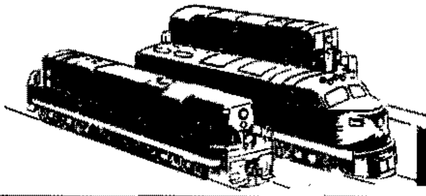
FAIRBANKS MORSE
Opposed Piston ENGINES

INSTRUCTIONS 3800D8$\frac{1}{8}$

MODEL 38D8$\frac{1}{8}$ Diesel

SEC. 308 – LOCOMOTIVE

Colt Industries POWER SYSTEMS DIVISION • BELOIT, WISCONSIN 53511



MAINTENANCE BULLETIN
Sec. 308, Feb., 1956
Supersedes Bulletin of March 1954

FAIRBANKS-MORSE

MODEL 38D8⅛ DIESEL ENGINE

The "Diesel Engine Maintenance Section 308" covers the description, operation, and maintenance of the Opposed Piston Diesel Engine as installed in Fairbanks-Morse locomotives.

This section is divided into chapters, with each chapter covering a single main assembly or group of items which may comprise a system . . . for example, "Cylinder Liner," "Scavenging System and Blower."

The "Table of Contents" list the chapters into which this section is divided.

The "General Index" is the group of colored pages, at the end of the section, and lists the most important items in alphabetical order.

The purpose of this bulletin is to provide maintenance information for the particular piece of equipment named. These instructions do not, however, purport to provide for every possible contingency to be met in connection with the maintenance of this equipment. Neither is the amount of material supplied by Fairbanks, Morse & Co. increased by anything shown in these instructions or associated drawings. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purpose, the matter should be referred to Fairbanks, Morse & Co., Diesel Locomotive Division, Chicago, Ill.

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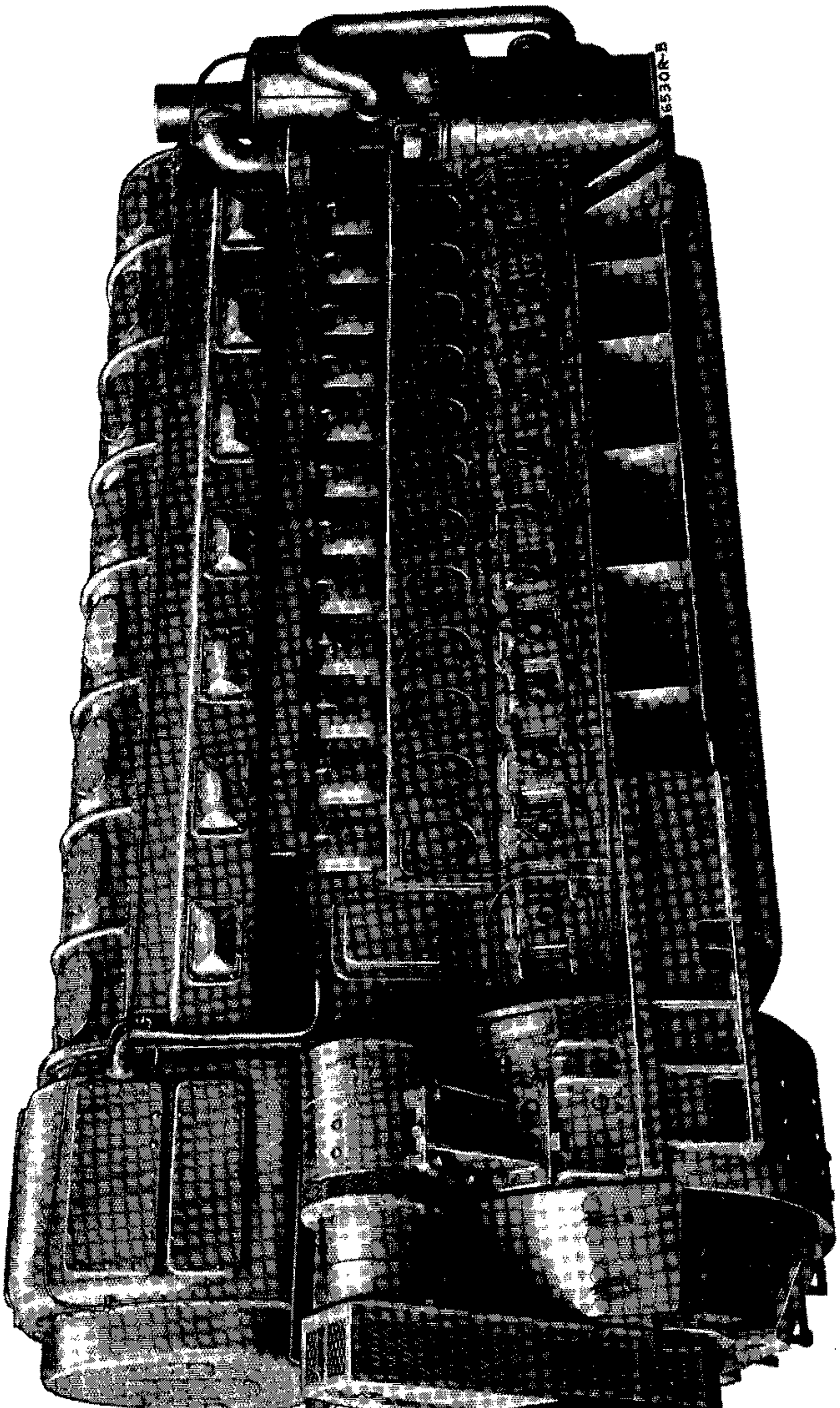
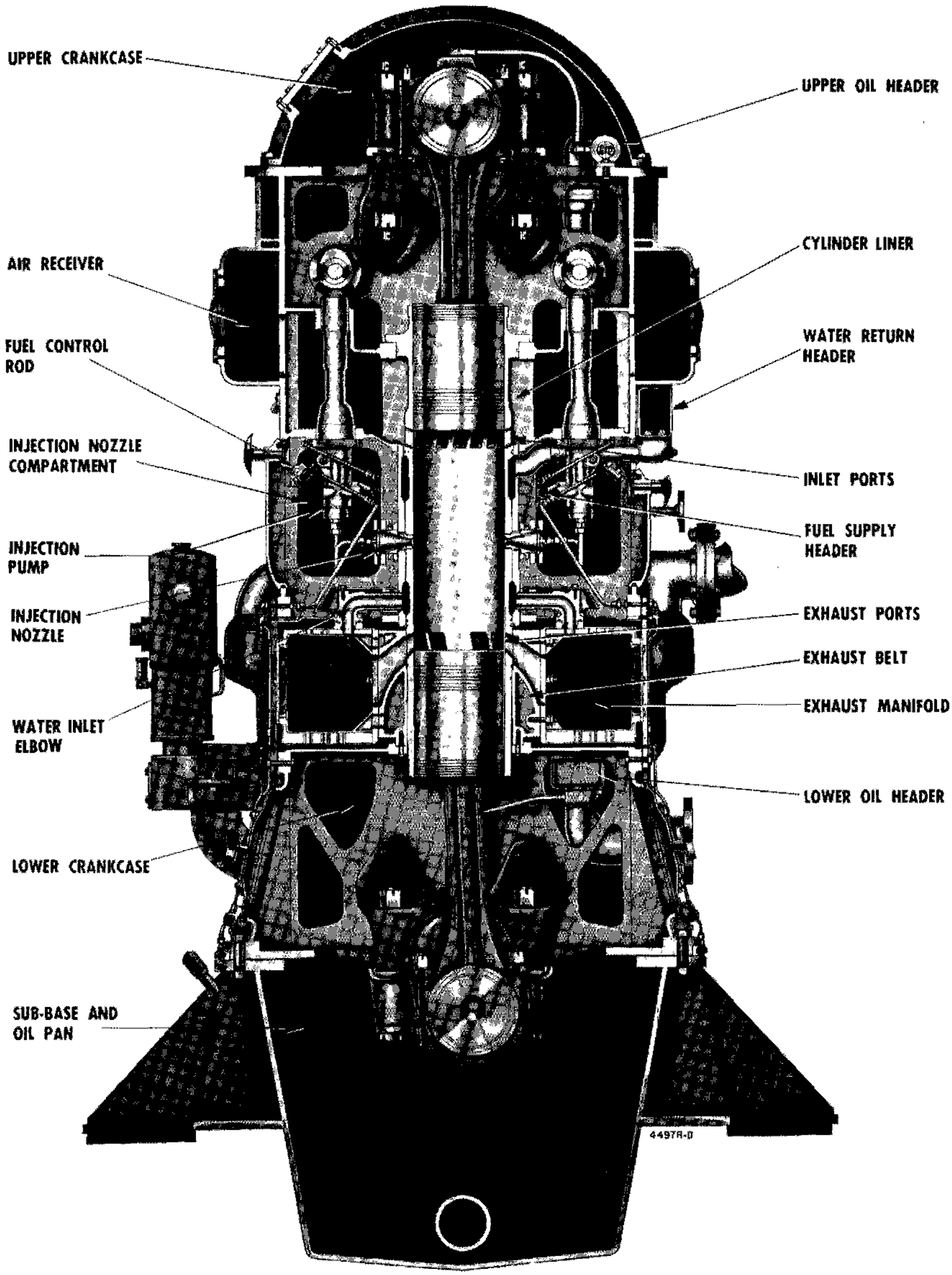
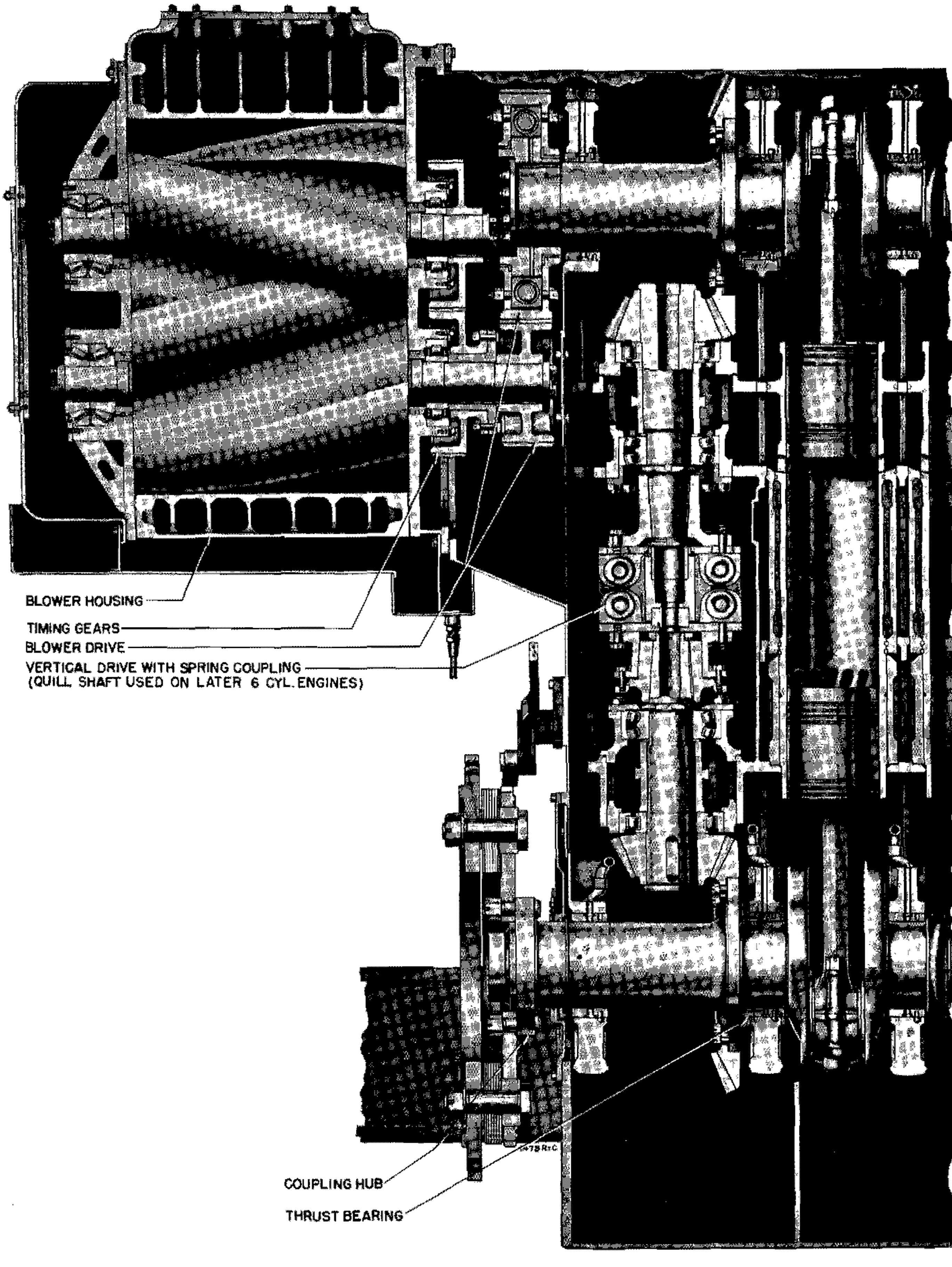


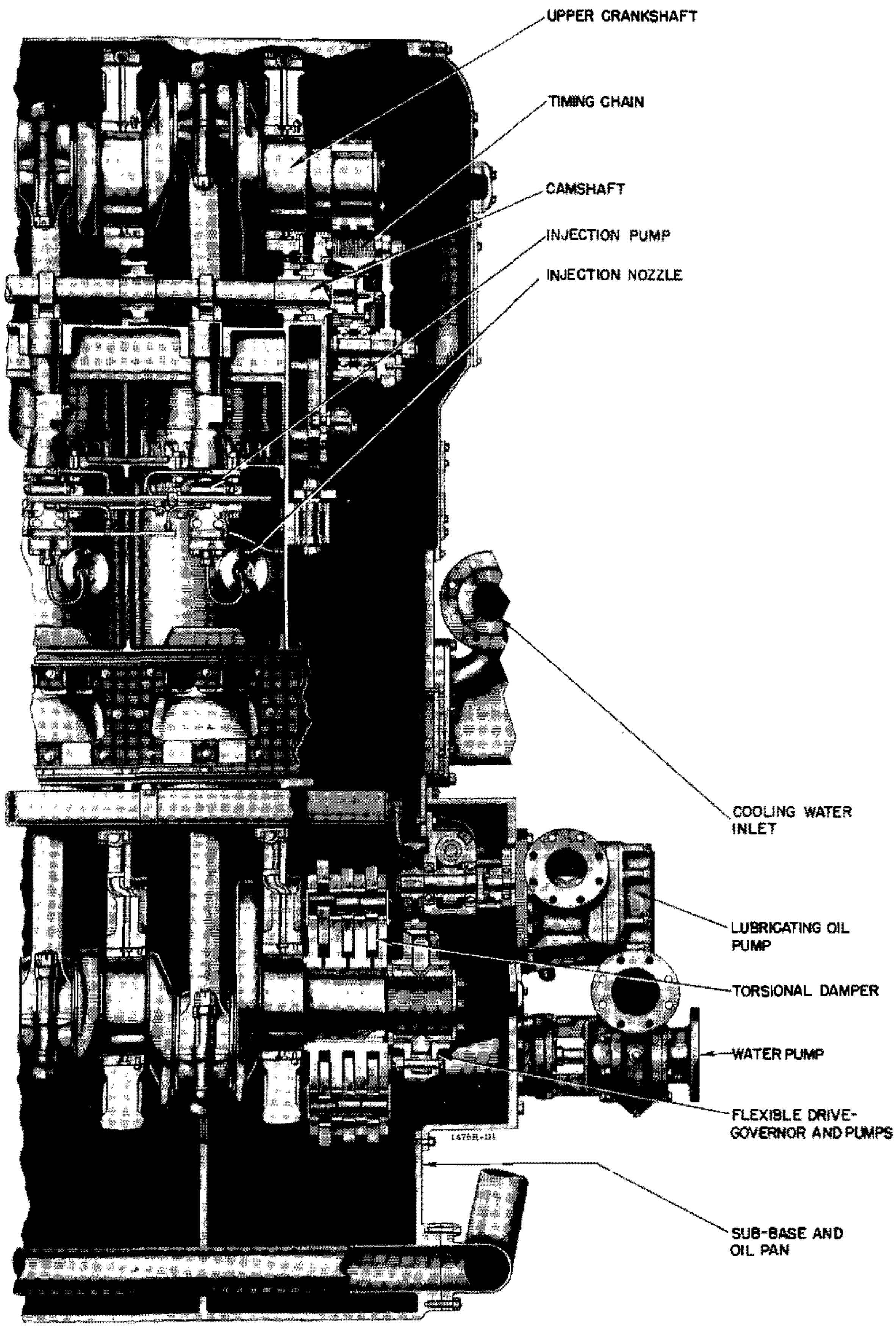
FAIRBANKS, MORSE & CO. 12 CYLINDER MODEL 38D8-1/8 DIESEL ENGINE
OPPOSITE CONTROL SIDE



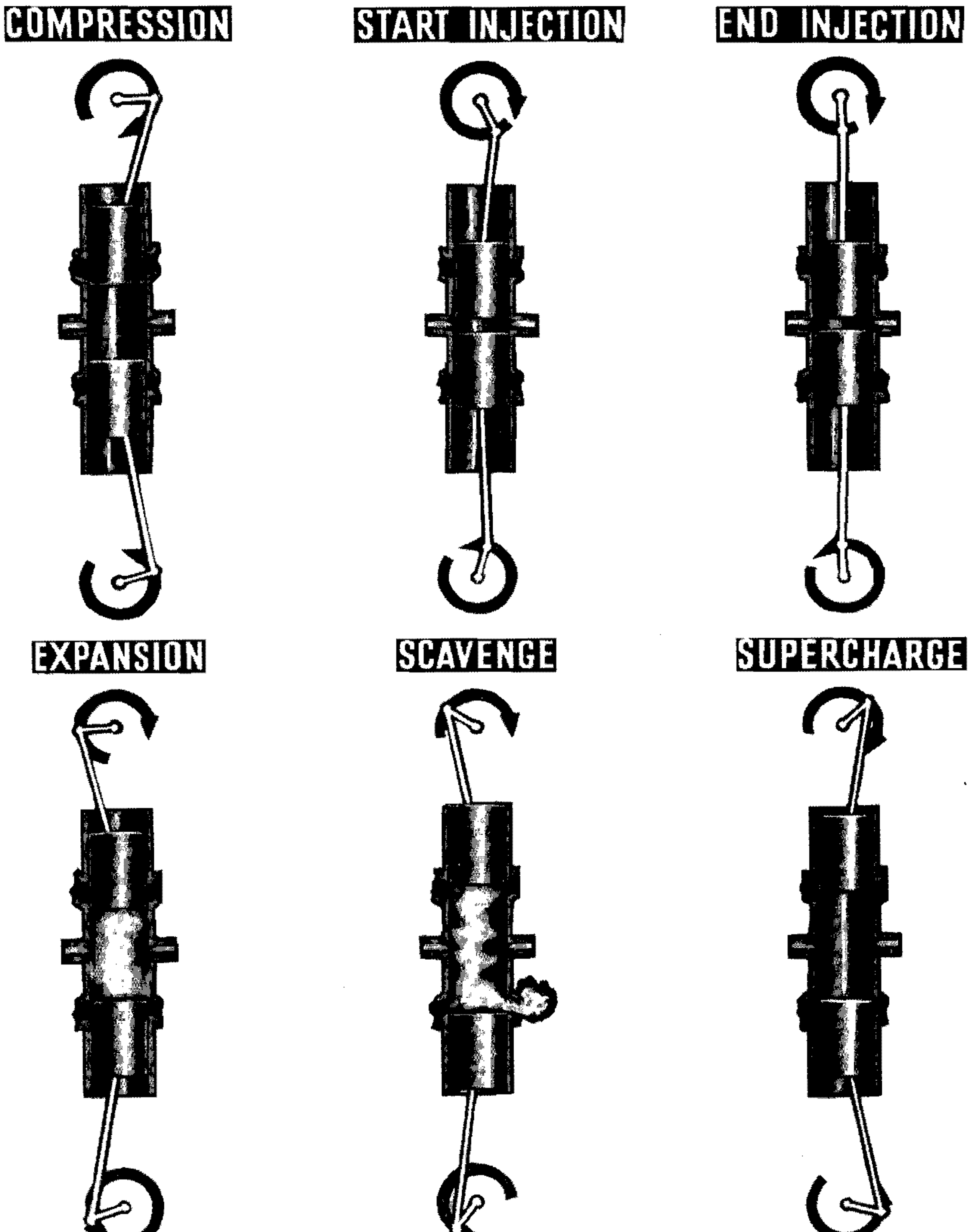
TRANSVERSE SECTION OF MODEL 38D8-1/8 DIESEL ENGINE



LONGITUDINAL SECTION - DRIVE END OF MODEL 38D8-1/8 DIESEL ENGINE



LONGITUDINAL SECTION - EXHAUST END OF MODEL 38D8-1/8 DIESEL ENGINE


COMPRESSION
START INJECTION
END INJECTION
EXPANSION
SCAVENGE
SUPERCHARGE

4334-R-B

CHAPTER A. BASIC ENGINE DESCRIPTION

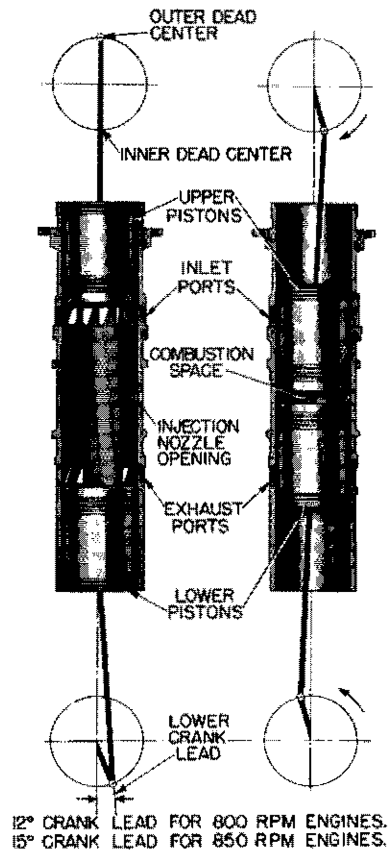
TYPE

This internal combustion diesel engine is of the opposed piston type. Air from a blower is introduced into the cylinder and compressed between the two pistons which work vertically towards each other in each cylinder. A charge of fuel under pressure is sprayed into the cylinder by two injection nozzles after the air has been compressed. Ignition is accomplished by the heat of compression.

The upper and lower pistons drive separate crankshafts which are inter-connected by a vertical drive.

Fresh air is admitted to the cylinder, and exhaust gases are expelled, by the pistons uncovering and covering the inlet and exhaust ports near the upper and lower ends of the cylinder respectively. The vertical drive connection of the two crankshafts is made with the lower crankshaft advanced in operating position ahead of the upper crankshaft. Illus. A1 shows the lower crankshaft past outer dead center and the upper crankshaft on outer dead center. This difference in crankshaft setting is called the "Lower Crank Lead."

The combustion space is formed between recessed heads of the two pistons as the crankshafts approach inner dead center. When the upper crank is one-half the crank lead before inner dead center and the lower crank one-half the crank lead past inner dead center, the two pistons are the closest together in operating position and the point midway between them is called the "Combustion Dead Center."



Illus. A1. Operation in Single Cylinder (Rotation Viewed from Drive End)

CYCLE

This engine operates on the "two-cycle" principle. Two strokes of each piston made by one complete revolution of the crankshafts are necessary to complete the cycle. Illus. A2 shows the action taking place in the cylinder with the engine operating at nominal rated load and full speed. It will be noted that a part of the injection period over-laps from the compression stroke into the power stroke. Likewise part of the exhaust and scavenging periods over-lap from the power stroke into the compression stroke.

The cycle begins with the movement of the pistons from their outer dead centers. After the pistons have covered the exhaust and inlet ports, they compress the air in the cylinder until the end of this stroke.

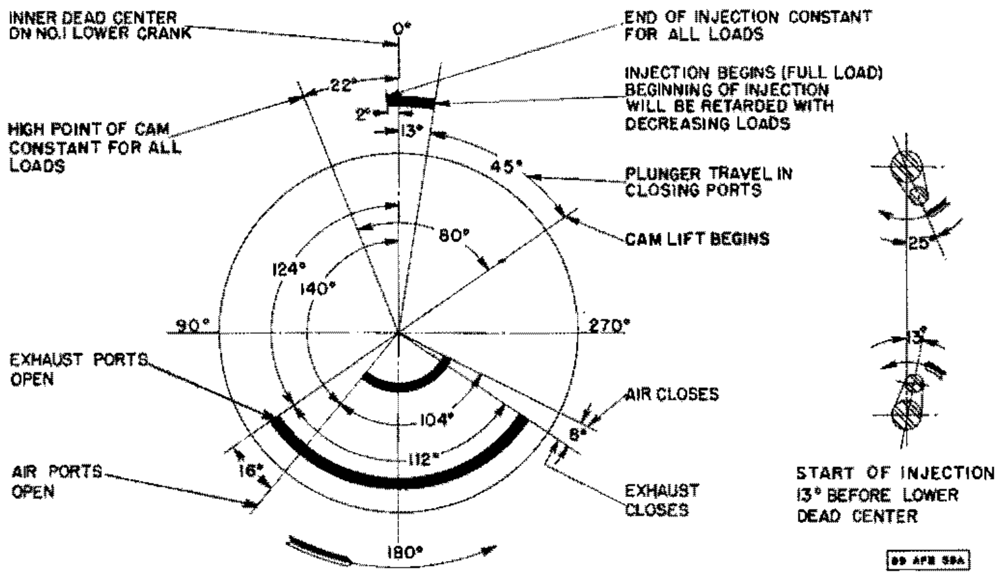
As the pistons approach inner dead center, fuel is injected into the combustion space. The injection at nominal rated load starts at approximately 13° before the lower crankshaft reaches inner dead center. The intense heat, generated during the high compression of the air, ignites the fine fuel spray. Combustion and the resulting expansion forces the pistons outward, thereby delivering work to the crankshafts and forming the power, or second stroke of the cycle.

The expanding of the gases continues until nearly the end of the power stroke, when the lower piston begins to uncover the exhaust ports allowing the burned gases to escape to the atmosphere thru the exhaust system. At about the time the pressure in the cylinder has dropped to almost atmospheric, the upper piston starts uncovering the inlet ports. Scavenging air in the air receiver under pressure, and supplied by the blower, rushes into the cylinder.

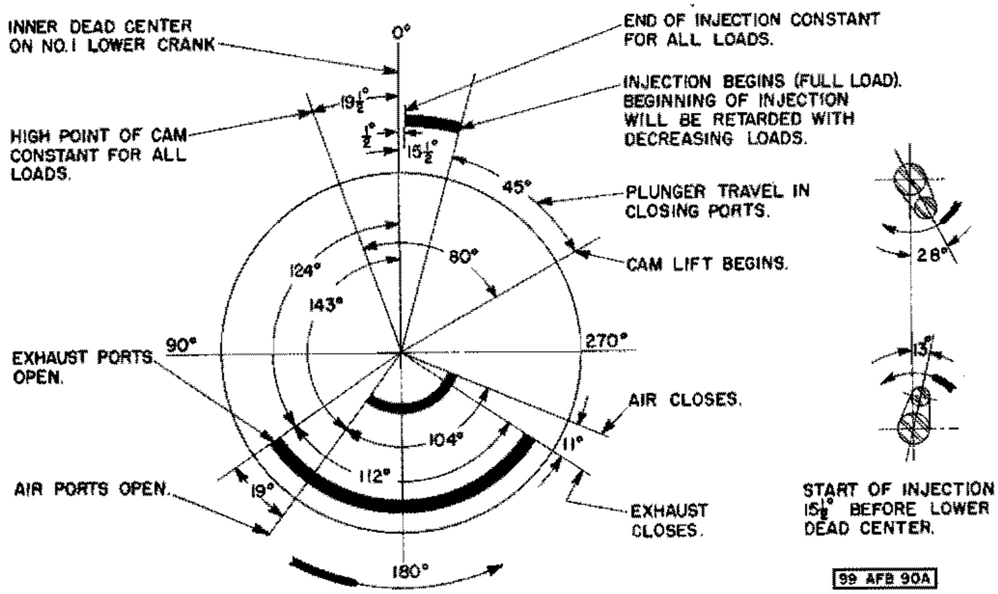
The cylinder is swept clean of the remaining exhaust gases and refilled with fresh air for the next compression stroke. The exhaust ports are covered ahead of the closing of the inlet ports. This permits scavenging air to continue to enter and fill the cylinder with supercharged air at approximately the scavenging air pressure. Thus during the one revolution of the crankshaft and two strokes of the pistons, compression, injection, combustion, expansion, exhaust and scavenging occur in the cylinder.

DIVISION OF POWER BETWEEN CRANKSHAFTS

Observing Illus. A1, it can be seen that when the upper piston reaches its inner dead center in the compression stroke, the lower piston has completed the total crank lead of its power stroke. This causes the lower piston to receive at full engine load, the greater part of the expansion work. The power delivered to the upper crankshaft is partially absorbed in driving the scavenging blower while the remainder is transmitted thru the vertical drive to the lower crankshaft which is connected to the final drive.



12° LOWER CRANK LEAD
APPLICABLE TO 800 R.P.M. ENGINES



16° LOWER CRANK LEAD
APPLICABLE TO 850 R.P.M. ENGINES.

Illus. A2. Sequence and Timing of Events
(Rotation Viewed from Drive End)

CHAPTER B. DATA

Engine Data (all data is based on nominal rated load engine speed).

SPECIFICATIONS AND RATINGS

	Number of Cylinders					
	6	6	8	8	10	12
Nominal Rated Load - BHP	1000	1200	1500	1600	2000	2400
Model No.	38D8-1/8					
Type	Opposed Piston					
Cycle	Two					
Bore and Stroke - Inches	8-1/8x10					
Rated Rpm	800	850	850	850	850	850
Total Piston Displacement - Cu. In.	6222	6222	8296	8296	10370	12444
Piston Speed - Ft. per Min.	1333	1417	1417	1417	1417	1417
Compression Ratio (Based on total swept volume)	16.1 to 1					
BLOWER						
Type	Spiral three lobe rotary					
Capacity - Cu. Ft. per Min.	4000	4550	5450	5800	7250	9300
Speed - Rpm	1468	1648	1560	1648	1810	1711
Power to Drive (Approx. Depends on Scav. Press)	110	118	163	190	258	310
Scavenging Pressure - Psi.	3.5 to 5.5					
INJECTION NOZZLE TIP (F.M. & CO. NOZZLE)						
Number of Holes	6		6			
Dia. of Holes	.0135		.0135			
INJECTION NOZZLE (Pintle)						
Type	ADE10R11					
PUMP - WATER						
Type	Centrifugal					
Capacity - Gal. per Min. (At 80 ft. total head)	375	540	540	540	540	685
Speed - Rpm	1940	2060	2060	2060	2060	2060
Impeller Dia.	8-3/16	8-3/16	8-3/16	8-3/16	8-3/16	9-1/4
PUMP - FUEL OIL (Not used on 10 cyl. Erie Built and later engines)						
Type	Gear					
Capacity - Gals. per Min.	6.6	-	7.1	-	7.1	-
Speed - Rpm	1333	-	1417	-	1417	-
PUMP - Lubricating Oil						
Type	Herringbone Gear					
Capacity - Gal. per Min.	225	235	300	300	350	425
Speed - Rpm	1422	1510	1510	1510	1510	918
Relief Valve Setting - Psi	70					

DIMENSIONS AND CLEARANCES OF PRINCIPAL PARTS

	Size	Clearance
BEARINGS - CAMSHAFT		
(Satco and Aluminum)		
Bearings Dia.	2.499 to 2.5005	.0035 to .006
Camshaft Dia.	2.4945 to 2.4955	
BEARINGS - CONNECTING ROD - CRANK END		
(Aluminum)		
Crankshaft Dia.	6.745 to 6.747	
Thickness - Shell	.3722 to .3730	
(Satco)		
Bearing Dia. Crank End	6.7505 to 6.753	.0035 to .0085
Crankshaft Dia.	6.745 to 6.747	
Thickness - Shell (90° from parting line)	.374 to .375	
BEARINGS - CONNECTING ROD - PISTON END		
Piston Pin Bushing Bore (Floating Bushing)	3.000 to 3.0005	.0045 to .0055
Piston Pin Dia.	2.995 to 2.9955	
BEARINGS - CONNECTING ROD - PISTON END - SIDE		
Slot in Insert	3.222 to 3.230	.035 to .048
Bushing - Length	3.182 to 3.187	
BEARINGS - MAIN		
(Aluminum)		
Crankshaft Dia.	7.994 to 7.996	
Thickness - Shell (90° from parting line)	.747 to .748	
(Satco)		
Bearing Dia.	8.0035 to 8.006	.0075 to .012
Crankshaft Dia.	7.994 to 7.996	
Thickness - Shell	.747 to .748	
BEARINGS - MAIN - THRUST		
Crankshaft Width	4.000 to 4.003	
Bearing Width (Satco)	3.993 to 3.995	.005 to .010
Bearing Width (Aluminum)	3.986 to 3.988	.012 to .017
BLOWER DRIVE - FLEXIBLE		
Drive Gear Wearing Ring Dia.	9.001 to 9.0025	.0005 to .003
Drive Gear Hub Dia.	8.9995 to 9.0005	
End Plate Wearing Ring Dia.	10.501 to 10.5025	.0005 to .003
End Plate Dia.	10.4995 to 10.5005	
PUMP DRIVE - FLEXIBLE		
Gear Bushing Dia.	6.250 to 6.251	.003 to .007
Drive Hub Dia.	6.243 to 6.244	
INJECTION NOZZLE (F.M. & CO.)		
Needle Dia. (Lapped with Sleeve)	.281	
Sleeve Dia. (Lapped with Needle)	.281	
Body Dia.	.5620 to .5630	.003 to .0045
Filter Dia. at Longitudinal Grooves	.5585 to .559	

	Size	Backlash	Clearance
INJECTION PUMP			
Barrel Dia. (Lapped with Plunger)	.500		
Plunger Dia. (Lapped with Barrel)	.500		
BLOWER			
Between Impellers			.028 to .032
Timing Gears		.002 to .004	
*Impeller Thrust Bearing End-Play (When Cold)			.001 to .006
Impeller to Housing			.025 to .029
Impeller to Inner Bearing Plate (Other than 12 cyl. engines)			.028 to .032
Impeller to Inner Bearing Plate (12 cyl. engines)			.033 to .037
Impeller to Outer Bearing Plate (Other than 12 cyl. engines)			.021 to .025
Impeller to Outer Bearing Plate (12 cyl. engines)			.026 to .030
Between Impellers (with Micarta strip gages)			.028 to .032

* Suitability of bearings is determined by visual inspection.

	Size	Backlash	Clearance
FLEXIBLE PUMP DRIVE - Attached Pumps - All Gears		.002 to .006	
BLOWER DRIVE - Flexible Drive Gear to Pinion		.002 to .008	
FLEXIBLE GEAR DRIVE - Governor Bevel Gears		.004 to .006	
CRANKSHAFT DRIVE - Vertical - Gear (Early Engines)		.012 to .016	
CRANKSHAFT DRIVE - Vertical - Gear (Later Engines)		.010 to .018	
PUMP - LUBRICATING OIL (With Timing Gears - Early Engines)			
Impellers		.0005 to .003	
Impellers to Wearing Plate - Inner			.002 to .004
Impellers to Wearing Plate - Outer			.002 to .004
Impellers to Housing			.003 to .0045
Internal Gear Drive Coupling		1/64 to 1/32	
PUMP - LUBRICATING OIL (For Later 6, 8, and 10 Cyl. Engines)			
Impellers		.005	
Driven Impeller Shaft to Bushing			.005 to .0065
Impeller to Housing			.008 to .011
PUMPS - LUBRICATING OIL (For 12 Cyl. Engines)			
Impellers		.015 to .020	
Impellers			.001 to .005
Impellers to Housing			.005 to .008
PISTON RINGS			
No. 1 and 2 Compression Ring - Side			.008 to .011
No. 1 and 2 Compression Ring - End			.045 to .055
No. 3 and 4 Compression Ring - Side			.045 to .008
No. 3 and 4 Compression Ring - End			.045 to .055
Oil Scraper Ring (1 on each piston) - Side			.0015 to .007
Oil Scraper Ring (1 on each piston) - End			.020 to .035
Oil Drain Ring (2 on each piston) - Side			.0015 to .0045
Oil Drain Ring (2 on each piston) - End			.015 to .030

SUMMARY OF OPERATING FIGURES

A summary of the normal operating figures covering these engines at full speed as determined by factory tests is given as follows for reference:

PRESSURES

Firing Pressure - Max.	1150
Lubricating Oil Pressure at Engine Upper Header (SAE 40 oil at 180-200° F.)	19-24

MISCELLANEOUS

	6 cyl. 1000 hp	6 cyl. 1200 hp	8 cyl. 1500 hp	8 cyl. 1600 hp	10 cyl. 2000 hp	12 cyl. 2400 hp
Overspeed governor trips at rpm	880-895	935-950	935-950	935-950	935-950	935-950
Approx. Weights - Lbs.						
Engine and subbase (dry)	28,000	26,000	33,000	34,000	39,000	45,000
Gen. and Elec. Equipment	12,000	12,000	16,000	16,000	18,000	17,000
Complete Unit	40,000	38,000	49,000	50,000	57,000	62,000

ENGINE WEAR LIMIT CHART

Part	New Dimension	Condemnable Dimension
CAMSHAFT		
(Satco and Aluminum Bearings)		
Shell Inside Diameter	2.499 to 2.5005	2.5025
Thrust Bearing End Clearance	.006 to .015	.022
CRANKSHAFT		
Crankpin Journal	6.745 to 6.747	6.743
Main Bearing Journal	7.994 to 7.996	*7.992
* Max. variation between adjacent journals	.002".	
CONNECTING ROD		
Shell Thickness (Satco)	.374 to .375	.370
Shell Thickness (Aluminum)	.3722 to .3730	.370
Bushing Bore Assembled (Steel)	3.4985 to 3.500	3.502
MAIN BEARING		
Shell Thickness (Satco)	.747 to .748	.745
Shell Thickness (Aluminum)	.747 to .748	.745
Thrust Bearing End Clearance (Satco)	.005 to .010	.015
Thrust Bearing End Clearance (Aluminum)	.012 to .017	.020
CYLINDER LINER		
Liner Bore - Unplated	8.125 to 8.127	
Liner Bore - Chrome Plated	8.124 to 8.127	8.141
Liner Bore - Unplated to Restandard Size)		8.141
Liner Bore - Unplated (Standard)	(Max. for 1/32" oversize)	8.141
Liner Bore - Unplated (1/32" Oversize)	(Max. for 1/16" oversize)	8.173
Liner Bore - Unplated (1/16" Oversize)		8.203
PISTON		
Piston Diameter		See Note
Piston Pin Diameter	2.995 to 2.9955	2.992
Piston Pin Bushing (Floating) O.D.	3.4955 to 3.496	3.492
Piston Pin Bushing (Floating) Bore	3.000 to 3.0005	3.004
Piston Insert Bushing Bore Assembled	2.999 to 3.0015	3.004

NOTE: Use ring groove dimension to determine replacement of piston.

