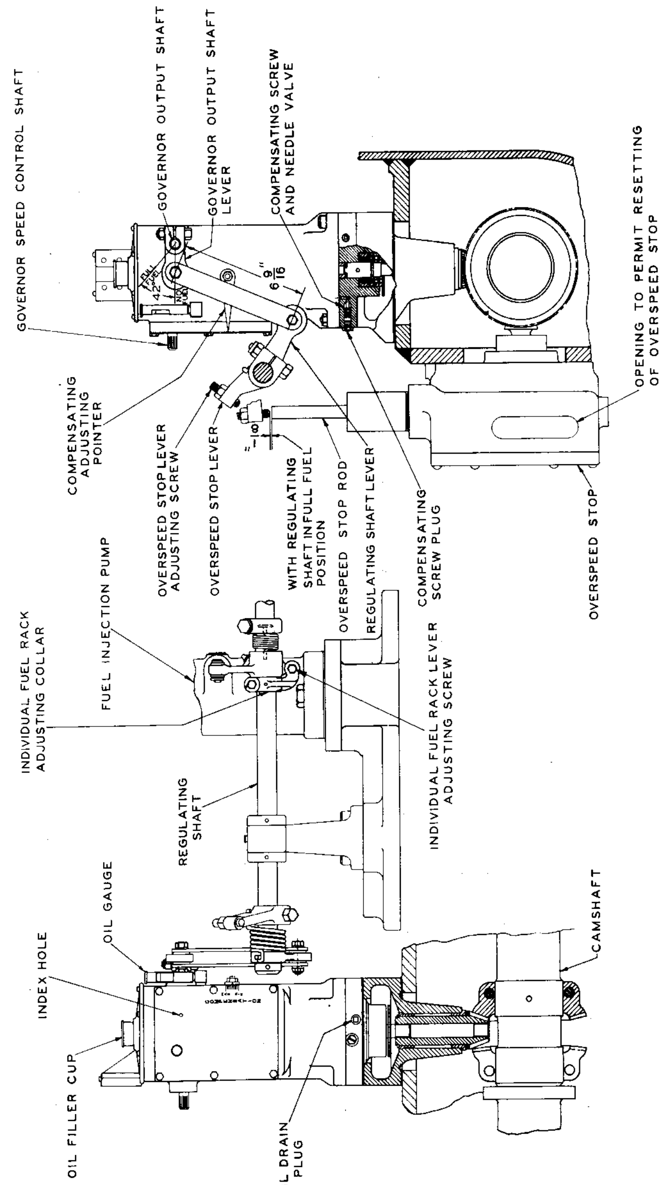
b. Move throttle to the first notch "power on" position and note that the engine speed does not increase.

c. Move throttle to "full speed" position and check the engine speed. Adjust the length of actuator arm to obtain an engine speed slightly higher than 625 RPM. Lengthening arm will increase the speed and shortening arm will decrease the speed.

d. Recheck engine idling speed. Idling speed may have been slightly disturbed by adjustment made under step "c." If idling speed is disturbed, then readjust linkage to proper idling speed as given in step "a."

e. Adjust the full speed to exactly 625 RPM by adjustment of the maximum speed stop on the actuator, refer to Figure 1. Lock all adjustments and recheck idle and full speeds.

The governor is connected to the fuel injection pump control shaft (regulating shaft) by two levers and a link. This shaft extends the full length of the engine with connections to each fuel injection pump rack, refer to Figure 2. With the governor output shaft in the no-fuel position, the output shaft lever should be in as nearly a horizontal position as the shaft serrations will permit.



Governor and Regulating Shaft Arrangement

Figure 2

LOAD CONTROL PILOT VALVE

The load control pilot valve which is mounted on the governor, controls the flow of oil between the engine governor and the load regulator operating cylinder, refer to Figure 3. The supply port of the pilot valve is connected to the oil pressure reservoir of the engine governor. The pilot valve stem is operated by the governor and its movement is directly proportionate to any movement of the fuel control shaft (regulating shaft). The retaining ring on upper end of the pilot valve link pin should line up with the indicating disc on the top of pilot valve when the pilot valve is in the lap position, i.e., full engine load (no movement of the load regulator). *Caution*: This indication is only for a quick visual check for radical misadjustment of the load regulation system. This indicator should never be used to set the pilot valve.

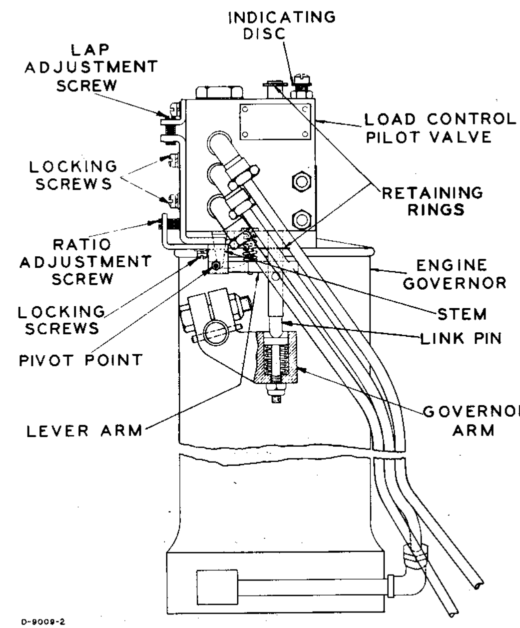
When the governor arm is in the full load position, the valve outlet port of the pilot valve is closed and the load regulator is not affected. When the governor arm is above the full load position (engine overloaded), the valve position permits oil to flow to the load regulator operating cylinder from the governor oil pressure reservoir, thereby forcing the load regulator operating cylinder piston to move to change setting of the load regulator. When the governor arm is below the full load position, the pilot valve permits oil to flow from the load regulator operating cylinder back to the governor sump. This back flow is due to the oil being under pressure behind the spring loaded piston of the load regulator operating cylinder.

The governor arm, as shown in Figure 3, is adjusted to lift the pilot valve stem above the closed position of the valve whenever the fuel control shaft (regulating shaft) is turned past the position which corresponds to "full engine load." It should be understood that "full engine load" as here used does not refer to maximum engine capacity, but applies to rated engine power at any particular engine speed. The fuel control shaft (regulating shaft) may attain the "full engine load" position at any engine speed in the upper speed range, however, the load control equipment will function to unload in the same manner at less than full engine speed as it does at full engine speed.

A metering valve is installed in the oil line between the pilot valve and the load regulator operating cylinder. The metering valve regulates the rate of flow of oil in the line.

Setting of the governor arm for "full engine load" can most conveniently be made at the full load, full speed fuel rack setting.

The full load rack setting for rated horsepower at full speed may be best determined by load testing the engine during which the generator output is measured. This load test is made by connecting the generator leads across a water rheostat then loading generator and adjusting output to obtain rated horsepower output. Current and voltage values based on engine delivering a specified horsepower to generator are given in the testing instructions for the particular locomotive. These specified current and voltage values take into consideration the losses involved. At the point of obtaining the rated horsepower output, an average reading is taken of the fuel pump racks. This reading is the rack setting for full load rated horsepower at maximum speed.



Load Control Pilot Valve

Figure 3

ADJUSTMENT AND CHECKING OF LOAD CONTROL PILOT VALVE

The pilot valve is provided with two types of adjustment; the lap adjustment which makes the loading time of the load regulator equal to the unloading time, and ratio adjustment which changes the total time for loading and unloading of the regulator. Checking of either of these adjustments must be made with the load regulator in the minimum resistance position and the engine running at 625 rpm. (locomotive throttle in "full speed" position). If the loading and unloading conditions of the regulator are not satisfactory, the lap adjustment and the ratio adjustment of the pilot valve should be adjusted. Refer to testing instructions for the particular locomotive being checked to obtain detailed instructions on the complete load regulation system.

Lap adjustment—Manually raise the pilot valve link pin until a position is reached where the load regulator piston starts to move; note the position of the pilot valve lever arm. Gradually lower the pilot valve link pin until a position is reached where the load regulator piston starts to move in a direction opposite to the movement outlined above; note the position of the pilot valve lever arm. Raise the pilot valve link pin so that the lever arm is positioned at a point half way between the two points established in the above instructions. At this point there should be no load regulator piston movement. Note that the retaining ring on the top of the operating link pin is aligned with the indicating disc. If these conditions are not satisfied, then the lap adjustment of the pilot valve is not correct. Loosen the locking screws on the side of the pilot valve and turn the lap adjustment screw to obtain the correct lap position as outlined above. Tighten the locking screws to hold the lap adjustment bracket in position. Only a small movement of the lap adjustment screw is needed to obtain proper lap adjustment. If the lap adjustment bracket is moved too far, the load regulator will not load or unload, depending upon which way the misadjustment is made.

Ratio adjustment—By-pass the metering valve in the oil line between the load regulator cylinder and pilot valve. Manually raise the pilot valve link pin to the maximum rate of unloading position, i.e., raise the link pin until it comes up against its lower retaining ring, and check the time required

for full travel of the load regulator operating cylinder piston. With the metering valve by-passed, this should be 3½ to 6 seconds unloading. Release the pilot valve link pin and note that the load regulator returns to the minimum resistance position. The timing for this should be 3 to 6 seconds for full travel loading. The oil temperature must be 100 to 120°F. If the time to unload does not fall within the above limits, reset the ratio adjustment. To make the adjustment, loosen the two locking screws under the ratio adjustment bracket and turn the adjusting screw about ½ turn at a time. Turn clockwise to decrease unloading time. This will also decrease the loading time.

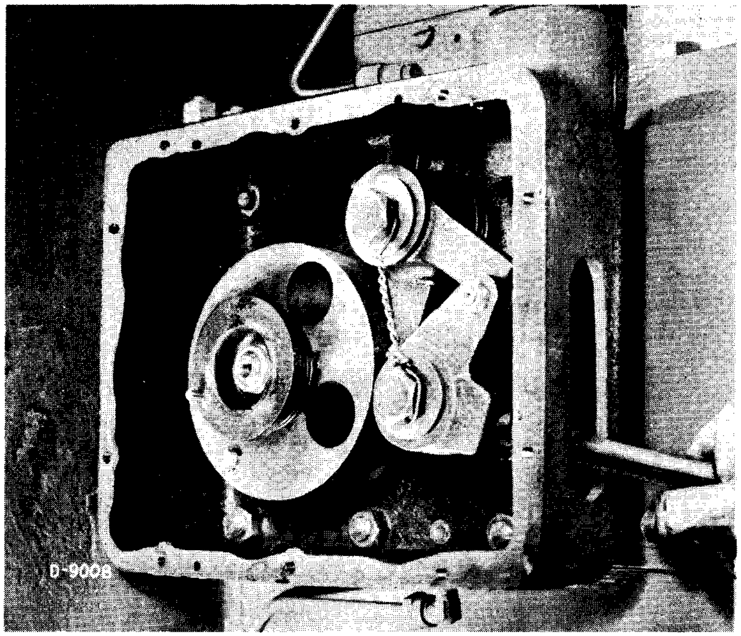
CAUTION: Tighten locking screws each time an adjustment is made, and set the adjusting screw in a neutral position, before checking the timing; otherwise false timing will be encountered. When tightening the locking screws be sure that the lever arm is centered in the pilot valve link pin slot; otherwise the linkage will have a tendency to bind with a resultant false timing indication.