Part	New Dimension	Condemnable Dimension
PISTON RINGS		
Compression - End Clearance	.045 to .055	3/16
Oil Scraper (1 per piston) - End Clearance	.020 to .035	3/32
Oil Drain (2 per piston) - End Clearance	.015 to .030	3/32
Compression (No. 1 and 2) - Side Clearance	.008 to .011	.017
Compression (No. 3 and 4) - Side Clearance	.005 to .008	.014
Oil Scraper (1 per piston) - Side Clearance	.0015 to .007	.010
Oil Drain (2 per piston) - Side Clearance	.0015 to .0045	.008
TORSIONAL DAMPER		
(Later 6 Cyl. Engines)		
Bushing Inside Dia.	1.9625 to 1.9635	1.9725
Pin Dia.	1.7475 to 1.7485	1.7455
(8 Cyl. Engines)		
Bushing Inside Dia.	1.9625 to 1.9635	1.9725
3rd Order Pin Dia.	1.1025 to 1.1035	1.1005
4th Order Pin Dia.	1.4775 to 1.4785	1.4755
5th Order Pin Dia.	1.6495 to 1.6505	1.6475
8th Order Pin Dia.	1.8395 to 1.8405	1.8375
(10 Cyl. Engines)		
Bushing Inside Dia.	1.9625 to 1.9635	1.9725
3rd Order Pin Dia.	1.1025 to 1.1035	1.1005
4th Order Pin Dia.	1.4775 to 1.4785	1.4755
6th Order Pin Dia.	1.7475 to 1.7485	1.7455
7th Order Pin Dia.	1.8055 to 1.8065	1.8035
10th Order Pin Dia.	1.8865 to 1.8875	1.8845
(12 Cyl. Engines) Upper		
Bushing Inside Dia.	1.9625 to 1.9635	1.9725
4th Order Pin Dia.	1.4775 to 1.4785	1.4755
6th Order Pin Dia.	1.7475 to 1.7485	1.7455
(12 Cyl. Engines) Lower		
Bushing Inside Dia.	1.9625 to 1.9635	1.9725
3rd Order Pin Dia.	1.1025 to 1.1035	1.1005
4th Order Pin Dia.	1.4775 to 1.4785	1.4755
6th Order Pin Dia.	1.7475 to 1.7485	1.7455

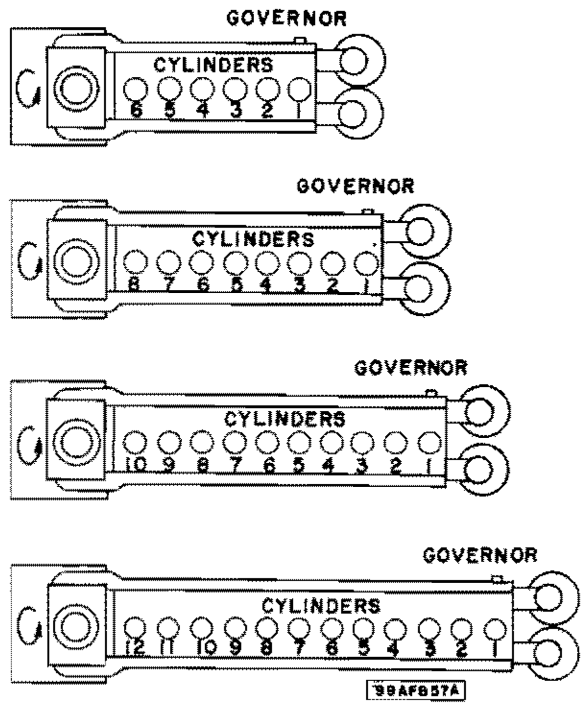
ARRANGEMENT OF CYLINDER AND FIRING ORDER

The cylinders are arranged in sequence with No. 1 cylinder at the opposite drive end. The firing order of the engines is as follows:

6 Cyl. Engines - 1-6-2-4-3-5
8 Cyl. Engines - 1-7-3-5-4-6-2-8
10 Cyl. Engines - 1-8-7-3-5-9-4-2-10-6
12 Cyl. Engines - 1-8-6-10-2-9-4-11-3-7-5-12

ROTATION

Left Hand Rotation Engine Rotates Left Hand (Counter-clockwise) When Viewed from the Drive End.)



Illus. B1. Cylinder Arrangement and Engine Rotation (The arrows designate lower crankshaft rotation as viewed from the drive end.)

MARKING OF ENGINE PARTS

Parts which occur in multiple in the engine, and which should always be replaced in the positions from which removed, are marked to permit positive identification of their correct positions. The marking system is as follows:

1. A certain letter is assigned to each engine and parts for that engine are marked to distinguish them from corresponding parts for other engines.
2. A number is assigned to each of such multiple parts as cylinders, main bearings, and camshaft bearings. These numbers begin with No. 1, at the opposite drive or exhaust end of the engine.
3. Parts pertaining to the upper crankshaft are marked "U" for "upper." Those pertaining to the lower crankshaft are marked "L" for "lower."
4. Parts for the right hand side (at the right when facing the engine from the blower end) are marked "R." Parts for the left side are marked "L."
5. Top halves of parts are marked "T." Bottom halves are marked "B."

The complete position identification marking, then, would consist of as many of the above five classes of letters and numbers as are necessary for the part in question. These letters and numbers would be arranged in the sequence of their appearance above. For example:

ABZ1 on a cylinder liner means that it is from engine "ABZ," cylinder No. 1 position (nearest to the exhaust end).

ABZ6UT on a connecting rod bearing shell half means that it is from engine "ABZ," cylinder No. 6 (sixth from exhaust end), that it is from the upper connecting rod, and that it is the top half of the bearing.

ABZ4RB on a camshaft bearing means that it is from engine "ABZ," No. 4 bearing position (fourth from the exhaust end) on right hand side of engine, and that it is the bottom half of the bearing.

Location of Markings

Marks are located wherever possible so as to be visible when the parts are in place in the engine or the assembly. When a choice of locations is offered, the surface toward the governor side or the exhaust end of the engine is chosen.

Marks are stamped or etched in such positions and by such methods as not to damage the parts. The size of the letters and numbers used in marking is naturally determined by the size of the part being marked.

The following table gives the locations of the position of the identification marks on many engine parts:

TABLE OF MARKING LOCATIONS

Name of Part	Location of Markings
Blower Impeller	Outer end face
Camshaft	Face of center flange
Camshaft Bearings	End adjacent to split
Camshaft Thrust Collar	End adjacent to split
Camshaft Timing Sprockets	End
Connecting Rod Bearing Shells	End adjacent to split
Connecting Rod Body	Side at split
Connecting Rod Cap	Side at split
Connecting Rod Piston Pin Bushing	End adjacent to pin dowel
Crankshaft	Machined web at exhaust end
Cylinder Block	Adjacent to main bearings
Cylinder Liner	Upper end
Injection Pump	Side at lower end
Injection Pump Tappet Housing	Side below drain (or plug)
Main Bearing Caps	Face
Main Bearing Oil Pipes	Side of flange at bearings
Main Bearing Shells	End
Piston	Crown, and end of skirt
Piston Bracket Cap	Outer face
Piston Cooling Oil Outlet Pipe (when used)	Outer face
Piston Cooling Oil Retainer	Spring seat
Piston Pin	End adjacent to dowel
Piston Pin Bracket	Side adjacent to dowel, and end
Vertical Drive Pinion Shaft	Big end

TORQUE LIMITS

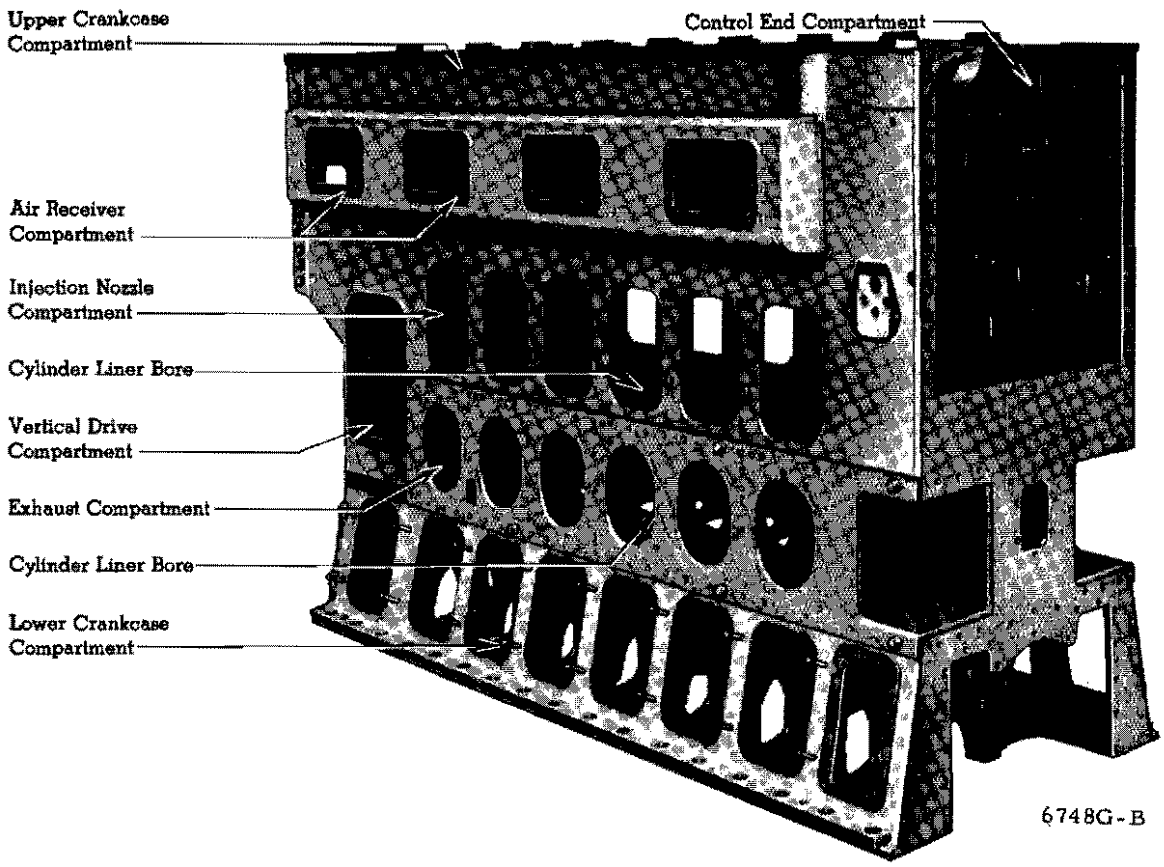
Name of Part	Torque Limit - Ft. Lbs.
Blower Flexible Drive Stud Nuts	110-120
Blower to Block Nuts	110-130
Blower Bearing Plate Nuts	80-90
Camshaft Coupling Bolt Nuts	60-80
Camshaft Sprocket Nuts	80-90
Camshaft Thrust Bearing Clamp Ring Capscrews	35-40
Connecting Rod Bolt Nuts	175-200
Crankshaft Coupling Bolt Nuts (1-1/2x12)	600-800
Crankshaft Coupling Bolt Nuts (1-1/8x12)	500-700
Crankshaft Flexible Drive Nuts	290-300
Cylinder Liner Holddown Stud Nuts	125
Cylinder Block to Subbase Bolts	300-350
Exhaust Manifold to Elbow or Snubber Nuts	60-80
Exhaust Manifold to Cylinder Block Capscrews	70-90
Exhaust Manifold to Belt Nuts	60-75
Exhaust Deck to Belt Capscrews	70-80
Exhaust Manifold Cover Nuts	25-30

TORQUE LIMITS (continued)

Name of Part	Torque Limit - Ft. Lbs.
Fuel Header Capscrews	80-90
Flexible Pump Drive Stud Nuts	110-120
Injection Pump Tappet Housing Nuts	110-120
Injection Pump Nuts	110-120
Injection Pump Discharge Valve Nuts	60-80
Lube Oil Pump Bearing Plate to Housing Nut	60-80
Lube Oil Pump Housing to Cylinder Block	100-120
Lube Oil Header Capscrews	35-40
Lube Oil Header Locknut	45-60
Main Bearing Bolt Nuts	700-1000
Nozzle Fuel Plug (Pintle Nozzle)	40
Nozzle Holder Collar Stud Nuts	35-40
Nozzle Spring Housing to Body (FM Nozzle)	100-120
Piston Insert Stud Nuts	45-50
Top Cover to Block Capscrews	90-100
Top Cover to Blower Capscrews	40-55
Vertical Drive Gear to Crank Bolt Nuts	110-120
* Vertical Drive Clamp Ring Bolt	140-160

* Criss cross tighten gradually, repeat tightening to specified torque limit.

CHAPTER C. CYLINDER BLOCK



Illus. C1. Cylinder Block
(Cylinder block illustrated is for 6 cylinder engine)

DESCRIPTION

The cylinder block is the main structural part of the engine and is designed to give it the necessary strength and rigidity. Steel plates of the proper dimensions are located in jigs and welded together into a unit that is compact, strong and light in weight.

Transverse vertical members with horizontal decks form enclosures, bearing housings and fastenings for the operating or functional parts. The horizontal decks are bored to receive the cylinder liners along the center line of the block. A mounting flange is provided for attaching the scavenging blower to the cylinder block.

The cylinder block consists of the following compartments:

Control end compartment forms enclosure for the timing chain, and control mechanism.

Vertical drive compartment forms enclosure for the bearing housings of the vertical drive connecting the upper and lower crankshafts.

Upper crankshaft compartment forms the bearing saddles for the upper crankshaft bearings and bearing hubs for the bearings of the two camshafts.

The air receiver compartment runs lengthwise on each side of the cylinder block and around the cylinders, forming a passage for scavenging air to the inlet ports of the cylinders.

Injection nozzle compartments form enclosures for the injection nozzles, injection pumps and fuel control rods.

The exhaust manifold compartment extends lengthwise on each side of cylinder block. An exhaust belt surrounds the lower part of each cylinder to conduct the exhaust gases from the cylinder to the manifold.

Lower crankcase compartment forms the bearing saddles for the lower crankshaft and encloses the drives for the attached pumps and governor.

The block is sand blasted after welding and is magnafluxed before and after being stress relieved as a check of the welding.

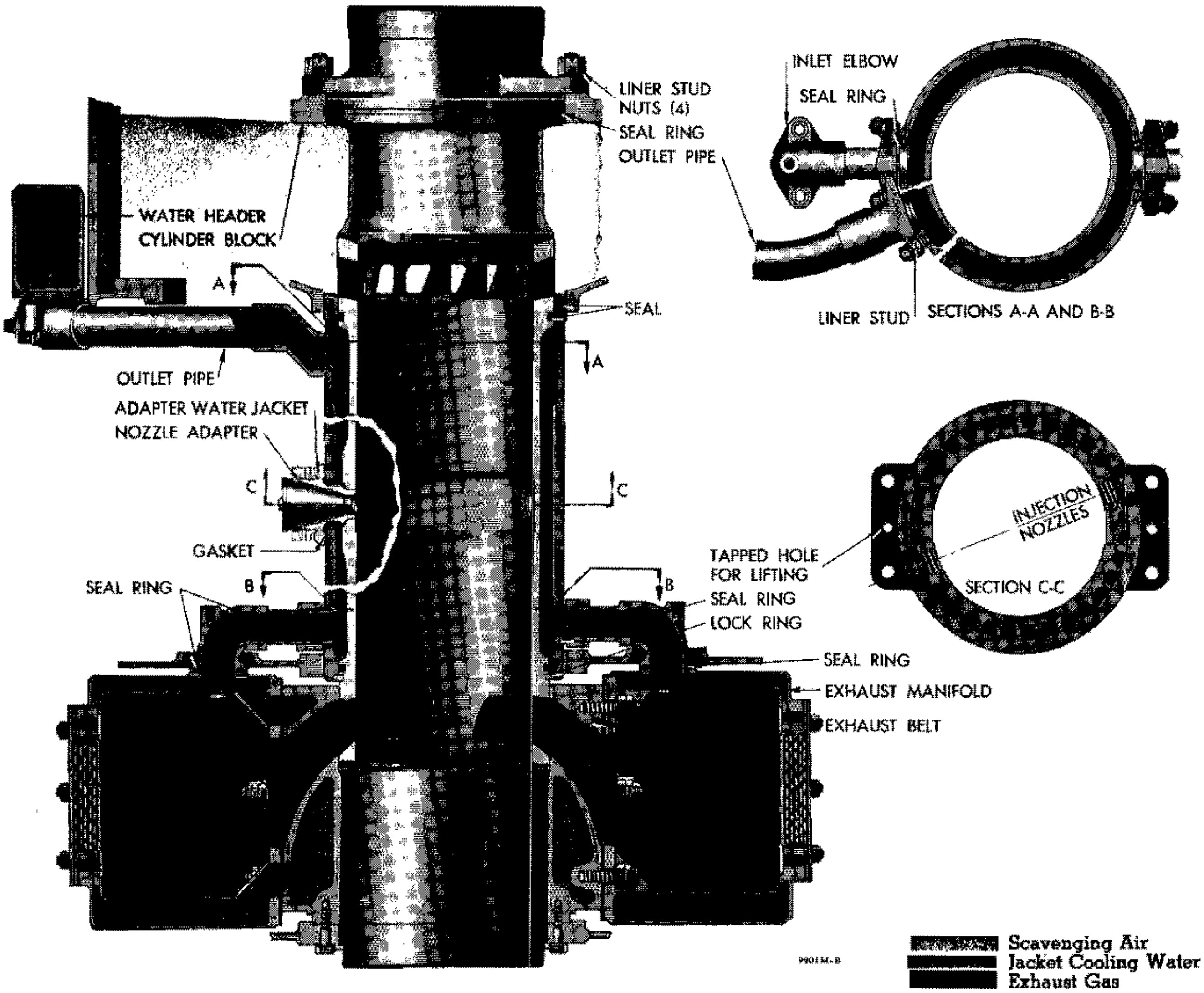
The air receiver, vertical drive and control or front end compartments are provided with covers. The upper crankcase compartment is closed with a steel top cover having several inspection covers. The subbase closes the lower crankcase compartment at the bottom and individual crankcase covers complete the closure at the sides.

The forged steel bearing caps are fitted to the cylinder block and match-marked to show proper location. The main bearing bores are then line-bored with the caps in place.

MAINTENANCE AND REPAIRS

Damage to the block caused by wreckage resulting in fracture of welded joints can with certain care be repaired by re-welding and re-machining. New bearing caps can be refitted if necessary. Contact the Locomotive Service Department.

CHAPTER D. CYLINDER LINER



Illus. D1. Cylinder Liner and Associated Parts
Viewed from the Exhaust End

DESCRIPTION

The cylinder liners are secured into the cylinder block in a row along the centerline of the engine. No. 1 cylinder, as referred to, is always at the exhaust or opposite drive end of the engine. See Illus. B1. Each cylinder consists of a liner assembly as shown in Illus. D1 and D2. The liner forms a unit enclosing water passages for cooling the combustion space. (The liner and jacket are always furnished together as an assembly.)

The rubber rings at the jacket and cylinder block form a lubricating oil and air seal between the injection nozzle compartments, the air receiver and the upper crankcase.

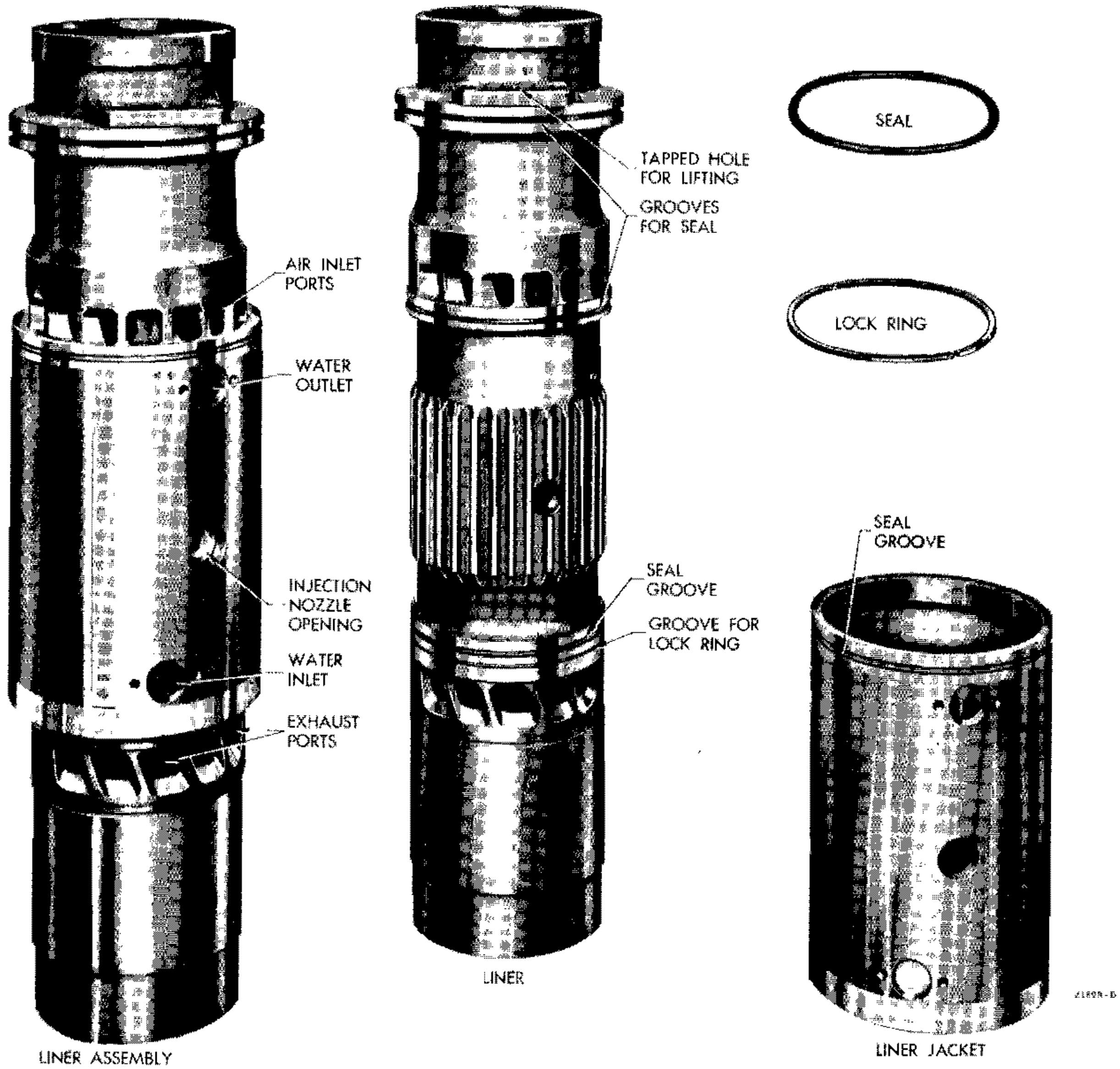
Scavenging air cools the upper portion of the liner. Vertical ribs on the cylinder liner directs the cooling water upward thru the water jacket space.

Midway of the liner, openings are provided for two injection nozzles located diametrically opposite. Liners furnished on early engines have four openings, two of which are closed by dummy plugs. Two hole liners are used on later engines. Tapped holes for lifting eyebolts are provided in the lugs used for securing the liner to the top deck of the cylinder block.

REMOVING AND CLEANING

The cylinder liners are removed from the top of the cylinder block after first removing the top cover, upper crankshaft and upper and lower connecting rods and pistons. Drain the jacket water cooling system.

Remove the injection nozzles from the adapters as directed in Chapter L.



Illus. D2. Cylinder Liner

Remove covers over the water inlet elbows when used. Take off the stud nuts holding the water inlet elbow flanges to the cylinder liners and the capscrews holding the elbows to the exhaust manifolds. Remove the inlet elbows and seal rings.

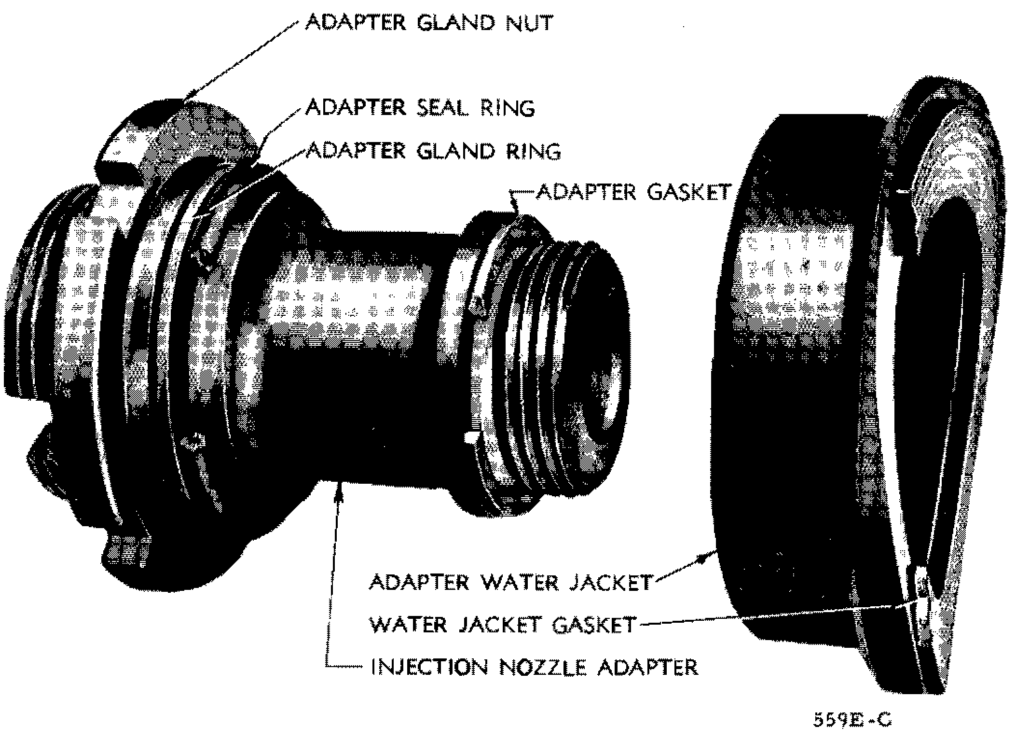
> NOTE: Early engines were furnished with gaskets and shims at the manifold end of the inlet elbows instead of the seal ring. The shims are used to correctly align the elbow with the liner. Always use a gasket on each side of the shim when making the connections.

Take off the stud nuts holding the water outlet pipe to the cylinder liner and the capscrews holding the pipe to the water header. Remove the outlet pipe and gasket at the water header end.

Using a small bar between the studs in the adapter collars, unscrew the collars from the two fuel injection nozzle adapters. Then with a screwdriver back out the setscrews (if used) in all gland nuts far enough so that they do not touch the adapter water jackets. Refer to Illus. D3 or D4.

With the gland nut removing tool, Illus. D5, remove all the gland nuts from the adapters (and dummy plugs if used). With the adapter tool, Illus. D6, remove the adapter (and dummy plug if used) assemblies from the liner.

Remove the upper crankshaft as outlined, Page E1, and the lower pistons and connecting

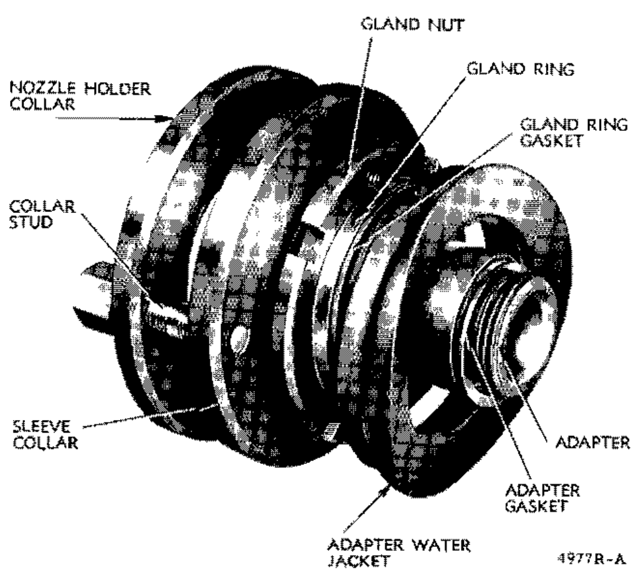


Illus. D3. Injection Nozzle Adapter - FM & Co. Nozzle

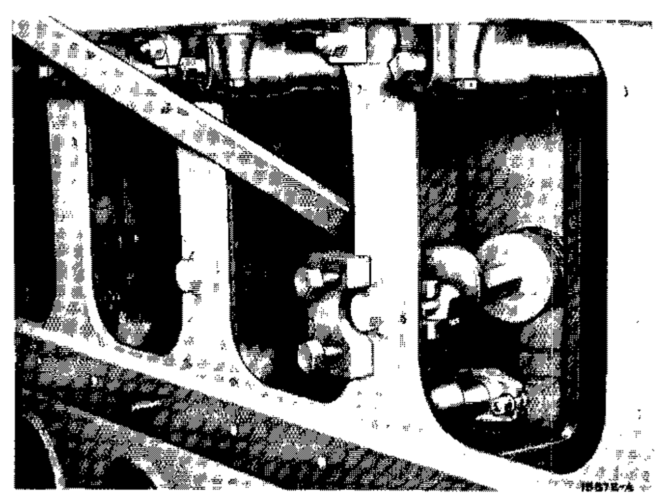
rods as outlined, Page G3. The upper piston and connecting rod should be removed before the liner is removed. After removing a lower piston and connecting rod, place a canvas or sheet metal pan across thru the lower crankcase to prevent dirt dropping into the lubricating oil.

Take off the nuts holding the liner to the upper deck of the cylinder block. Next install two 5/8"-11 N.C. thread jackscrews at the lugs at the top of the liner. The liner can now be jacked free and lifted out.

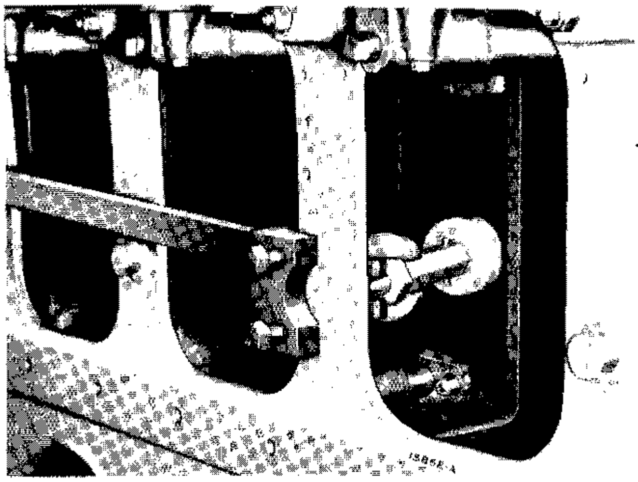
If the liner is stuck in the cylinder block bore due to the rubber rings, the liner must be jacked from below. Place a bar across thru the crankcase to support the jack. Jack against a block across the bottom of the liner. An alternate method of jacking the liner is to use a wood block between the crankpin and bottom of the liner and bar the engine over. To obtain the



Illus. D4. Injection Nozzle Adapter - Pintle Nozzle with Flat Adapter Water Jacket Gasket



Illus. D5. Adapter Gland Nut Tool Pintle Nozzle



Illus. D6. Adapter Tool
Pintle Nozzle

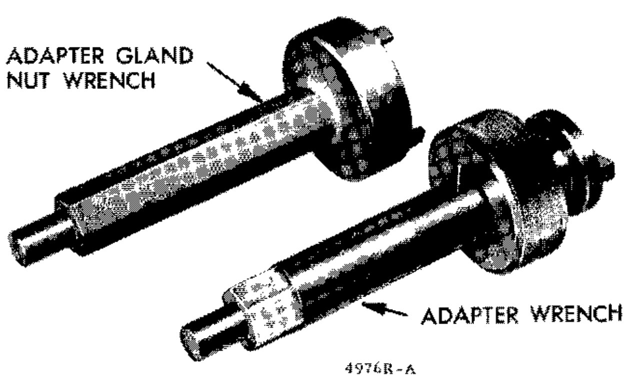
greatest leverage, the crankshaft should be barred from a position near inner dead center.

CAUTION: IF UNDUE PRESSURE IS REQUIRED TO PULL THE LINER AFTER IT HAS BEEN FREED BY JACKING, CHECK TO SEE IF ALL THE CYLINDER LINER STUDS HAVE BEEN REMOVED.

INSTALLING

Before replacing a liner after a period of use, clean the scavenging air ports and the exhaust ports, as well as the combustion zone at the injection nozzle level. Clean any sediment or scale formations from the water jacket space with a mild solution of "Oakite" or the equivalent. Also clean all joint surfaces on the liner and cylinder block. The liner may be lightly honed before replacement is made.

NOTE: Cylinder liners over the standard and 1/32" condemnable dimension, Page B4, can be re-sized to 1/32" or 1/16" oversize, or re-standard size by chrome plating. Contact the Locomotive Service Department.

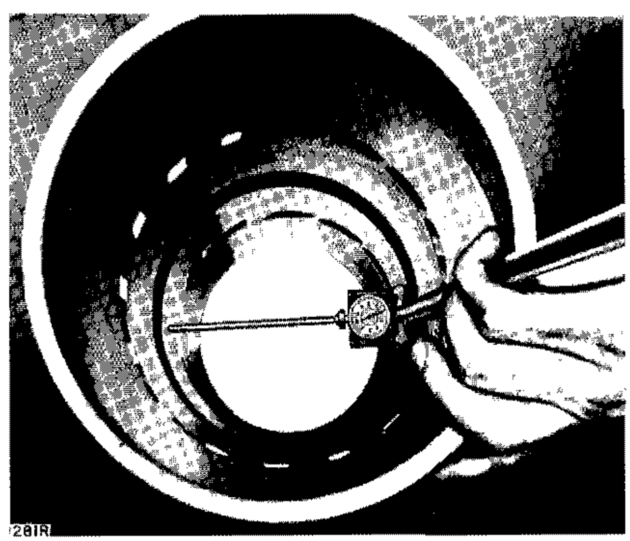


Illus. D7. Tools for Removing Adapter Gland Nuts and Adapters (Pintle Nozzle)

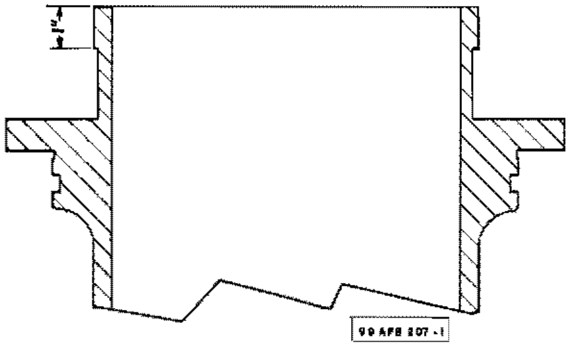
Liners being returned to the engine should be water tested at 100 psi. Install the cylinder liner adapters to close the adapter holes. Block off the outlet and provide a petcock to bleed off air at the outlet. Connect the pressure line to one inlet hole and block off the other inlet hole. Open the pressure line and bleed off the air. Close the petcock and with 100 psi water pressure in the jacket check for leaks.

It is good practice on replacement liners to tap out the water jumper stud holes to remove the rust preventive coating.

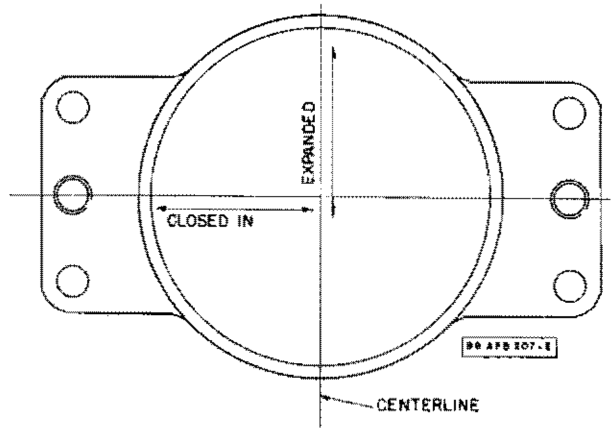
Install new seal rings over the liner. Support the liner from a chain fall and have ready to install in the cylinder block. Install one seal ring in the upper groove and leave the other free over the air ports. Apply surgical green soap to the upper seal ring and to the groove below the air ports. Insert the liner into the cylinder block with the water outlet opening at the opposite control side of the engine. Lower the liner so that the groove below the air ports is below the upper deck of the block. Reach in thru the air receiver inspection openings and roll the seal ring in the groove. It may be necessary to reach in from the top of the liner and thru the air ports to position the seal rings in the groove. Lower the liner into place and remove the eyebolts. To force the liner to its seat against the top face of the cylinder block, use standard 3/4" SAE nuts on the two long cylinder block to liner studs. After applying white lead to the studs carefully bring the liner to its seat by tightening the nuts about 1/4 turn each



Illus. D8. Using Bore Gage



Illus. D9. Location of Measurement



Illus. D10. Direction of Out-of-Roundness

time. Be sure the liner is not binding in the cylinder block bore. Excessive force should not be required. Remove the standard SAE nuts and replace nuts and tighten to limits given on page B7.

Check the liner for out-of-roundness using a bore gage, Illus. D8, one inch down from the top of the liner. If a liner is over .003" out-of-round at assembly, certain conditions of the liner pads can be corrected by shimming.

Liner Shimming

The out-of-round condition which can be corrected by shimming is specific, therefore certain procedures and precautions must be taken.

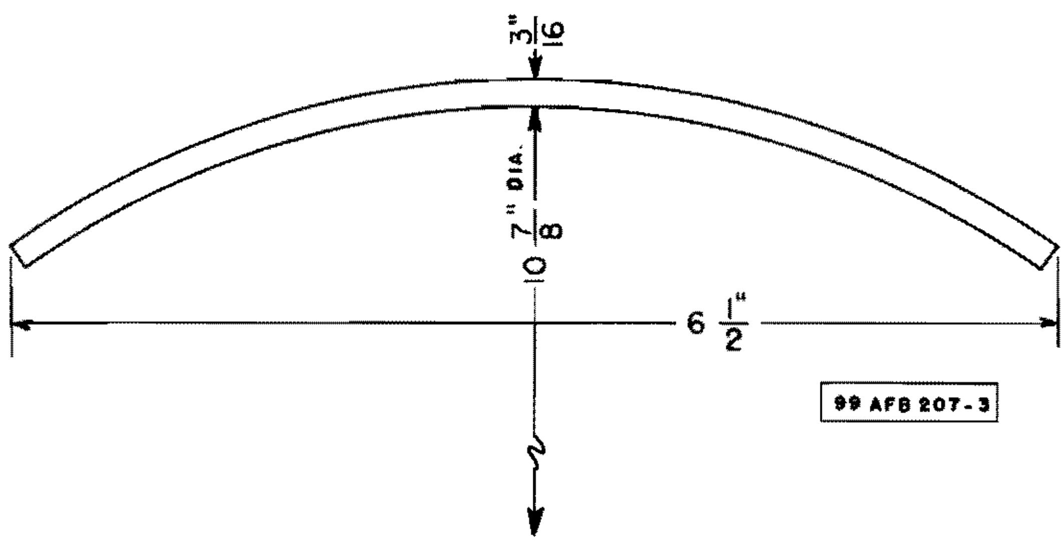
1. With the cylinder liner in place in the engine and tightened down, measure the out-of-round condition one inch down from the top of the liner across, and with the engine certerline as shown in Illus. D9 and D10.

2. Check all liners for comparison out-of-round condition. They should all compare. If one specific liner is found out-of-round and the rest are round, within the .003" tolerances, it will not be corrected by shimming as conditions requiring shimming will be general throughout an engine. An individual liner found out-of-round at assembly should have the pad fits and block to liner fits inspected for burrs.

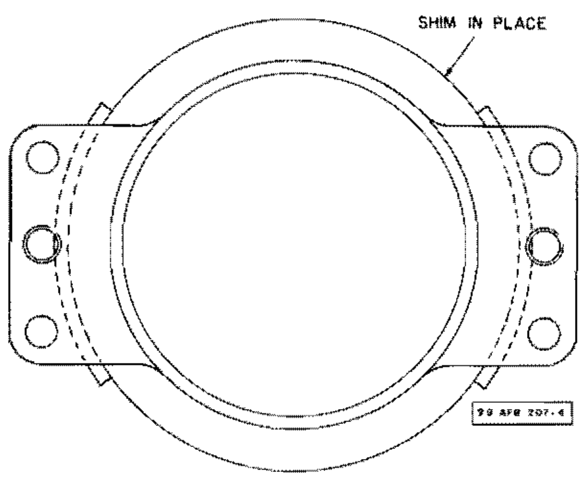
3. The out-of-round condition due to the fit of the liner to the pads on the block is the only cause to be corrected by shimming. It will always be found that the liners will be squeezed in across the ears making the liner larger with the centerline of the engine, Illus. D10, when the taper condition of the liner pads exists.

Procedure for Shimming

1. Cut shims 3/16" wide, approximately



Illus. D11. Liner Shim (Full Size)



Illus. D12. Shims Shown in Place

6-1/2" long, .003" thick. The shims are cut to follow contour of outside of liner under the liner ears as shown in Illus. D11.

2. Jack liner up slightly, using a jackscrew at each ear, just enough to insert a .003" shim under each ear, Illus. D12. It is important not to jack liner too high as it is possible to drag the shim down between the liner and bore fit when the liner is pulled down into position. Over-jacking will also result in breaking the water connection seals where correction is found necessary on liners having been previously installed and all water connections applied.

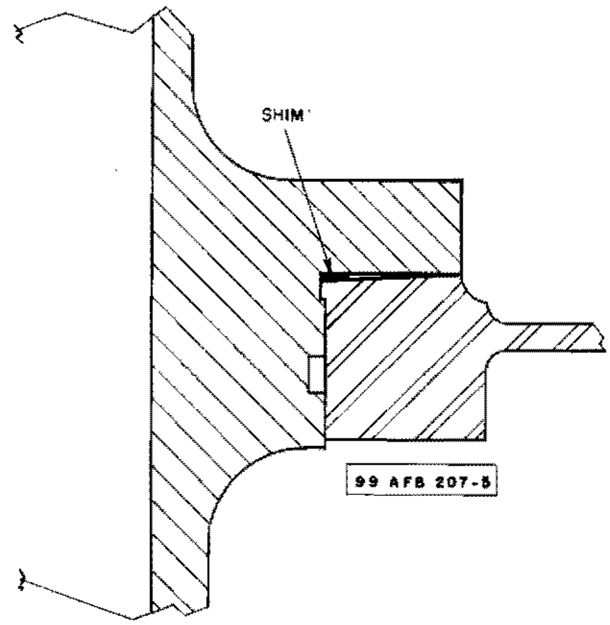
3. Raise one of the jackscrews and insert the shim into place. Lower the jackscrew and raise the jackscrew from the other ear. Insert the shim. Remove the jackscrews and tighten the stud nuts to the proper torque limit. Measure liner one inch down from the top. If the out-of-roundness is not corrected, it is possible that a burr on the liner ear to block pad fit or a burr on the block to liner fits is causing the distortion.

4. A .003" shim will correct a .005" out-of-round condition. One .003" shim inserted under each ear will be the only amount of shimming permitted where correction is needed, Illus. D13. Liners .003" out-of-round and over will be corrected.

5. In all cases water test of engine will follow liner shimming.

Assembling Liner

Next, replace the cylinder liner studs adjacent to the water inlet and outlet holes. Clean ends of the water outlet pipe and opening in liner and put in place with gasket at the water header end. The fit at the cylinder end is spherical and fits metal to metal. Secure outlet pipe



Illus. D13. Correcting Out-of-Round Condition with Shim

to water header with capscrews and to the liner with the stud nuts.

New seal rings should be used at both ends of the inlet elbows. (Earlier engines were furnished with gaskets and shims at the manifold end of the inlet elbows; use new gaskets.) Secure the inlet elbows to the exhaust manifolds with capscrews and to the liner with stud nuts.

Next, replace the injection nozzle adapter (and dummy plug assemblies if used) as follows:

Lubricate the adapter and dummy plug threads with a small amount of graphite. Apply a light coating of grease (graphite grease preferred) to the adapter seat and install a new gasket with the bevel seating into the groove in the adapter. The grease should hold the gasket in its seat. Invert the adapter to be sure the gasket stays in place. With the adapter tool, Illus. D6, screw the adapters (and dummy plug if used) securely into their proper locations in the liner.

Assembling Adapters
(Flat Water Jacket Gasket)

Clean the surface on the liner and adapter water jacket. Cement a new gasket to the adapter water jacket using "Primoid." Let set a few minutes and install. Do not cement the gasket to the cylinder liner. Reinstall the gland ring using a new gland ring gasket.

Screw the gland nuts on the adapters and dummy plugs in place as far as possible by hand being careful that the water jackets are properly seated against the cylinder liner and the gaskets are in place. With the gland nut inserting tool, Illus. D5, screw the gland nuts tightly in place until the rubber is slightly compressed; excessive tightening should be avoided. Retighten the gland nut after the water jacket gasket has positioned itself (approx. 15 min. after the first tightening).

Screw the sleeve collars in place on the injection nozzle adapters. Install the injection nozzles. Refer to Chapter L.

Assembling Adapters
(Seal Ring Water Jacket Gasket)

Clean the surface on the liner and adapter water jacket. Install a new seal ring in the adapter water jacket. Oil the surface of the cylinder liner. Position the adapter water jacket over the adapter and install the gland ring gasket, gland ring, and gland nut, Illus. D14.

Screw the gland nuts on the adapters in place as far as possible by hand. Be sure that the water jackets are properly positioned to the cylinder liner. With the gland nut inserting tool, Illus. D6, tighten the gland nut until the adapter water jacket is in contact with the cylinder liner. Use a .0015" feeler gage to determine that the water jacket is properly positioned to the cylinder liner.

Screw the adapter sleeve collars in place on the injection nozzle adapters. Install the injection nozzles. Refer to Chapter L.

* * * *

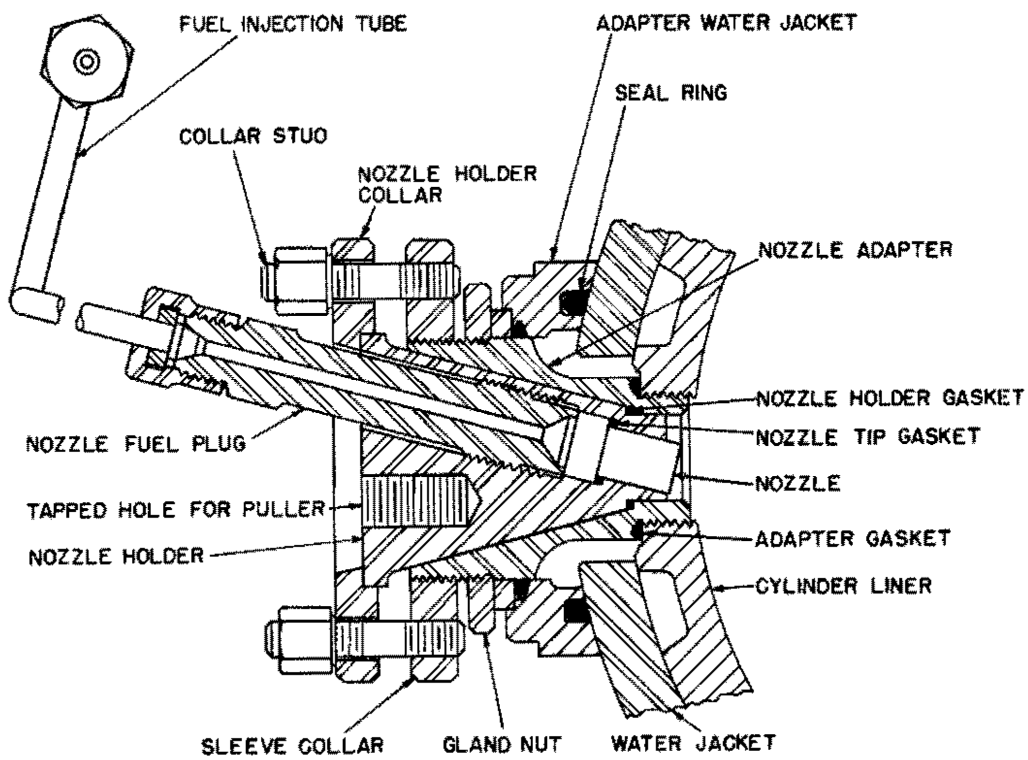
Check all connections with 50 lbs. of water pressure. Hold the pressure for 30 minutes. The water test applies to the engine only and not to the external piping and radiators. Use pump or hydrant pressure and block off the inlet and outlet. Observe all connections for possible leakage. If none are found make necessary reconnections.

Install the pistons and connecting rods as outlined in Chapter G. CAUTION: DO NOT USE CHROME PLATED COMPRESSION RINGS IN A CHROME PLATED CYLINDER LINER.

Replace the upper crankshaft as directed in Chapter E. Refill the cooling system.

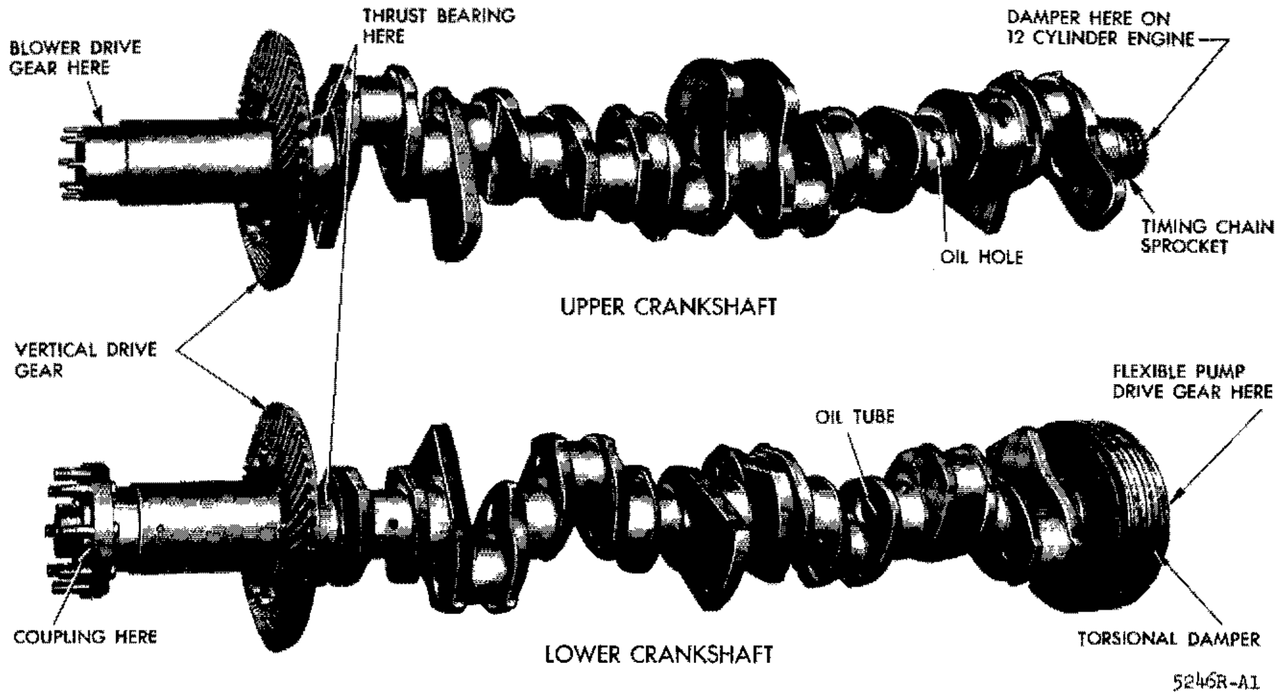
CHECKING CYLINDER LINER BORE

A cylinder gage is used for checking the cylinder liner bore as shown in Illus. D9. The liner to piston clearance and wear limits are given in Chapter B.



Illus. D14. Injection Nozzle Adapter -
Pintle Nozzle with seal ring water jacket gasket.

CHAPTER E. CRANKSHAFTS AND MAIN BEARINGS



Illus. E1. Upper and Lower Crankshafts - 8 Cyl. Engine

CRANKSHAFTS

Description

The upper and lower crankshafts, Illus. E1, are designed to transmit the power produced in the cylinders to the vertical drive gears and crankshaft coupling. Thrust bearings are provided next to the vertical drive gears and plain main bearings at each transverse vertical member of the cylinder block. Precision machined bearing surfaces are provided for the main and connecting rod bearings.

The crankshaft sprocket for the timing chain drive is secured to the upper crankshaft at the exhaust end. At the drive end, the blower drive gear is keyed and also held with a retainer plate to the crankshaft.

The flexible pump drive gear for driving the governor and attached pumps is secured to the lower crankshaft at the exhaust end.

At the drive end, the flexible crankshaft coupling half is fastened with fitted bolts to a flange on the crankshaft. This flexible coupling delivers the power developed by the engine to the generator.

Lower Crank Lead

The crankshafts of early engines were timed with the lower crankshaft leading the upper by 12°. Later 850 rpm engines have 15° lower crank lead and have an identification plate located on the governor side near the vertical drive inspection cover. Engines modified in the field also have the identification plate.

Crankshaft Lead Timing

A. Checking Timing with Top Cover Installed

The crankshaft timing can be checked with the top cover installed by removing the exhaust end top cover inspection cover. Illus. E2 shows the crankpin positions for checking the timing from the governor or opposite governor side depending on the location of the top cover inspection cover.

1. The lower crankshaft leads the upper by 12° or 15°. The crankshafts rotate in opposite directions. Refer to Illus. E2.

2. Set protractor for 90° protractor reading.

3. Bar the engine to position the machined surface of the No. 1 upper crankweb (No. 1 outer crankweb on 8 and 10 cyl. engines or No. 1 inner crankweb on 6 and 12 cyl. engines) so that the protractor as set will have the bubble centered as viewed thru the top cover inspection opening, Illus. E3.

4. Do not rotate engine. Check posi-

tion of lower crankshaft using a protractor on machined surface of No. 1 lower crankpin.

5. Determine protractor reading in relation to inner or outer dead center position of the crankpin.

6. Determine rotation of the crankshafts. Refer to Illus. E2.

7. Compute the crank lead from the protractor readings. The computed value should be within $\pm 1/2^{\circ}$ of the specified 12° or 15° crank lead.

8. Bar the engine in reverse rotation 15° to 20°. Then bar in direction of rotation and recheck crankshaft lead timing. If timing is not within the specified limit of 12° or 15°, the vertical drive coupling hub or quill shaft (6 cyl. engines) must be repositioned. Refer to Chapter Fa or Fb.

B. Checking Timing with Top Cover Removed

1. Bar the engine until the No. 1 lower crankpin is 12° or 15° past inner dead center. Use a protractor on the machined surface to check the crank position.

2. Check the position of upper crankshaft using a protractor.

3. The machined surface, Illus. E3, on the No. 1 upper crankweb (No. 1 outer crankweb on 8 and 10 cyl. engines or No. 1 inner crankweb on the 6 and 12 cyl. engines) must be in the vertical position so the crankpin is at inner dead center.

4. Bar the engine in reverse rotation 15° to 20°. Then bar in direction of rotation and recheck crankshaft lead timing. If timing is not within the specified limit of 12° or 15°, the vertical drive coupling hub or quill shaft (6 cyl. engines) must be repositioned. Refer to Chapter Fa or Fb.

5. The lead gage can be used instead of the protractor after the pointer has been checked and is correct.

C. Checking Crankshaft Coupling Pointer

1. Check vertical position of cylinder block with a protractor.

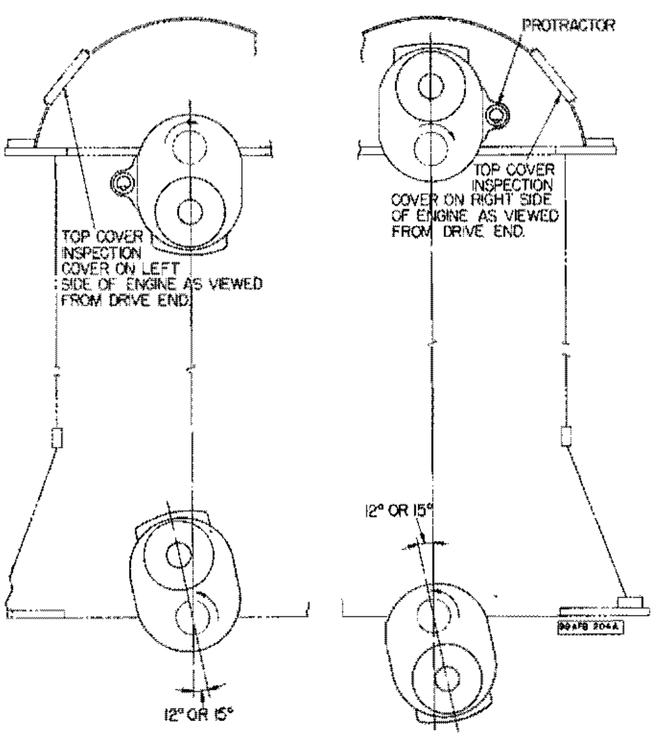
2. Bar engine until machined surface on No. 1 lower crankweb is positioned so protractor reading is the same as the block reading.

3. The pointer should read "O" on the coupling. If not, correct the pointer.

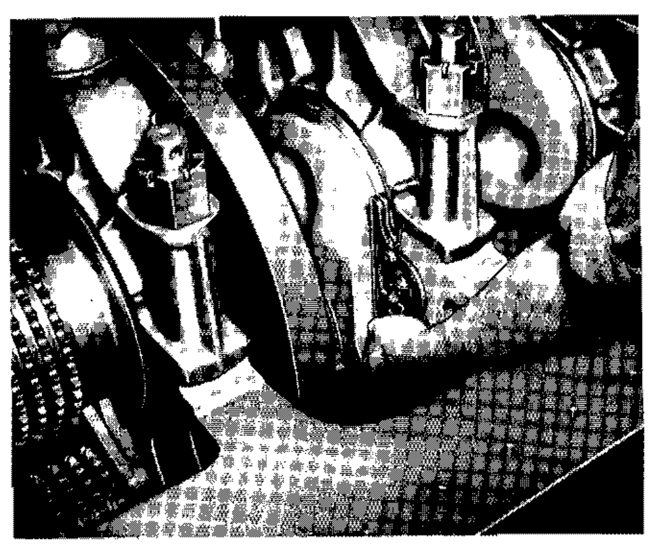
Upper Crankshaft - Removal

Before working on the engine, the battery switch MUST be blocked open to avoid accidentally starting the engine. As an additional precaution, the starting contactors MUST be blocked open with wooden blocks.

CAUTION: NEVER REMOVE OR REPLACE AN UPPER CRANKSHAFT WITH ITS LOWER THRUST BEARING SHELL IN PLACE.



Illus. E2. Crank Lead Timing



Illus. E3. Protractor in Position on Crankshaft

Remove the exhaust end cover and top cover. Lifting eyebolts (1/2"-20) are used for handling the top cover.

Refer to Page E11 for removal procedure of main bearing caps and thrust bearing shells.

Refer to Chapter G for removal of crankpin bearings.

Refer to Chapter H for timing chain removal procedure.

Rotate the engine so that the No. 1 upper crankpin is at outer dead center position. Secure a rope sling to the No. 1 crankpin and around the crankshaft beyond the vertical drive gear. (12 cylinder crankshafts must be lifted at the ends and at the center.) In this position the crankshaft should be nearly balanced.

Slowly lift the crankshaft from the engine. After raising the crankshaft approximately one inch, check and remove any bearing shells which have adhered to the shaft.

> NOTE: On early engine without modified blowers, be sure the nuts on the blower drive gear clear the end of the impeller shaft as the crankshaft is removed.

Carefully remove the lower halves of the plain main bearing. Keep the engine clean while work is in progress.

Clean crankshaft, all bearing caps, shells, connecting rod bolts and nuts in fuel oil or non-inflammable solvent. Wipe all parts carefully with clean lint free cloths, especially the bearing surfaces of the crankshaft and the bearing shells.

If aluminum from the bearings has been transferred or adhered to the bearing bores or crankshaft journals, this material must be removed. Refer to procedure page E14.

Upper Crankshaft - Installing

> CAUTION: NEVER REMOVE OR REPLACE AN UPPER CRANKSHAFT WITH ITS LOWER THRUST BEARING SHELL IN PLACE.

Replace the lower halves of the plain main bearings, being careful that each bearing has the matchmarked letters toward the exhaust end of the engine and on the governor side. Apply lubricating oil to the bearing shells. The thrust bearing is rolled in place after the crankshaft is installed.

Use a protractor to position the lower crankshaft. Set 9^{o} after outer dead center for 15^{o} crank lead or 6^{o} after outer dead center for 12^{o} crank lead.

Secure a sling to the crankshaft in the same position as when removed. With the crankshaft suspended, adjust the crank so No. 1 crankpin is at outer dead center (protractor reading). Lower the crankshaft into position. This will enable the proper vertical drive gear tooth to mesh with the proper pinion position for correct crank lead.

Check the crankshaft lead timing as outlined on page E1.

Checking Backlash

> NOTE: If a different crankshaft than the one removed is being installed, the backlash of the vertical drive gears must be checked.

Check the gear and pinion to be sure the end of the teeth are in line. Raise or lower the pinion by adding or removing shims under the bearing housing.

Determine the distance from the thrust face of the crankshaft to the gear face of the crankshaft using a micrometer. Take the same measurements on both old and new crankshaft. If the measurements are the same and the position of the pinion was not changed, the same shims can be installed on the new crankshaft and the backlash will be the same as before. If the measurements are not the same or the shims were changed under the bearing housing, the correct backlash must be determined by changing the bevel gear shims. Removal or addition of one shim will change the backlash approximately one-half the shim thickness.

Use a small pinch bar to force the crankshaft towards the exhaust end of the engine against the thrust bearing. With a dial indicator on the pinion, rotate the pinion shaft each way to determine the backlash between the gear and pinion. The correct amount of backlash is stamped on the gear and pinion by the manufacturer and is also listed in Chapter B. The halves of the shims should not overlap.

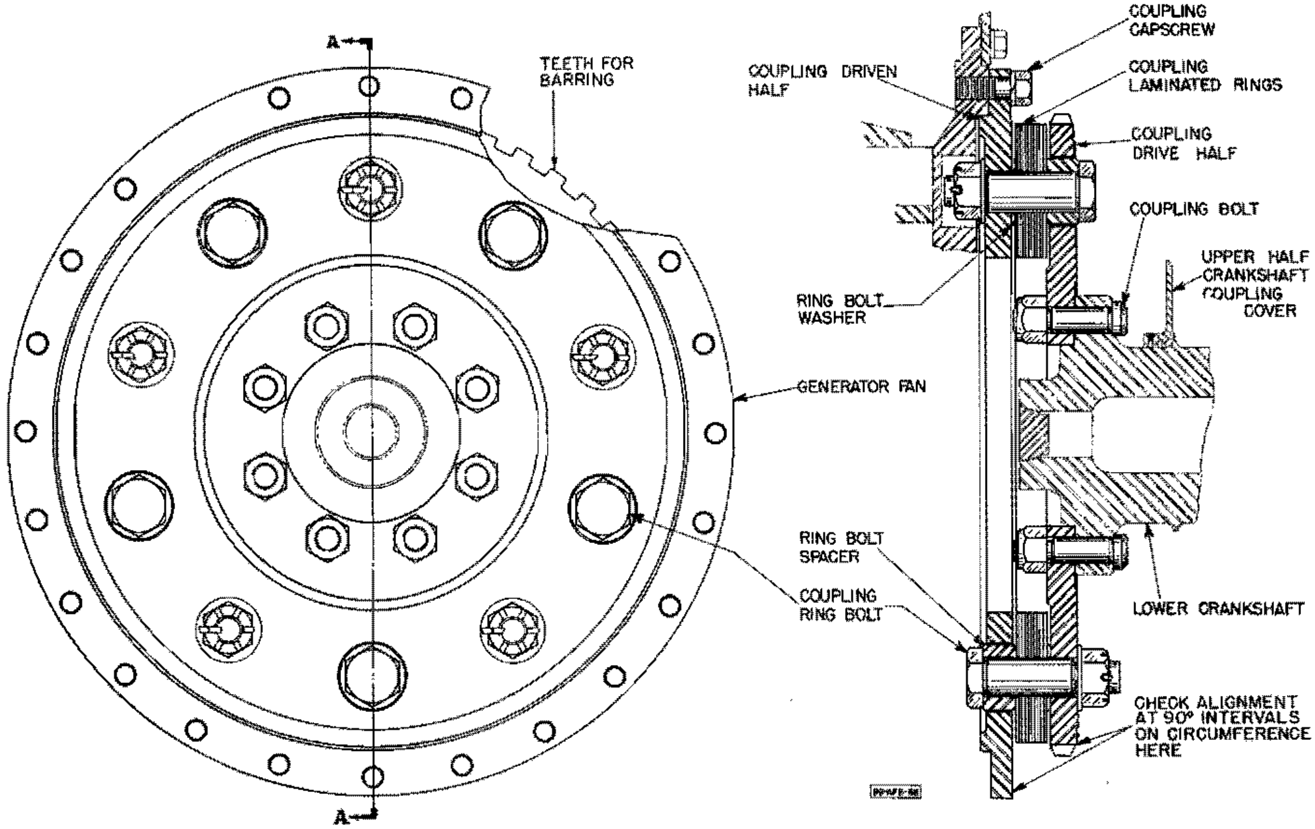
The backlash of the lower bevel gear and pinion is checked in a similar manner.

Refer to Page E12 for installation of bearing caps and thrust bearing shell.

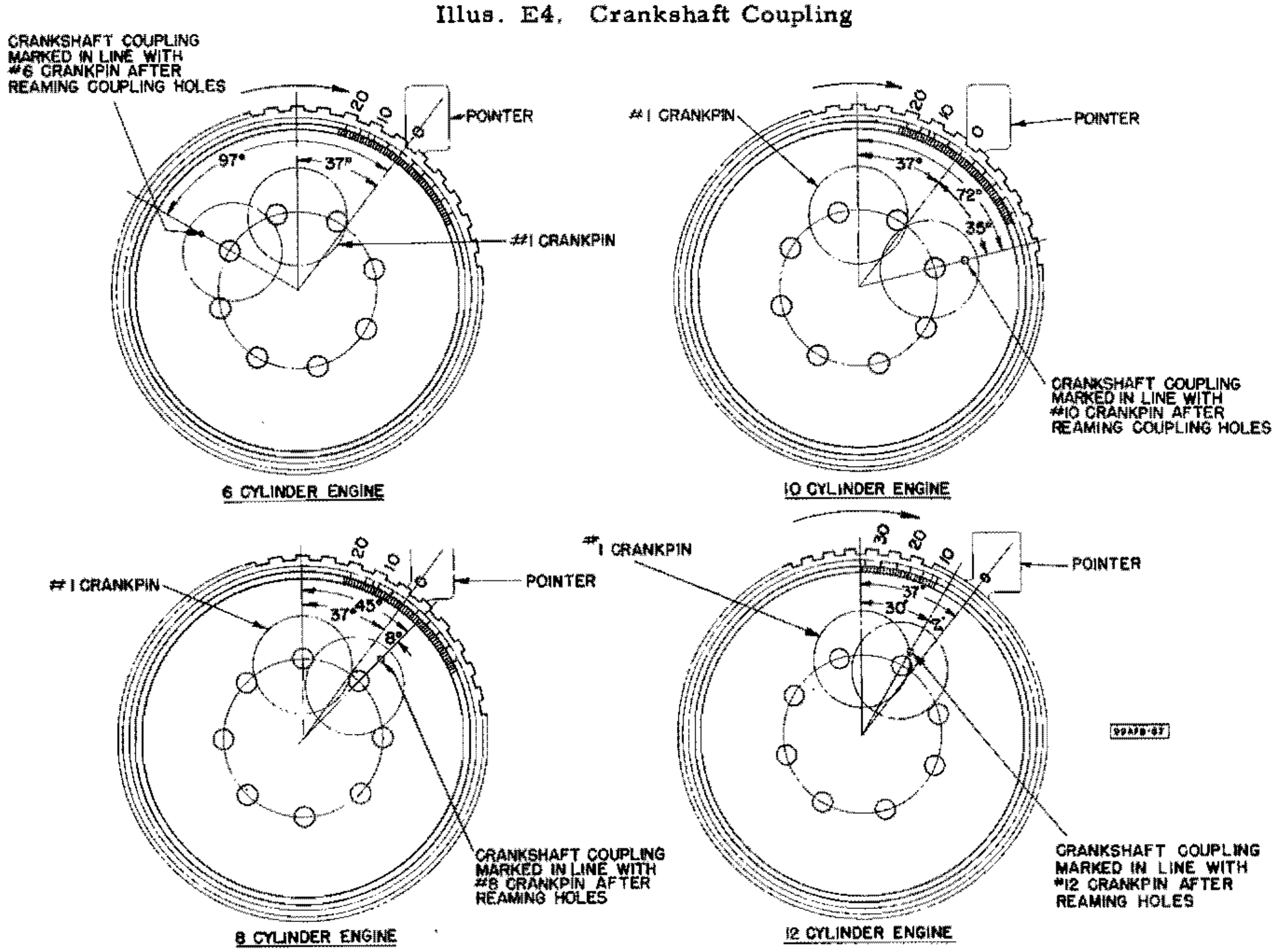
Refer to Chapter G for installation of crankpin bearings.

Replace the timing chain, reversing the removal procedure. Be sure the chain meshes with the proper teeth on the camshaft and crankshaft sprockets and has the proper slack. Refer to Section H.

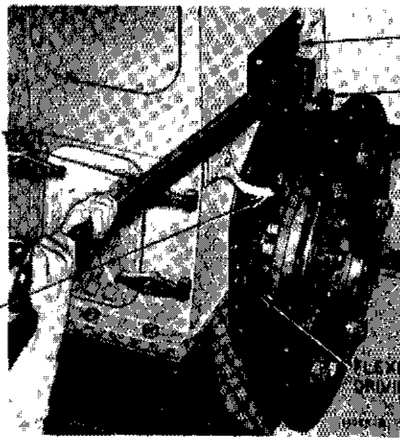
A new crankshaft will always be furnished with oversize bolts for the vertical drive gear. It will be necessary to rebore and reream the holes in the vertical drive gear and the flange of the crankshaft, as well as grind the new bolts to fit the re-reamed holes.



Illus. E4. Crankshaft Coupling



Illus. E5. Crankshaft Coupling Markings
(Viewed from engine side of coupling with No. 1 lower piston on inner dead center.)



Illus. E6. Barring Device

CRANKSHAFT AIR SEAL

An air seal is provided to prevent leakage of oil from around the crankshaft at the drive end.

This seal consists of a grooved split housing closely fitting the crankshaft and bolted to the cylinder block. Air from the discharge side of the blower is piped to the seal and prevents dirt from entering the seal and oil from leaking from the crankcase.

CRANKSHAFT COUPLING

Description

The crankshaft coupling, Illus. E4, consists of three parts: the engine coupling drive half; the laminated discs and the coupling driven half. The coupling driving half is fastened to the lower crankshaft with fitted bolts and the coupling driven half is fastened to the generator shaft with capscrews. Power from the engine is transmitted thru the laminated discs by means of a second set of fitted bolts held in place by ring bolt spacers.

Servicing

The reamed holes in the three major parts mentioned above are undersize on replacement parts. The bolts are oversize. The driving halves have a letter "O" stamped on the edges for proper assembly location. The laminated discs have a notch on the outside edge for the same purpose. When assembling the parts the "O," notches, and "O" must be in line.

The coupling drive half can be removed from the lower crankshaft with the shaft in place. Remove the flywheel end cover halves and the end main bearing cap. Drive out the coupling bolts on the lower side. Bar the engine to remove the remaining bolts.

Fit the new coupling drive half to the crankshaft flange. Refer to Illus. E5 for correct positioning of the coupling. Ream the bolt holes to nearly the oversize bolt size. Grind the bolts for a light drive fit. Mark the spacers, bolts and holes and assemble the parts in proper arrangement. Tighten the bolts to the torque limit given in Chapter B.

Coupling Alignment and Fit

The main generator must be aligned and fitted to the coupling whenever a new coupling is installed or the main generator fitted to the engine and subbase.

Reference is made to the "Maintenance Bulletins" Sec. 411.1 series for fitting the various types of main generators.

BARRING DEVICE

A barring tool, Illus. E6, is provided for rotating the engine when servicing. This tool consists of a removable lever and pawl arrangement which can be mounted on the pivot of the barring device bracket. The crankshaft coupling (drive half) edge is notched for engagement of the pawl so that movement of the lever rotates the lower crankshaft. Direction of rotation is controlled by changing the position of the pawl on the lever.

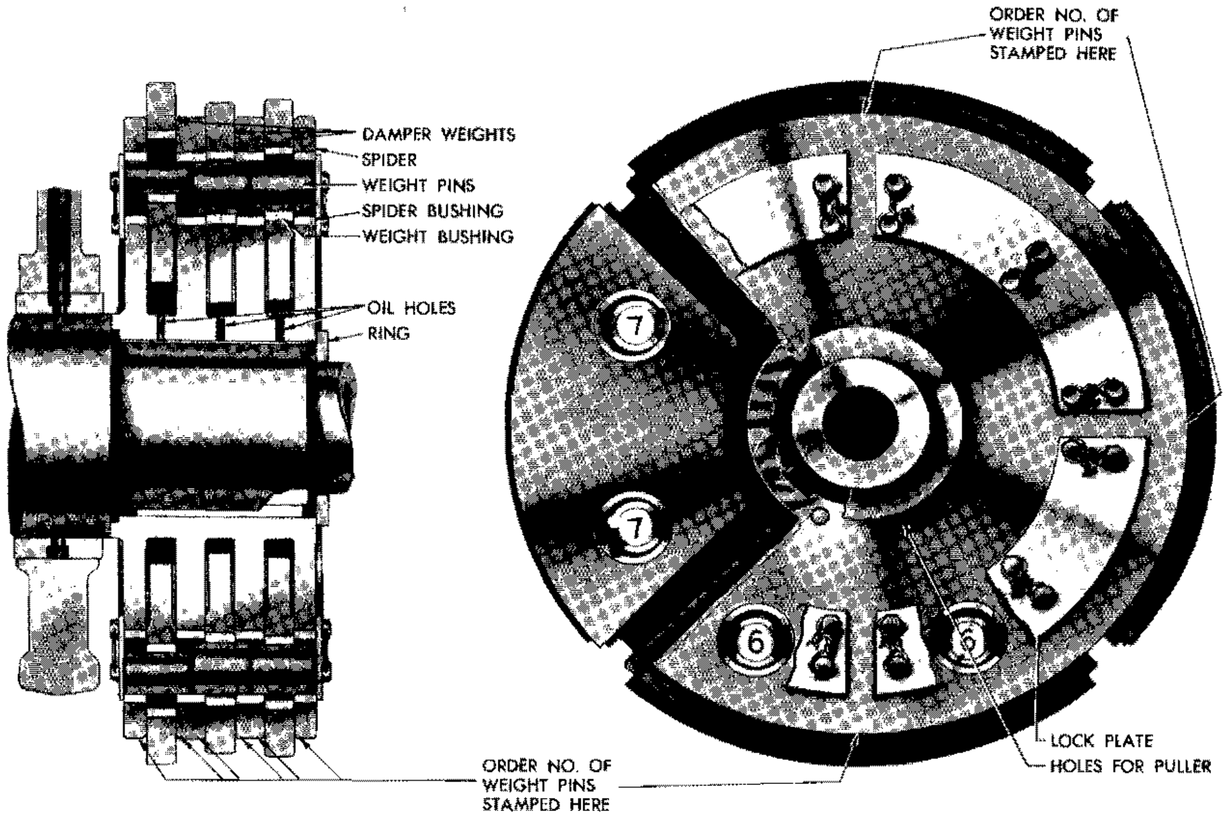
> CAUTION: WHEN USING THE BARRING TOOL, THE BATTERY SWITCH MUST BE BLOCKED OPEN TO AVOID ACCIDENTALLY STARTING THE ENGINE. AS AN ADDITIONAL PRECAUTION THE STARTING CONTACTORS MUST BE BLOCKED OPEN WITH WOODEN BLOCKS.

TORSIONAL DAMPERS

Torsional dampers are mounted on the crankshafts at the exhaust end of the engine to eliminate torsional vibrations at critical speeds.

(A damper was provided on the lower crankshaft of early 8 and 10 cylinder engines. All later engines have a damper on the lower crankshaft. The 12 cylinder engine has a damper on both the upper and lower crankshafts.)

The dampers shown in Illus. E7, E8, and E9 consist of a spider fitted with weights. These weights are installed in rows in slots in the spider. Each weight is located and free to move in or out on two weight pins. Lubrication is furnished to the moving parts of the damper from the engine pressure system by means of



Illus. E7. Torsional Damper - 8 and 10 Cyl. Engines

grooves and holes in the spider hub.

Inspection - Lower Damper

Inspection of the lower damper pins and bushings must be made at regular periods as outlined in the Maintenance Bulletin Sec. 206 to assure trouble free operation of the damper.

It is assumed the lube oil pump has been removed from the pump mounting plate (also the tachometer-generator and drive housing when used).

Remove the governor and bracket from the pump mounting plate.

Remove the water pump (or pumps) and the pump mounting plate. Refer to Chapter N.

Remove the lockplates from the outer face of the damper. Inspect the inner surface. If wear is shown, reverse or replace the lockplates. Use new capscrews.

Bar the engine so that the trailing edge of one section of weights is even with the lower edge of the cylinder block (governor side).

Use a strong magnet or solenoid arrangement to pull the two pins to free the outer damper weight which is in line with the governor side crankcase inspection opening. Remove the remaining pins and weights in the damper section in a manner similar for the outer weight.