After the correct timing has been set, with the metering valve by-passed, recheck the lap adjustment as there is a possibility that changing the ratio adjustment will affect the lap adjustment.

Governor Arm Adjustment: After the above adjustments have been made and the system is operating properly, it is possible that the system will regulate to more or less than full rated engine horsepower. If this condition exists, it will be necessary to change the position of the governor arm so that the pilot valve will regulate properly. A slight adjustment can be made without moving the governor arm by changing the position of the spring loaded plunger. *Caution:* The plunger spring must not be compressed to a solid condition, i.e., when pressure is applied to the top of plunger it must move 1/8" to 3/16".

OVERSPEED STOP

The overspeed stop is located directly below the governor and is gear driven from the camshaft. Its function is to shut down the engine if the speed should exceed the maximum safe limit. The shaft of the overspeed stop operates at twice engine speed. The normal setting is approximately 10% higher than the rated maximum speed of the engine. The overspeed stop is of the centrifugal trip type in which a spring holds a weight in position until the engine speed reaches the tripping point. At this point the centrifugal force of the weight becomes greater than the spring tension, and the weight turns sufficiently on its pivot to strike one arm on the latch lever; the other arm releases the trip lever which actuates the stop, thus shutting down the engine.



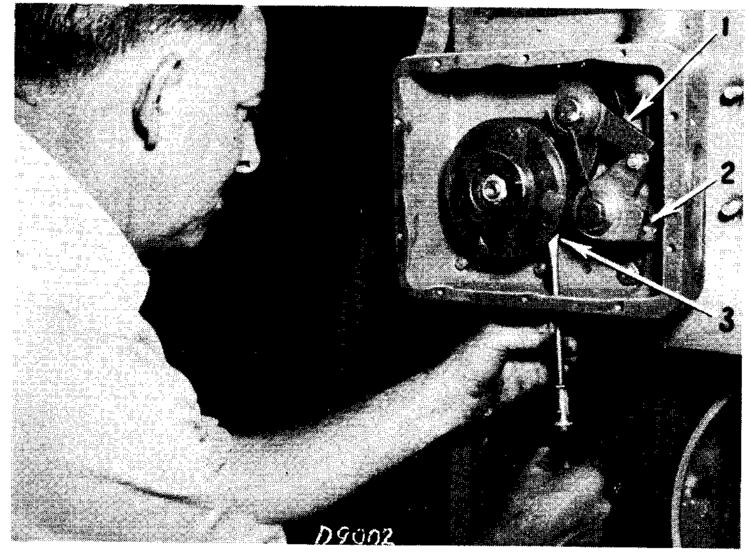
Resetting Overspeed Stop
Figure 4

The overspeed stop is reset by inserting the reset bar through the hole in the housing and prying the bar down until the latch lever catches, refer to Figure 4.

MAINTENANCE

GOVERNOR CONTROL

The governor control linkage through to the fuel injection pumps should require very little maintenance other than lubrication periodically. Excessive play or looseness in linkage should be corrected immediately. For adjusting pumps to balance engine see section devoted to fuel pumps and injectors.



Adjusting Overspeed Stop
FIGURE 5

1. Latch Lever
2. Hole for Resetting Bar
3. Tripping Speed Adjustment

OVERSPEED STOP

The overspeed stop tripping speed may be adjusted by turning the spring adjusting screw, refer to Figure 5. This changes the spring pressure on the weight so that the centrifugal force necessary to trip the latch lever is altered.

At regular intervals the overspeed stop should be inspected and tested to make sure that all parts are in proper working order and that the tripping speed is correct. When adjusting overspeed stop setting, the following procedure should be followed:

a. The tripping speed should be set at 1380 RPM of the cverspeed shaft (this shaft turns twice engine speed rate). The engine should be barred over until the overspeed spring tension adjusting screw is visible through the opening in the bottom of the overspeed housing. The drain pipe or plug in this opening must be removed to gain access to the adjusting screw.

b. Insert a screw driver through the opening of housing underside to engage the screw head as shown in Figure 5. Turn screw clockwise to increase the speed at which the lever trips or turn screw counter-clockwise to lower the tripping speed.

c. The overspeed stop lever adjusting screw, refer to Figure 2, should be adjusted to ⅛″ clearance above the overspeed stop rod when fuel pump racks are at full fuel position.

d. If overspeed stop has been tripped, insert a ½″ diameter bar in hole of lever through slot in right side of housing and pry down until the latch lever catches in the lower position.

If after resetting the overspeed stop, the engine continues to be shut down by overspeeding, the cause should be determined and corrected.

SPECIFICATIONS

OVERSPEED STOP

	New	Limit
Tripping Speed	1380 RPM—speed of overspeed shaft (this shaft runs twice engine speed)	
Backlash for drive gears	.002″-.004″	.006″

FUEL INJECTION PUMPS AND FUEL INJECTORS

FUEL INJECTION PUMP

The fuel injection pump is of the constant stroke type, refer to Page 1004, Figures 3 and 4. An individual pump is provided for each cylinder. The pumps deliver the oil properly timed to the fuel injectors. The pump elements consist of an accurately ground and lap-fitted steel plunger and cylinder (or barrel) assembly. The plunger and its guide are held by a spring against a tappet and roller guide assembly, which are caused to reciprocate by the fuel pump cam. The fuel enters the supply chamber through the header connection. The quantity of fuel delivered by the pump is altered by changing the angular position of the plunger with respect to the pump cylinder. The plunger is provided with a double helix (upper and lower) which gives a variable beginning of fuel delivery also a variable ending of delivery since both conditions are dependent upon the relation of the helixes to the ports. The position of the plunger is altered by means of a control rack which is connected to the governor through the fuel control shaft.

Operation of the fuel injection pump is illustrated on Page 1002, Figures 1 and 2. When the plunger is at the bottom of its stroke, the cylinder ports are uncovered. The fuel is then delivered into the pump cylinder and fills the clearance space above plunger. On the upstroke of plunger, part of the fuel is displaced back through the by-pass port until upper helix on the pump plunger covers this port, after which the oil remaining in the cylinder is forced through the pump delivery valve and the connecting piping to the injector in the engine cylinder head. Delivery of fuel to the injector continues as long as the cylinder ports are covered by the plunger. As the plunger moves toward the top of the stroke, the lower helix on the plunger will start to uncover the by-pass port. During the balance of the upward stroke of plunger, the pump supply chamber is connected to the space above the plunger, permitting the fuel displaced by further upward plunger movement to return to the supply chamber. The effective pump plunger stroke is thus controlled by the angular position of plunger with respect to the pump cylinder.

Operation of Fuel Injection Pump

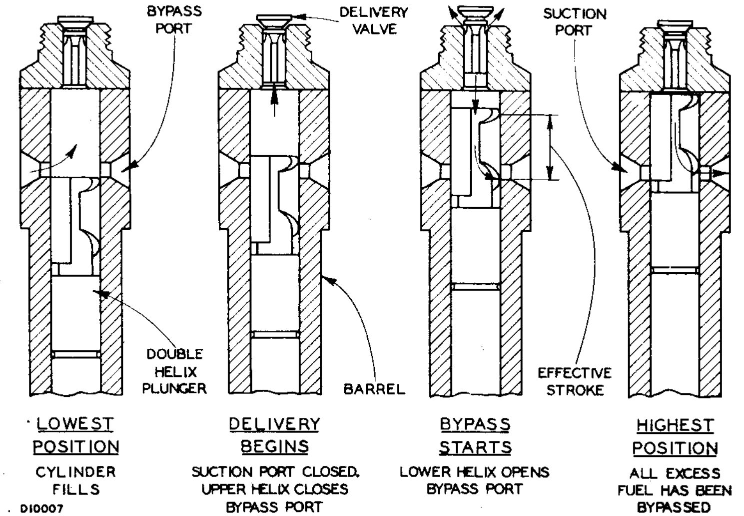


Figure 1—"Bosch"

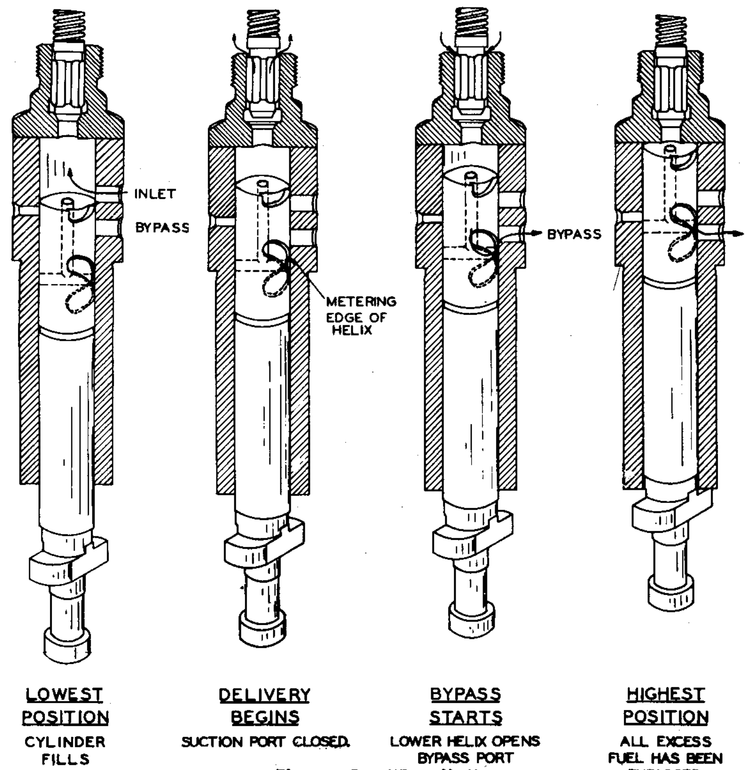


Figure 2—"Bendix"

The slopes of the upper and lower helix on the plunger are so arranged that close regulation of fuel pump discharge is obtained by small movements of the control rack which is actuated by the governor through the fuel control shaft. The word "stop" and an arrow are stamped on one end of each control rack. Movement of the rack in the direction of the arrow results in reducing the pump discharge. In the extreme inner position in direction of the arrow, the plunger will be in such a position that no fuel is discharged from the pump to the injector. In this position, the vertical grooving of the plunger aligns with the by-pass port in the cylinder and during the entire stroke the space above the plunger is in direct communication with supply chamber. If the control rack is moved in the opposite direction to the arrow, the plunger finally reaches its angular position of maximum fuel delivery. When the engine is operating under normal load conditions the angular position of plunger will be intermediate to these extremes. The top helix on the plunger varies the position of the plunger at which port closure occurs. This will result in a retarding in fuel injection timing at decreasing rack settings and will make the engine operate much smoother at lower speeds and loads than it would if a single helix pump was used. The upper helix exists from zero fuel position up to 18 mm. From this point on to the maximum fuel position, the point of port closure is fixed as would be the case in a single helix pump.

For fuel injection pump timing refer to Engine Timing Section.

FUEL INJECTOR

The fuel injector is illustrated on Page 1006, Figures 5 and 6. The injector consists of a nozzle holder and nozzle body with valve. The nozzle body and valve are lap fitted together and the initial pairing of these two parts should be maintained carefully. The valve cannot be used interchangeably in any other nozzle body. A pressure adjusting spring, which exerts pressure on the nozzle spindle or pressure pin, is located in the upper section of the nozzle holder. The nozzle valve contacts this spindle and is seated by pressure of the spring. The valve is opened when fuel is delivered through the passage under sufficient pressure to lift the valve against the spring pressure. During the period when

Fuel Injection Pump

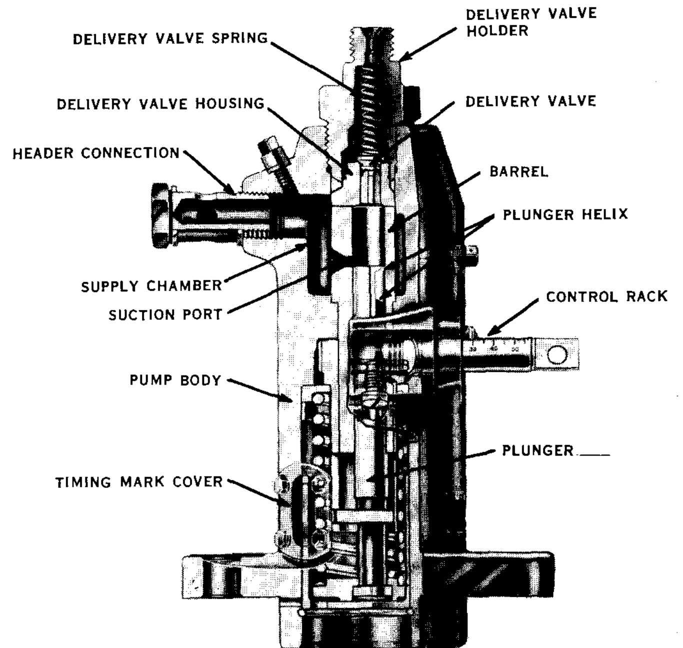


Figure 3—"Bosch"

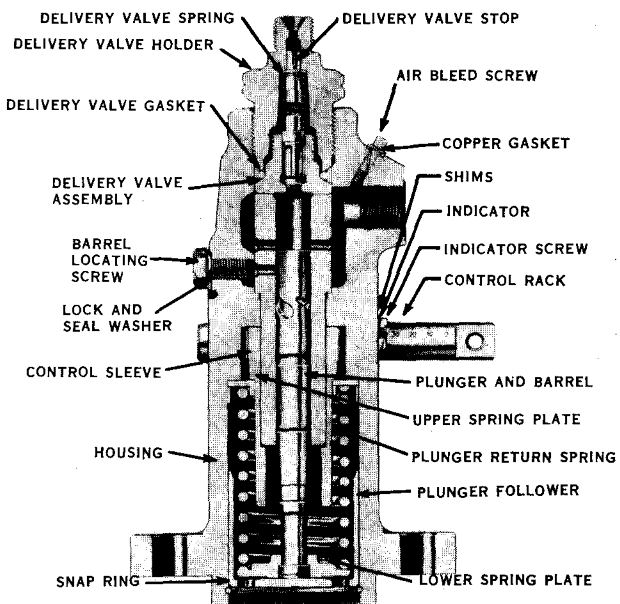


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Figure 4—"Bendix"

valve is raised off the seat, oil is delivered through the nozzle orifices, under high pressure, which results in delivery of the fuel into the combustion chamber in a finely atomized state.

A small metal edge filter is provided in the adapter attached to each fuel injector, to prevent dirt and scale from entering the injector.

MAINTENANCE OF FUEL INJECTORS

The fuel injectors should be removed for cleaning and inspection at regular intervals, refer to Maintenance Bulletin. Remove one injector at a time in order to check the fuel spray in the open air. Clean the metal edge filter, located in the injection nozzle adapter by flushing out the inside of the adapter with clean fuel oil. An injector testing device should be used for testing the injector spray. Remove any carbon that may have deposited on the nozzle tip and check the spray of injector by operating the testing device. A few strokes of the testing device may be required to remove air from injector. After the air is expelled and when operating the testing device quickly, the spray from the nozzle tip should be finely atomized and uniform in shape. All the orifices should discharge the same size and shape of spray. There should be no dribble when pumping action is stopped. If the injector does not function properly during this test, disassemble the nozzle body and valve by unscrewing the nozzle cap nut. Wash the nozzle body and valve in clean kerosene or fuel oil. The orifice holes may be cleaned with a fine wire of suitable size. (See specifications at the end of this section.) Work the valve in the nozzle body in a pumping action under the surface of clear kerosene or fuel oil, then in air, and observe whether or not the valve moves freely in any position in the nozzle body. When nozzle difficulties cannot be rectified by careful cleaning, install a new nozzle and valve assembly. Defective valves and nozzles may be returned for reconditioning. The final assembly of the valve and nozzle should always be done with the parts submerged under the surface of clean fuel oil. When applying the cap nut, make sure that it is properly tightened, (350 to 375 ft. lbs. torque), but do not overtighten it as overtightening may cause the valve to bind in the nozzle. *Caution:* A six (6) point wrench must be used when tightening nozzle cap nuts

Fuel Injector

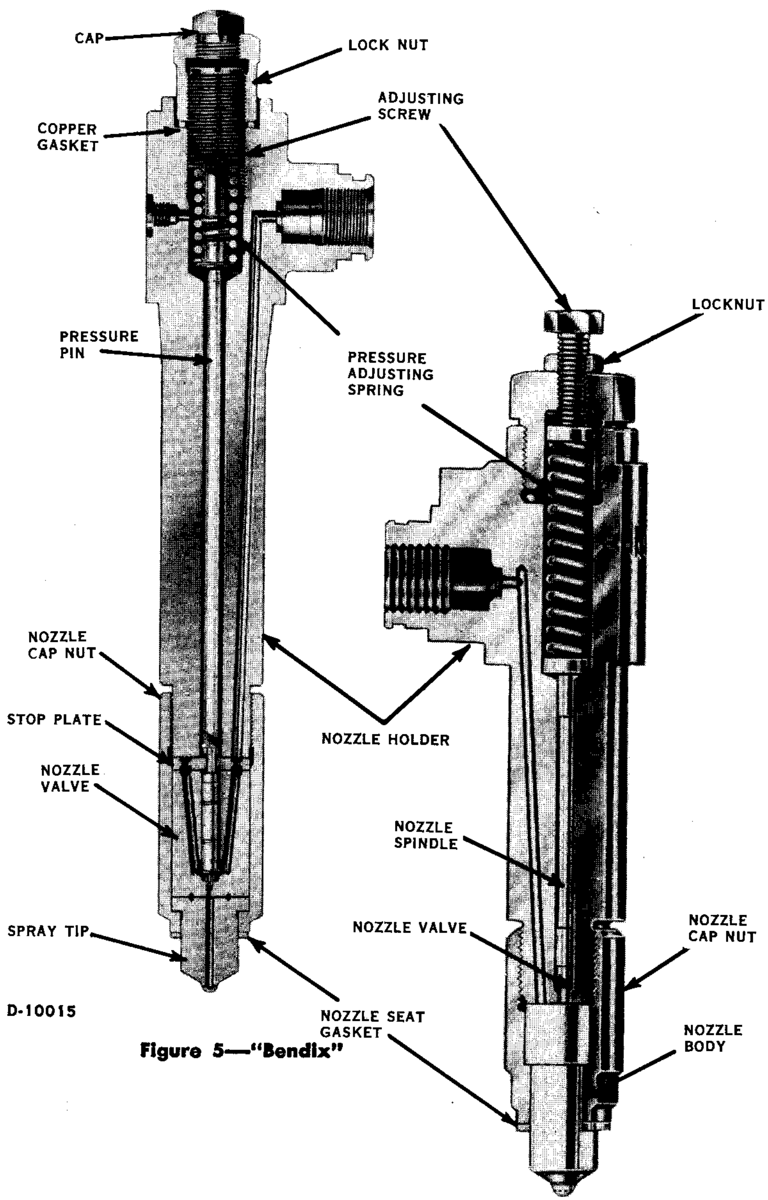


Figure 5—"Bendix"

Figure 6—"Bosch"

on "Bendix" fuel injectors. After assembling the injector, check the valve unseating pressure with the injector testing device. The opening pressure should be approximately 4000 pounds and can be altered by turning the adjusting screw inside the cap nut on top of nozzle holder.

The injection nozzle adapter is tack welded to the nozzle holder and it will be necessary to cut the welds whenever the metal edge filter is to be replaced. After adapter is removed inspect the seat in the fuel inlet connection in the nozzle holder for rough spots or burrs. Recondition seat as required with reamer B.L.H. Part No. 600-70-045. Install a new metal edge filter and spring and assemble the adapter to the nozzle holder before injector is installed in cylinder head. The adapter must be tightened sufficiently to prevent leaks, (250 to 300 ft. lbs. torque). *Caution:* The metal edge filter must be installed in the adapter, otherwise the injection characteristics will be altered and have a detrimental effect on injection. After the adapter is properly tightened it should be locked in place by tack welding it to the nozzle holder. Use a small filler piece of stainless steel welding rod, ⅛″ dia. x ⅜″ long, and place it in the space between the adapter and nozzle holder; then apply weld over the filler piece.

Before application of injector to cylinder head, inspect the condition of gasket seat in counterbore of cylinder head. If necessary, remove carbon from seat with reamer (B.L.H. part No. 600-70-110).

Application of the fuel injection pipe should be made by tightening the fuel line nuts to injector and injection pump before tightening the injector mounting bolts. This will permit proper centering of the fuel injection pipe and relieve strain on the pipe. In order to prevent fuel leaks it is essential to check tightness of all fuel line nuts and injector drain line connections at regular intervals.

MAINTENANCE OF FUEL INJECTION PUMPS

The injection pumps should be checked on a test stand rather than on the engine. The pumps should operate freely and produce the same size spray for each stroke. If the pump action is irregular or does not discharge a sufficient amount of fuel during each stroke, the pump should be disassembled for inspection. Inspect the delivery valve, valve seat and valve spring and make corrections or replacements as required. The valve and valve seat are lap fitted and original pairing of these parts must be maintained. Remove the plunger and cylinder from the pump body. Each plunger and cylinder assembly is lapped to a precision fit, therefore these parts are not interchangeable and it is important to maintain the parts paired as originally assembled. If any pump plunger and cylinder requires servicing, return the complete assembly to Baldwin-Lima-Hamilton Corp., refer to Page 1.

Before applying pump, inspect fuel pump tappet and umbrella assemblies to make sure that the umbrella is permanently secured to tappet and that no fuel leakage occurs at junction of tappet and umbrella.

When reassembling a pump, tighten the delivery valve holder, with a torque wrench, to 650 ft.-lbs.

After pumps and injectors have been reassembled on engine, the fuel system should be primed (free from air) before starting the engine. Priming is accomplished by opening the air bleed screw on each fuel injection pump about one turn, also opening the vent on the generator end of the fuel supply header and vents on top of fuel filter and fuel strainer. Then start the fuel supply pump and run it until the system is free of air. Bar engine over several complete revolutions to prime the fuel pumps and injectors. Care should be exercised in priming to avoid pumping an excessive amount of fuel into the cylinder as this may cause excessive firing pressures when the engine is started.