Carefully note the position of each pin and weight as it is removed. If inspection of these parts discloses that they can be reused, weights and pins must be returned to their original location in the spider. Also pins and weights must not be turned end for end. In use, these parts had become "worn-in" and the reversal of parts would require a new "wear-in" which could materially shorten the life of the pins and bushings.

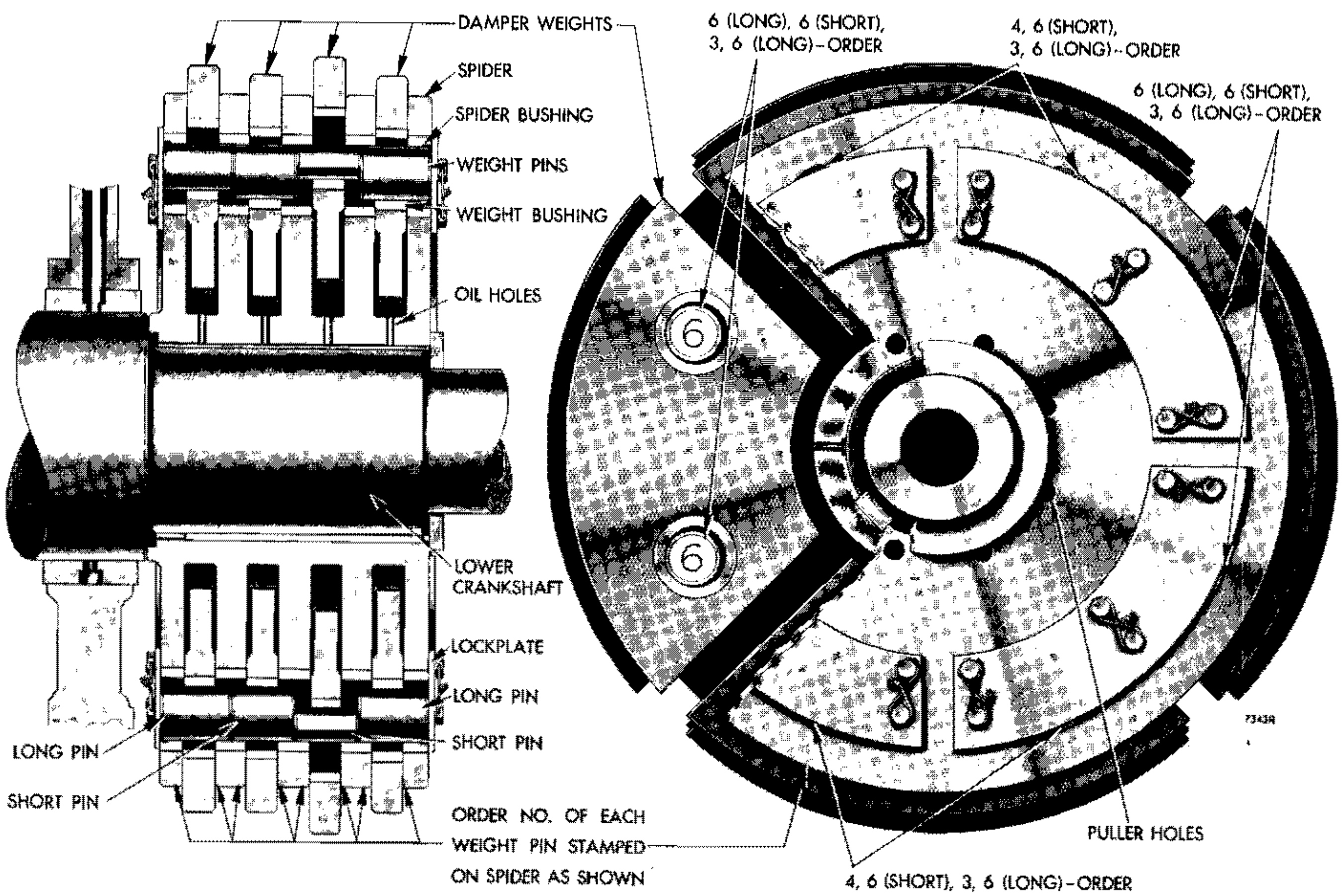
NOTE: The 12 cylinder upper damper and the 6 cylinder damper have two rows of weights, 8 and 10 cylinder dampers have three rows of weights and the 12 cylinder lower damper has four rows of weights.

Each section of the damper is considered separately. A section consists of two adjacent axial rows of pins and bushing supporting each row of weights.

Bar the engine to position the next section of weights and remove in a manner similar as for the first section of weights.

Visually inspect pins and bushings for pitting or fretting conditions. Also inspect the lockplates for wear on the pin side.

Check the weight pins for wear. The pins are of different sizes. This size is designated by an order number etched into the end of the pin. Check the pins for wear with a micrometer. Check the diameter at several points as the wear may not be uniform. If the diameter



Illus. E8. Torsional Damper - Lower - 12 Cyl. Engines
(Order number of the weight pins as shown are from inner to outer positions)

reaches the minimum shown in the "Wear Limit Chart" Chapter B, new pins must be used.

Damaged or worn pins may be replaced individually.

Also check the bushings (both weight and spider) for wear with a star gage. Carefully check the outer bearing surface of the spider bushings and inner surface of the weight bushings for slight wear indentations. If the bore reaches the maximum shown in the "Wear Limit Chart" Chapter B, the bushings must be replaced.

Replacement of a worn or damaged spider or weight bushing requires replacing or turning all spider and weight bushings in the two affected axial pin rows regardless of condition. (Worn undamaged bushings may be reused by turning 180°. Caution must be taken when installing the old bushing to be sure it has been turned.)

Inspection - Upper Damper - 12 Cyl. Engine

The upper damper, Illus. E9, should be inspected at the same periods as apply for the lower dampers. The damper can be inspected and overhauled while the upper crankshaft is in the engine. Remove the control end cover.

Remove the lockplates from both sides of the damper. Inspect the inner surface. If wear is shown, reverse or replace the lockplates. Use new capscrews. Remove the pins and weights. Arrange parts in systematic order so that parts may be returned to their original location and position.

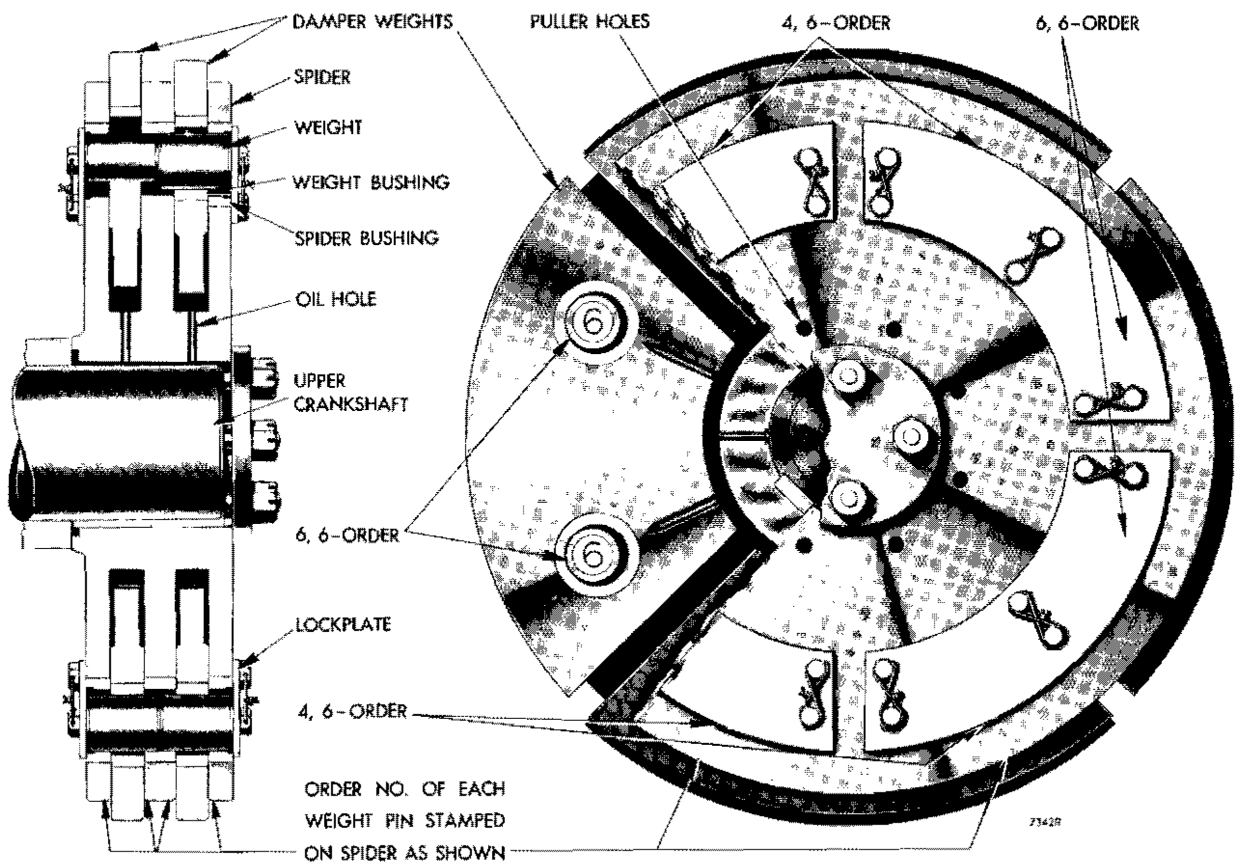
Inspect the pins, weight and spider bushings in accordance with procedure outlined for inspecting lower damper parts. The same recommendations for replacement of parts apply.

Weight Bushing Replacement - All Dampers

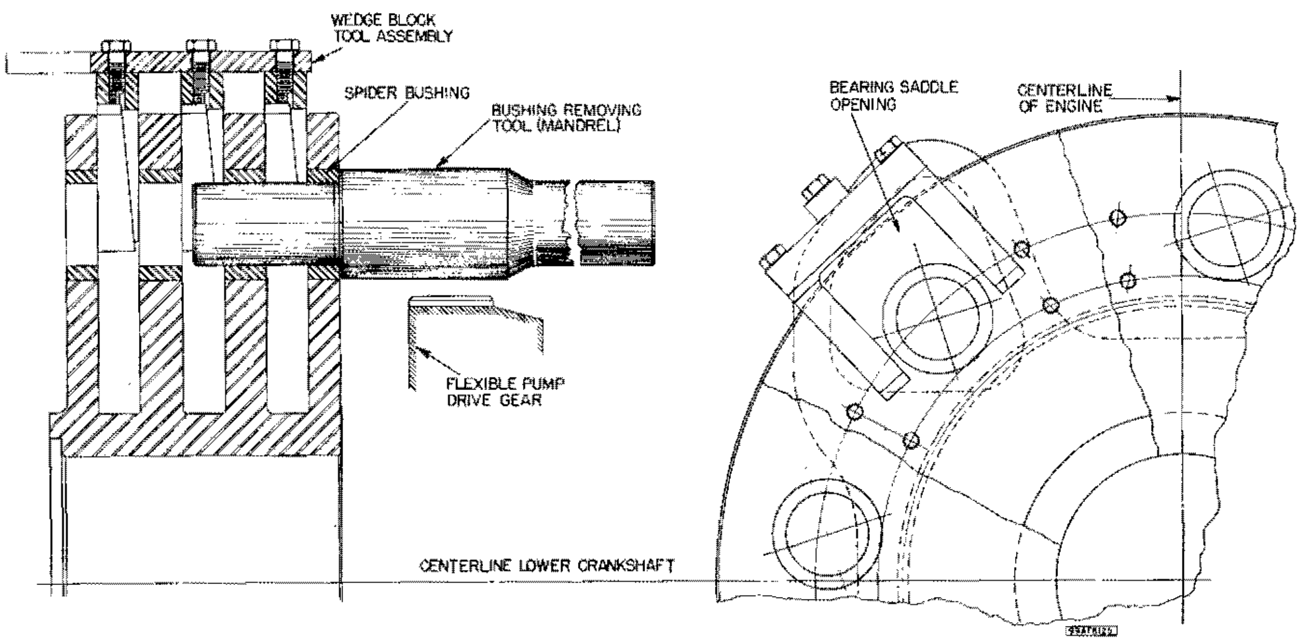
Remove the weight bushings by pressing out using the mandrel, shown in Illus. E10. Properly support the damper weight. The bushings may be driven out if a press is not available. The mandrel must be held square to the damper weight.

Inspect weight bores for burrs. Stone down sharp edges. Be sure the bore is clean.

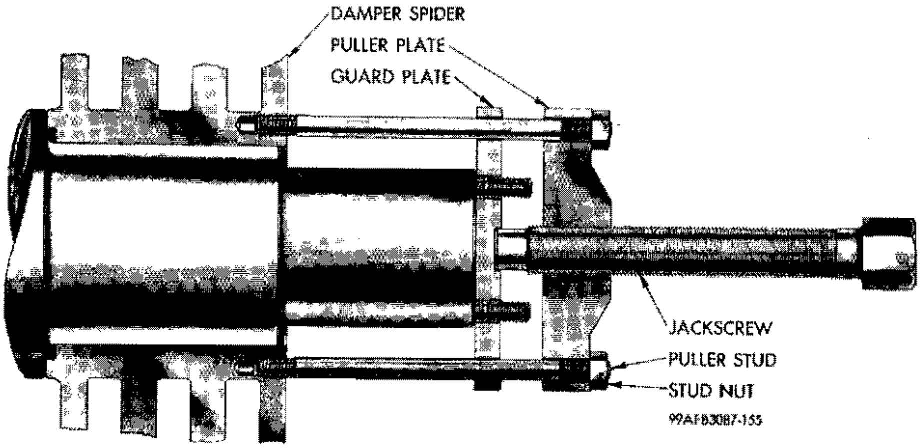
Heat the weights in an oil bath to approxi-



Illus. E9. Torsional Damper - Upper - 12 Cyl. Engines



Illus. E10. Torsional Damper Tools



Illus. E11. Torsional Damper Spider Puller

mately 320° F. and cool the bushings and mandrel in a solution of dry ice and alcohol. Set the heated weight on a surface plate and insert the cooled bushing. The bushing must be flush with the face of the weight. If provision for heating the weights to the limit specified above is not available the cooled bushing will require pressing into the weight. Press the bushing square into the weight bore and flush with the face of the weight.

Spider Bushing Replacement

Lower Dampers -
Bar the engine so that the row of bushings to be removed lines up with the bearing saddle opening (either side of the engine) as shown in Illus. E10.

Place the wedge block tool, Illus. E10, straddling the bushing row to be removed. Tighten the wedge blocks sufficiently to be snug but not so tight to cause distortion to the spider.

Block with metal wedges between the inner face of the damper spider and the bearing saddle opening.

Insert the mandrel and drive out the outer bushing. Remove the mandrel and bushing. Continue the same procedure to remove the remaining bushings in the one row.

Remove the blocking wedges and wedge block tool and bar the engine to line up the next row of bushings in line with the bearing saddle opening.

After all bushings are removed, inspect the spider bores for burrs or other defects. Stone down sharp edges. Be sure the bore is clean.

Heat the spider with steam if available. Place a canvas around the spider and direct live steam on the spider and heat as hot as possible.

Cool the bushings in the same manner as the weight bushings.

Remove the spider heating (if used) and position a cooled bushing over the bore in the inner slot of the spider. Insert the mandrel and lightly drive the bushing in flush to the face of the spider. Insert remaining bushing in a similar manner.

NOTE: Be sure to check the width of the bushings. The bushings for the first and last rows in the spider are 3/4" wide, other bushings are 1" wide.

In addition on the 12 cylinder dampers, the first and last rows of spider bushings have a relief. The bushings must be installed so that the relief is next to the lockplate.

Reassembly

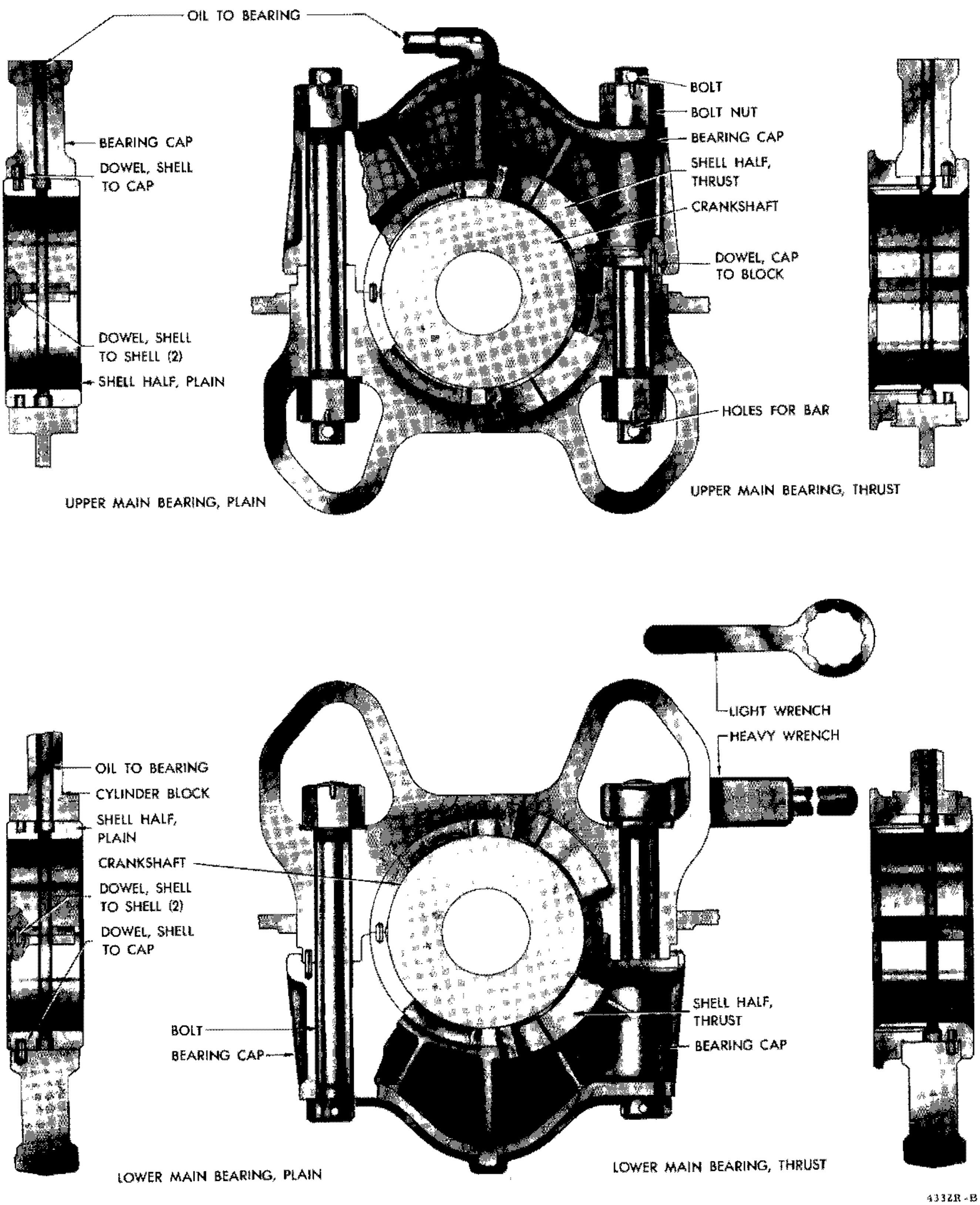
The dampers can now be reassembled by replacing the weights, pins, and lockplates.

EXTREME CAUTION MUST BE TAKEN WHEN REPLACING WEIGHT PINS TO BE SURE THAT THE CORRECT ORDER OF PINS IS REPLACED IN THE PROPER HOLE IN THE SPIDER. AS NOTED ON ILLUS. E7, E8, AND E9, THE ORDER NUMBER OF THE TWO ADJACENT WEIGHT PINS IS STAMPED ON THE WEBS OF THE SPIDER. THE ORDER NUMBER IS ALSO ETCHED INTO THE END OF THE WEIGHT PIN. THE TWO PINS IN EACH WEIGHT ARE OF THE SAME ORDER NUMBER.

Replace assemblies removed to make the inspection.

Spider Removal

If the damper spider must be removed, use the puller as shown in Illus. E11. Install the puller and tighten down on the jackscrew. Use white lead or oil on the jackscrew. Tighten on



Illus. E12. Main Bearings

the jackscrew until the spider loosens. If available steam may be used to facilitate removal. Do not use an open flame. Start heating at the circumference, keeping strain on the puller. Tapped holes are provided in the damper spider for lifting eyebolts to facilitate handling the spider.

To reinstall the spider, heat the assembly slowly in oil (or an electric furnace) to about 320° F. temperature of the heating medium. The hole in the spider should then be slightly expanded.

NOTE: The damper must be correctly installed on the crankshaft. Be sure the undercut at the hub is toward the engine, also the tapped puller holes must be on the side away from the engine.

Some lifting means should be provided for placing the spider in position. The following is suggested:

Use a temporary 2-1/4" diameter guide shaft about 30" long with an eyebolt located about 3" from one end. Also provide some heavy object that can be used as a counterweight on the guide shaft. Make a trial lift on the spider with shaft and weight in position.

Rotate the engine crankshaft until keyway is at the top. Check the keyways in crankshaft and spider, and fit key in crankshaft. Apply white lead and oil to the surface of the crankshaft where the damper is to be installed.

Observing the hole in the spider and using the temporary shaft for lifting and guiding, install the spider to seat on the crankshaft.

DO NOT DAMAGE THE DAMPER BY EXCESSIVELY POUNDING TO SEAT.

Cool slowly with compressed air starting at the center.

Reassemble flexible pump drive as outlined in Chapter N. Reconnect governor (tachometer-generator if used) and replace covers and connections removed in preliminary procedure.

The upper damper used on the 12 cylinder engine is installed using a procedure similar to that outlined for lower dampers.

MAIN BEARINGS

Description

The main bearing shells fit into the enclosures formed by the saddles in the cylinder block and the bearing caps. They are made in halves and dowelled together and marked for proper location on the edge toward the exhaust end of the engine.

Lubricating oil from the engine pressure system enters the bearing surface thru an internal oil groove in the bearing. Slots conduct oil to the thrust surfaces.

Bearing Inspection

Aluminum main and thrust bearings which have flashed or failed can be easily detected. Use a .002" feeler gage to check for clearance between the bearing shell and the bearing cap fit near the parting line. If the feeler gage can be inserted, it is evidence that the bearing has flashed and must be removed. The parting lines between the two shells of a flashed bearing will also be open so that the .002" feeler gage can be inserted.

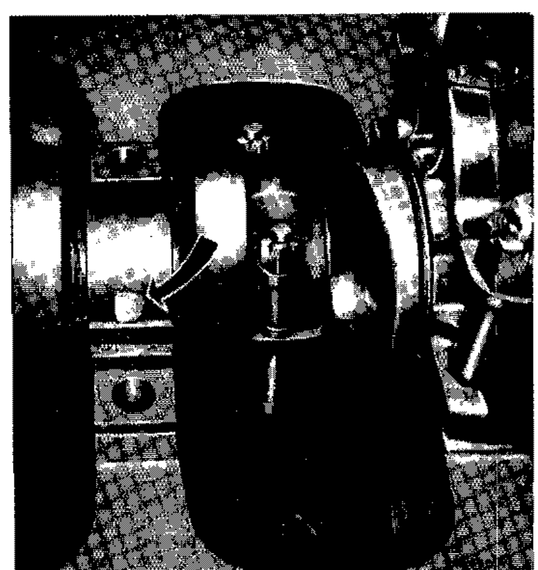
Refer to Maintenance Bulletin Sec. 206 for the manufacturers "Recommended Bearing Inspection Periods."

Upper Main and Thrust Bearing Removal

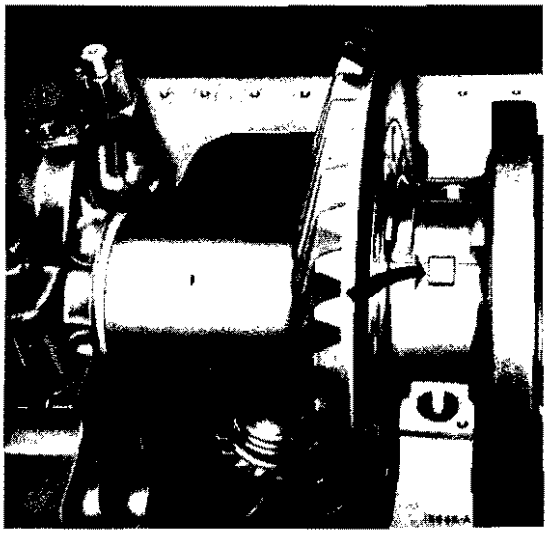
(Bearing bolts and nuts are matchmarked on early engines and should not be interchanged.) The bearings are accessible after removing the exhaust end cover and the top cover. Also remove the lubricating oil supply pipe leading from the upper header to the top of the bearing caps.

A heavy offset box wrench, a light 12 point box wrench, Illus. E12, and a power wrench are available to fit the bolt nuts. Hold the bolt from turning by inserting a tapered bar in the hole in the bolt. Then, using the wrenches, loosen and remove the nuts.

With a small pinch bar, first on one side and then on the other, raise the bearing cap evenly. If necessary, the bolts can be removed



Illus. E13. Main Bearing Shell Removing Tool



Illus. E14. Thrust Bearing Removing Tool

by holding the bolt with a pin in the upper hole in the bolt, and unscrewing the lower nut.

With the bearing cap and upper half of the shell removed, the lower half of the shell can be rolled out by using the tools shown in Illus. E13. The tool for rolling out the plain bearing should be inserted in the diagonal oil hole at the particular crankshaft bearing. Use the thrust bearing tool with the square head for rolling out the thrust bearing, Illus. E14.

As the crankshaft is revolved, the button head on the tool is brought into contact with the edge of the shell, rolling the shell around with the crankshaft inside the bearing saddle. When the shell is in the position of the top half, it can be lifted from the engine. If the crankshaft is to be removed, only the thrust bearing shell need be rolled out before removing the crankshaft.

Lower Main and Thrust Bearing Removal

When removing lower main bearings, always leave the center and end main bearing caps and shells in place, for crankshaft support, until new shells have been installed in, and bearing caps replaced on, all the other bearings.

The main bearing bolts and nuts on early engines are matchmarked and should not be interchanged. The lower bearings are reached by removing the crankcase side covers from both sides of the engine adjacent to the bearing to be removed.

Using the wrenches referred to above, loosen the nuts to the last thread while holding the bolt from turning with a tapered bar inserted in the hole in the lower end of the bolt.

The bearing cap should next be pried apart evenly from the recessed fit in the bearing saddle so that the weight rests on the nuts of the bolts. Support the bearing cap while removing the nuts and bolts. The bearing cap is supported by inserting two tapered hooked bars into the holes in the bolt heads. The bars are held thru the two adjacent crankcase openings. Remove the bearing shell.

The top half of the shell can now be rolled out. Be prepared to prevent the shell from dropping when it moves out from between the journal and the bearing saddle.

Check the wear on the bearing shell by measuring the minimum thickness of the shell with a micrometer using a ballpoint attachment. Refer to the "Wear Limit Chart" Chapter B for the minimum shell thickness of the main bearing shells.

Thrust Bearing Clearance

To check the thrust bearing clearance, force the crankshaft against the thrust bearing in one direction with a pinch bar. Check the clearance between the face of the bearing and the side of the crankshaft cheek with feelers. Recheck in the opposite direction. Another method is to take two readings with a dial indicator against the face of the crankshaft coupling. Take one reading with the crankshaft pried one way, and the other reading with the shaft pried the other way. The clearance is the difference between the two readings. New bearings should be installed if this clearance exceeds the value given in the "Wear Limit Chart," Chapter B. The thrust faces and inner faces of the flanges must be parallel and square to the bore with .002" measured on the outside diameter of the thrust face; the bearing should provide the original endwise clearance shown on the "Wear Limit Chart" Chapter B. In some instances, it may be necessary to lightly scrape the bearing to provide these conditions.

BEARING REPLACEMENT

Main Bearings

The bearings are replaced by following the procedure outlined for disassembly in reverse order. The weight of the lower bearing caps may be supported by passing a clean rope thru under the journal snubbed to some engine part on the opposite side such as a vertical member of the cylinder block.

The lower main bearing caps are replaced with the shell half in place in the cap. Likewise the upper and lower thrust bearing caps are replaced with the shell half in place. The upper main bearing caps and shell are replaced separately. Note the markings. New shells must be marked in the same manner and location as the old shells.

Before replacing the bearing shells, apply "Oil Dag" to the journals.

Set the main bearing caps in place. With a soft hammer tap them on one side and then on the other until seated. Be sure the dowels are entering the dowel holes correctly.

Tighten the main bearing bolts to 700-1000 ft. lbs. or use the following procedure.

1. Assemble bearing hand tight with 8" light wrench.
2. Pull hand tight (one hand) with 20" wrench (200-250 ft. lbs.).
3. Turn nut an additional flat (60^{o}).
4. Continue tightening (no more than an additional one-half flat to line up the cotter pin hole.

TIGHTEN BOTH BOLTS OF EACH BEARING CAP AT THE SAME TIME TO PREVENT DISTORTING THE BEARING BORE.

Thrust Bearings

Mark the new shells in the same manner and location as the old shells.

Apply "Oil Dag" to the journal and thrust surfaces.

Replace the lower thrust bearing shell in place in the cap. Upper shells are replaced separately.

Move the crankshaft in either direction until the block half of the thrust bearing shell slides into the fit in the cylinder block. Roll the shell in place with the square tool shown in Illus. E14.

Set the upper bearing cap in place and tap with soft hammer to seat. The lower bearing cap is pulled in place by tightening the bolts evenly. Be sure the dowels are properly located.

1. Pull up bolts using a 20" wrench.
2. Loosen the bolts and retighten with the 8" wrench.
3. Force the crankshaft against narrow face and back against the thrust face.
4. Continue tightening the bolts to 700-1000 ft. lbs. or use the following procedure.
5. Pull hand tight (one hand) with 20" wrench (200-250 ft. lbs.).
6. Turn nut an addition flat (60^{o}).
7. Continue tightening (no more than an additional one-half flat to line up the cotter pin hole.)

TIGHTEN BOTH BOLTS OF EACH BEARING CAP AT THE SAME TIME TO PREVENT DISTORTING THE BEARING BORE.

NOTE: Later engines have aluminum thrust bearings. Refer to Chapter B for wear limits.

MAIN BEARING CAPS

Main bearing caps are not an interchangeable stock repair item. When required for specific engine replacements, (which would be in very rare instances), the Locomotive Service Department should be contacted.

(1) Special machined caps can be supplied by the factory. An adjacent bearing cap must be supplied by the customer to enable the factory to machine the replacement caps.

(2) Rough bored caps with finished cylinder block fit surfaces can be furnished. Finish boring of the cap must be done in the field by the customer.

(3) Finish bored caps with unfinished cylinder block fit surfaces can be furnished. Hand fitting of the cap must be done in the field by the customer.

BEARING FAILURE AND CORRECTION

After the feeler gage check of main and thrust bearings has revealed the failure of a bearing shell, recondition the bearing journal as follows:

Main Bearing Journals

1. Remove the main bearing cap and shells.
2. Remove the adjacent connecting rod and piston assembly if failure is on the lower shaft. If failure is on the upper shaft, disconnect the connecting rod from crank. By adjacent it is meant the connecting rod and piston assembly that is lubricated and cooled by oil that is relayed thru the failed main bearing. No. 1 main feeds No. 1 piston, No. 2 feeds No. 2 piston, etc. The reason for removing this adjacent assembly is to prevent the sodium hydroxide (NaOH) solution used in cleaning the failed crankshaft journal from entering the interconnected oil tube and damaging the connecting rod bearing.
3. Clean and condition main bearing journal according to instructions outlined under, "Conditioning of Crankshaft after Aluminum Bearing Failure," page E14.
4. Inspect bearing cap for distortion. This is accomplished by the use of a mandrel check gage and an outside micrometer. See "Bearing Cap Inspection and Repair," page E15.
5. Install new bearing using special bearing journal conditioner C-1401ND-B. Follow the instructions closely.

a. Mix thoroughly before each application.

b. Apply a liberal coating of compound to bearing shell and install in engine and tighten as outlined, page E12.

c. Bar the engine one complete turn prior to, and one-quarter turn during prelubrication.

Thrust Bearing Journals

1. Remove thrust bearing cap and bearing shells.

2. Clean and condition crank journal and thrust faces according to instructions outlined under, "Conditioning of Crankshaft after Aluminum Bearing Failure."

3. Inspect bearing cap for distortion. This is accomplished by the use of a mandrel check gage and on outside micrometer. See "Bearing Cap Inspection and Repair," page E15.

4. Check block saddle for distortion, correct and clean as outlined under, "Thrust Bearing Block Saddle Repair," page E18.

5. Install new bearing using special bearing journal conditioner C-1401ND-B. Follow the instructions closely.

a. Mix thoroughly before each application.

b. Apply a liberal coating of compound to bearing shell and install in engine and tighten as outlined, page E13.

c. Bar the engine one complete turn prior to, and one quarter turn during prelubrication.

Conditioning Crankshaft after Aluminum Bearing Failure

When an aluminum bearing has been found on a crankshaft, the crankshaft journal shall be reconditioned according to the following procedure:

1. Clean crankshaft journal with fine grade emery cloth dipped in fuel oil. This is to remove the surface aluminum that has adhered to the shaft at the time of failure. The emery cloth should be cut in long narrow strips approximately 2" wide, long enough to go around the crankpin or journal and pulled from both sides so that a see-saw action is used when pulling the ends of the strips.

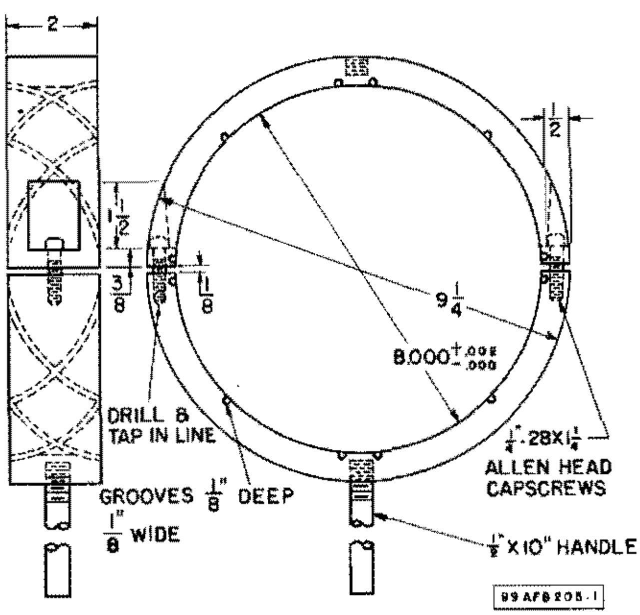
2. Remove all surface oil with a solvent.

3. Saturate the journal or crankpin surface with a sodium hydroxide solution (NaOH) for approximately 30 minutes or until all aluminum has been removed. The period of exposure to NaOH solution will vary depending upon the quantity of aluminum adhered to the affected surface or the strength of the solution. A stronger solution of NaOH will lessen the period of immersion or saturation.

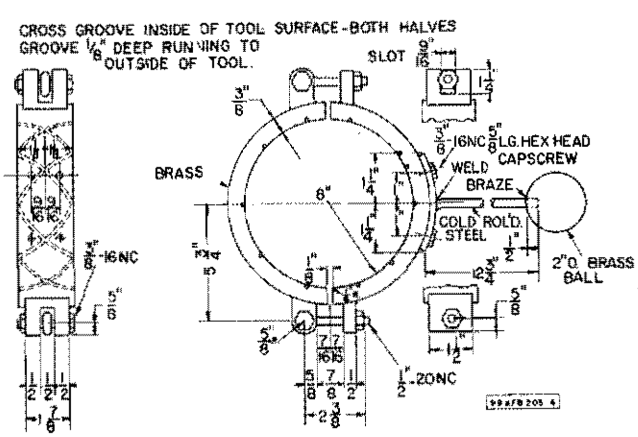
a. Experimental tests were conducted with a solution of 10% NaOH by weight, however, this is not necessarily the strength that must be used.

b. Precautions must be taken to prevent the solution of NaOH from contaminating the crankcase while cleaning procedure is taking place.

PERSONNEL WORKING WITH NaOH MUST WEAR RUBBER GLOVES BECAUSE THIS HIGHLY CAUSTIC SOLUTION IS HARMFUL TO BARE SKIN.



Illus. E15. Main Bearing Lapping Tool



Illus. E16. Main Bearing Lapping Tool (Crankshaft removed)

4. With the proper lapping tool, Illus. E15 or E16, lap in the affected main bearing journal. Illus. E15 is for lapping the main bearing journals with the crankshaft in place in the block. Illus. E16 is for lapping tools for the main journals. For lapping the thrust faces, use tool shown in Illus. E17.

a. The lapping compound used is No. 111 Green Label Time-saver which is mixed to a consistance of a soft paste by adding No. 10 lube oil. This mixture should be used generously. The crank journal should be lapped until it receives a satin finish. The depth of the lap finish can be checked by using the edge of a piece of clean wood block or a piece of round wood stock. After lapping, rub the wood across the surface lapped; if the satin finish remains, the lapping has penetrated. If the wood removes the satin finish, additional lapping will be required.

5. Clean journal with lube oil. The No. 111 Green Label compound has a break down quality, therefore, a thorough job of removing the compound left on the journal is not necessary. A flushing off of the lapped surface with lube oil is all that is necessary.

6. After the crankshaft has been reconditioned, the bearing caps inspected and "conditioner" used on the journal, reapply the bearing as outlined on page E12 for main bearings and page E13, for thrust bearings.

Main Bearing Cap Inspection and Repair

1. Remove bearing cap dowels.

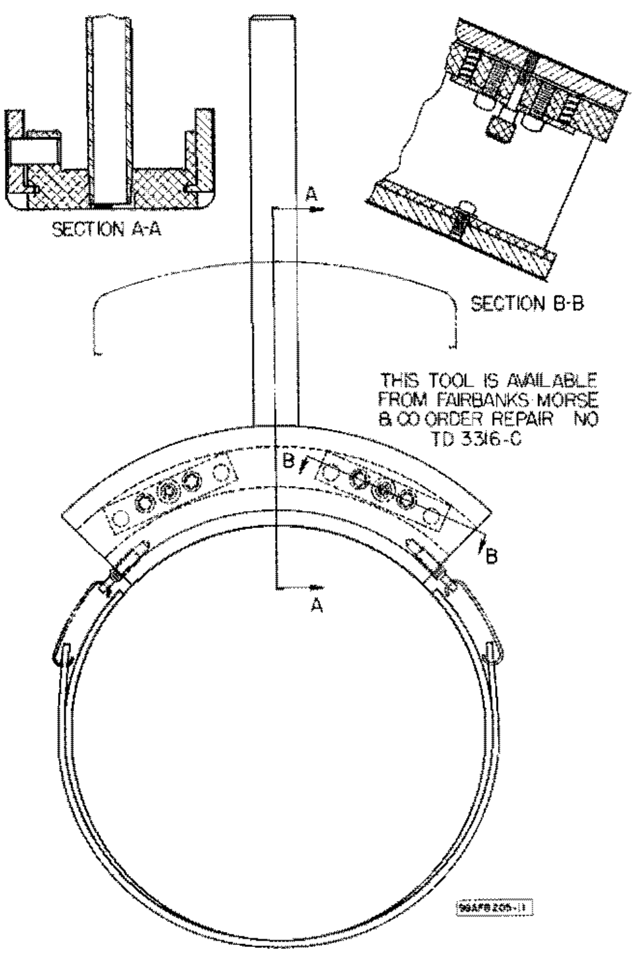
2. Using mandrel, Illus. E18, check bearing cap for distortion.

a. Set mandrel in cap so that side "A," Illus. E19, is centered in the cap proper.