CYLINDER LOAD DISTRIBUTION

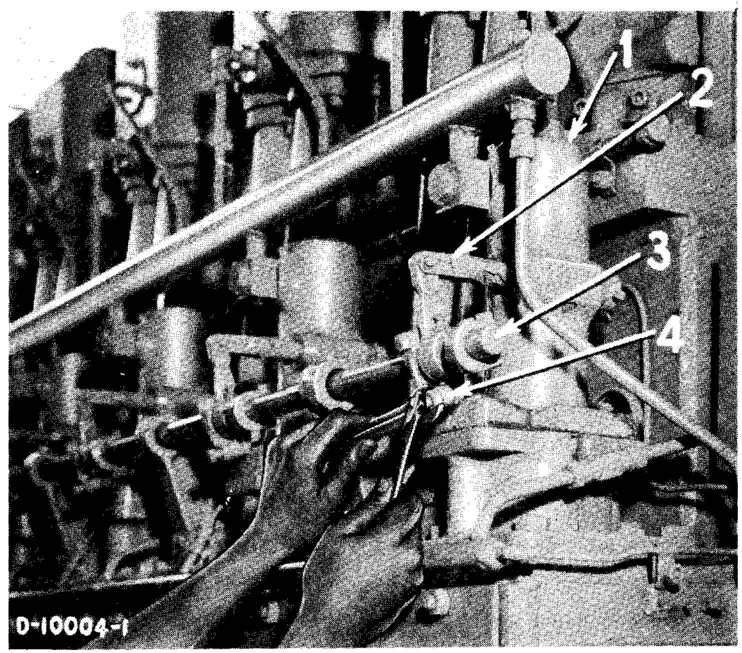
The load distribution between cylinders, as indicated by the exhaust temperatures, is checked by means of a pyrometer. The exhaust temperature difference between cylinders should not vary more than 30°. The pyrometer being used should be checked for accuracy at regular intervals.

Before adjusting any fuel pumps to correct load distribution make sure the fuel supply and injection equipment is functioning properly as outlined in foregoing paragraphs. Also, the fuel injection timing must be correct as described in Engine Timing Section.

Adjustments should be made only after engine is thoroughly warmed up and operating under reasonably steady load. The load distribution is equalized between cylinders

by altering the setting of the adjusting screw on lever adjustment collar located on the fuel control shaft at each fuel pump. Loosen the locknut on adjusting screw and turn the adjusting screw clockwise to increase the fuel discharge, or counter clockwise to decrease the fuel discharge. The adjusting screw should be turned only about one-half turn at a time until proper exhaust temperature is obtained. After the correct adjustment is obtained, the locknut should be tightened on the adjusting screw. Adjust only one cylinder at a time.

The control rack of each fuel pump is provided with millimeter graduations indicating load position of the plunger. However, these graduations should not be used as a basis



Balancing Fuel Pumps

Figure 7

1. **Fuel Injection Pump**
2. **Control Rack**
3. **Fuel Control Shaft**
4. **Rack Adjusting Screw & Lock-Nut**

for readjusting any fuel pumps for load distribution. When injection equipment is in good condition and the load between cylinders properly equalized, the maximum variation in rack setting of all pumps should not exceed 2 mm. If the variation in rack setting is greater than this amount, the injection system should be inspected and replacement or reconditioning of parts done as required.

After the exhaust temperatures have been balanced, check the maximum firing pressure and compression pressure for each cylinder. Excessive exhaust temperatures and low maximum firing pressures with normal compression pressures is an indication that the fuel timing is late and should be corrected before placing engine in service. Low compression pressure is an indication that the intake or exhaust valves are not seating properly or that the piston rings are worn excessively or stuck in the ring grooves.

SPECIFICATIONS

FUEL INJECTOR

Opening pressure	4000 P.S.I.
Number of holes	9
Diameter of holes	.0177″
Spray angle	160°

CYLINDER CONDITIONS AT FULL LOAD

	Supercharged	
	8 Cylinder	6 Cylinder
*Compression pressure—P.S.I.	690 ± 50	690 ± 50
Maximum firing pressure—P.S.I.	1,120	1,120
Exhaust elbow temperature, Max.—°F.	925	925

	Normally Aspirated
	6 Cylinder
*Compression pressure—P.S.I.	540 ± 40
Maximum firing pressure—P.S.I.	1,120
Exhaust elbow temperature, Max.—°F.	1,000

* Variation in pressures between the individual cylinders of same engine should not exceed 50 P.S.I.

AUXILIARY CHAIN DRIVE

The auxiliary chains which drive the lubricating oil and the jacket water pumps are located at the pump end of the engine. Each chain is provided with an adjustable idler sprocket.

MAINTENANCE

Adjustment of slack in the chains is made by changing the position of the brackets on which the idler sprockets are mounted. The chains are adjusted as follows:

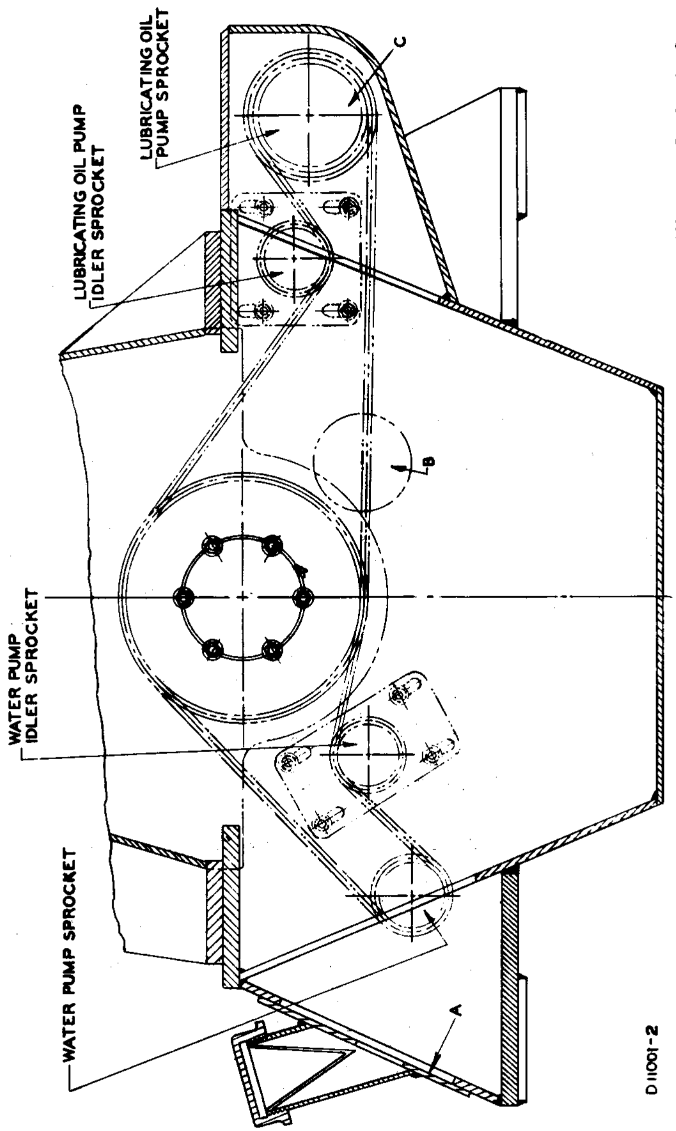
a. Remove the three inspection covers "A", "B" and "C" (Figure #1). Cover "A" carries the crankcase oil filler connection.

b. Loosen the nuts, that secure the idler brackets, sufficiently to permit movement of brackets. The idler bracket for the lubricating oil pump drive chain should be moved down to tighten the chain. The idler bracket for the water pump drive chain should be moved upward to tighten the chain. Tension of chains is checked by reaching in through the inspection openings and applying strong hand pressure in the middle of the longest span of each chain. When adjusted properly the total movement or slack should be approximately ¼″. When new chains are installed, they should be installed with the proper slack.

c. After proper tension has been obtained tighten the nuts that secure the idler brackets.

The tension in a new chain must be checked after approximately 150 hours of operation and the chain adjusted as required. This also applies to the chain in a new engine. After the initial stretch has been taken up, it will only be necessary to inspect and possibly adjust the chain after each period of 1000 hours of operation.

After the full range of idler sprocket adjustment has been utilized, a new chain should be installed. Do not use an offset or half link in the chain. Inspect the teeth of all sprockets for wear before installing a new chain.



Auxiliary Chain Drive
Figure 1

COOLING WATER SYSTEM

The cooling water system is of the closed type. A centrifugal pump, chain driven from the engine crankshaft, circulates the water through the engine jackets to the cooling radiators and thence through the lubricating oil heat exchanger before returning the water to the engine. An expansion tank is provided for the system. Refer to cooling water system diagrams Figures 3 and 4.

COOLING WATER SUPPLY

Any water regardless of source should be subjected to chemical analysis, in order to determine the suitability of the water for diesel engine cooling. Although it may appear clean and pure, water in general contains impurities as suspended matter, chemicals which are classed as "hardness" in the water, excess oxygen, and acids.

Suspended matter and oil in the water, even in the smallest degree, will impair the proper heat transfer condition of the system. Sludge and mud will form and excessive foaming occur if the oil and suspended matter are not filtered out of the water. Proper coagulation and passage through a sand filter will remove the oil and suspended matter from the water.

Refer to B.L.H. Maintenance Bulletin for additional information on water treatment and flushing of the cooling system.

CLEANING OF COOLING SYSTEM

If the condition of the cooling water has been neglected, causing scale to deposit in engine jackets and radiators, it should be removed as soon as possible. A chemical solution such at Oakite No. 32 made by Oakite Products Inc., New York, N. Y., or Dearborn No. 134 made by Dearborn Chemical Co., Chicago, Ill., may be used. Instructions furnished by the manufacturer of the cleaning compound should be followed carefully. It is important to thoroughly flush and neutralize the system after cleaning.

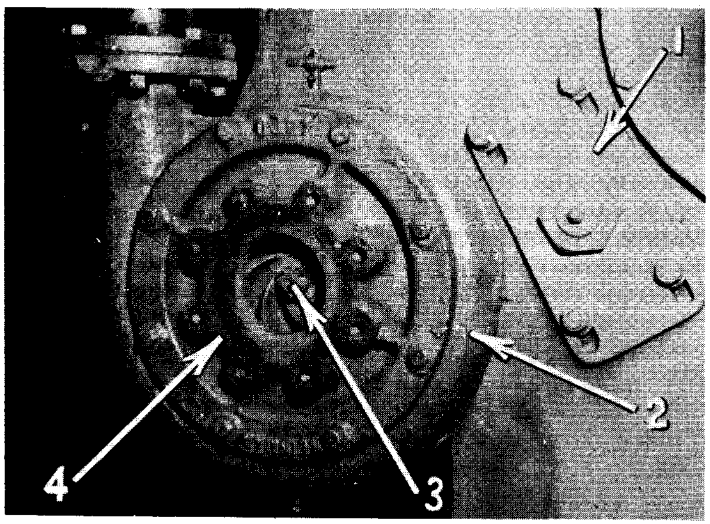
DRAINING AND FILLING THE COOLING SYSTEM

When draining the cooling system, do not drain while engine is hot (over 120° F.). All sediment which may have accumulated at the bottom of the water jackets should be flushed out carefully. Be sure that all water is drained from turbocharger.

When refilling the system, use only treated water. Operate the engine a few minutes to expel any air trapped in the system, after the air has been removed; add water as required to completely fill the system. Make-up water should be added to the system when engine is not in operation and preferably when engine is cold. If make-up water must be added to system while engine is warm (above 120°F.), the water should be heated or added to the system very slowly.

WATER CIRCULATION AND TEMPERATURE

The cooling water temperature may vary between 145° F. and 175° F. depending on engine load and atmospheric conditions, although safe operation can be achieved with temperatures up to 200° F. Radiators cooled by either engine or motor-driven fans remove the heat from the engine cooling water. Consult the Operator's Manual for your locomotive for details on the automatic temperature control system.



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Water Pump

Figure 1

1. **Chain Idler Adjustment Bracket**
2. **Pump Casing**
3. **Impeller Nut (Left Hand Thread)**
4. **Pump Suction Head**

WATER PUMP

The water pump requires no outside lubrication. The bearings are lubricated by the crankcase oil.

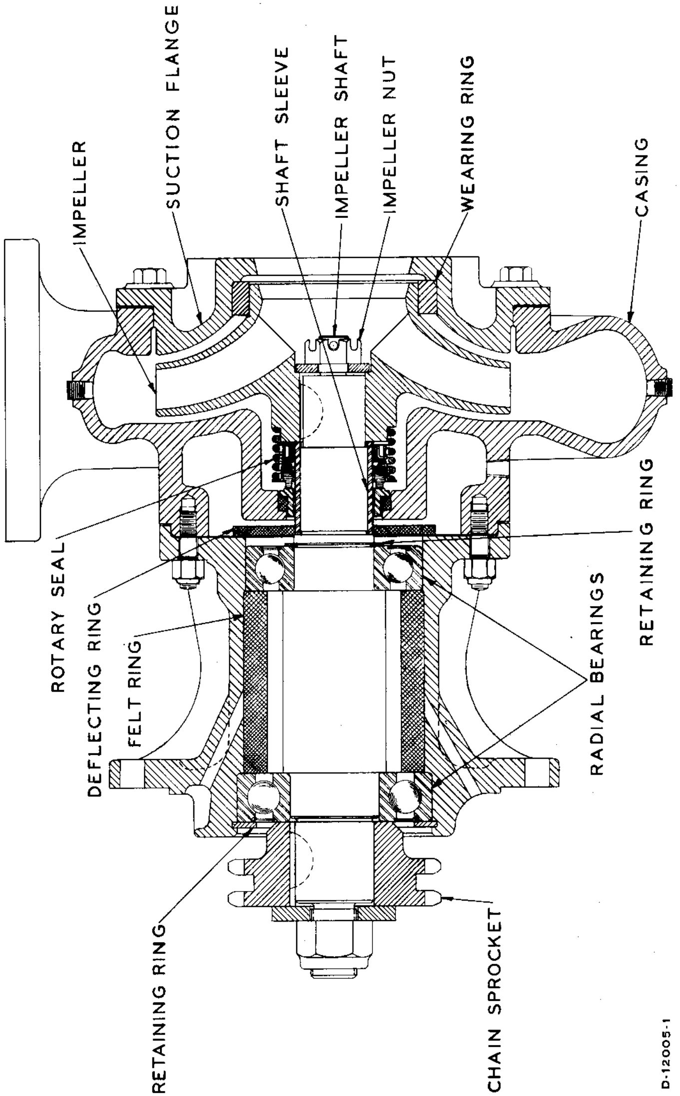
MAINTENANCE

If the pump leaks excessively, the rotary seal may be defective, refer to Figure 2. The pump must be removed from the engine to replace this seal but it is not necessary to completely disassemble the pump. Refer to B.L.H. Maintenance Bulletin for detailed maintenance instructions.

The entire pump unit must be removed from engine for bearing replacement. When reassembling pump spread a thin film of permatex on the frame to hold gasket in place. After replacing pump drive chain it must be adjusted as described in Auxiliary Chain Drive Section.

SPECIFICATIONS

Water Pump Capacity in GPM 500



Cross Section Drawing of Water Pump

Figure 2

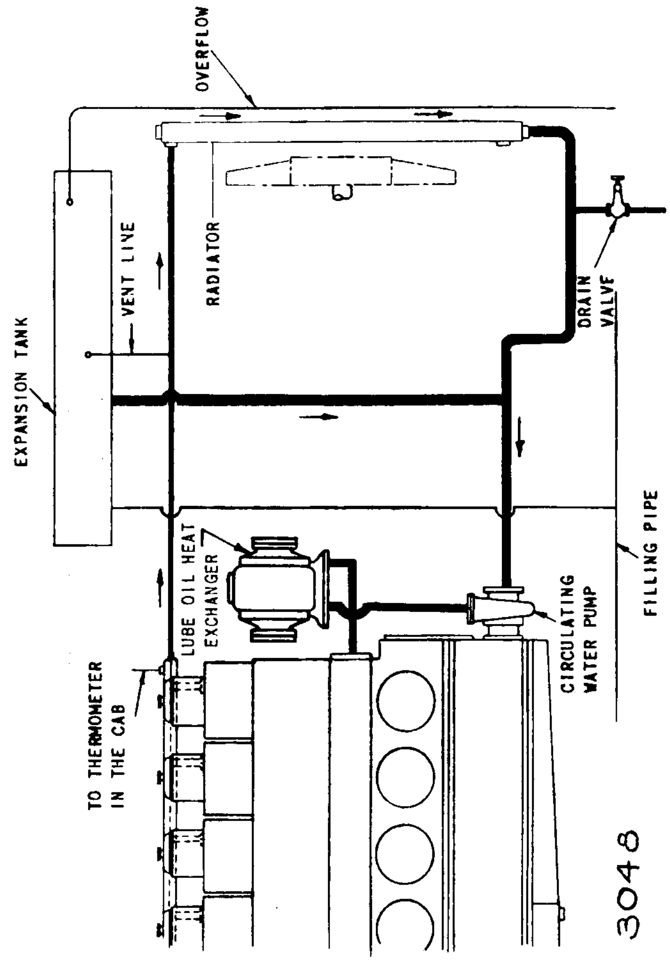


Diagram of Engine Cooling Water System (Engine-Driven Radiator Fan)

Figure 3

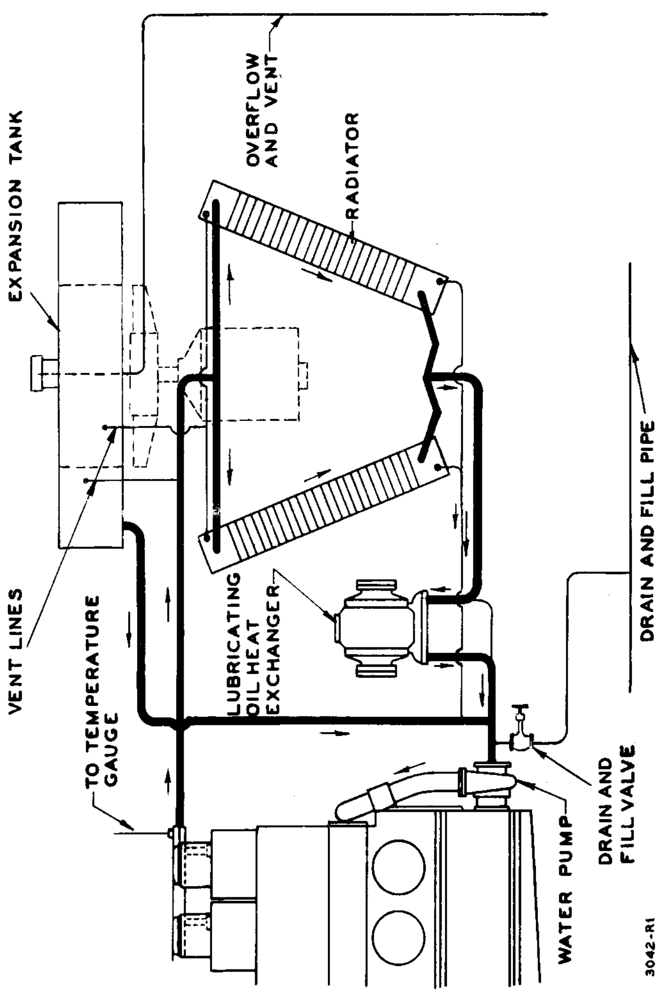


Diagram of Engine Cooling Water System (Motor-Driven Radiator Fans)

Figure 4

FUEL SUPPLY SYSTEM

The fuel oil is pumped from the tank by means of a motor-driven supply pump. A strainer is provided in the suction line to protect the supply pump. A cartridge type filter is located in the pressure line between the supply pump and the injection pumps.

In the suction line to the supply pump is located a fuel shut-off valve which can be manually operated from the cab or from the outside in an emergency. A relief valve is provided in the supply pump discharge set to open at approximately 35 P.S.I. pressure.

A relief valve set to open at approximately 25 P.S.I. is connected to the fuel injection pump supply header. The excess oil supplied to the header returns to the fuel tank through this relief valve.

The fuel injection pumps and injectors are described in a separate section. Any leakage from injectors or pumps is collected in a header and returned to the fuel supply tank.

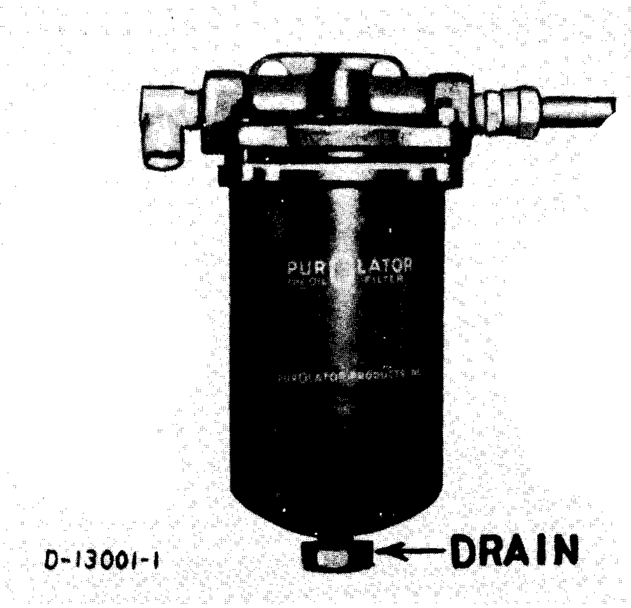
A protective system actuates the fuel injection pump control shaft and shuts the engine down in case dangerous conditions occur which are controlled by safety switches. This system is described under Lube Oil System.

A good grade of fuel oil should be used at all times. For recommended fuel oil refer to B.L.H. Specification MBG-102.

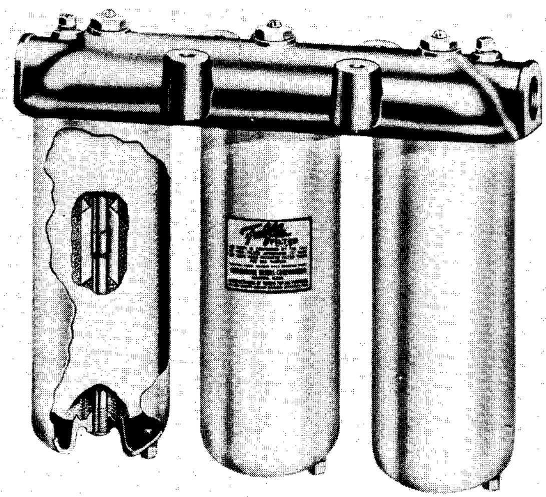
FUEL OIL PURIFICATION

Proper functioning of the engine depends upon mechanical condition and fits of parts of the fuel injection system. Therefore, it is important that the fuel oil as delivered to the engine is free of water and all impurities. It is a good practice to filter the fuel oil before it is permitted to enter the tank. At regular intervals the fuel tank should be flushed clean to remove dirt and water settled at bottom.