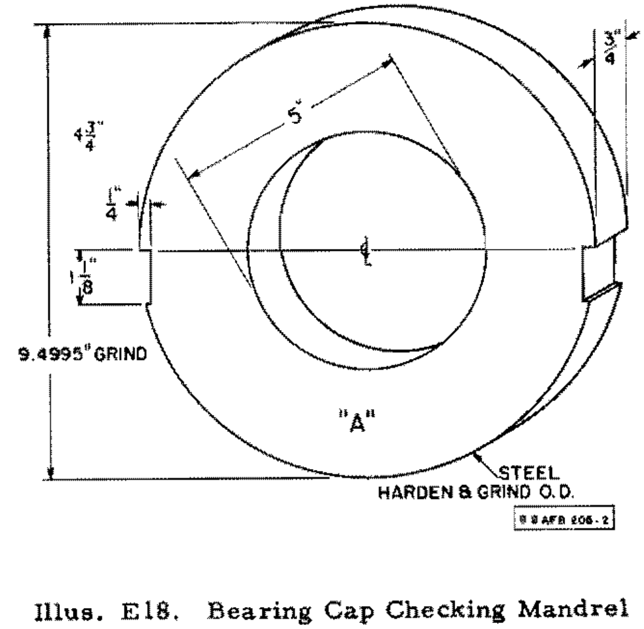
b. Check for distortion with feeler gage. This check is to determine if the bearing cap proper has distorted in any way. In placing the mandrel in the cap bore, be sure that the mandrel is set in straight. Tap the mandrel in place lightly with a plastic hammer to insure that the mandrel is positioned properly.

c. If in making check with mandrel in position A, no clearance is noted between the mandrel and the cap, there is no distortion. If it shows where a .003 or more feeler gage can be inserted between the mandrel and the center of the cap saddle, the cap has closed in and will require repair or renewal, depending on the severity of the distortion which can be determined as further inspection and repair of the cap is made.

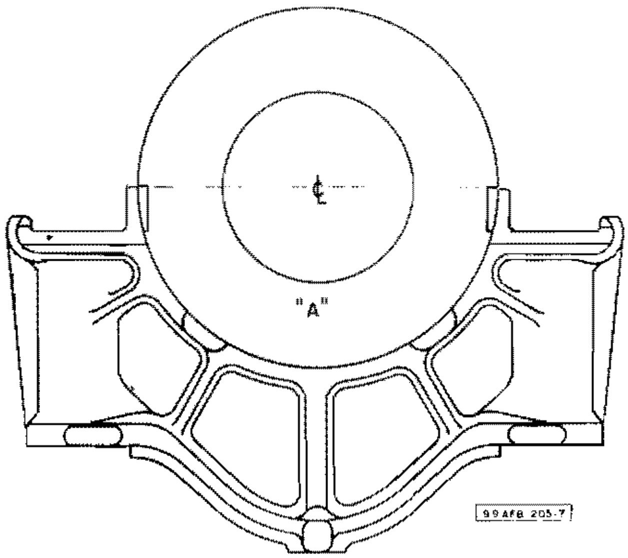
d. With mandrel set in cap as shown in Illus. E19 and no clearance is found between mandrel and the cap, the cap bore is not distorted.



Illus. E17. Crankshaft Thrust Face Lapping Tool



Illus. E18. Bearing Cap Checking Mandrel



Illus, E19. Checking Cap with Mandrel

3. Check dimension across the outside of the ears as shown in Illus. E20. This distance should be 10.125 plus .002, minus .000.

a. If the ears show close-in only, the necessary repair will be to the ears only. Caution: Be sure that all inspections on the cap are made before repair of cap is attempted. A correction of the cap proper will very possibly correct the ear pull-in also. Before the ears are corrected, the cap proper must be correct.

b. For correction of distorted cap, see the following outline.

Repair of Distorted Bearing Cap

1. Material Required

a. Press mandrel - See Illus. E21.

b. Shim stock, 2 pieces .003", .005", .007" and .010" cut 4" x 1-1/2".

c. Hydraulic press - (15 to 20 ton capacity).

2. With bearing cap to shell dowel removed from the cap saddle, set cap over press mandrel as shown in Illus. E22. Level cap on mandrel using a liquid level set on machined surface.

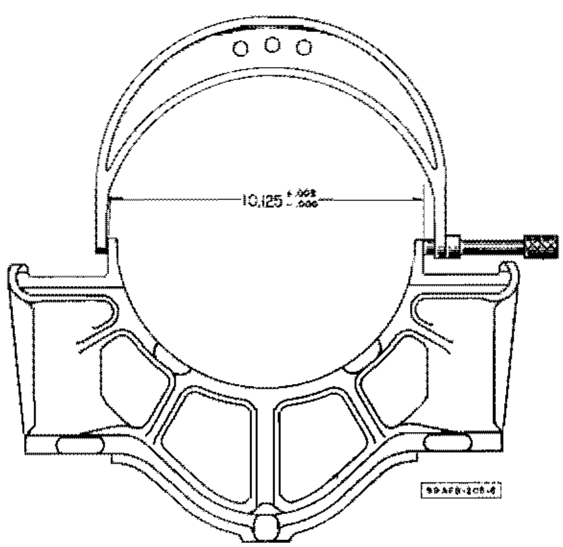
3. Apply pressure at "A," as shown on Illus. E22, (approximately 15 tons, not over 20 tons).

4. Remove cap from press mandrel and check with checking mandrel, Illus. E19. If further correction is needed place .003" shims between cap and press mandrel as shown in Illus. E22 and apply pressure as in 3 above.

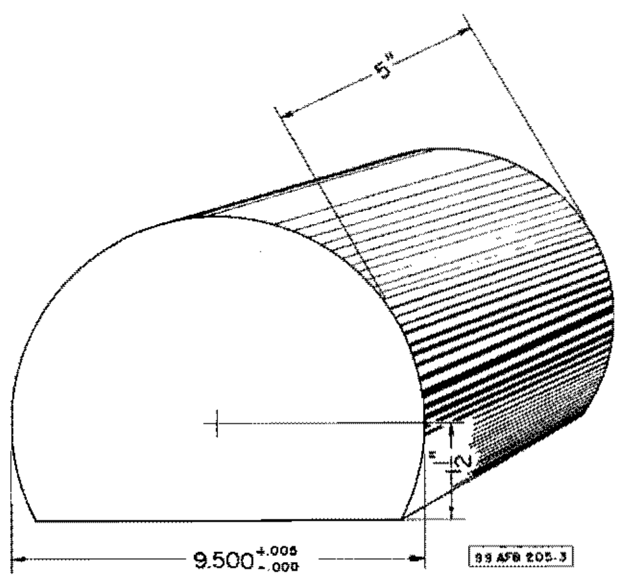
5. Continue checking and adding shims in sequence to their thickness until cap proper is correct to checking mandrel. Be sure that the cap contour meets the checking mandrel in every respect. Check cap bore in different places across the bore with checking mandrel to determine if a taper condition exists.

6. When the cap proper follows the checking mandrel contour but the ears still show some close-in when measured as in Illus. E20, place .003" shims between the cap ears and the press mandrel as shown in Illus. E23. Apply pressure, (5 ton) then remove and check with a micrometer across the ears. If not within the dimension of 10.125 plus .002, minus .000 add additional shims and reapply pressure until ears are within the given dimension.

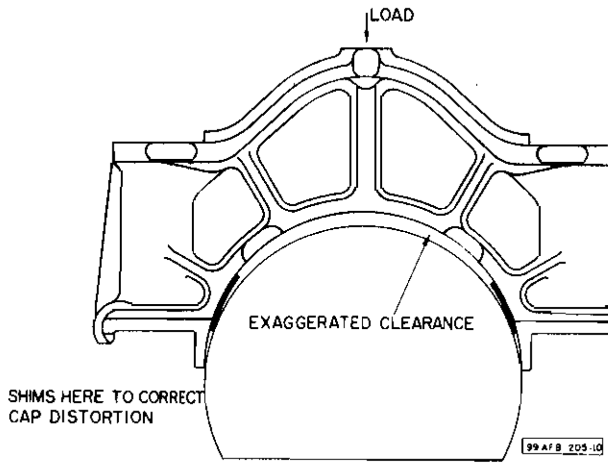
7. After the cap has been repaired to follow the contour of the checking mandrel and the



Illus. E20. Measuring Cap Ear Deflection



Illus. E21. Press Mandrel

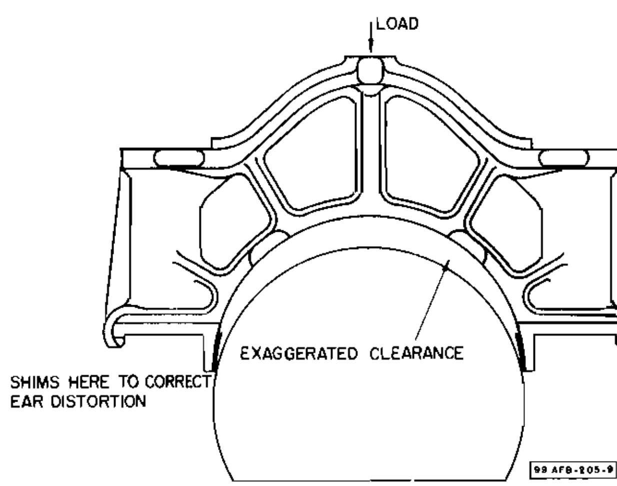


Illus. E22. Cap Positioned on Press Mandrel

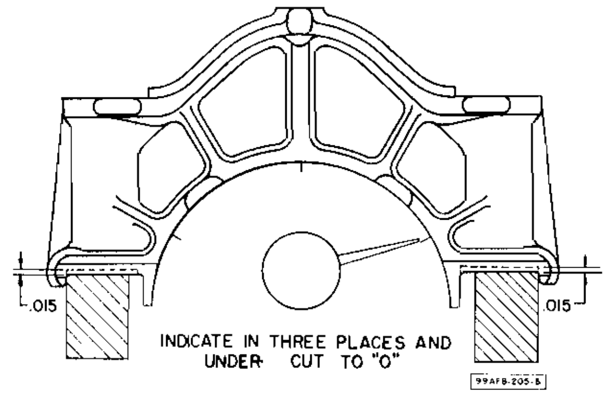
dimension of the ears meets the proper tolerance, the cap may be used. If a thrust bearing cap is being reconditioned and the cap is found with the thrust face surface out of parallel or uneven, a new cap is required. If the cap shows that it has an uneven bore even after the correction has been made by pressing according to the above procedure, further repairs will have to be made. Be sure that the cap is not twisted in any way because a cap in such a shape is not repairable, and a new cap will have to be machined for its place.

8. If the bore contour of the cap is uneven and the cap does not have any twist, proceed in the following manner with repair:

a. Machine .015" off the pad contact surfaces of the cap. See Illus. E24. Care must be taken in machining these two surfaces so that the exact amount is removed from each surface, and the parallelism of the surfaces is



Illus. E23. Correcting Cap Ear Deflection



Illus. E24. Bearing Cap Machining

not lost.

b. Remove from the engine an adjacent cap to the one being machined. This cap must pass the mandrel check, Illus. E19. This cap will be used as a pattern for the cap to be repaired. Due to line boring of the crank bores in the cylinder block, the adjacent cap only can be used for the pattern.

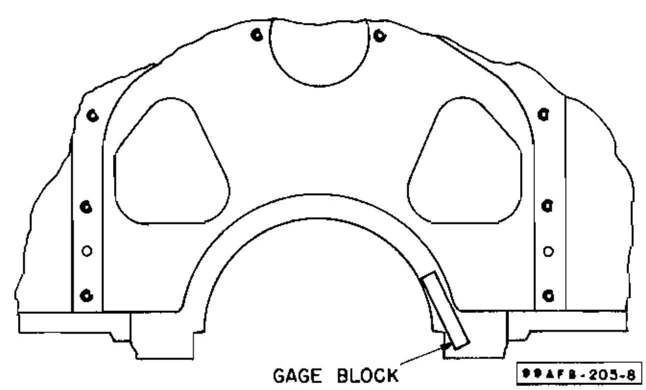
c. Set pattern cap up on parallels on the machine to be used in reboring damaged caps to that common parallel set-up can be used for positioning the cap to be rebored. Indicate the pattern cap to zero bore contour in relation to swing of indicator on tool stock. See Illus. E24.

d. Bore damaged cap to zero indication of pattern cap.

e. Burr cap and replace dowel. Check cap with mandrel.

9. When the cap has been distorted beyond repair and a new cap must be machined, follow the procedure outlined under 8 above omitting step a. New caps are rough bored and have the correct parting line dimensions.

New thrust bearing caps will require the thrust face surfaces to be machined to meet the dimensions of the cap being replaced.



Illus. E25. Thrust Bearing Block Saddle

Thrust Bearing Block Saddle Repair

The block saddle must be checked for distortion as well as the bearing cap after an aluminum thrust bearing failure. Refer to outline "Repair of Distorted Bearing Caps," page E10. Proceed as follows for block saddle inspection and repair:

1. With bearings removed, check the cylinder block saddle machined surface that is contacted by the inner side of the thrust bearing narrow thrust face. See Illus. E25.

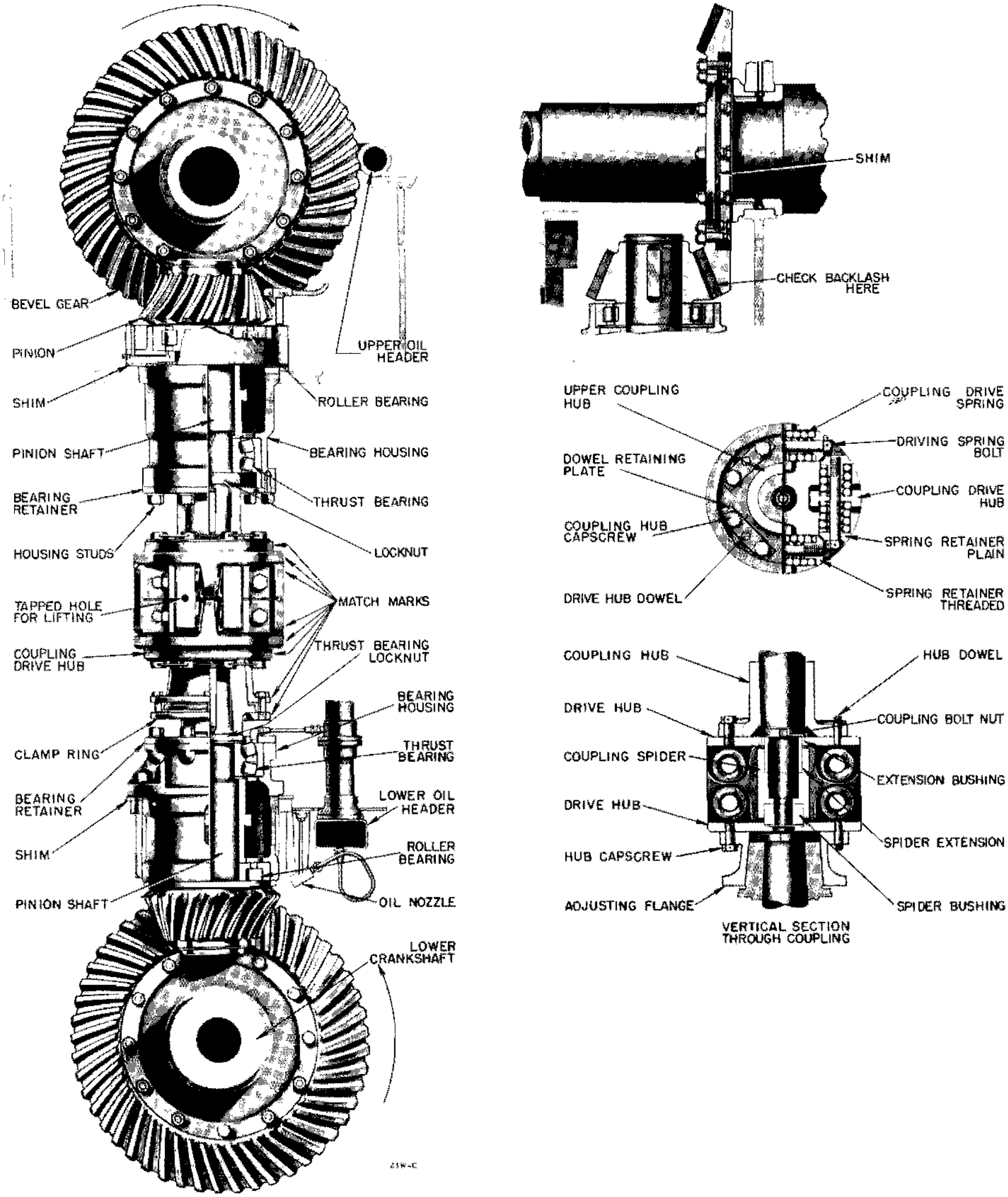
2. This surface can be checked by using surface blue and a surface block, as shown in E25. The area affected or swell-out is near the parting line of the saddle. The check will also include the micrometer reading across the saddle. The normal dimension is 2.375, plus .001, minus .000. Both sides of the saddle should be checked for this distortion.

Correction can be made by removing the over dimension of stock from area shown in above check by using a pencil grinder and checking intermittently with the surface block to be sure the correction is being made properly. Be sure grinding chips do not get into the engine. When the surface block shows that the excess material has been removed from the saddle thrust face, check dimension across the saddle as before to be sure that the dimension from face to face is not over the machining dimension.

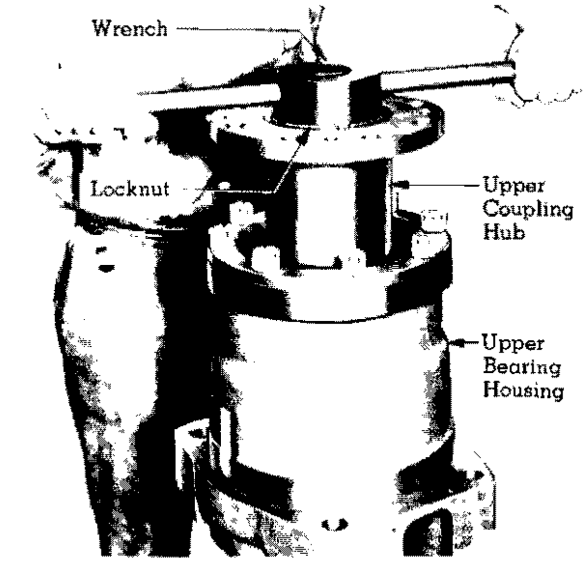
The above procedure will correct the distortion in the block. In order to remove the aluminum that has adhered to the block saddle, clean with tool, repair No. TD3402-C, available from Fairbanks, Morse & Company.

CHAPTER Fa. VERTICAL DRIVE

This Chapter covers the Vertical Drive with a flexible coil spring coupling unit. (Refer to Chapter Fb for the Vertical Drive with a quill shaft coupling)



Illus. Fa1. Crankshaft Vertical Drive



Illus. Fa2. Using Coupling Hub Locknut Tool

DESCRIPTION

As outlined in Chapter A, the two crankshafts are interconnected by a flexible drive, Illus. Fa1, thru which the power from the upper crankshaft is delivered to the lower crankshaft.

A bevel gear is secured with fitted bolts to a flange on the end of each crankshaft at the drive end of the engine.

Pinions mounted on pinion shafts mesh with these gears. The pinion shafts rotate in roller and thrust bearings located in the upper and lower drive housings. These are bolted to the horizontal decks of the cylinder block. Coupling hubs are keyed to the pinion shafts.

A flexible coil spring coupling unit, an adjustable flange and a flexible coupling hub connect the two coupling hubs together and complete the drive. The drive can be disconnected to reset the crankshaft lead.

The coil spring coupling isolates the torsional between the upper and lower crankshafts.

The internal tapered lapped fit of the adjusting flange fits over the external tapered lapped fit of the lower coupling hub. As the clamp ring is tightened to the adjusting flange, the tapered lapped fits of the coupling hub and the adjusting flange are pulled together to secure the drive between the crankshafts.

The holes in the coupling drive hubs, upper coupling hub and adjusting flange are reamed at assembly and are match-marked. Fitted bolts are used. The coupling hubs, spider, adjusting flange and clamp ring are also match-marked, Illus. Fa1.

Oil lines from the upper and lower oil headers of the engine pressure system furnish lubrication to the bearings. An oil nozzle directs oil onto the teeth of the pinions and gears. (Early engines had two oil nozzles.)

Lubrication is provided for the bushings of the spring drive unit thru the hollow upper pinion shaft.

SERVICING

The following outline covers complete disassembly of the vertical drive.

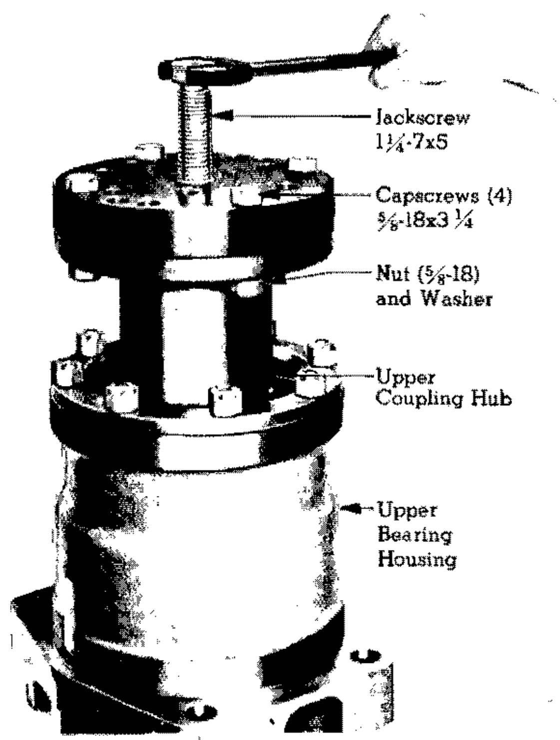
Upper Housing

Remove the vertical drive inspection covers from both sides of the engine.

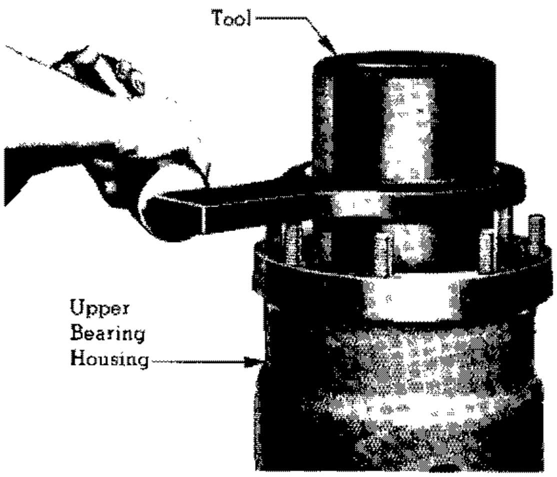
If both upper and lower bearing housings are to be removed, remove the upper housing first. Remove the coupling hub capscrews and dowels. Use a spacer when pulling the dowels. The spring coupling and lower housing can then be removed thru the vertical drive inspection opening.

To remove the upper bearing housing, and pinion shaft unit, take off the engine top cover and remove the upper crankshaft as outlined in Chapter E.

Disconnect the lubricating oil connections to the housing and oil nozzle. Remove the spring coupling unit as outlined.



Illus. Fa3. Pulling Upper Coupling Hub from Pinion Shaft



Illus. Fa4. Using Thrust Bearing Locknut Tool

Remove the studnuts holding the housing to the cylinder block deck. The complete unit can be lifted out of the engine by installing a 5/8"-18 eyebolt into the tapped hole in the end of the pinion shaft. Note the shims used between the housing and the cylinder block when lifting the unit. These .010" thick shims are used in setting the proper height of the vertical drive assembly with respect to the crankshaft bevel gear.

Remove the locknut from the upper coupling hub with the tool shown in Illus. Fa2. Next, pull the upper coupling hub from the pinion shaft as illustrated in Illus. Fa3 using a jackscrew socket on the end of the pinion shaft under the jackscrew.

Then take off the bearing retainer and remove the thrust bearing locknut with the tool shown in Illus. Fa4. Pull the thrust and roller bearings, using the thrust bearing puller, Illus. Fa5, and the roller bearing puller, Illus. Fa6.

Reassembly is the reverse of the above procedure. Replace parts according to matchmarkings and readings made and noted during disassembly.

NOTE: If the thrust bearing has been replaced, be sure the bearing spacer has been modified in accordance with the print received with the new bearing. A spacer and spacer ring are used on engine No. 967910 and all thereafter. Be sure the spacer ring is next to the thrust bearing.

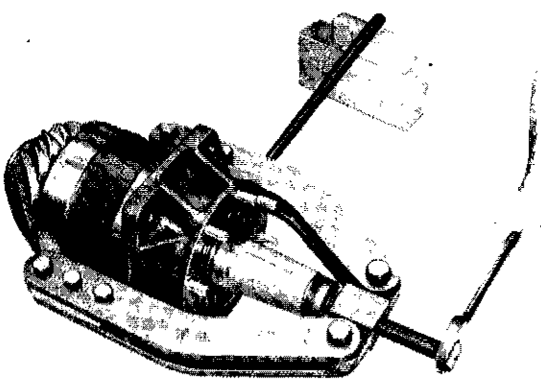
Spring Coupling

The flexible spring coupling, Illus. Fa1, can be removed as a unit from the vertical drive inspection opening.

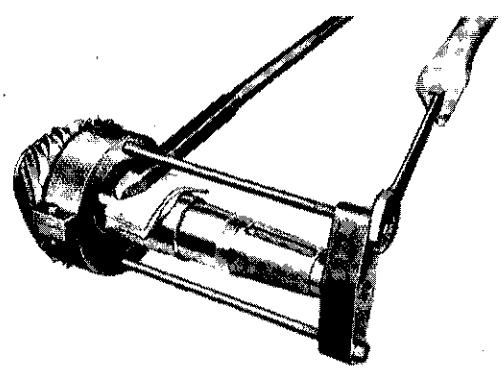
Note the markings and take out the hub capscrews, retaining plate and dowels holding the spring coupling to the upper hub and adjusting flange. Use a spacer when pulling the dowels. There is 1/8" clearance between the extension bushing and the coupling spider, allowing the unit to be pulled from between the drive hubs. Provide suitable blocking on the deck of the compartment. Screw the 1/2"-20 eyebolts into the coupling spider. Withdraw the unit and turn sidewise. In this position it can be taken from the engine thru the vertical drive inspection opening on the control side of the engine.

The bushings and springs should be inspected and replaced if necessary. The extension bushing and upper spring coupling can be removed by taking out the spring bolts, the spider bushing and bushing washer. (Early engines have a coupling bolt to position the spider bushing.)

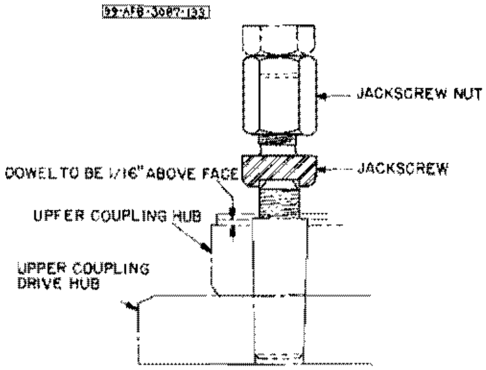
Springs, washers and spring bolts can be replaced without removing the unit from the engine. A spring in the plain retainer or bolt head end can be replaced by removing the bolt and retainer.



Illus. Fa5. Thrust Bearing Puller



Illus. Fa6. Roller Bearing Puller



Illus. Fa7. Dowel Inserting Tool

THE RETAINER AT THE THREADED END OF THE BOLT CANNOT BE REMOVED UNTIL THE BOLT AND PLAIN RETAINER NEXT TO IT HAVE BEEN TAKEN OUT. THIS WILL GIVE SUFFICIENT CLEARANCE FOR THE THREADED RETAINER.

The flexible spring coupling unit is replaced by reversing the removing procedure. Note the markings so that the tapered dowels can be installed. A jackscrew, Illus. Fa7, is available for inserting these dowels in the upper coupling hub and the adjusting flange.

The crankshaft timing must be checked after replacement of the spring coupling. Refer to Chapter E.

Should new spring drive hubs be used with an old upper coupling hub or adjusting flange, it will be necessary to ream new holes for the tapered dowels. These are 37/64" drill and reamed for No. 10 taper.

Lower Housing

The lower bearing housing and pinion shaft unit are also removable thru the inspection cover opening after lifting space has been provided by removal of the spring coupling unit or upper housing. Disconnect the lubricating oil connections to the housing and oil nozzle. Remove the stud nuts holding the housing to the cylinder block deck. Take out the clamp bolts connecting the adjusting flange to the clamp ring. Also, remove the capscrews holding each of the two lockplates (when used) to the adjusting flange and take out the lockplates.

Screw two 5/8"-18 eyebolts into the tapped holes in the end of the lower coupling hub.

Then with suitable blocking on the deck of the compartment, gradually lift the unit using a bar thru the eyebolts. Block and turn until the unit can be removed thru the inspection opening.

Remove the locknut from the lower coupling hub with the tool shown in Illus. Fa2. Next, pull the lower coupling hub and adjusting flange from the pinion shaft as shown in Illus. Fa3 using a jackscrew socket on the end of the pinion shaft under the jackscrew.

NOTE: The locked fit between the adjusting flange and the coupling hub should not be broken. If the coupling and flange have slipped, press the flange from the coupling and dress the lapped fits. Replacements of parts must be made in sets.

Then remove the bearing retainer and the thrust bearing locknut with the tool shown in Illus. Fa4. Pull the thrust and roller bearings, using the thrust bearing puller, Illus. Fa5, and the roller bearing puller, Illus. Fa6.

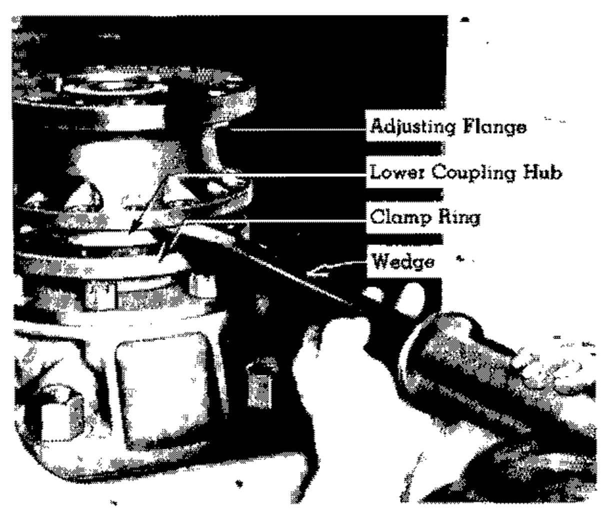
Reassembly is the reverse of the above procedure. Replace parts according to matchmarkings and readings made and noted during disassembly. Be sure the spacer ring is next to the thrust bearing.

When new parts are to be installed, use the old parts as jigs for reaming the holes in the new parts. Grind the bolts to give a light drive fit.

The adjusting flange and lower coupling hub, and the pinion and gear are lapped together and must always be replaced together.

Vertical Drive Lockplates

The vertical drive lockplates as used on early engines may be omitted when reassembling the vertical drive. The lockplates are not used on latest engines.



Illus. Fa8. Loosening Adjusting Flange from Lower Coupling Hub

CHECKING BACKLASH

Remove the vertical drive inspection covers from each side of the cylinder block. Remove the dowels and capscrews from the top side of the spring coupling unit.

Refer to Chapter E for procedure for checking backlash.

CRANKSHAFT LEAD TIMING

The vertical drive can be disconnected to reset the crank lead. The crank lead can be corrected by either of two methods.

1. If the upper crankshaft was replaced and the engine assembled with the crank lead incorrect 7° or a multiple of 7°.

a. Bar the engine so the No. 1 upper crankpin is at inner dead center.

b. Remove the coupling hub to drive hub capscrews.

c. Use a spacer when pulling the dowels. Chalk mark one set of dowel holes.

d. Bar the engine one revolution and check the alignment of a dowel and the coupling for 12° or 15° reading. Nine turns are required to correct one tooth or 7°.

e. When the crank lead is correct, replace the dowels and capscrews to secure the drive.

2. If the crank lead is incorrect a few degrees indicating the adjusting flange has slipped.

a. Bar the engine so the No. 1 upper crankpin is at inner dead center.

b. Remove the coupling hub capscrews. Use a spacer when removing the dowels. Loosen the clamp ring.

c. Break the tapered lapped fit between the adjusting flange and the coupling hub by driving the wedge tool between the parts as shown in Illus. Fa8. Use the wedges on opposite sides and drive at the same time with a heavy bar rather than using a sledge.

d. Remove the spring coupling to remove the coupling hub.

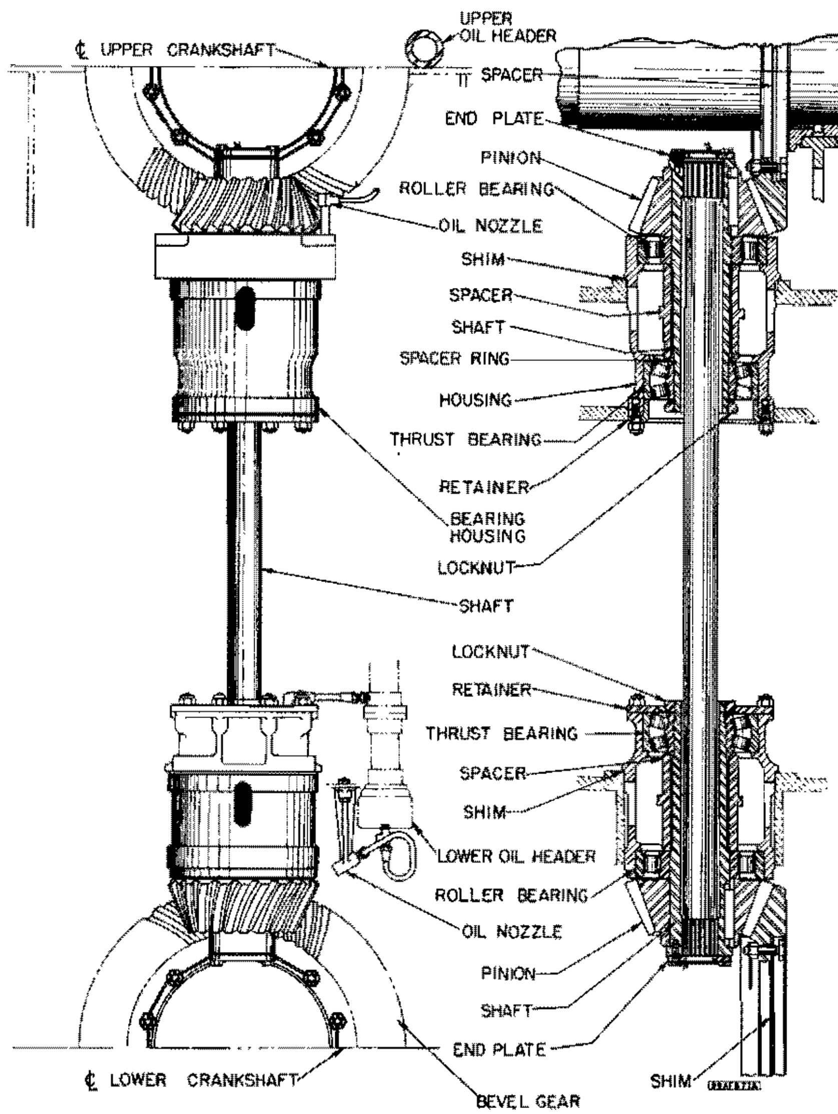
e. Dress the lapped fits using surface blue for checking.

f. Install the coupling bub, spring coupling and align with the dowels. Be sure the lapped fits are clean and dry.

g. Position the lower crankshaft for the correct crank lead and tighten the clamp ring to coupling hub capscrews securely.

CHAPTER Fb. VERTICAL DRIVE

This Chapter covers the Vertical Drive with a quill shaft coupling.
(Refer to Chapter Fa for the Vertical Drive with a flexible coil spring coupling unit)



Illus. Fb1. Crankshaft Vertical Drive

DESCRIPTION

As described in Chapter A, the two crankshafts are interconnected by a drive, Illus. Fb1, thru which the power from the upper crankshaft is delivered to the lower crankshaft.

A bevel gear is driven by fitted bolts from the flange on the end of each crankshaft at the drive end of the engine.

Pinions mounted on short shafts mesh with these gears. The shafts rotate in roller and thrust bearings located in the upper and lower drive housings. The housings are bolted to the horizontal decks of the cylinder block.

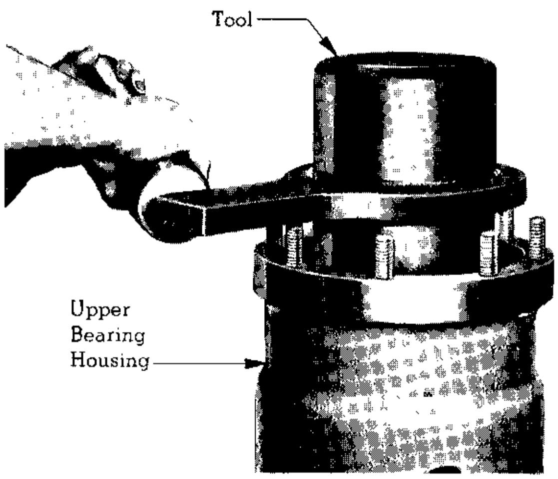
The short upper and lower shafts are provided with an internal spline at the pinion end. A long shaft with a spline on each end connects the two short shafts to complete the drive.

The upper splines have a different number of teeth than the lower splines which enables the correct crankshaft lead or timing to be easily set by positioning the crankshafts and inserting the long drive shaft.

Oil lines from the upper and lower oil headers of the engine pressure system furnish lubrication, to the bearings. An oil nozzle directs a stream of oil onto the teeth of the gears.

SERVICING

The following outline covers complete disassembly of the vertical drive.



Illus. Fb2. Using Thrust Bearing Locknut Tool

If both upper and lower bearing housings are to be removed, remove the upper crankshaft. Refer to Chapter E. Remove the end plate from the upper pinion and remove the long drive shaft. Remove the stud nuts holding the housing to the cylinder block deck. The complete housing can then be lifted out of the engine.

Note the shims used between the housing and the cylinder block when lifting the unit. These .010" thick shims are used in setting the proper height of the vertical drive assembly with respect to the upper crankshaft bevel gear.

Tools are available for disassembling the unit in the following order. Remove the thrust bearing locknut with the tool shown in Illus. Fb2. Pull the thrust and roller bearing, using the pullers, Illus. Fb3 and Fb4.

Reassemble in the reverse of the removal procedure.

NOTE: If the thrust bearing has been replaced, be sure the bearing spacer has been modified in accordance with the print received with the new bearing. **A spacer and spacer ring are used on engine No. 967910 and all thereafter. Be sure the spacer ring is next to the thrust bearing.**

The lower bearing housing and shaft unit is removable thru the inspection cover opening.

Disconnect the lubricating oil connections to the housing and oil nozzle. Remove the stud nuts holding the housing to the cylinder block deck.

Remove the housing from the vertical drive compartment and disassemble using the tools mentioned previously. Reassemble in a manner similar to the outline as specified above for the upper housing.

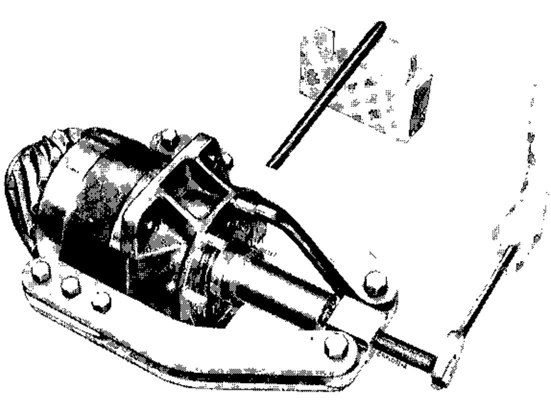
CHECKING BACKLASH

Refer to Chapter E for procedure to check backlash of the vertical drive bevel gear and pinion. The backlash check should be made before installing the long drive shaft as a more accurate reading can be obtained before the drive is secured.

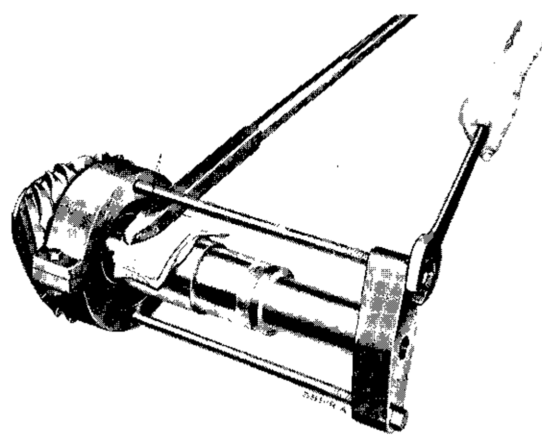
CRANKSHAFT LEAD TIMING

Position the crankshafts as outlined in Chapter E for correct lead and install the long drive shaft. (The splines on the upper end of the shaft engage the internal spline of the short shaft before the lower splines engage. Raise the shaft out of the splines, rotate a few splines and lower to engage the lower splines. Various trials may be required before both sets of splines will engage. Lower the shaft into position. Slight tapping may be required. Replace the end plate.

Bar the engine in reverse rotation 15° to 20°. Then bar in direction of rotation and recheck the crank lead.

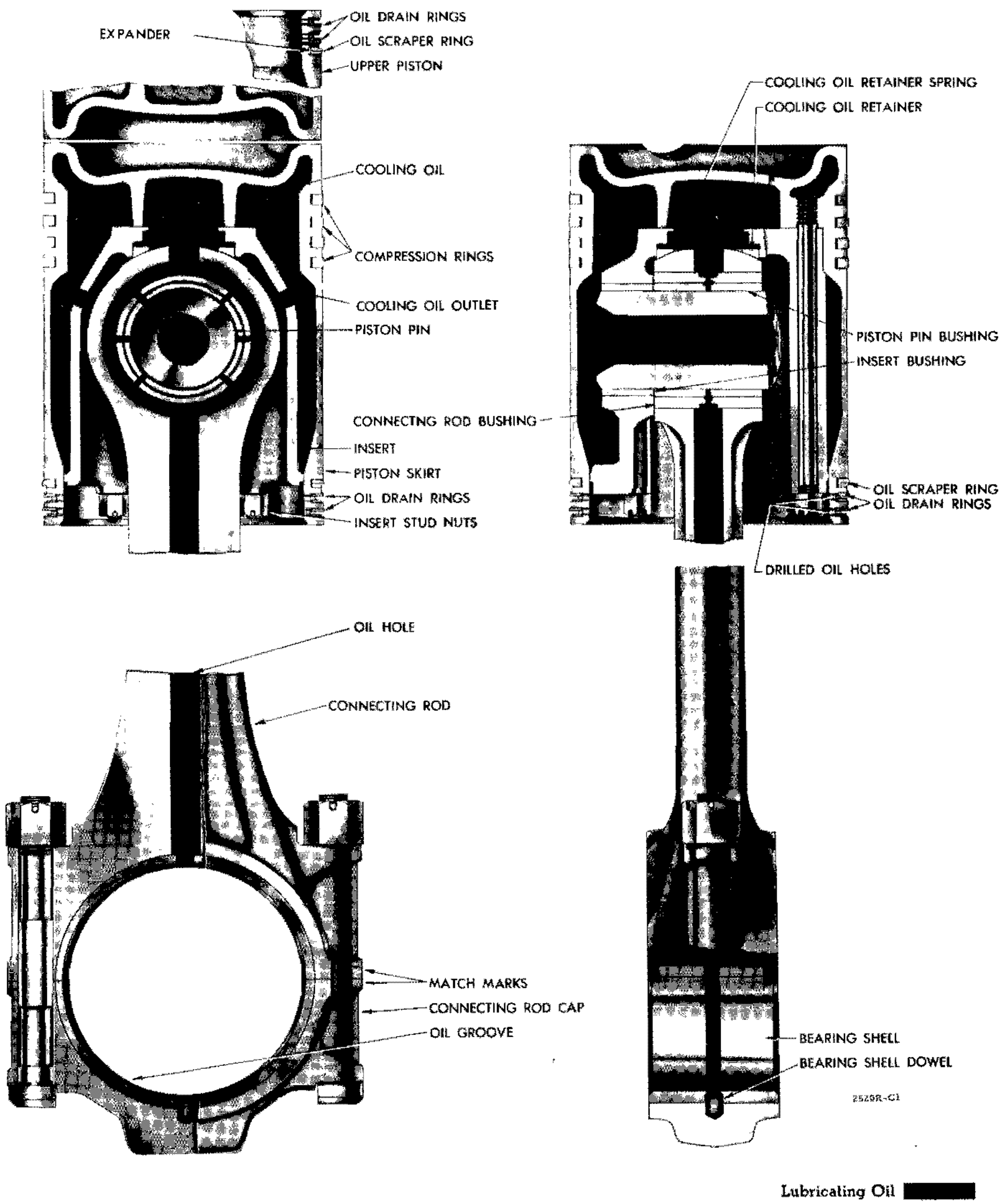


Illus. Fb3. Thrust Bearing Puller



Illus. Fb4. Roller Bearing Puller

CHAPTER G. CONNECTING ROD, CONNECTING ROD BEARINGS AND PISTONS



Illus. G1. Piston and Connecting Rod

DESCRIPTION

The pistons, Illus. G1 and G2, have four compression type piston rings near the closed end or crown. (Early engines have three compression rings.) One oil scraper and two oil drain rings are located at the open end of both pistons. Oil drained from the cylinder walls by the oil drain rings flows thru drilled holes in the ring grooves to the inside of the piston skirt.

The piston pin is supported in the piston insert. The insert is secured into the piston and forms an enclosure for the piston cooling oil. Cooling oil is circulated to the piston thru the drilled passage in the connecting rod. As noted in Illus. G1 the lubricating oil flows thru the rod, around the annular groove in the connecting rod bushing, into the piston crown from where it is discharged. The piston retainer acts as a seal for the cooling oil in the piston crown.

The connecting rod bushing is pressed into the connecting rod eye. As noted in Illus. G1, lubricating oil from the hole in the connecting rod flows around the outer annular groove and up into the piston crown. Part of the oil flows thru the holes in the connecting rod bushing and piston pin bushing lubricating the piston pin bushing and piston pin. A complete description of the lubricating oil pressure system is given in Chapter P.

The crankpin bearing shells are of the split type. One half of the shell is dowelled into the connecting rod cap and the other half fits into the connecting rod. (On older engines, the rod half shell was also dowelled.)

CRANKPIN BEARING

Checking Bearing Shells

Refer to Maintenance Bulletin Sec. 206 for the manufacturers "Recommended Bearing Inspection Periods."

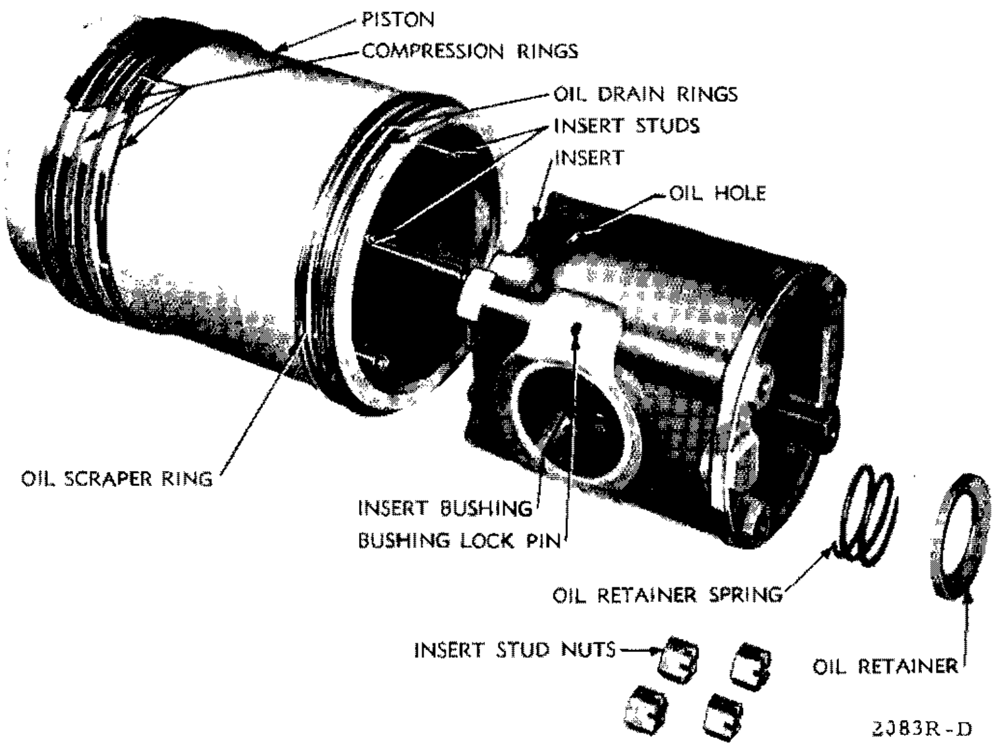
Make a visual check and observe the parting line of the shell halves and parting line between cap and rod.

The shell half and cap and rod half parting line should be in alignment. An aluminum bearing shell which has flaked slightly, indicating failure of the bearing will show up as a turn at the parting line shell halves. Refer to "Bearing Failure and Correction" page G9 for reconditioning procedure.

UPPER CRANKPIN BEARINGS

The crankpin bearings are accessible after removing the exhaust end cover and top cover.

As each connecting rod cap comes to outer dead center position, as the engine is barred over, remove the bolt and nut from one side and



Illus. G2. Piston Disassembled

use a hook and rope fall to support the piston and connecting rod assembly while removing the bolt and nut from the other side. Notice the matchmarking so that the caps will be returned to their original position. Separate the cap from the rod. Then lower the rod and piston sufficient so that the swing of the crankpin will clear the connecting rod.

By using this procedure all the connecting rod caps can be removed by barring the engine one revolution.

The crankpin bearings are replaced using the procedure above in reverse order.

Apply lubricating oil to the bearing surface of the crankpins.

Tighten all of the connecting rod bolt nuts to 175-200 ft. lbs. using a torque wrench. Tighten, do not back off to line up the cotter pin hole.

CAUTION: When replacing connecting rod bearing shells, it is imperative that complete sets of Satco or Aluminum shells be installed. If Satco and Aluminum connecting rod bearing shells are used in mixed sets in the engine, vibration due to the unbalance of the crankpins will damage the engine.

The Satco or Aluminum main bearing shells may be used in mixed sets.

LOWER CRANKPIN BEARINGS

After removing the crankcase handhole covers, bar the engine to inner dead center so that the connecting rod bolt nuts can be removed. Support the cap while removing the bolts. Remove the cap and bearing shell.

Install the winches and cables as shown in Illus. G6 and insert the washers under the nuts. The washer must be positioned so the shell can be removed.

Bar the engine over so that the crankpin of the bearing being removed moves away enough to allow the rod half of the shell to be removed.

When new bearing shells are to be used, stamp them with similar marks and in the same location as the old shells. After reassembly, use a torque wrench and tighten the connecting rod bolt nuts to 175-200 ft. lbs. Tighten, do not back off to line up the cotter pin hole.

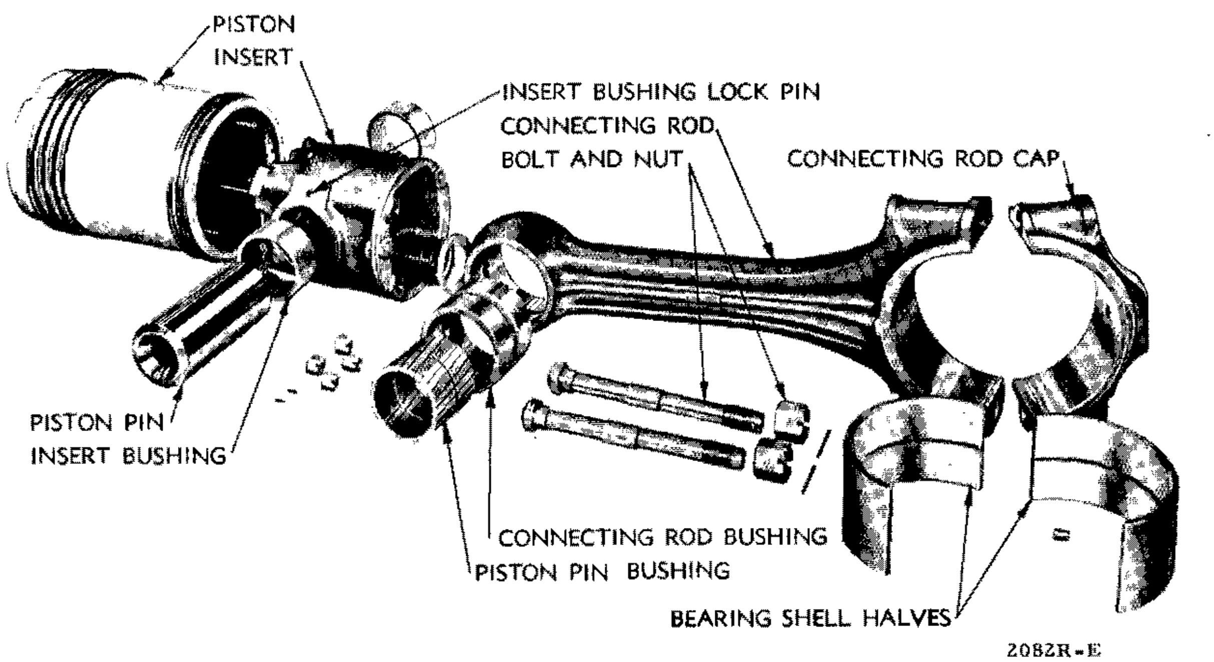
CONNECTING ROD AND PISTON

Removing Lower Connecting Rod and Piston

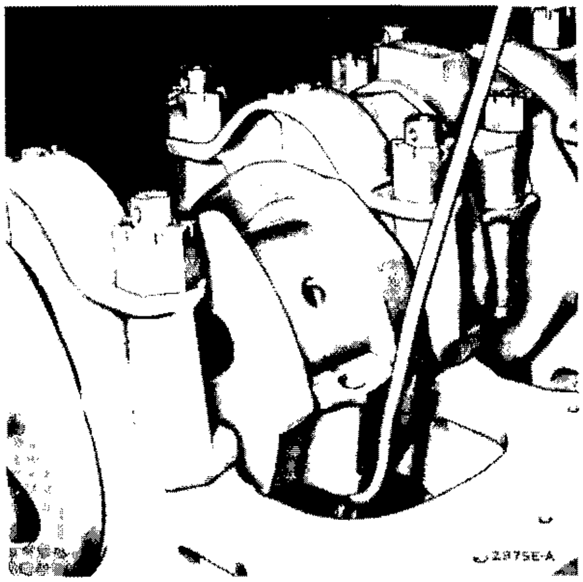
Note the matchmarks on the rod and cap located on the governor side of the engine.

Remove a nozzle holder assembly from one of the nozzle adapters to relieve the vacuum in the cylinder as the lower piston is removed.

Remove the bearing cap and shell and support the connecting rod and piston with the hook and rope fall as shown in Illus. G5. Fasten a round bar to the plates between the injection nozzle compartment openings on the side from which the rod and piston are to be removed. Secure the rope to the hook, over the bar and pull up tight.



Illus. G3. Connecting Rod and Piston Disassembled



Illus. G4. Removing Bearing Shells

Insert the slide bars across thru the opening in the crankcase close to each side of the connecting rod. The ends of the bars on the governor side should rest on the inner flange of the cylinder block. Illus. G7 shows the side of the engine from which to remove the connecting rod and piston on engines with counterweighted crankshafts.

Bar the engine over approximately 3/4 of a revolution (until the web of the crankpin is flush with the slide bars). Install the crankpin guard as soon as the crankpin has moved away from the connecting rod. Slacken off slowly on the rope and lower the piston and connecting rod onto the slide bars. Slide the piston on the bars to the opening. Lay a cloth on the edge of the opening. Reach in with a cloth over the rings. Pull out and swing downward to remove the piston and connecting rod.

Set the assembly on the closed end of the piston and support the connecting rod in a near vertical position by inserting a wooden wedge against the skirt of the piston. Do not allow the rod to be dropped over hard against the piston.

Clean piston, rings, and connecting rod, arranging parts in a systematic order.

ENGINES WITH COUNTERWEIGHTED CRANKSHAFTS REQUIRE THE REMOVAL OF CERTAIN LOWER CONNECTING RODS AND PISTONS FROM ONLY ONE SIDE OF THE ENGINE AS SHOWN IN ILLUS. G7.

The removal procedure specified above is applicable for engines with counterweighted crankshafts except for the side of the engine from which removal is required. Be sure the rope fall and slide bars are located correctly. The crankshaft may require slight additional barring in either direction to remove the connecting rod and piston.

Reinstalling Lower Connecting Rod and Piston

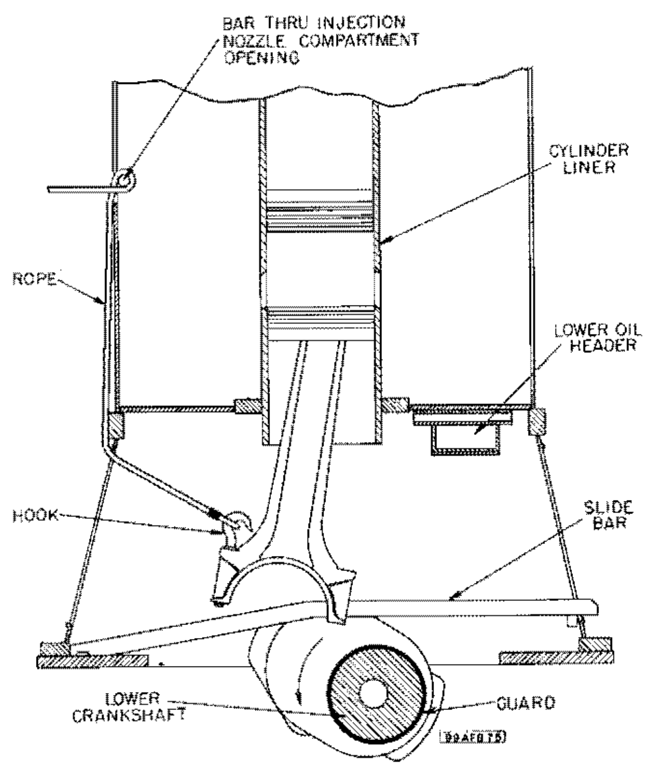
With the leather crankpin guard in place, bar the crankshaft approximately 3/4 of a revolution from inner dead center (flat on crank web to be horizontal).

Place the proper rod half of the bearing shell in place. Install the hooks, Illus. G6, using the washers under the nuts to hold the shell in place.

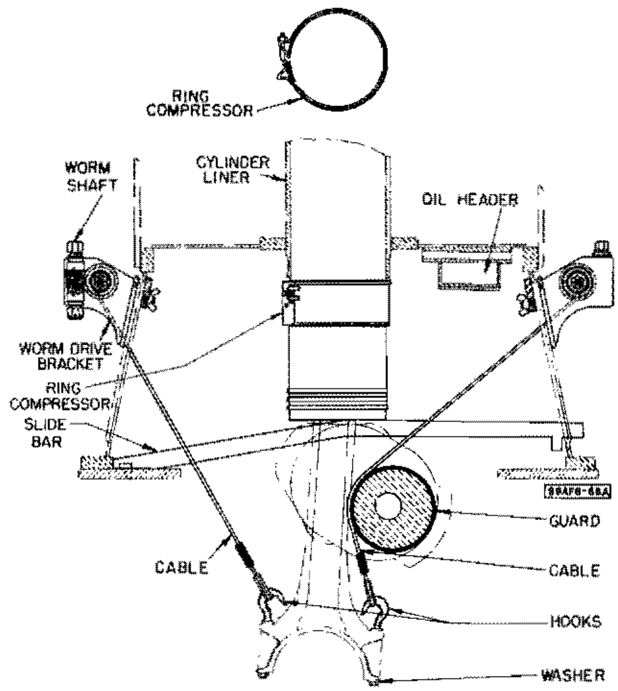
With the piston ring gaps staggered, apply lubricating oil over the surface of the piston. Apply the piston ring compressor in such a manner that the clamp end is at the closed end of the piston and the gap in the compressor lines up so that the connecting rod can swing into position. Check to be sure that the compressor is set sufficiently loose to allow the piston to slide thru.

Set the two slide bars in position.

Place the assembly thru the crankcase markings should be towards the exhaust end and governor side of the engine. Fasten the winch to control side of the engine. Fasten the winch to the crankcase with the clamp plates and wing nuts provided. Make sure that the offset of the



Illus. G5. Removing Lower Piston



Illus. E6. Lower Piston Inserting Tools

winches is over the top flange of the crankcase opening.

Attach the cables to the hooks and slide the assembly along the bars until it is directly under the cylinder liner. The piston is then raised from the compressor and inserted into the cylinder liner by tightening the winches. Be sure that the piston is not allowed to drop down as insertion is made. Pull the cables by hand and take up the slack by turning the worm shafts. Most of the pulling is done from the side insertion is made. The compressor is forced off the piston as insertion is made.

Remove the piston ring compressor. Raise the piston and rod assembly to clear the crankpin. By use of the winches swing the connecting rod over the crankpin. Remove the crankpin guard and apply "Oil Dag" to the crankpin journal. Lower the assembly to the crankpin. Remove the hooks, slide bars and winches.

Install the bearing shell, cap, bolts and nuts. Note the location of the matchmarks. Tighten nuts evenly to 175-200 ft. lbs. using a torque wrench.

Inspect subbase for any loose parts and foreign material. Replace the covers.

Removing Upper Connecting Rod and Piston

> NOTE: If more than one-half of the pistons are to be removed, time can be saved by removing the upper crankshaft and pulling the pistons and rods from above.

The upper piston can be removed thru the lower crankcase opening after the lower piston has been removed as outlined, and after the following preparatory procedure:

Remove one of the air receiver handhole covers.

> **NOTE: Before lowering the upper piston thru the liner, it is imperative that the nozzle holder assembly be removed from the nozzle adapter. This is necessary as the nozzle tip assembly protrudes slightly inside the cylinder liner. Attempting to lower the piston thru the liner without first removing the Pintle nozzle will seriously damage the piston, rings, and Pintle nozzle.**

Stretch a piece of canvas across thru the lower crankcase to keep dirt or carbon from dropping into the crankcase.

Reaching thru from the lower end of the cylinder liner, clean the combustion space at the injection nozzle level. Lubricate the liner with lubricating oil. It is important that the combustion space be lubricated and clean to prevent the piston from sticking in the subsequent operation. Remove the canvas.

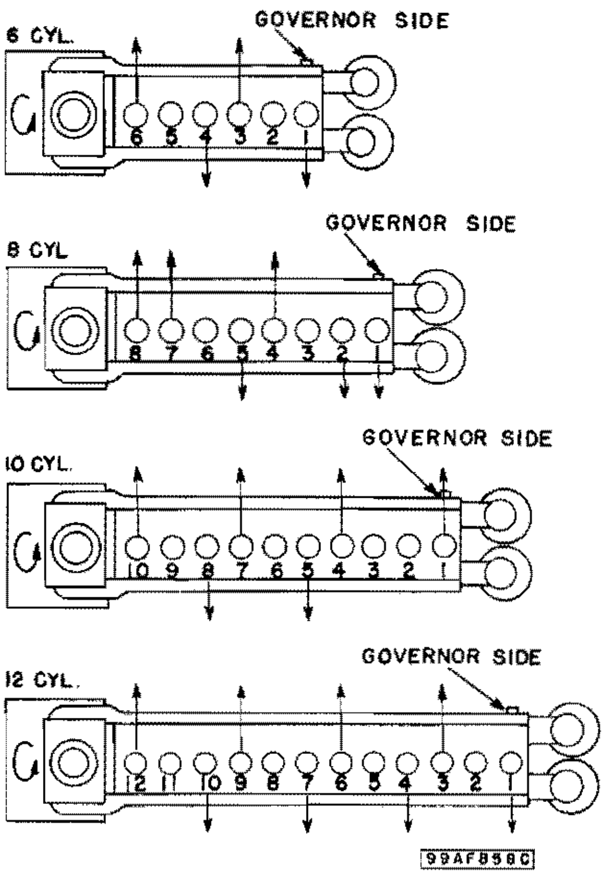
Bar the engine until the upper connecting rod to be removed is at outer dead center. Loosen the piston insert stud nuts. Leave one in place and remove the remaining three. Loosen the connecting rod bolt nuts. Use a hook and rope fall to support the connecting rod and piston assembly and remove the connecting rod bolts and nuts. Note the matchmarks on the rod, cap and bearings. Separate the cap from the rod. Do not drop the bearing shell from the cap.

Lower the assembly and swing the connecting rod to one side of the crankpin. Then pull the assembly up and insert the support bar, Illus. G10, thru the air receiver handhole previously removed. Lower the assembly onto the support bar and bar the crankshaft over until the crankpin moves to a horizontal position.

As a precautionary measure, wire the support bar to one of the air receiver cover capscrew holes. This will prevent forgetting to remove the support bar.

Remove the nut from the piston insert stud and lift the connecting rod and insert from the piston. Run a wire thru the piston pin hole and tie the ends to hold the assembly together. Place the lifting yoke down in the piston over the studs and install the nuts. Fasten a rope thru the eyebolt.

Bar the engine until the lower crankpin of the particular cylinder moves to a position so



Illus. G7. Piston Removing Diagram

that the flat on the crankweb is horizontal. Place a slide bar on each side of the crankweb, with the low ends resting on the inner flange of the cylinder block. Remove the upper piston from the same side as the lower piston is removed.

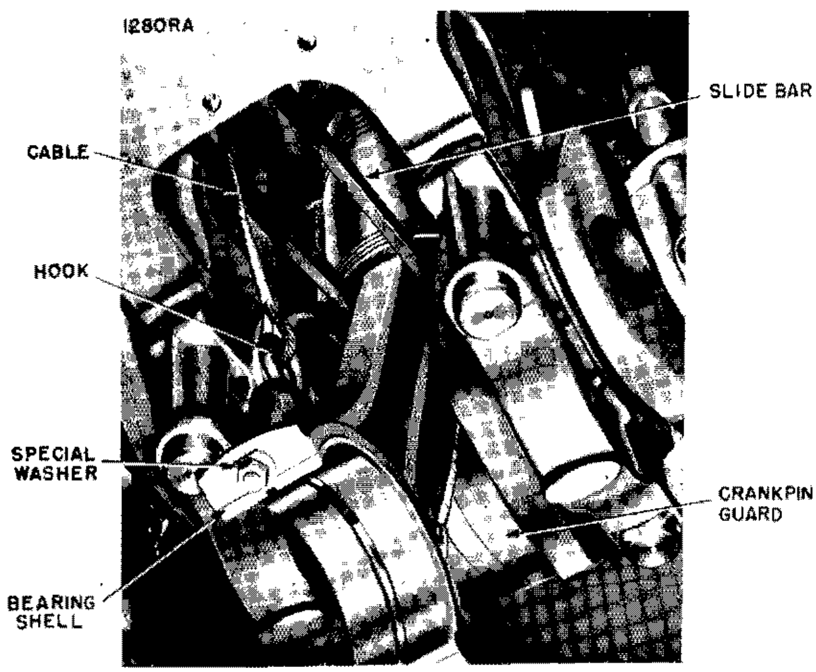
While holding the piston with the rope, pry the piston up slightly so that the support bar can be removed. Caution should be exercised so that the piston is not forced too far out of the liner. This would free the rings at the open end. Lower the piston down thru the liner until it rests on the slide bars.

If the piston is stuck and cannot be removed, replace the lower connecting rod and piston. With the lower piston positioned part way to inner dead center, add a few quarts of lubricating oil into the cylinder thru a nozzle opening. Replace the nozzles to plug the cylinder. Bar the engine thru inner dead center. The oil pressure will free the upper piston. Remove the lower rod and piston and reclean the combustion area. Proceed to remove the upper piston thru the liner. Move the piston to the crankcase opening and note the compression rings. Lift from the crankcase compartment.

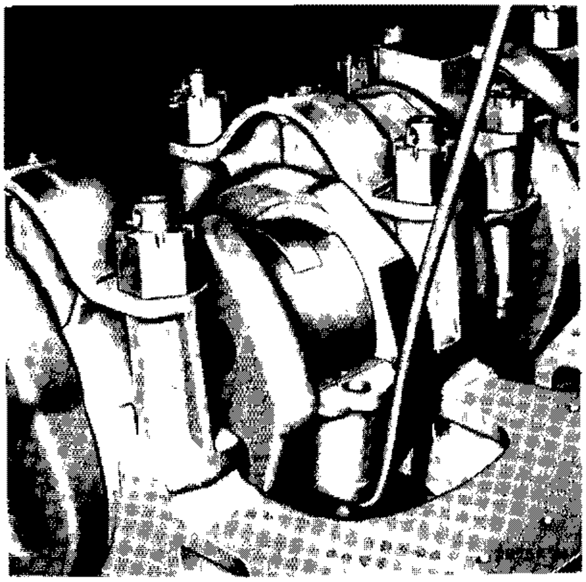
Remove rope and lifting yoke from the piston. Clean and check piston rings.

Installing Upper Connecting Rod and Piston

The upper piston is reinstalled thru the



Illus. G8. Lower Piston and Connecting Rod on Slide Bars



Illus. G9. Crankpin Guard in Place

lower crankcase handhole with the tools shown in Illus. G10.

With the gap of the compression rings staggered, apply lubricating oil over the surface of the piston. Do not install the oil rings at this time. Apply the piston ring compressor, Illus. G11, in such a manner that the clamp is at the open end of the piston. Using the stud nuts, fasten the lifting yoke in place over the studs.

Bar the engine until the lower crankpin of the particular cylinder moves to a position so that the flat of the crankwebs is horizontal. Install the slide bars as previously outlined.

Place the piston on the slide bars. Lower the rope and fasten to the eyebolt and slide the piston directly under the cylinder liner.

Raise the piston into the liner until the support bar, Illus. G10, can be inserted thru an air inlet port. Raise the piston above the top of the liner until the oil ring grooves are exposed.

Install the oil rings. Be sure the scraper and drain rings are in the proper groove. Handle the rings carefully and do not over-expand.

Install the ring compressor over the oil rings and push the piston into the liner. Remove the inserting tools.

Assemble piston insert and connecting rod assembly into the piston. Remove the support bar.

Use a torque wrench to tighten the insert stud nuts to 45-50 ft. lbs. and the connecting rod bolt nuts to 175-200 ft. lbs.

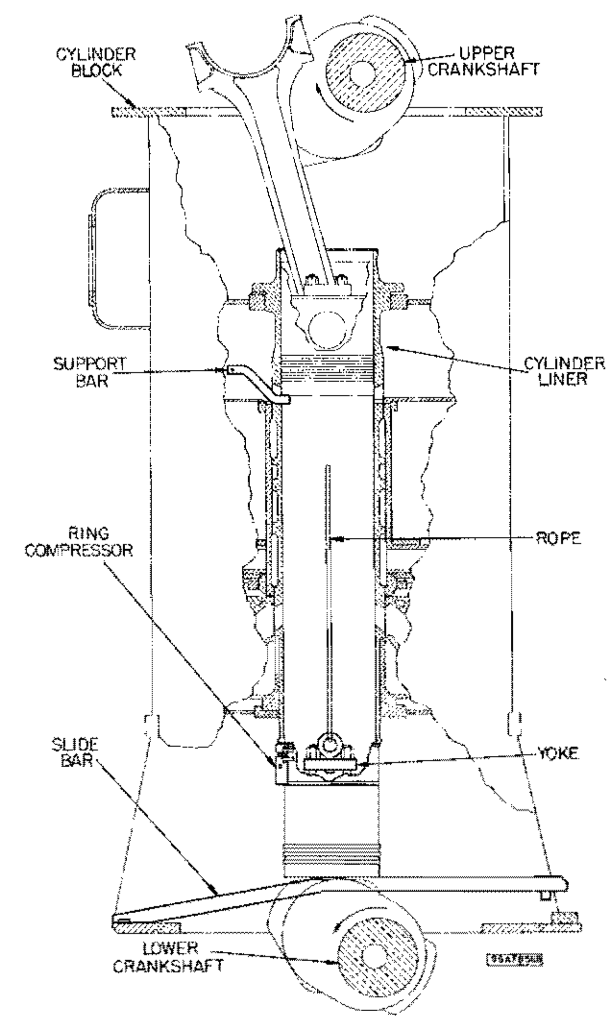
Note the matchmarks.

Replace all lockwires, cotters, covers and gaskets.

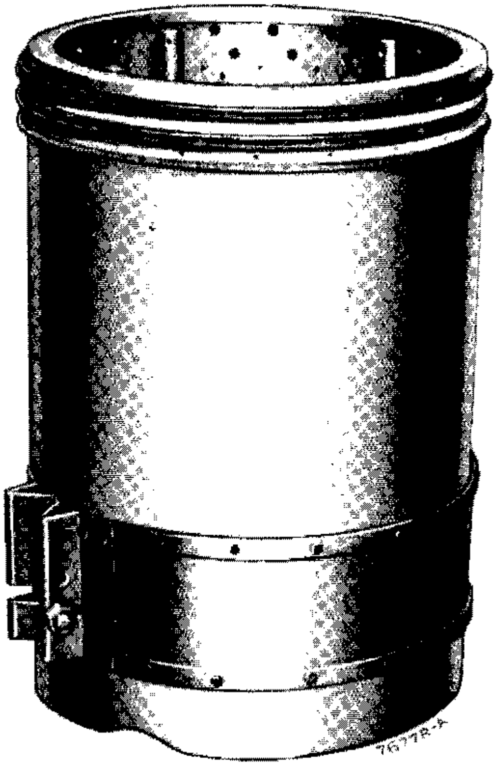
BEARING FAILURE AND CORRECTION

After the visual check of crankpin bearings has revealed the failure of a bearing shell, recondition the bearing journal as follows:

1. If inspection reveals that a failed bearing exists, remove the affected rod and piston insert assembly and bearings from the engine.
2. Remove the related main bearing before cleaning and conditioning shaft. The related main bearing is the one thru which the oil passes before it reached the connecting rod. No. 1 main feeds No. 1 piston, No. 2 main feeds No. 2 piston, etc. The reason for removing the adjacent assembly is to prevent the NaOH used in cleaning the journal from entering the interconnected oil tube and damaging the crank journal.
3. Clean and condition crankpin surface as outlined under "Conditioning of Crankshaft after



Illus. G10. Upper Piston Inserting and Removing Tools



Illus. G11. Piston Ring Compressor

an Aluminum Bearing Failure."

4. Check connecting rod bore with cap in place for distortion.

5. Check connecting rod and piston insert assembly after disassembly for scoring and overheating of bushing, etc.

6. Install new bearing using special bearing journal conditioner C-1401ND-B. Follow the instructions closely.

a. Mix thoroughly before each application.

b. Apply a liberal coating of compound to bearing shell and install in engine and tighten as outlined.

c. Bar the engine one complete turn prior to, and one-fourth turn during pre-lubrication.

Conditioning Crankshaft after Aluminum Bearing Failure

When an aluminum bearing failure has been found on a crankshaft, the crankpin journal shall be reconditioned according to the following procedure:

1. Clean crankpin journal with fine grade emery cloth dipped in fuel oil. This is to remove the surface aluminum that has adhered to the journal at the time of failure. The emery cloth should be cut in long narrow strips approximately 2" wide, long enough to go around the crankpin and pulled from both sides so that a see-saw action is used when pulling the ends of the strips.

2. Remove all surface oil with a solvent.

3. Saturate the crankpin surface with a sodium hydroxide solution (NaOH) for approximately 30 minutes or until all aluminum has been removed. The period of exposure to NaOH solution will vary depending upon the quantity of aluminum adhered to the affected surface or the strength of the solution. A stronger solution of NaOH will lessen the period of immersion or saturation.

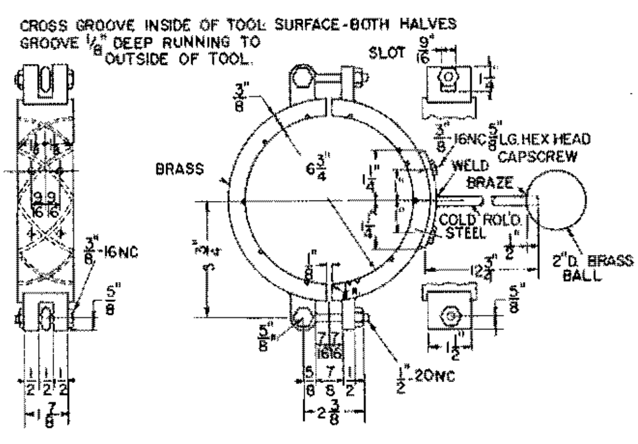
a. Experimental tests were conducted with a solution of 10% NaOH by weight, however, this is not necessarily the strength that must be used.

b. Precautions must be taken to prevent the solution of NaOH from contaminating the crankcase while cleaning procedure is taking place.

c. Personnel working with NaOH must wear rubber gloves as this highly caustic solution is harmful to the skin.