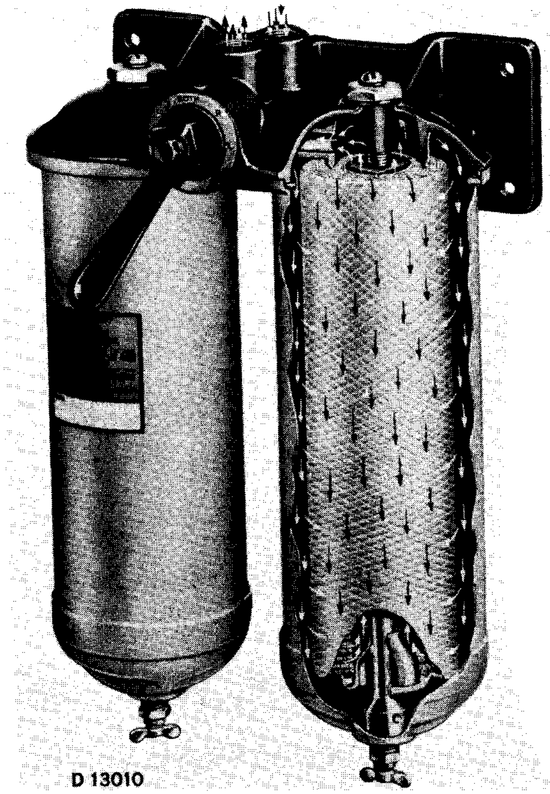
The strainer in the suction line should be cleaned by removing the casing and thoroughly washing the element and casing at intervals as shown on your Maintenance Chart. Never open the drain on the strainer while the fuel supply pump is in operation.



Metal Edge Type Fuel Oil Suction Strainer
Figure 1



Cartridge Type Fuel Oil Filter
Figure 2

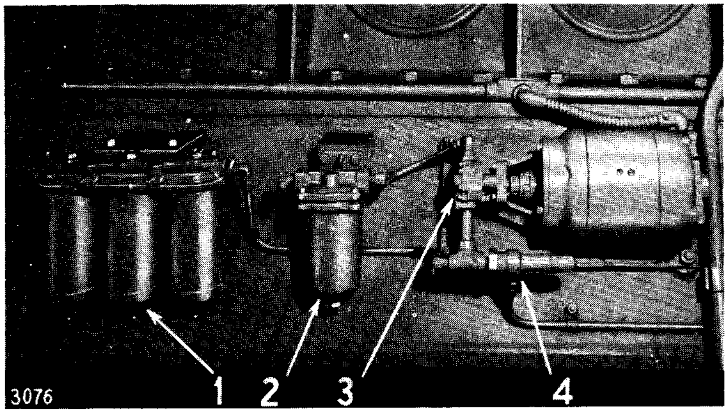


Cartridge Type Duplex Fuel Oil Filter
Figure 3

Open the drain plug at the bottom of the cartridge type filter to drain off dirt and water. This should be done while the supply pump is in operation. If the pressure in the fuel injection supply header drops below normal it may indicate the filter is becoming clogged. The cartridge should then be replaced. However, it is best to renew the cartridge as indicated on your Maintenance Chart. After renewal of the filter element it will be necessary to open the vent on the top of the filter to permit the air to escape. The system is cleared of air by operating the supply pump until all air has been expelled from filter and piping.

FUEL SUPPLY PUMP

The fuel supply pump is located on the engine base on valve gear side of engine. The pump is a motor-driven positive displacement gear pump, mounted on the drive end of motor. A flexible coupling is used between the motor and pump.



Fuel Oil Supply Pump

Figure 4

1. **Cartridge Type Filter**
2. **Metal Edge Strainer**
3. **Motor Driven Supply Pump**
4. **Discharge Relief Valve**

MAINTENANCE OF FUEL SUPPLY PUMP

The pump should be lubricated as indicated on your Maintenance Chart at the fitting provided on the drive end.

Excessive noise or failure to maintain pressure should be investigated by dismantling the pump and checking all parts thoroughly. (Refer to the Maintenance Bulletin covering this pump.)

SPECIFICATIONS

Fuel Supply Pump Capacity in GPM at 35 P.S.I. . . . 3

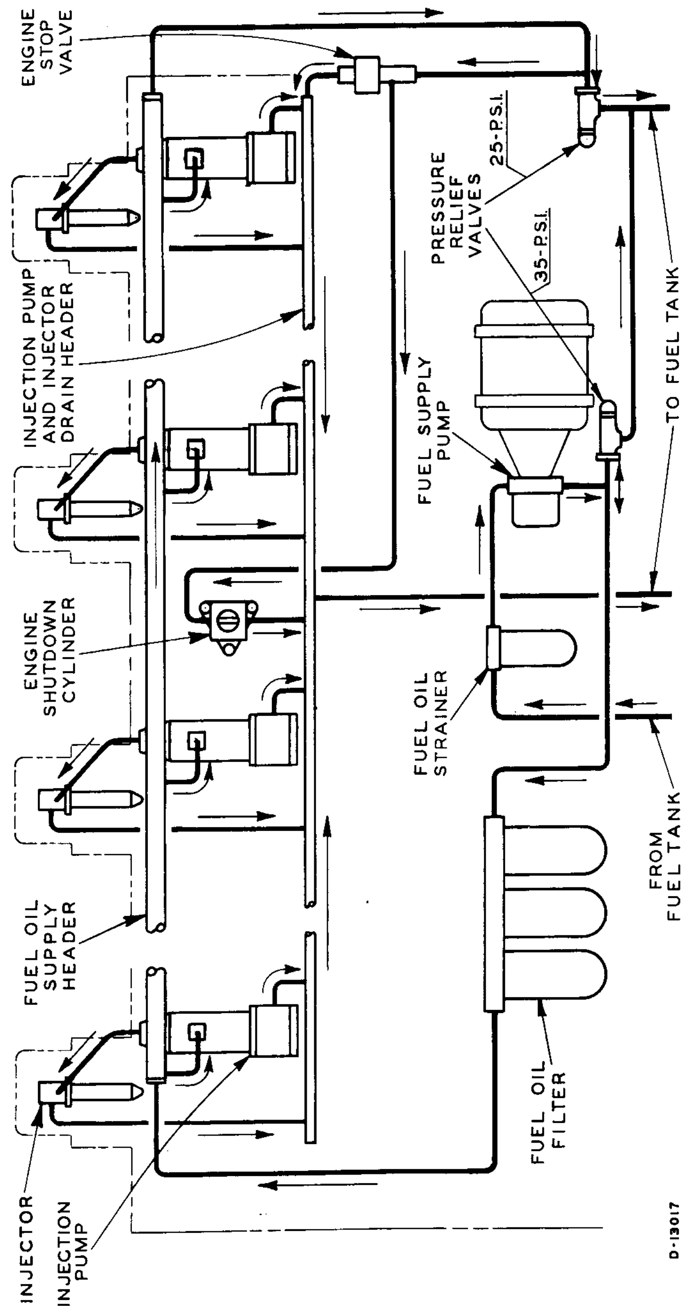


Diagram of Engine Fuel Oil System

Figure 5

NOTES

LUBRICATING OIL SYSTEM

A positive displacement gear pump, chain driven from the crankshaft at the pump end of the engine, draws the lubricating oil from the engine base and circulates it through the system. The oil passes through a check valve and a suction strainer before entering the pump. After leaving the pump the oil passes through a full flow filter, a heat exchanger and a metal edge strainer before entering the engine distributing system.

ENGINE DISTRIBUTING SYSTEM

This system supplies the oil under pressure to all engine bearings, camshaft and pump chain drives, valve rocker arms and push rods, also for piston cooling. The rollers and guides for the push rods and fuel pumps are pressure lubricated. The push rod roller guides are also lubricated by oil draining down along the push rods from the valve rocker arms. The oil in the camshaft trough provides lubrication for the cams and this oil supply is replenished continuously from the engine pressure system and is kept at a constant level by means of overflow connections to the crankcase.

The engine base is provided with an oil filler connection, also an oil level gauge rod. The oil level should be checked at regular intervals, refer to B.L.H. Maintenance Bulletin. The oil level should not be below the "low" mark or above the "high" mark on the gauge rod.

An engine shut-down device is provided which will stop the engine if the lubricating oil pressure should drop below 15 pounds pressure.

LUBRICATING OIL PURIFICATION

The lubricating oil in the engine must be kept in as clean a condition as possible. The oil, before it reaches the pres-

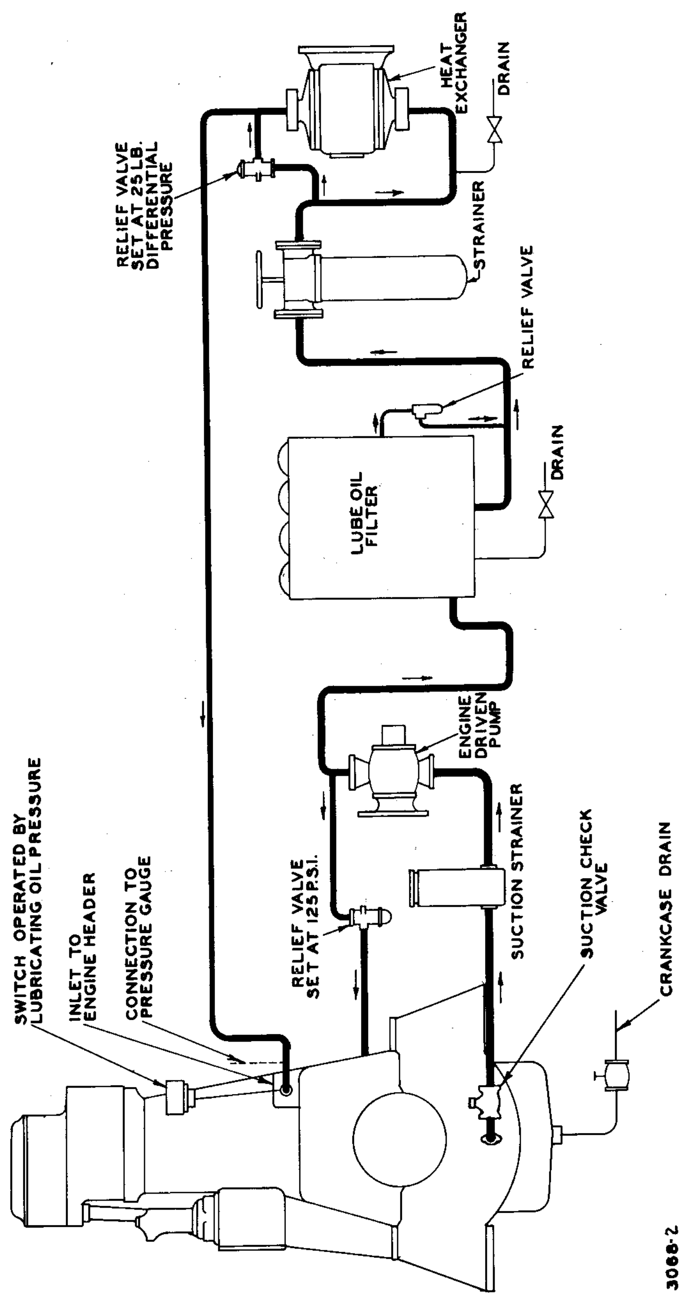
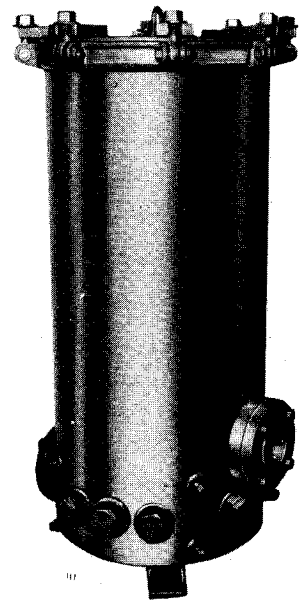