4. With the proper lapping tool, Illus. G12, lap in the affected crankpin journal.

a. The lapping compound used is No. 111 Green Label Timesaver which is mixed to a consistancy of a soft paste by adding No. 10 lube oil. This mixture should be used generously. The crank should be lapped until it receives a satin finish. The depth of the lap finish can be checked by using the edge of a piece of clean wood block or a piece of round wood stock. After lapping rub the wood across the surface lapped, if the satin finish remains, the lapping has penetrated. If the wood removes



Illus. G12. Crankpin Lapping Tool

the satin finish, additional lapping will be required.

5. Clean journal with lube oil. The No. 111 Green Label compound has a breakdown quality, therefore, a thorough job of removing the compound left on the journal is not necessary. A flushing off of the surface lapped with lube oil is all that is necessary.

6. After the crankpin has been reconditioned, and "conditioner" used on the journal, reapply the bearing as outlined.

PISTON AND PISTON PIN

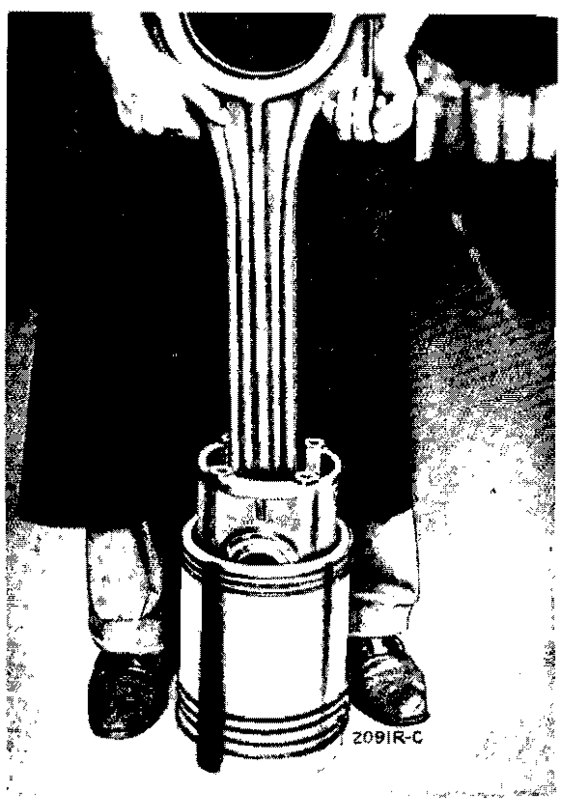
Removing Piston Pin and Bearing

The piston pin bearings furnished on this engine are of the floating bushing type.

To disassemble the piston, remove the piston insert stud nuts. Lift out the connecting rod and piston insert as a unit, Illus. G13. (The upper piston would be disassembled to this extent if it was removed without taking out the upper crankshaft.)

The connecting rod and piston insert assembly is disassembled after sliding out the piston pin. The piston insert is free of the connecting rod eye as soon as the pin is removed.

Check the disassembled parts for wear. Wear limit dimensions are given in Chapter B.



Illus. G13. Removing Insert from Piston

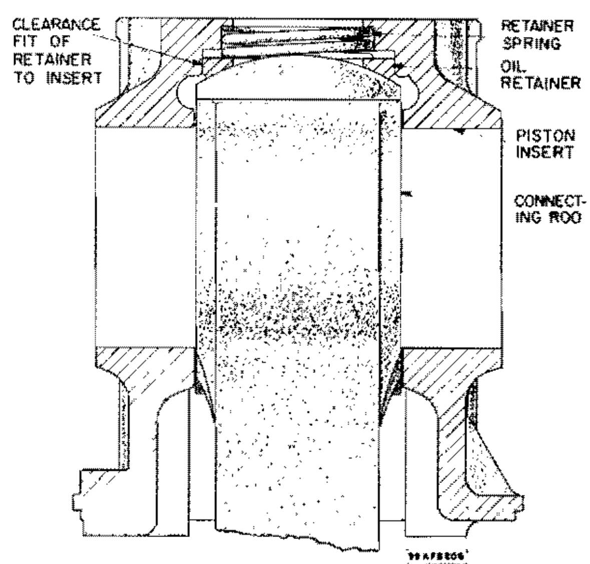
If the connecting rod bushing must be replaced, place the end of the connecting rod on an arbor press to remove the bushing.

If the piston insert bushings must be replaced, first drill out the old piston insert lock pins using a #17 (.173") drill. Then press the old bushings out. When replacing the new bushings, be sure the bevel matches the bevel of the insert. The bushings must be pressed in flush with the inner face of the piston insert. Using a #17 (.173") drill thru the new bushings using the lock pin holes in the piston insert as a jig. Check the end of the hole for burrs. Install the insert lock pin leaving 1/16" clearance between the pin and the bushing bore.

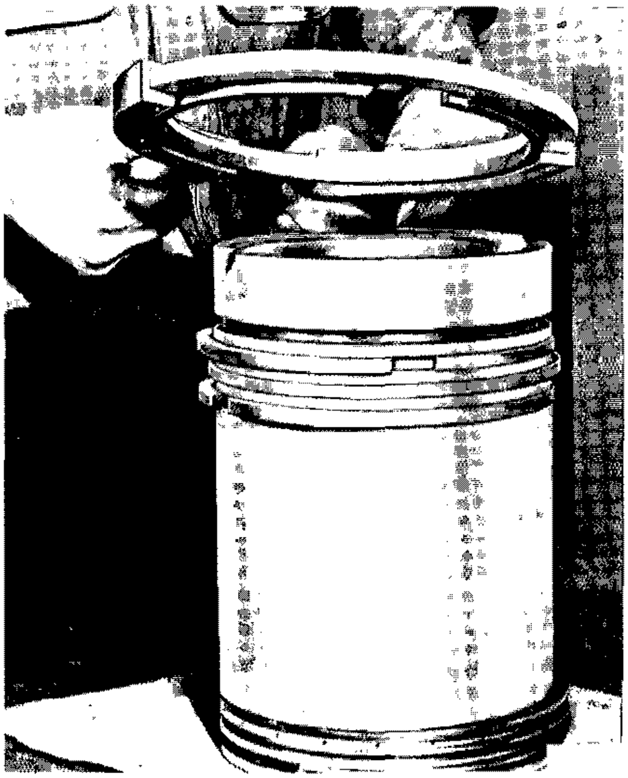
The cooling oil retainer and spring should be removed from the piston insert and cleaned. The oil hole running lengthwise in the connecting rod should also be cleaned.

To prevent loss of oil for piston crown cooling, it is important that the fit between the oil retainer and the connecting rod is compatible, Illus. G14. If it is found that the contours do not coincide, it will be necessary to lap the retainer to the rod fit using 111 Green Label Timesaver before the piston is assembled. If a considerable amount of lapping is necessary, the retainer can be scraped to reduce the lapping time. Do not over scrape so that the contour of the retainer is changed. Lap the retainer after scraping. Be sure that the O.D. fit of the retainer is a free fit in the insert relief. Friction drag of the retainer in the insert fit can prevent the lap fit of the retainer and connecting rod from locating.

With the piston insert open end up, replace the spring and retainer. Apply lubricating oil



Illus. G14. Piston Oil Retainer



Illus. G15. Using Piston Ring Expander

to the spherical end of the connecting rod. Install the piston pin bushing in the connecting rod.

Lower the connecting rod into the insert in proper position. Then push the piston pin in place.

Check the line up for the insert studs, Keeping the proper position of parts, lower the connecting rod and insert over the studs. Replace the stud nuts, and tighten to 45-50 ft. lbs. torque. Install lockwires.

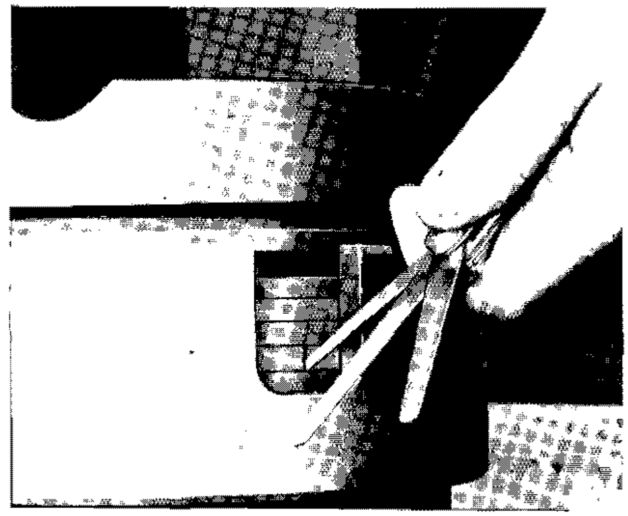
Assembling the upper piston and connecting rod is completed in the cylinder if the upper crankshaft has not been removed. If the upper crankshaft has been removed, assembling may be completed before installing.

PISTON RING REPLACEMENT

Pistons are removed from the liner other than at complete overhaul periods, to check the condition of the liner, piston, or rings.

Install new piston rings if the cylinder liner or piston is to be replaced with a new liner or piston. Use the ring expander, Illus. G15, on compression rings only. Do not over expand the rings.

CAUTION: DO NOT USE CHROME PLATED COMPRESSION RINGS IN A CHROME PLATED CYLINDER LINER.



Illus. G16. Checking Piston Ring End Clearance

Check piston rings for side and end clearance as follows:

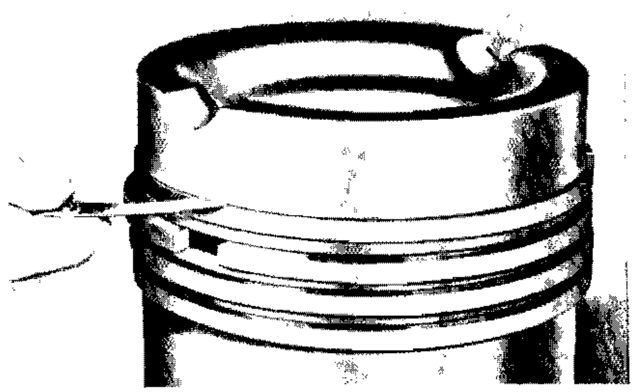
End Clearance

The end clearance is checked by placing the ring in a ring gage or in the cylinder, Illus. G16.

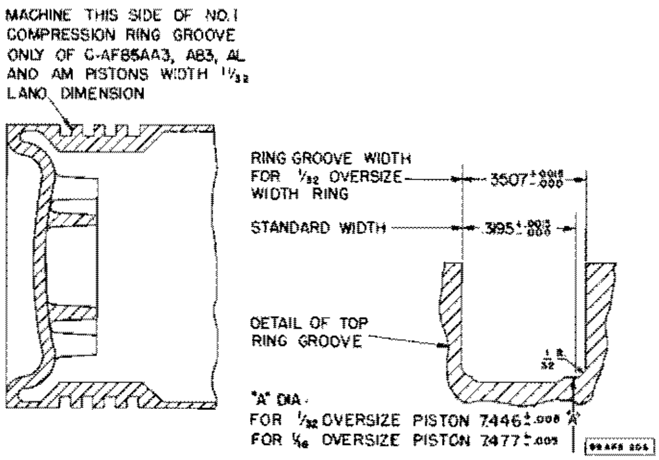
The maximum end clearance permitted is listed in Chapter B. If the end clearance indicates that the condemnable limit will be exceeded before the next regular overhaul, the piston ring should be replaced with a new one.

Side Clearance

Side clearance is checked with a feeler gage as shown on Illus. G17. The maximum side clearance permitted is listed in Chapter B. If the side clearance indicates that the condemnable limit will be exceeded before the next regular overhaul, the piston ring should be replaced



Illus. G17. Checking Piston Ring Side Clearance



Illus. G18. Piston Ring Groove Machining

with a new one.

When examining piston ring side clearance, the pressure side of the ring groove should also be examined. The pressure side of the ring groove will frequently wear more than the ring. Be sure the ring groove is not tapered. The top ring groove can be machined for oversize width rings on pistons which have the land width increased. Refer to Illus. G18.

FIRING PRESSURE TEST TO DETERMINE CRACKED PISTONS

General

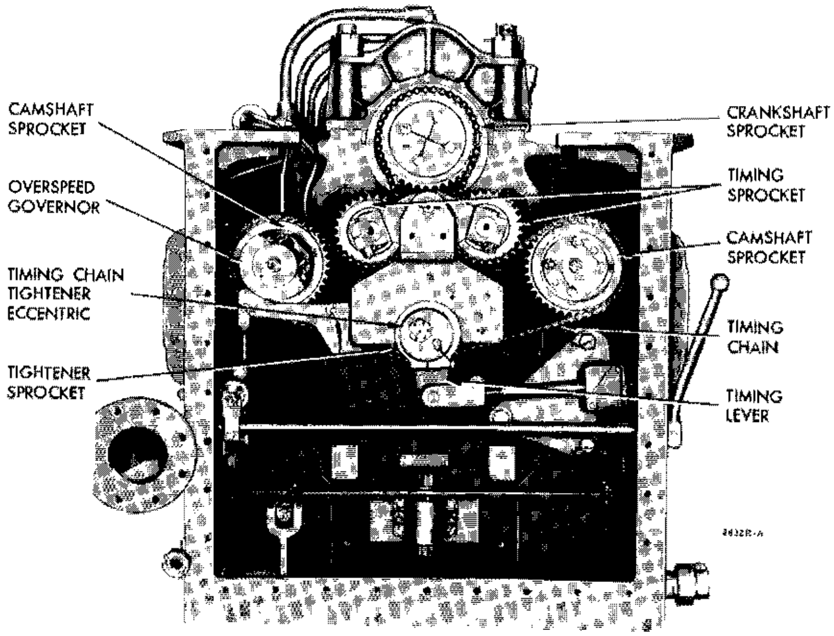
The procedure below is recommended to test individual cylinders for cracked pistons. The method will indicate presence of cracks in the crown or ring area. This test is more readily applied and has proven to be more positive than the air pressure test. It will show up cracks which are too small to be found by the air pressure method. In addition, the test can be made in much less time and with no dismantling of the fuel injectors or their connections.

Procedure

The test should be made on a hot engine immediately after shutdown.

1. Remove the crankcase inspection covers on the upper and lower crankcases, taking off the governor side covers only on the lower crankcase.
2. Remove the side covers over the injection pump area.
3. Trip the overspeed trip by pushing the emergency engine stop button. Check to see that all pumps are at zero rack.
4. Start the fuel pump and obtain full fuel header pressure.
5. Have one man stationed to observe the upper pistons thru the top cover, a second man to check the lower pistons and a third man placed to manipulate the "start" button or lever.
6. Starting at either end of the engine, the man assigned to check the lower pistons moves the control rack of the governor side injection pump to about rack 8 by pressing on the control rack adjusting screw. With the rack held in this position, he signals the man at the engineer's control station to roll the engine over. Usually, one or two revolutions of the engine will be sufficient.
7. Use a good light to check the skirt end of the piston being fired for combustion smoke or strong exhaust odor which will indicate a cracked piston. Continue to observe for several seconds after the engine has stopped. Also check the upper pistons for bubbles forming at the top of the insert. This indication, rather than smoke, will appear in the case of a very small crack (such as a slight ring groove crack) in an upper piston if it is filled with oil. A piston which has a hole in the crown will not always fire and can be detected by a load hissing noise.
8. The procedure is repeated for the other cylinders, checking each in turn.

CHAPTER H. CAMSHAFT, CAMSHAFT BEARINGS AND TIMING CHAIN



Illus. H1. Timing Chain in Place on Sprockets
(Balanced fuel control arm and adjustable timing arrangement shown)

DESCRIPTION

Two camshafts, Illus. H1 and H2, are located in the upper crankshaft compartment of the engine with the driving sprockets in the exhaust (control) end compartment. They are driven in unison from a sprocket on the upper crankshaft by means of a timing chain.

The function of the two camshafts is to actuate the two fuel injection pumps of each cylinder at the same time and in the proper sequence with relation to the crankshafts.

The camshaft sprockets are bolted to the ends of the camshafts at the exhaust end of the engine, Illus. H1. For a detailed discussion of fuel injection timing, see Chapter L.

To facilitate removal, the camshafts are made in piloted sections and joined with fitted bolts. These flanges are matchmarked, Illus. H2.

The overspeed governor is driven from the camshaft at the opposite governor side.

The camshafts rotate in intermediate bearings at each vertical member of the cylinder block with the thrust bearings at the blower end. The camshaft bearings are made in halves as shown in Illus. H3.

Camshaft bearing lubrication is provided from the upper lubricating oil header, thru oil tubes leading to the exhaust end bearing of each camshaft. Passing thru holes in this bearing, lubrication is supplied and oil is conducted to the hollow camshaft, then out thru holes at each bearing. Oil holes in the sprocket plate and overspeed governor shaft of the exhaust end section of the camshaft provide oil for the timing chain thru holes in the camshaft sprockets.

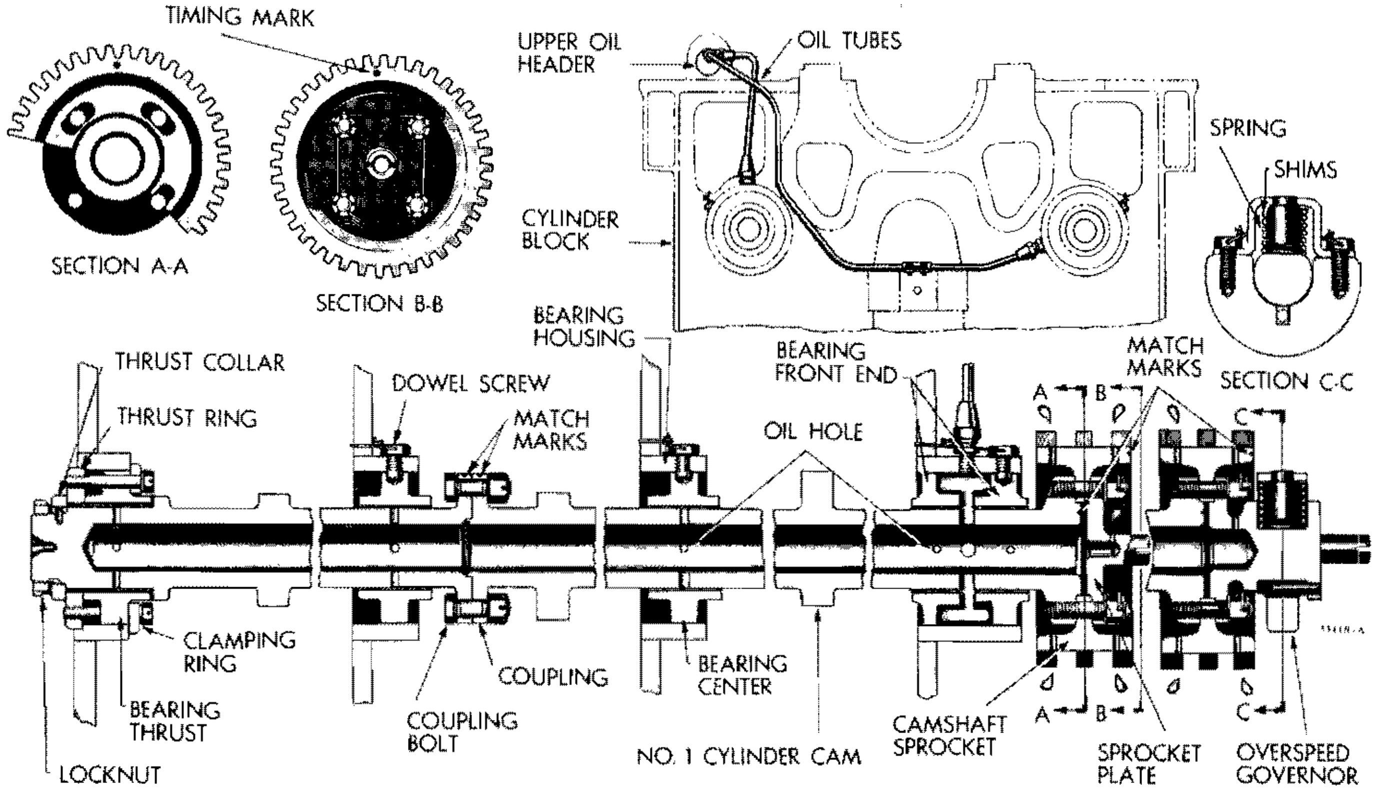
The camshafts and bearings are matchmarked so that they may be returned to their original location. For example, with a camshaft bearing marked "ARIT," letter "A" would be the engine sequence, "I" the bearing number, "R" the right side, and "T" the top half. For a complete description, refer to the Repair Parts Section.

Removing and Replacing Bearings

The thrust bearing at the blower end is held in place in the vertical member of the cylinder block by means of a clamp ring, thrust ring, and capscrews. Endwise movement of the camshaft is controlled by the thrust collars and collar locknut. The other bearings are held in place by dowel screws.

To permit removing a camshaft bearing, loosen the control end cover and take off the engine top cover. Then loosen the dowel screw and slide the bearing along the camshaft until it is free of the bearing bore in the cylinder block. After removal of the snap ring (when used), the bearing halves can be lifted out. Note the matchmarkings. Refer to Chapter B for wear limits for Satco and aluminum bearings.

After removal of the thrust collar locknut, the thrust bearing can be removed.



Illus. H2. Camshaft and Camshaft Bearings

Removing and Replacing Camshaft

Installation conditions govern whether the camshaft may be taken out as a unit or must be separated and removed in sections. The removal is made at the exhaust end of engine after taking off the exhaust end cover and removing the chain from the sprocket. Remove the injection pumps and lower the tappet assembly to relieve the spring pressure on the cams.

If sectional removal of the camshaft is necessary, note the matchmarks on the couplings. Unbolt and take the sections out, starting at the exhaust end.

When replacing a camshaft section, be sure matchmarks on the coupling hub coincide. When replacement of a marked part is made, similar marking should be stamped on the new part in the same location.

TIMING CHAIN

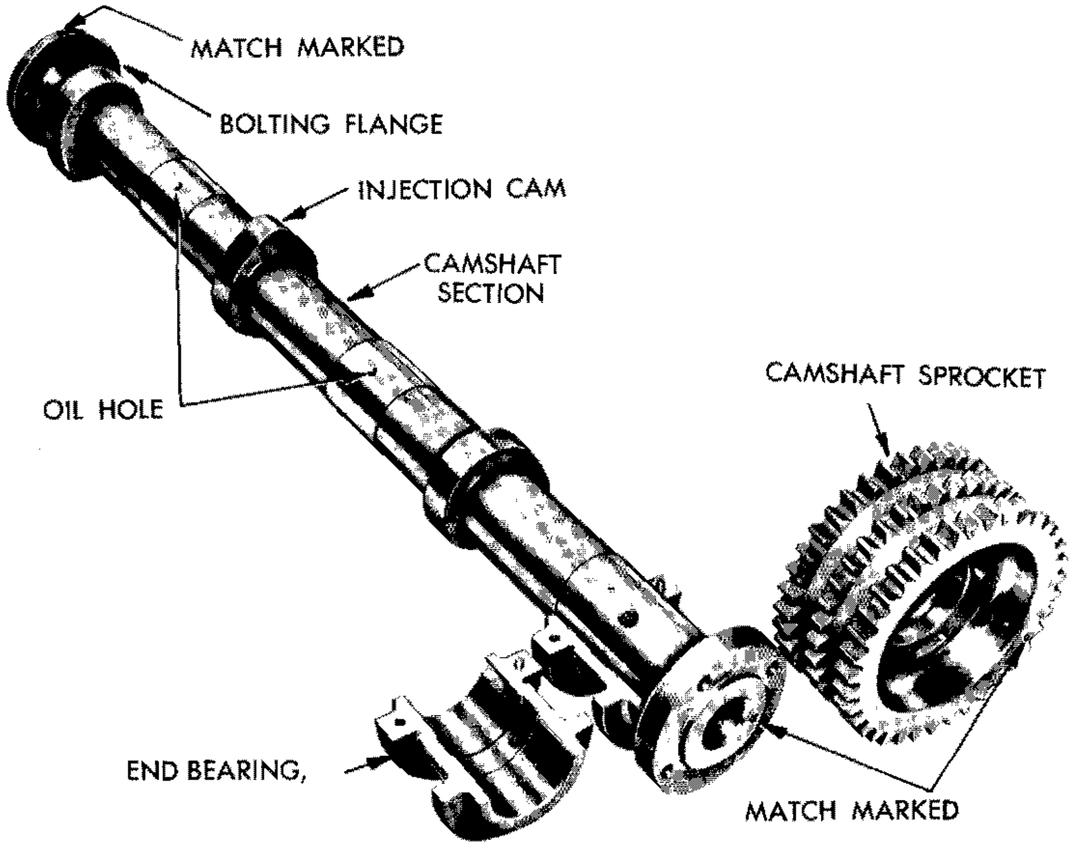
The timing chain used on engines previous to No. 968232 is a No. 780 Duplex 5/8" pitch 3" wide center guide chain of 154 pitches. It is assembled to operate as shown on Illus. H5 with the guide links for guiding the chain on the sprockets operating in slots in the sprockets. The inner teeth of the chain mesh with the crankshaft, camshaft, and tightener sprockets and the outer teeth mesh with the timing sprockets. A roller timing chain is used on engine No. 968232 and engines thereafter, and is assembled on the sprockets with the same marking as shown in Illus. H5. A connecting link is provided for disconnecting the chain.

Disconnecting and Removing Timing Chain

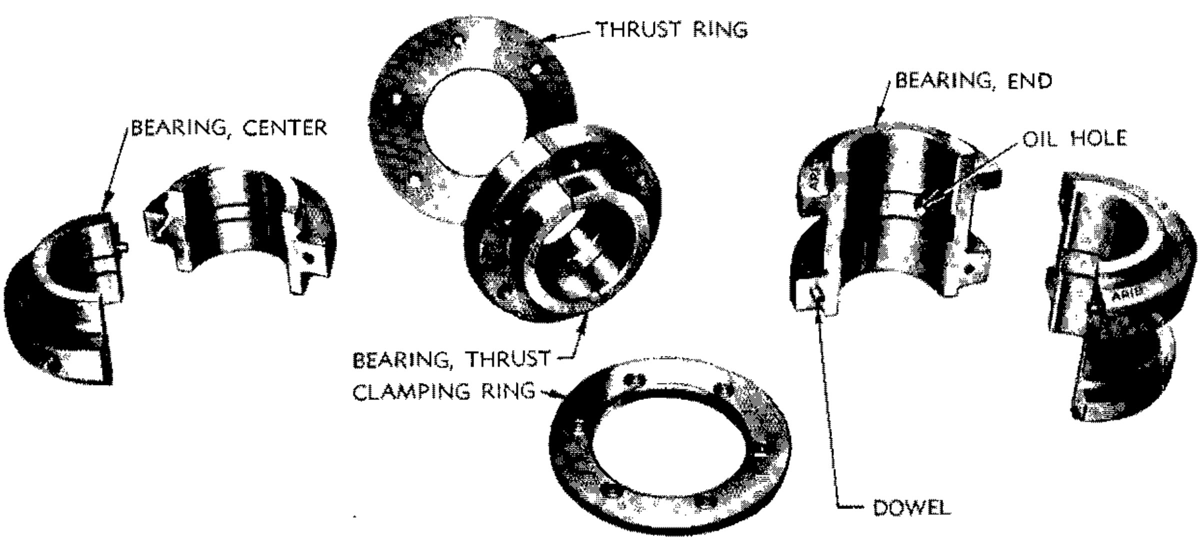
Loosen the clamp screw on the tightener sprocket bracket. Place a bar between the dowel and the tightener eccentric shaft nut, Illus. H5, and bar until the tightener sprocket moves to a high position releasing tension of the timing chain. The chain is provided with a removable joint pin (or connecting link) to facilitate removal of the chain. (Early engines used on endless chain requiring the following procedure for removal.) Slacken the chain by turning the tightener eccentric. Remove the clamp bolts from one side of the timing lever. Pull the timing sprocket shaft using a 1/2"-20 capscrew in the end of the shaft as a puller. After removing the timing sprocket and disconnecting the overspeed governor lever, the chain can be removed from the engine.

Reinstalling Timing Chain

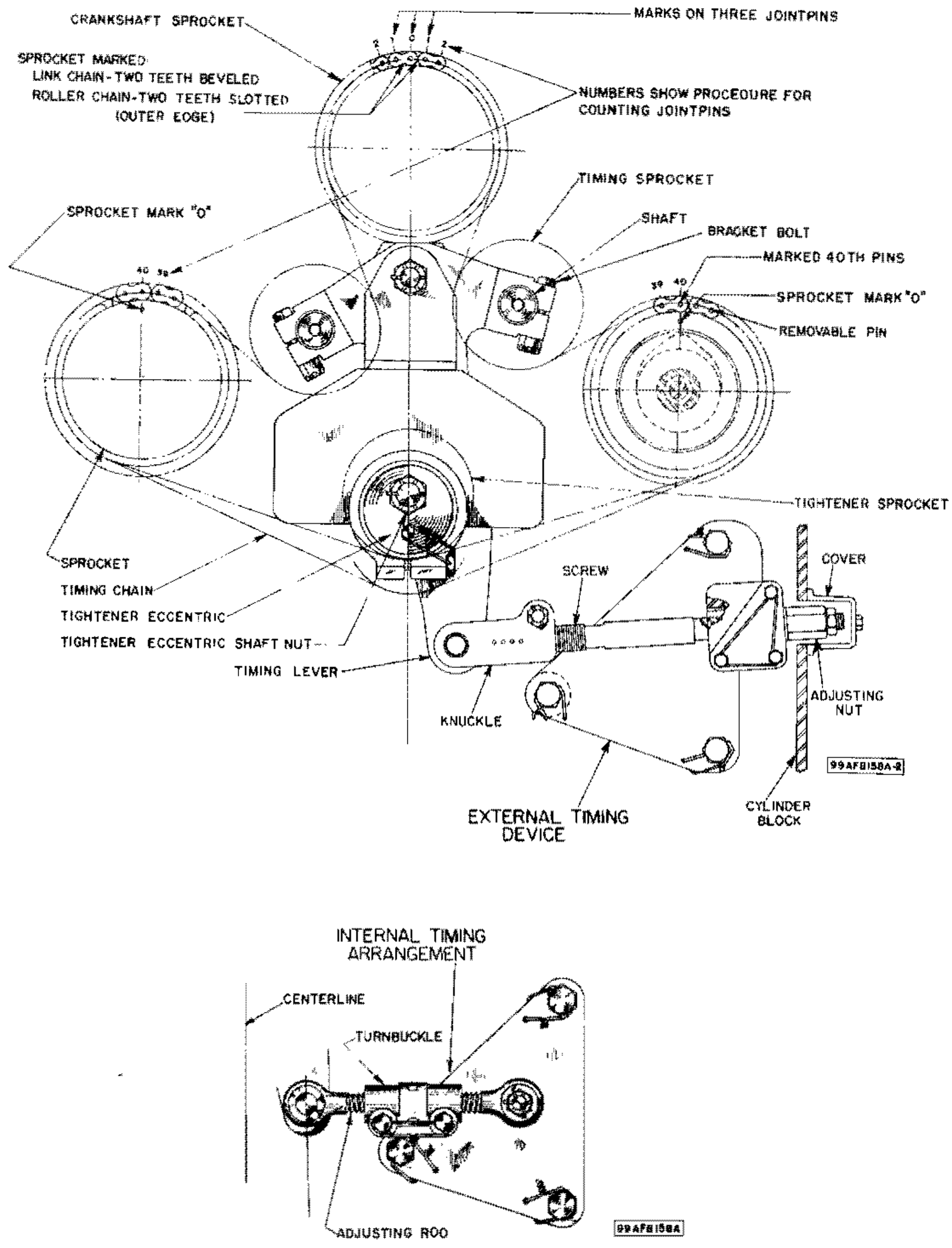
Reinstalling a chain is the reverse of the procedure outlined for removing. See that the



Illus. H3. Camshaft - Exhaust End Section



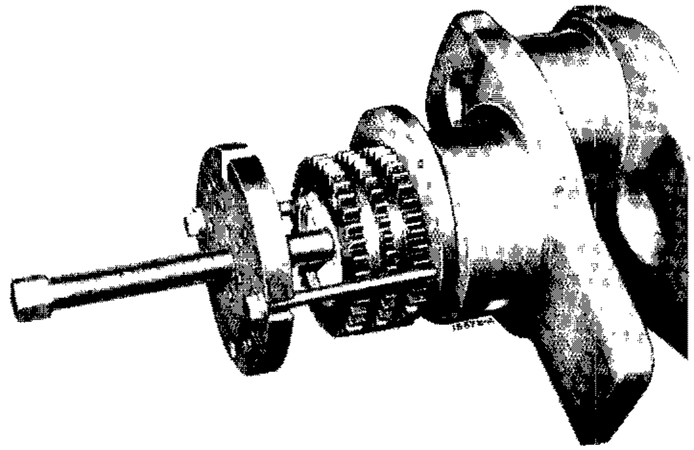
Illus. H4. Camshaft Bearings



Illus. H5. Timing Chain Installation

sprockets are in proper relation to each other by following the marking as shown in Illus. H5. The three punched marked or grinder marked pins on the timing chain must be centered over the two marked teeth on the crankshaft sprocket. The middle marked pin will be between the two marked teeth. The sprocket teeth for the link chain has two teeth beveled. The roller chain sprocket has a slot on the outer edge of two teeth. Starting with the middle pin as "O" count 40 pins in each direction. The punch or grinder marked 40th pin must be aligned with the "O" marks on the camshaft sprockets. Adjust the slack so that the chain can be depressed 3/16 to 1/4" each way of the centerline for a total of 3/8 to 1/2" slack.

Illus. H6. Sprocket Bearing Tool



Illus. H7. Crankshaft Sprocket Removing Tool

Chain Inspection

When a chain is worn so that it is "out of pitch" or elongated, injection pump timing will be incorrect resulting in poor engine performance. The chain may "climb" the sprocket teeth and if allowed to run in this condition will jump out of mesh and serious damage to sprockets may result.

If the slack can no longer be taken up by the tightener eccentric a new chain must be installed.

Serious wear or breakage is invited by operating chains with incorrect tension.

TIMING SPROCKET BEARING REMOVING TOOL

The timing sprockets operate on two ball bearing, Illus. H6. The tool for pulling these bearings consists of a body with collapsible arms and a yoke. The arms lock back of the bearing when removing.

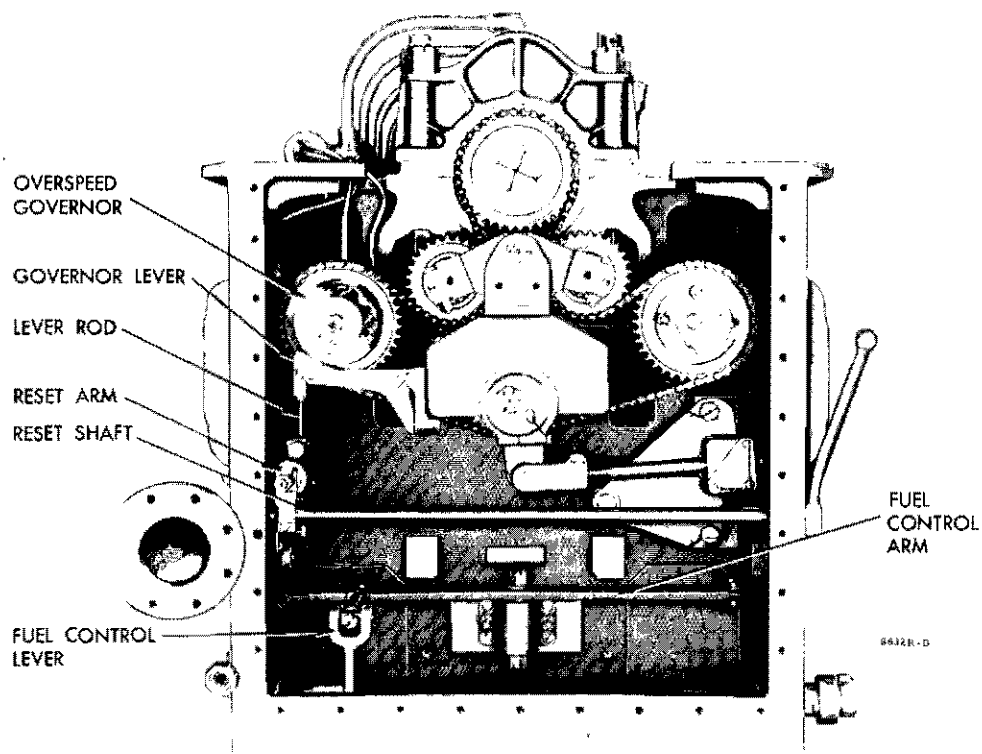
Removing Crankshaft Sprocket

Illus. H7 shows the application of the tool available for removing the timing chain sprocket from the upper crankshaft. (On the 12 cylinder engine, it is necessary to first pull the torsional damper.)

Installing

To reinstall the crankshaft sprocket heat slowly in oil (or an electric furnace) to about 320° F. Apply white lead and oil to the crankshaft surface. Line up the keyway and install on the crankshaft. Cool slowly with compressed air starting at the crankshaft and work out.

CHAPTER J. CONTROL SYSTEM



Illus. J1. Fuel Control Mechanism

DESCRIPTION AND OPERATION

The controls which must be shifted in starting, running, and stopping the engine are all remotely manipulated from the control panel in the cab of the locomotive. These manipulations are, for the most part, performed electrically or pneumatically.

In addition to the controls used in normal operation, the engine has the following protective controls: an overspeed governor and a manual emergency stop. The mechanical control parts on the engine are shown in Illus. J1.

NORMAL ENGINE SHUTDOWN

The early 6 cylinder engines were normally stopped from the cab by use of the rotair valve. This actuates the air shutdown device on the governor power piston. Refer to Chapter Ma.

Later 6 cylinder engines and all 8, 10, and 12 cylinder engines are normally stopped from the cab by using the proper electrical controls. This causes the governor to move the control arm to the "no fuel" position. Refer to Chapter Mb, Mc, or Md.

OVERSPEED GOVERNOR

The overspeed governor is mounted on the exhaust end of the opposite governor side camshaft as shown in Illus. J2. Its function is to stop the engine should the governor fail to hold the engine below its maximum permissable speed. Refer to Chapter B for overspeed governor settings.