Diagram of Engine Lubricating Oil System

Figure 1

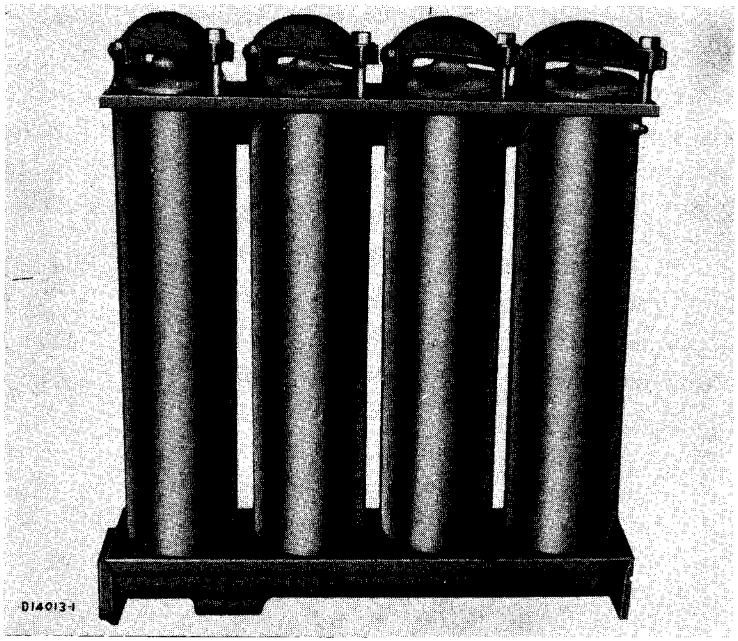
sure pump, passes through a suction strainer. This strainer is of the perforated metal basket type and should be cleaned of all dirt and impurities as indicated on your Maintenance Chart. Before the oil reaches the engine distributing system, it passes a cartridge type lubricating oil filter, refer to Figure 1.

The lubricating oil filter, either the circular or the flat type has absorbent type elements which remove the finer impurities in the oil. These filters are equipped with elements composed of waste or other fibrous material. It is necessary



Lubricating Oil Filter (Circular Type)

Figure 2



Lubricating Oil Filter (Flat Type)

Figure 3

to change the filter elements at regular intervals, as specified on the Maintenance Charts, in order to keep the lubricating oil in as clean a condition as possible.

LUBRICATING OIL RENEWAL

The lubricating oil in the system should be changed completely at regular intervals. See recommendations on Maintenance Chart. It may be necessary to change the time period between renewals as the operating conditions vary. A laboratory analysis of a sample of the crankcase oil will indicate if renewal is necessary. A viscosity gauge may be used for this purpose although it is not as accurate as a laboratory analysis.

When adding lubricating oil or changing the lubricating oil, care should be taken to be sure that the proper lubricating oil is used. Refer to B.L.H. Specification MBG-101 for recommended lubricating oil.

The oil should be removed shortly after engine has been shut down and while oil is still warm. Drain the oil from camshaft trough, heat exchanger and lubricating oil filter. Repack the filters with new elements. Use a flushing oil for cleaning crankcase, heat exchanger, strainer and filter. Never use gasoline or waste to clean or wipe inside of engine. Always use clean cloths which do not deposit lint.

When adding new oil, fill crankcase up to the high mark on the gauge. Also fill camshaft trough until it overflows into the crankcase through level pipes. Open vents on the filter. After the system is primed, check the oil level and add more oil as necessary to bring the oil level up to the high mark on the gauge rod.

LUBRICATING OIL PRESSURE

The lubricating oil pressure gauge should normally indicate a pressure of 50 P.S.I. in the locomotive cab and 65 P.S.I. at engine at rated speed. At lower speeds the pressure will be proportionately lower. At no time should the pressure drop below 15 P.S.I. pressure.

If the lubricating oil pressure drops below normal, this may be caused by excessive dirt in the filter element increasing the flow resistance. When the filter element becomes clogged, undue by-passing of oil will take place through the pressure relief valve. Check the pressure relief valve in the by-pass line and make corrections as necessary. If the cleaning of the filter and resetting the pressure relief valve does not correct the low pressure condition, the entire lubricating oil system should be inspected for undue restrictions or leaks.

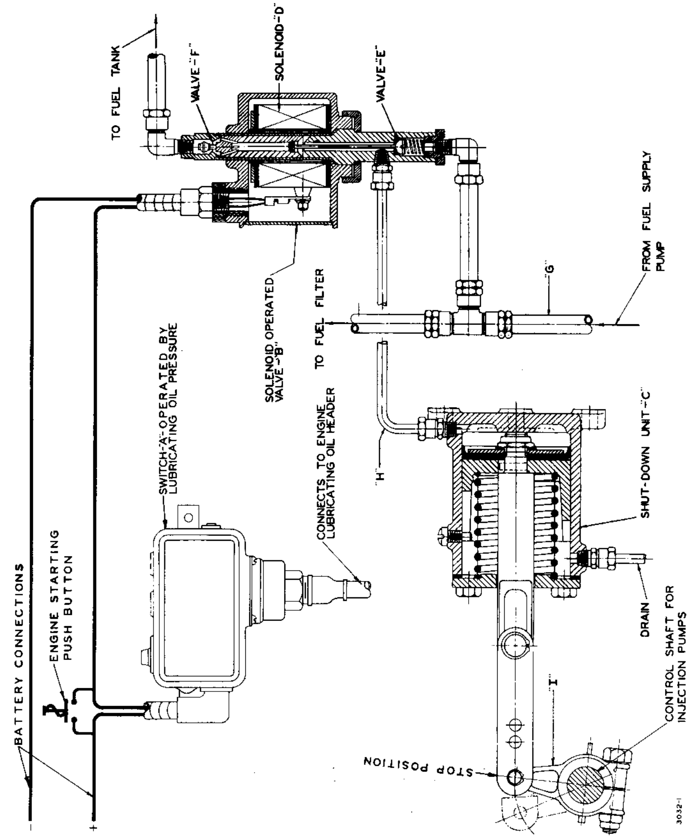
If the lubricating oil pressure is appreciably higher than normal, this may be caused by unusually heavy lubricating oil, lubricating oil temperature below normal, or sticking of the pressure relief valve in the by-pass line. Investigate and make corrections as necessary.

LOW LUBRICATING OIL PRESSURE SHUT DOWN

The engine protective shut-down system shown in Fig. 4 includes the low lubricating oil pressure switch which is set to shut down the engine if the lubricating oil pressure drops to approximately 15 P.S.I. This device consists of a pressure operated switch "A," a solenoid operated double acting valve "B" and a shut-down unit "C." The switch "A" is operated by the pressure in the lubricating oil system. During normal operation the switch "A" is held in the closed position by the lubricating oil pressure, thus permitting the electric current to energize the solenoid "D" which then keeps the valve "E" open and the valve "F" closed. When the valve "E" is open the fuel supply line "G" is in direct communication with the shut-down unit "C" through the line "H." The piston inside the shut-down unit "C" is then pushed out by the fuel pressure thus moving the lever "I" to a position which releases the fuel pump control shaft from the stop position.

If the pressure in the lubricating oil header drops to 15 P.S.I. or lower the switch "A" breaks the current to the solenoid "D" which then closes the valve "E" and opens the valve "F." The fuel under pressure in cylinder "C" is then released through line "H" and valve "F" to the tank. When the fuel pressure in cylinder "C" is released, the piston is pushed in the opposite direction by means of a spring. The lever "I" operated by the piston, then turns the fuel injection pump control shaft to the stop position thus shutting the engine down. A torsion spring at the governor end of the control shaft permits the shaft to turn to the stop position independently of the governor.

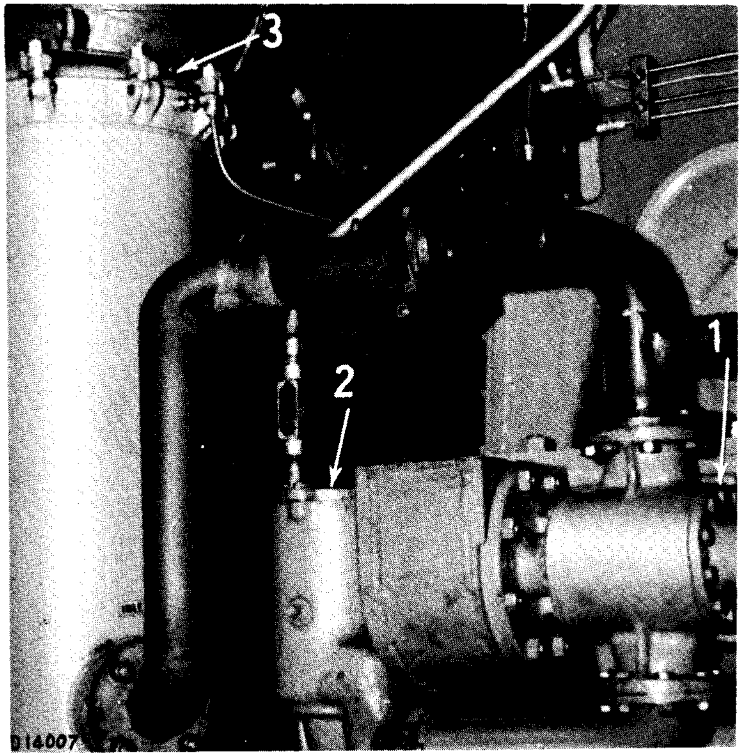
During the starting period when there is no pressure in the lubricating oil header to close switch "A," the solenoid circuit is closed by means of the engine starting push button. The switch "A" requires approximately 19 P.S.I. pressure for contact closing. The starting button must be held closed until the engine speed is sufficient to build up an oil pressure in excess of 19 P.S.I.; otherwise, switch "A" would stop the engine. When the oil pressure is high enough to close switch "A" and the starting button is released, the circuit is complete through switch "A" to the solenoid valve "B."



Engine Protective Shut-Down System
Figure 4

LUBRICATING OIL PUMP

Worn gears or bearings will be indicated by excessive noise even though the pump is delivering oil properly. If the pump is unable to maintain pressure, there may be excessive clearance between the gears and the casing.



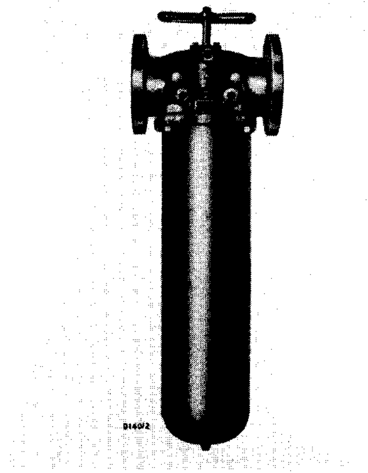
Lubricating Oil Pump

Figure 5

1. **Engine Driven Pump**
2. **Lube Oil Suction Strainer**
3. **Lube Oil Full Flow Filter**

MAINTENANCE OF LUBRICATING OIL PUMP

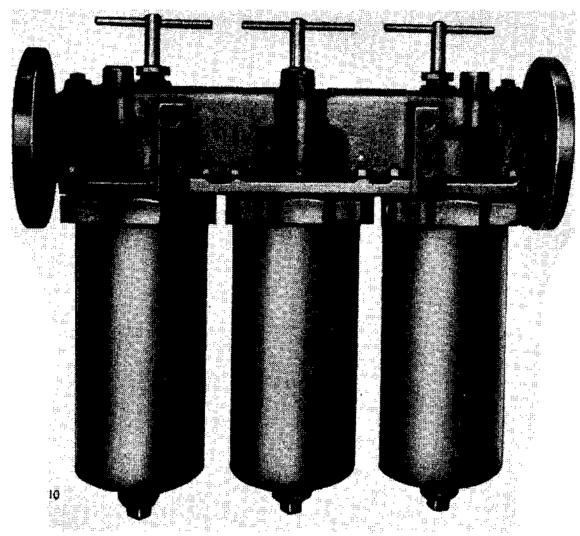
In order to service the pump properly it should be removed from the engine. Disconnect the drive chain from the pump sprocket before removing the bolts which fasten



Lubricating Oil Strainer

(Single Unit Type)

Figure 6



Lubricating Oil Strainer

(Three Unit Type)

Figure 7

the pump to the engine base. Remove the drive sprocket from the shaft, also the key. The pump can then be completely dis-assembled. (See Maintenance Bulletin.)

When replacing a pump and gasket, use permatex on bedplate only. After the pump drive chain is connected, it should be checked for tension as described in Auxiliary Chain Drive Section.

SPECIFICATIONS

Lubricating Oil Maximum Operating Temperature—°F.	200
*Lubricating Oil Pump Relief Valve Setting—P.S.I.	125
Lubricating Oil Filter Relief Valve Setting—P.S.I.	35

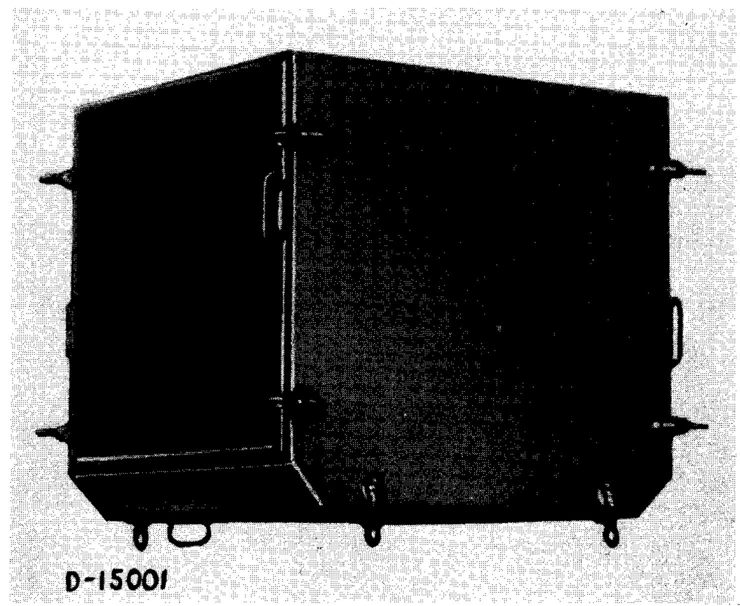
* The setting shown is approximate and must be adjusted to obtain 50 P.S.I. pressure on gauge, located in the locomotive cab, when engine is operating at full speed with normal lubricating oil temperature (at least 155°F.) and clean elements in the lubricating oil filter.

AIR INTAKE FILTER

The engine air intake filter and silencer is made up of a sheet metal and expanded metal housing containing two, three, or four removable elements filled with finely shredded metal. The oiled surfaces of the shredded metal remove dust from the intake air insuring a clean air supply to the engine.

MAINTENANCE OF AIR INTAKE FILTER

The maintenance of air filters consists of regular cleaning and re-oiling of the elements. Consult your Maintenance Chart and Maintenance Bulletins for schedule and cleaning procedure.



Three Element Air Intake Filter and Silencer

Figure 1

NOTES

TURBOCHARGER

The engine when supercharged is equipped with an Elliott Model-H turbocharger located at the generator end of engine. The turbocharger is a self-contained unit consisting of a gas turbine and a centrifugal blower mounted on a common shaft. The exhaust gas turbine utilizes the energy in the exhaust gases to drive the centrifugal blower. The blower supplies air to the engine cylinders, through the air intake manifold, at a pressure above atmospheric pressure.

TURBOCHARGER LUBRICATING OIL SYSTEM

The turbocharger is lubricated from the engine lubricating oil system. The lubricating oil pressure will vary somewhat as the engine speed varies but the pressure at the turbocharger inlet should be 22 to 25 P.S.I. at full engine speed. If the inlet pressure is not 22 P.S.I. at full engine speed, check the setting of the by-pass relief valve located in the lubricating oil inlet line to the turbocharger.

The lubricating oil flowing to the turbocharger should be kept in as clean a condition as possible and care should be taken to change the cartridges, in the engine lubricating oil filter, at regular intervals to insure that the lubricating oil is clean. The temperature of the lubricating oil leaving the turbocharger should not exceed 210°F.

When installing a new turbocharger, the lubricating oil inlet, located on the top of turbocharger, should be filled with new lubricating oil before connecting the lubricating oil supply line.

TURBOCHARGER COOLING WATER SYSTEM

The turbocharger is cooled by circulating the engine jacket water through the turbocharger. The cooling water enters at the bottom of the intermediate casing and is circulated through the turbocharger by means of internal passages. The water temperature rise through the turbocharger should not exceed 30°F. Before shutting down the engine it should be operated without load for approximately 10 minutes in order to dissipate as much heat as possible from the turbocharger. There are two drain plugs located at the bottom of the turbine casing. The plug located on the right hand of the turbocharger center-line, when looking toward the turbine inlet, provides a means of draining the turbocharger cooling water jacket. This plug should be removed whenever the engine cooling system is being drained, refer to Cooling Water System. The other plug is the turbine casing drain and provides a means of draining any condensate or rain which might collect in the bottom of the turbine casing. This plug should be opened when the engine is shut down for any length of time and left open until starting up again.

AIR INTAKE MANIFOLD PRESSURE

The pressure in the intake manifold should be checked occasionally. An increase in manifold pressure above normal indicates that the engine is burning an excessive amount of fuel and adjustments should be made to correct the condition. A decrease in manifold pressure below normal may be caused by any one or several of the following conditions:

a. Leaks in the air intake manifold.
b. Nozzle ring failed or damaged.
c. Faulty bearings in turbocharger.
d. Restrictions in air filter due to dirt.
e. Excessive dirt on blower impeller and diffuser ring.

MAINTENANCE OF TURBOCHARGER

If any failure occurs which requires disassembly of the turbocharger or its components, contact the nearest Baldwin-Lima-Hamilton Sales Office where arrangements can be made for reconditioning the turbocharger. Use care in handling a dismounted turbocharger.

SPECIFICATIONS

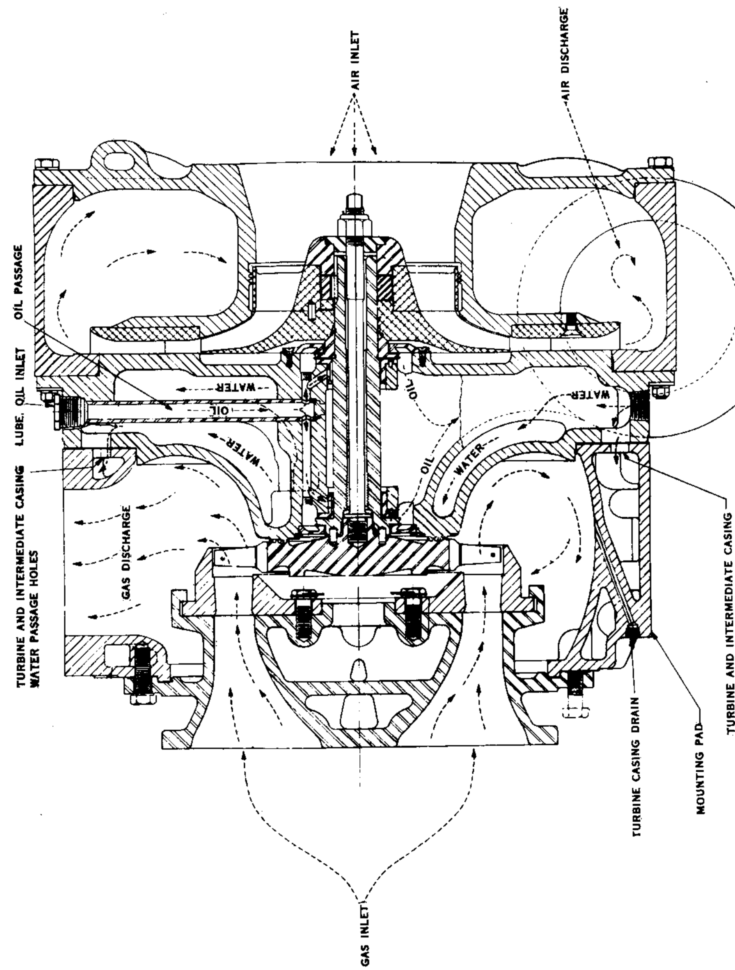
The following data will be useful for checking condition and performance of the turbocharger:

AVERAGE OPERATING CONDITIONS:	4 Pipe	3 Pipe
Turbocharger discharge pressure at full load, P.S.I.	6-8	6-8
Blower speed at full load, R.P.M.	9900	12000
Blower speed at idle, R.P.M.	1450	1700
Rundown Time—minimum, seconds	100	50
*Approximate temperature of exhaust gases °F. at:		
Exhaust elbows	800	800
Turbine inlet	1000	1000
Turbine outlet	800	800

* ±50°F. is an acceptable variation.

TURBOCHARGER ALLOWABLE LIMITS:		
Blower speed—maximum, R.P.M.	14000	17000
Exhaust temperature—turbine inlet °F.	1200	1200
†Maximum exhaust temperature—turbine inlet °F.	1250	1250

† A maximum of four periods of ½ hour each per day.



Cross Section Drawing of Turbocharger
Figure 1

D-18003

CRANKCASE BREATHER

The crankcase breather is located on the exhaust side of the engine. The connection to the crankcase is located at the pump end of engine and is provided with a breather and oil separator unit. The breather and oil separator unit is connected to a breather pipe which is connected to the air inlet to the turbocharger. The oil-laden vapor is drawn from the crankcase, by means of the suction set up in the turbocharger inlet, creating a slight vacuum (approximately ½" of water) in the crankcase. The oil separator removes the lubricating oil from the vapor and it returns to the crankcase through a drain pipe attached to the bottom of the separator.

MAINTENANCE OF CRANKCASE BREATHER

The oil separator element should be removed and washed thoroughly in a solvent at regular intervals, refer to B.L.H. Maintenance Bulletin. The element must be completely dry before it is replaced in the separator.

It is essential that the crankcase be perfectly sealed against the admission of air and great care must be taken to assure that the crankcase inspection covers and other openings are tight. The crankcase pressure should be checked at regular intervals to be sure that there is a slight vacuum in the crankcase.

Section Drawing of Series 600 Engine Showing Fuel Oil, Lubricating Oil and Cooling Water Systems on Engine