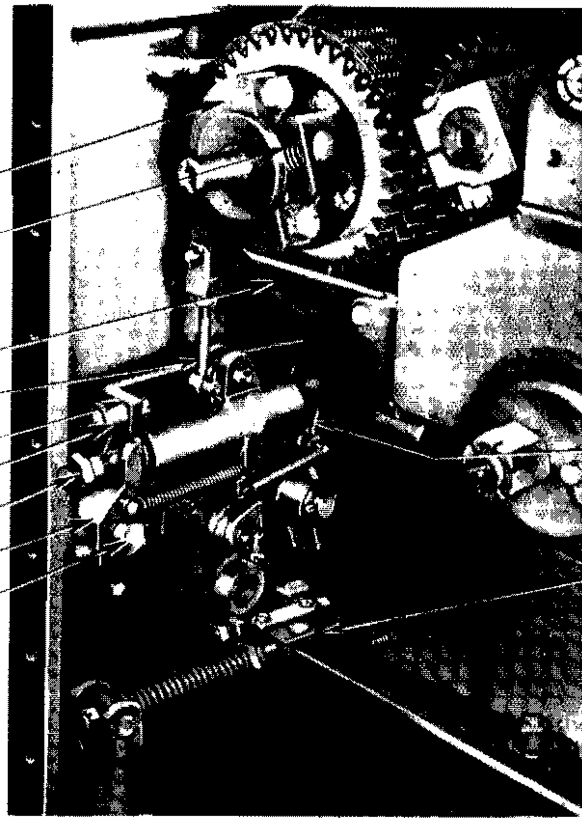
The overspeed governor consists of a single weight and a spring. The spring is adjusted with shims to prevent the weight from moving outward until the maximum safe speed is reached. Then, centrifugal force overcomes the spring pressure. The governor weight moves outward, forcing the overspeed governor lever and its rod, Illus. J2, downward.

Moving the overspeed governor lever rod downward trips the stop latch permitting the plunger spring to force the plunger rod against the fuel cutout lever. This lever then moves the fuel control arm to "no-fuel" position, stopping the engine. Illus. J3 shows the relationship of the governor lever rod, stop latch, plunger and the fuel cutout lever.

EMERGENCY STOP AND RESET LEVER

The hand operated push button, Illus. J4, of the emergency stop extends thru the exhaust end cover above the governor.

The button acts thru linkage and the stop



Illus. J2. Overspeed Governor and Emergency Stop Mechanism

shaft cam to depress the stop latch. This releases the spring loaded plunger. The plunger forces the fuel cutout lever against the fuel control arm thus moving the injection pump control racks to "no fuel" position.

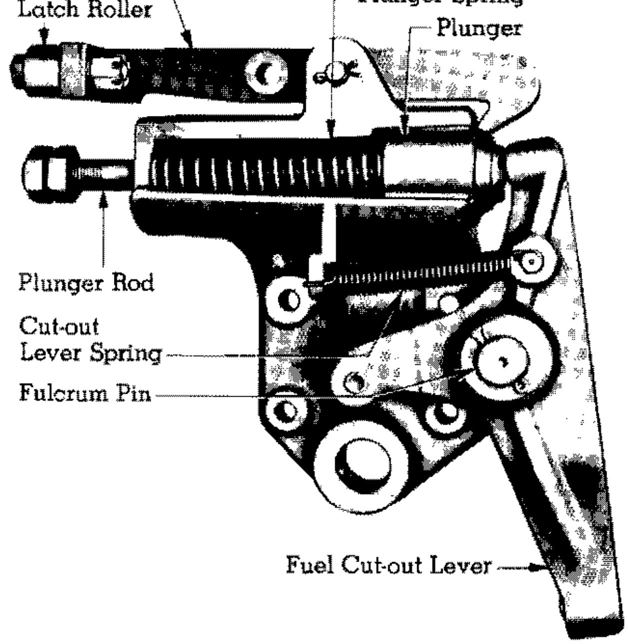
When the engine has been stopped by the emergency stop button or by the overspeed governor, it cannot be started again until the overspeed stop plunger has been returned to its normal spring loaded position, Illus. J3.

This is done with the reset lever. Moving this lever in the direction indicated on the adjacent nameplate swings the reset arm, Illus. J2, pulling the plunger against the spring to the position where the stop latch will drop into position.

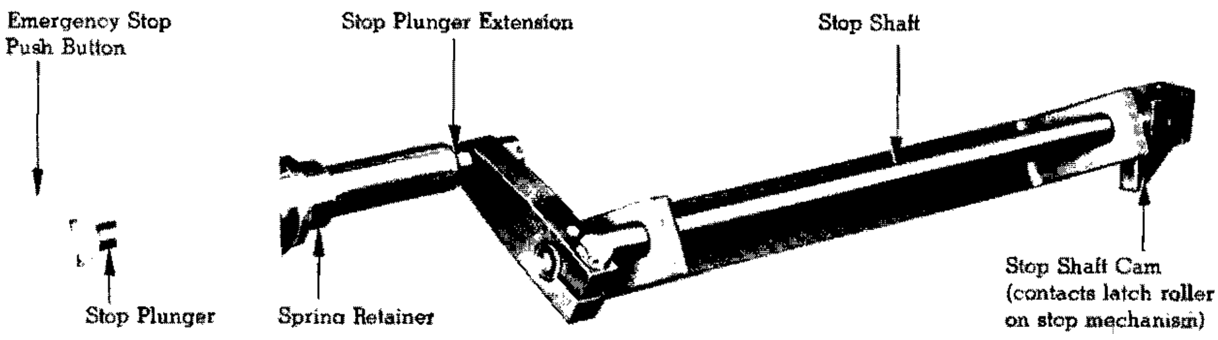
IT IS ADVISABLE TO RESET THE STOP PLUNGER IMMEDIATELY AFTER AN OVERSPEED OR EMERGENCY STOP TO AVOID THE POSSIBILITY OF ATTEMPTING TO START THE ENGINE WITHOUT RESETTING THE STOP MECHANISM.

LOW LUBRICATING OIL PRESSURE SHUTDOWN
(Early 6 cyl. Engines with Pneumatic Shutdown)

The engine is provided with a low lubricating oil pressure shutdown device connected to the



Illus. J3. Stop Latch and Plunger in "Run" Position



Illus. J4. Emergency Stop Push Button and Linkage

discharge side of the lubricating oil pump. This device is mounted so that the piston can move the fuel control arm and return the injection pumps to "no fuel" position when the lubricating system oil pressure drops to 4-5 lbs. When the pressure is normal the piston is held to the inner end of its stroke by pressure from the pump allowing the fuel control arm full travel.

This condition must also be duplicated when starting the engine by pulling the shutdown reset cable handle (in the cab) to overcome the spring pressure. As soon as the engine starts, the oil pressure builds up and the handle can be released.

CAUTION: DO NOT BLOCK OUT LOW LUBRICATING OIL PRESSURE RELEASE IN ANY WAY.

When the oil pressure drops, the shutdown piston spring forces the piston against the fuel control arm adjusting screw to shut off fuel and stop the engine.

LOW LUBRICATING OIL PRESSURE SHUTDOWN

(Early 6 Cyl. Engines with Electrical Shutdown and Early 8 and 10 Cyl. Engines Except 10 Cyl. Erie Built)

These engines are provided with pressure actuated switches connected to the lubricating oil header. In case of low lubricating oil pressure these switches act thru the governor solenoid to shut the engine down.

LOW LUBRICATING OIL PRESSURE SHUTDOWN

(Later Engines with Woodward Governors)

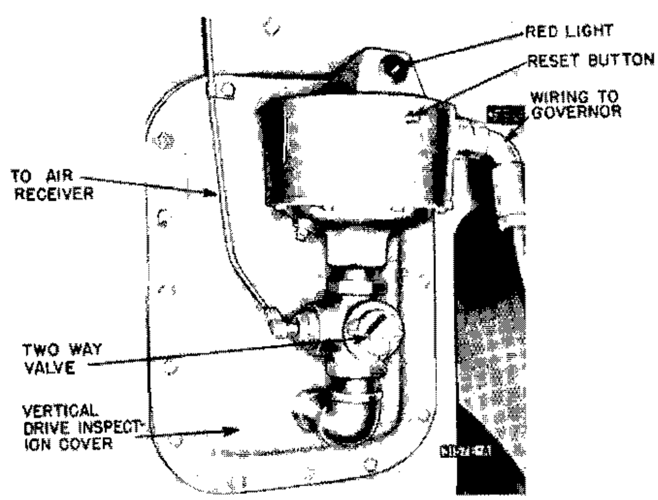
These engines are provided with a low lubricating oil pressure mechanism which is incorporated into the engine governor. The mechanism provides complete protection against low oil pressure in the engine. Refer to Chapter Mb, Mc, or Md.

ENGINE PROTECTOR

An engine protector relay is mounted on the governor side vertical drive cover. It is piped into the engine crankcase which is normally at a pressure of less than atmospheric. If a pressure slightly above atmospheric develops, the switch will shut down the engine thru the governor shutdown solenoid. A reset button is provided for resetting the switch. The red light indicates when the switch is tripped.

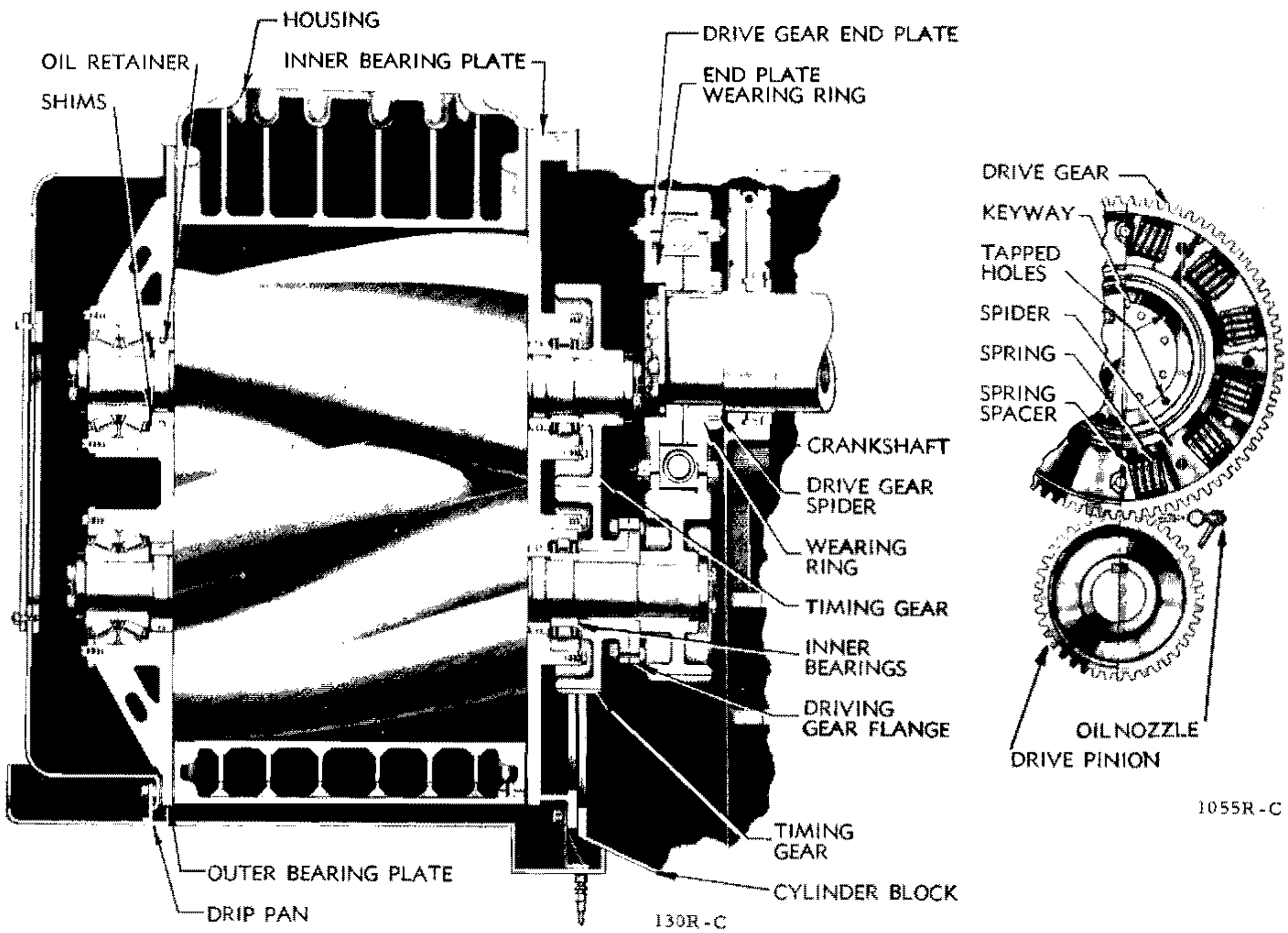
A build-up of pressure in the crankcase sufficient to operate the switch indicates a defective part within the engine such as a cracked piston. Instant detection of the defective part prevents excessive engine damage.

A two-way valve is provided so that operation of the switch may be checked by admitting air from the engine air receiver with the engine running. A defective switch should be returned to the Paxton-Mitchell Company, Omaha, Neb.



Illus. J5. Engine Protector

CHAPTER K. SCAVENGING SYSTEM AND BLOWER



Illus. K1. Scavenging Air Blower (Longitudinal Section)

DESCRIPTION

Scavenging air is supplied to the cylinders under a pressure of 3.5 to 5.5 lbs. (full nominal load - full speed) by means of a positive displacement impeller type blower. The blower consists of a housing containing inlet and discharge passages enclosing 2 three-lobe spiral impellers. The blower is driven by a flexible drive from the upper crankshaft, Illus. K1.

OPERATION

Air is drawn from the atmosphere thru the air filter and enters the inlet passage of the blower. The air is compressed by the lobes and forced thru the outlet passages.

Ducts conduct the scavenging air to the air receiver compartment of the cylinder block. (The ducts are not used on engine No. 966820 and thereafter.) The air receivers run the full length of the cylinder block and completely surround the cylinders at the air port area.

The scavenging air enters the cylinder under pressure, sweeping the exhaust gases out thru the exhaust ports producing complete scavenging.

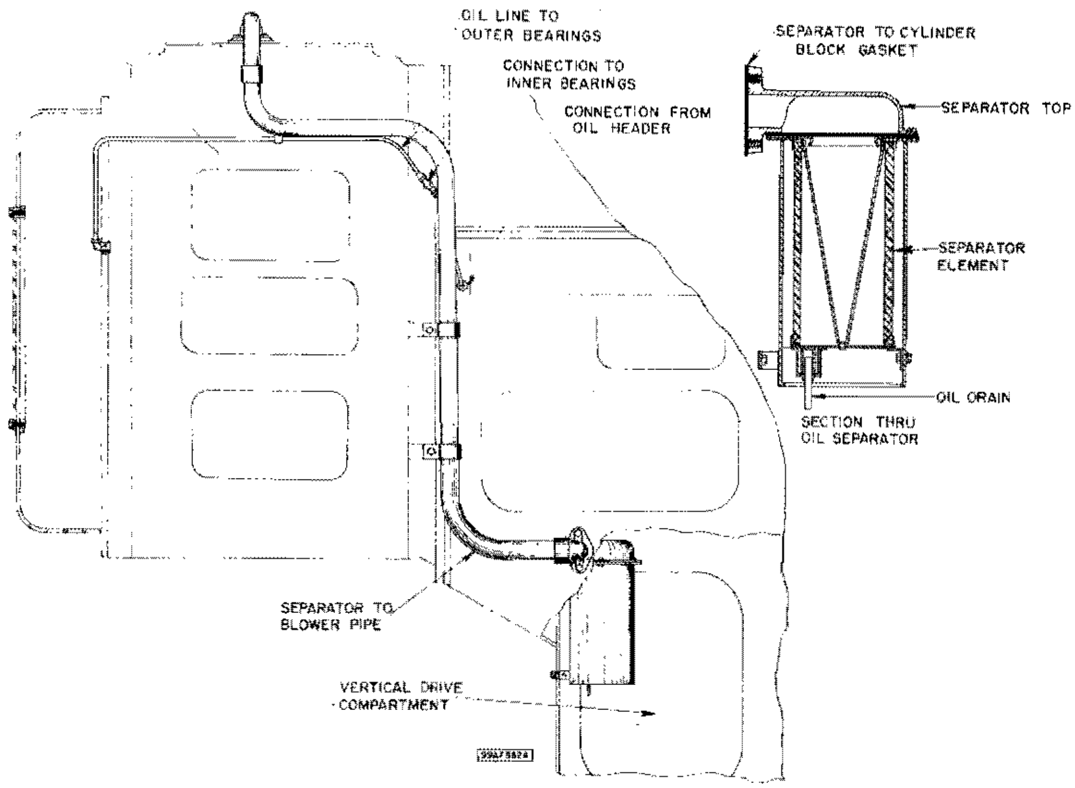
The scavenging air trapped in the cylinder by the lower piston closing the exhaust ports provides fresh air for the next compression stroke.

The blower bearings and timing gears are lubricated by oil lines from the upper header.

The blower specifications are listed in Chapter B.

OIL SEPARATOR

The upper and lower crankcase compartments are placed under a vacuum by means of a pipe, Illus. K2, connected to the suction side of the blower. In the vertical drive compartment, this pipe is connected to an oil separator, where a separator element prevents oil from being carried into the blower with air from the crankcase.



Illus. K2. Oil Separator (Early 6 Cyl. Engines had top inlet)

The separator should be removed and cleaned in a solvent at the regular maintenance periods. Blow any excess solvent from the element before replacing the separator back into service.

INSPECTION

Oil leakage of the seals, condition of the thrust bearings and impeller clearances can be checked with the blower on the engine.

The seals when not functioning properly will allow lube oil to enter the inside of the blower between the bearing plates and rotor shafts.

Seal trouble is sometimes evident where the blower in general is extremely oily on the inside but it must be recognized that oil can enter the blower from other sources. The crankcase breather may allow atomized oil to enter the blower thru the breather line due to high crankcase vacuum conditions brought on by: (a) Dirty air intake filters, (b) Improper breather line orifice. Oil can also be driven back from the air receiver if the internal tappet drain lines are leaking. Unseated oil rings may saturate the air receiver with oil. Each of the above possibilities must be eliminated before determining that seals are the cause of the oily condition in the blower.

The thrust bearings can be inspected for condition of the rollers after removing the outer end cover. Also a feeler gage check can be made for excessive clearances between the rollers and the race. End clearances of the thrust bearing can be checked by indicating the lateral movement of the impeller shafts.

Check and record all blower clearances. Refer to Page B3 for values and Illus. K3 for location of check points.

Remove inspection plugs on the outer bearing plate, Illus. K4, and check condition of ends of the impellers for possible galling.

Blower Removal

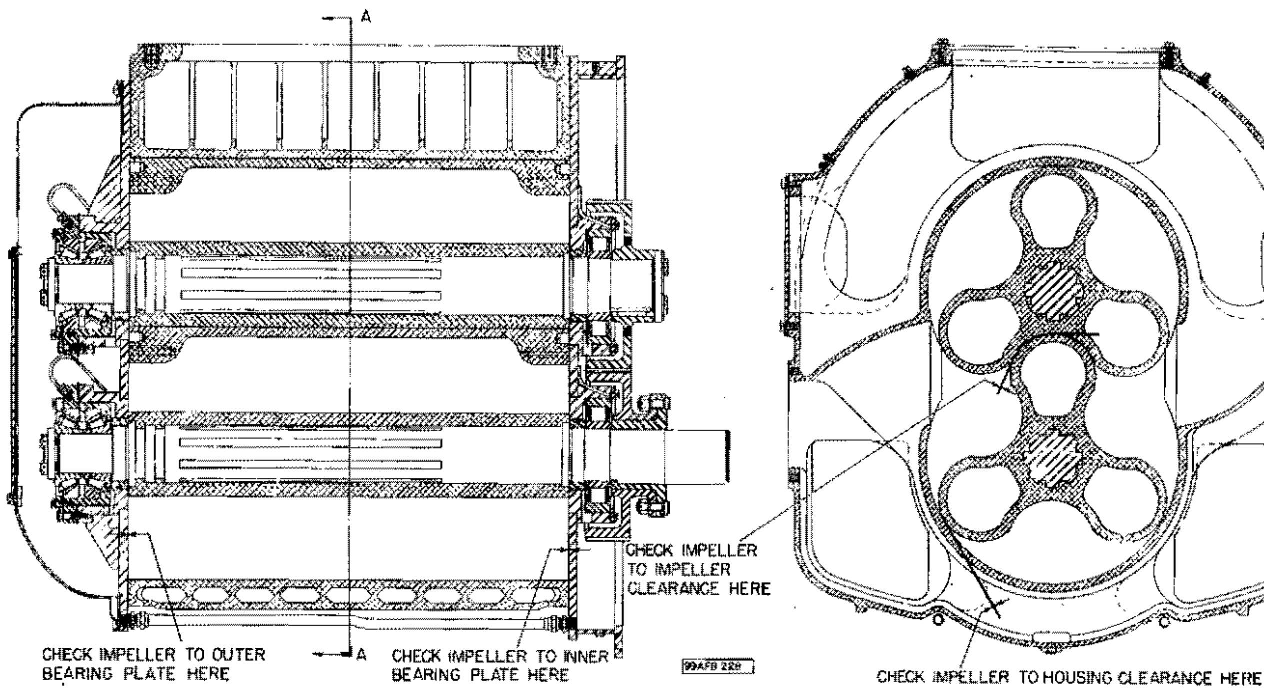
To remove the blower from the engine, first remove the air filter connections. It is advisable to cover the openings in the blower to prevent dirt or foreign material from getting into the blower housing.

Then, remove the following parts in the order named:

Blower drip pan (after disconnecting the drain tube connection).

Air receiver ducts (when used). The ducts may be left off when removed. Cover plates and gaskets can be made up to cover the openings.

Oil lines to blower. (Later engines have the connections on the outside of the cylinder



Illus. K3. Location of Clearance Check Points

block, see Illus. K2. On early engines, these connections were inside the upper crankcase and required removing a top inspection cover adjacent to the blower, or the entire top cover, if the one piece top cover was used.)

Crankcase oil separator pipe.

Disconnect the crankshaft air seal tube.

Next referring to Illus. K5, remove the following.

The dowels which locate the blower to the cylinder block.

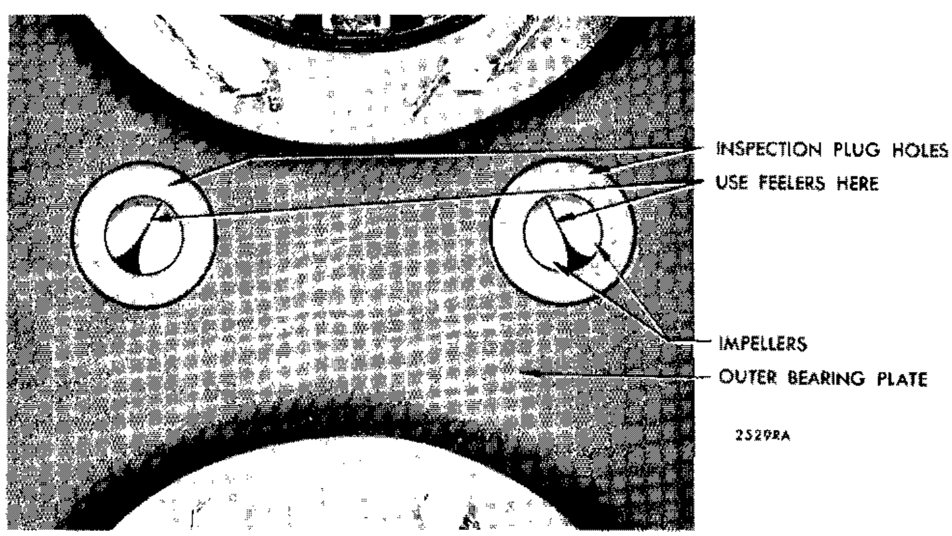
The capscrews which hold the top cover to the blower housing.

The stud nuts that hold the blower to the cylinder block. These nuts are located on the inside of the air receiver.

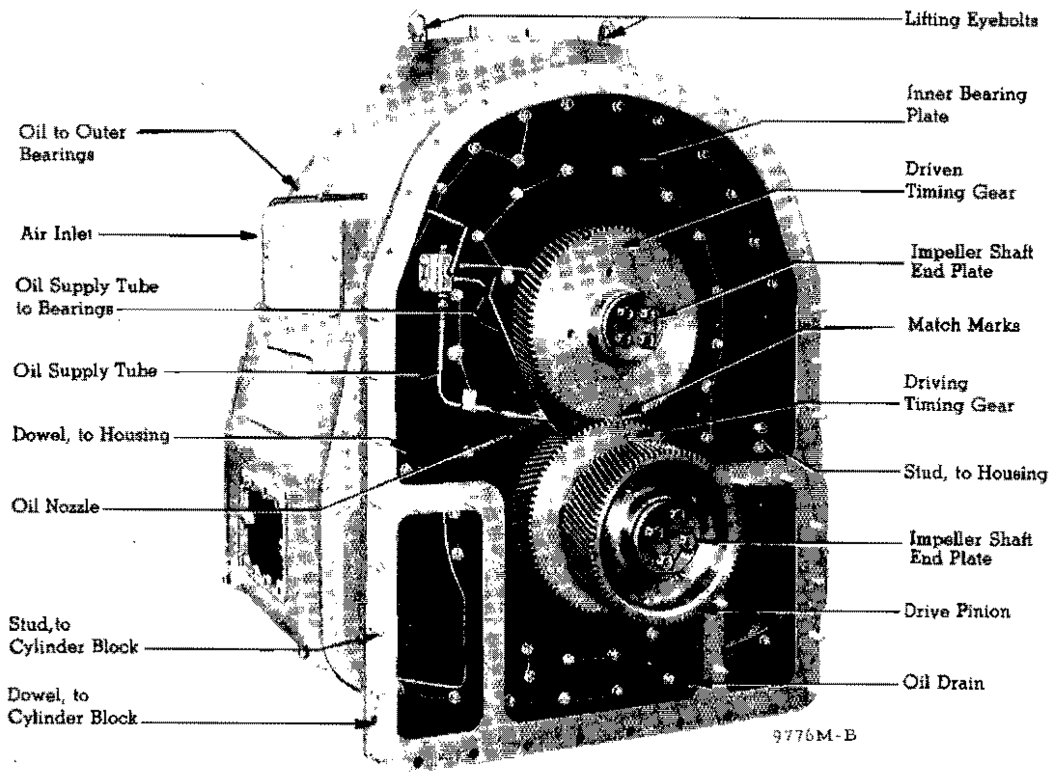
The outer end cover on 12 cyl. Train Master locomotives to obtain proper clearance to remove the blower from the carbody.

Insert 5/8"-18 eyebolts in the tapped holes provided in the housing top flange, and attach to a suitable hoist or crane. Then remove all nuts that hold the blower to the cylinder block.

The blower can now be moved endwise to



Illus. K4. Inspection Plug Holes in Outer Bearing Plate



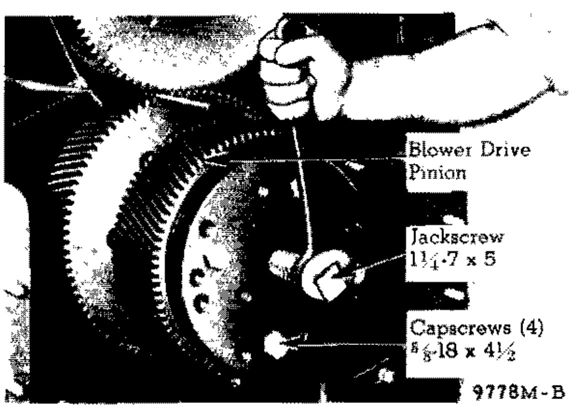
Illus. K5. Blower - Drive End

clear the drive gear, and lifted away from the engine.

Precautions

When a blower has been removed from an engine for overhaul, there are several important points that must be followed to enable the overhaul work to be done systematically and the results of the reassembly more certain.

1. Routine overhaul of a blower involves only two points which require inspection - the blower seals and the bearings. Other inspections would include the inspection of the lobes for galling and proper clearance values.



Illus. K6. Blower Drive Pinion Puller

2. The blower prior to dismantling should have all clearances checked and recorded. If the clearances are found within tolerances, the blower can be reassembled with the same shim combinations.

3. During the disassembly of the blower, tag location of parts removed, i.e. keep bearings separate for their exact position and measure all shims and record their location, etc.

4. Be sure to follow the procedure accurately when removing the outer (thrust bearing) end plate. If the thrust bearings are not removed evenly, trouble can be encountered.

5. In the replacement of the seal rings, be sure that they are not twisted or bent on application. The seal rings do not normally turn with the shaft but may if bent or distorted at application so that the ring binds in the retainer groove. Seal leakage as well as wear of the bore fit can result. It is important that the bores in the bearing plates be checked to be sure that there are no ridges or out of round conditions existing from previous wear. Be sure the retainer is not worn.

6. Be sure to apply the seals correctly. The seals are used to seal the air in and the oil out.

7. Do not use Permatex or any other seal-

ing compound on the blower assembly. Clearances in the blower are vital and a sealing compound will confuse the correct adjustment.

8. In the application of the paper shim gaskets, a light oil application will make them lie flat. Be sure there are no pleats or folds in the paper shims when applying the bearing end plates.

9. Be sure to use proper length capscrews in all assemblies.

10. In tightening down the impeller shaft end plate, be sure they are pulled in all the way. It must be realized that the shaft is being pulled thru the bore of the inner thrust bearing race with the impeller shaft end plate. There is an interference fit between the inner race of the thrust bearing and the shaft so a drag pull is involved. If all the movement is not taken up, erradic clearance readings can be expected. It is also possible that further positioning of the bearing on the shaft during operation can be expected if the tightening of the shaft end plate was not complete. It is recommended that special end plates (1-1/2" wide) be made to pull or position the thrust bearing. When pulled in place, the special puller plates are to be removed and the standard plates installed.

11. Be sure to reassemble bearings to exact position from which removed if the bearings are to be reused.

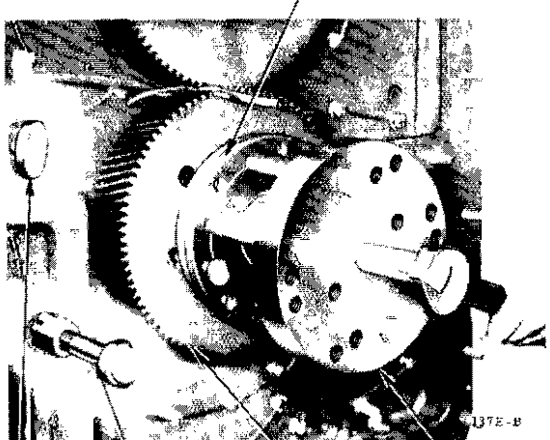
12. If the timing must be reset, be sure the impeller clearances are equally divided.

13. It is imperative that the blower inlet be covered as soon as the filter housings are removed so that foreign material is not allowed to get into the blower.

14. On early blowers the oil drain pockets in the blower end cover extend below the bearing plate. Never set blower down on oil pockets. Block blower off the floor using two pieces of wood under the blower so they come in contact with the flat surface of the housing on the outside of each oil drain line. Never block across the underside of the blower housing.

15. Never use flame heat on parts.

16. It is important the gear to shaft keys be properly fitted.



Illus. K7. Timing Gear Flange Puller

Blower Disassembly

Tools Required

1. Offset bracket for turning blower over.
2. One set of thrust bearing pullers.
3. Two impeller shaft end puller plates and capscrews.
4. One blower pinion puller.
5. One timing gear puller.
6. Two blower stands 14" high.
7. Two 2"x2"x5' wood blocks.
8. Micarda strips varying in thickness from .028 to .032". The strips should be 3/4" wide - 30" long.
9. One oil emersion tank that can be heated to 400° F. or an oven where the gear teeth can be suspended. Never use flame heat on any part.
10. Normal hand tools - Socket wrenches, etc.
11. Feeler gage with string attached. The string will prevent the loss of the feeler gage in the blower if accidentally dropped.
12. Seal ring retainer puller.
13. Seal Ring Expander
14. Impeller shaft spacer tool.
15. Blower drive gear spring removing tool.

Removing Drive Pinion

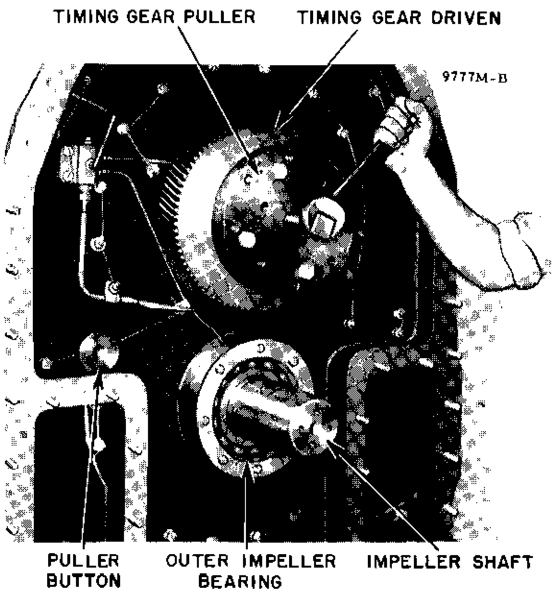
The first step of this procedure is to remove the pinion from the lower shaft. This is accomplished by first removing the impeller shaft end plate and then installing the blower drive pinion puller, Illus. K6. Do not use flame heat to assist in the removal of the pinion. Wedge the timing gears with a piece of copper tubing as shown to keep the gears from turning.

Remove Timing Gears

After the pinion is removed, remove the timing gears.

1. Remove the fitted bolts from the timing flange.

2. Install timing gear flange puller and button, Illus. K7, and pull the lower timing gear



Illus. K8. Driven Gear Puller

hub flange and gear together. (Note: The fitted bolts must be removed to allow free movement of the gear to hub when pulling. Severe damage can result if an attempt to pull the lower timing gear and flange hub is made without first removing the fitted bolts.)

After the lower gear has been removed, pull the upper timing gear from the upper shaft as shown in Illus. K8.

At this point all the gears have been removed from the blower. The impellers are removed by pulling the shafts thru the inner bearing races. In order to remove the impellers, remove the outer bearing plate as follows.

Removal of Outer Bearing Plate and Thrust Bearings (6 - 8 - 10 Cyl. Engines)

1. Remove blower end cover.
2. Remove top cover from air intake opening and bolt on offset lifting bracket, Illus. K9. The purpose of this lifting bracket is to facilitate turning the blower over.
3. With blower set on a stand, remove the dowels from bearing plate to housing.
4. Remove the capscrews from the impeller shaft end plates and bearing retainers. This will allow removal of impeller shaft end plates and thrust bearing retaining rings.
5. Remove the oil drain tubes from the bearing plates. At this point all parts necessary to allow removal of the outer bearing plate have been removed.
6. Install the thrust bearing pullers to both bearings. The puller housing is bolted to the bearing plate thru retainer ring capscrew holes and the puller screw pressure is on the end of the impeller shafts. This action lifts the outer bearing plate and thrust bearing from the shafts. Be sure the puller buttons are on the end of the shafts, as shown in Illus. K10, so that the shafts are protected.
7. Turn the jackscrew of each puller equal small amounts until the outer bearing plate complete with bearings is drawn from the impeller shafts and the blower housing. Caution: Hand wrenches only shall be used in turning puller jackscrews to prevent cocking of the plate due to puller action of unequal amounts.

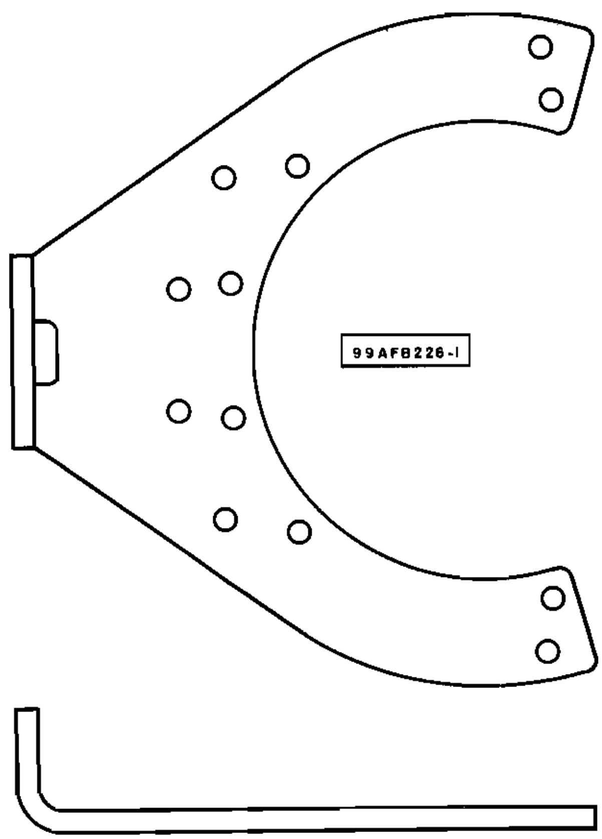
The bearings can be driven from the plate with a wood block or a lead bar.

The impellers can now be removed. Use 7/8-14 eyebolts in the end of the impeller shafts. Lift out separately.

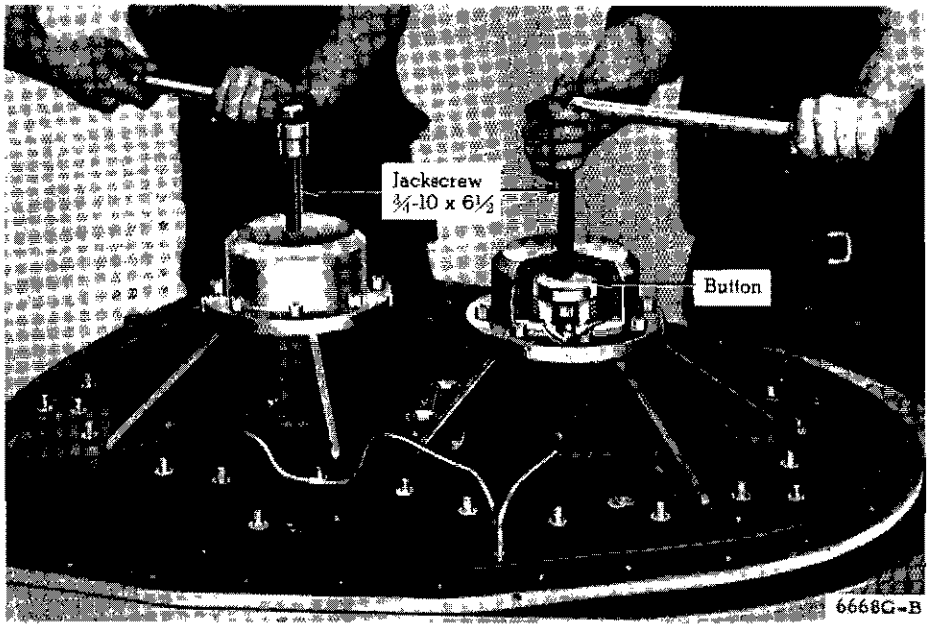
If it is necessary to remove the inner bearing plate for repair, stand blower erect and remove dowels and capscrews.

Removal of Outer Bearing Plate and Thrust Bearings (12 Cyl. Engine)

1. Remove blower end cover.
2. Remove top cover from air intake opening and bolt on an offset lifting bracket as



Illus. K9. Lifting Bracket



Illus. K10. Blower Outer (Thrust) Bearing Pullers
(For other than 12 Cyl. Blowers)

shown, Illus. K9. The purpose of this lifting bracket is to facilitate turning the blower over.

3. By removing the capscrews from the thrust bearing retainer rings and the thrust bearing adapter flange, the bearings may be removed independently of the bearing plate, Illus. K11. Apply the thrust bearing puller to the end of the impeller shaft. This action lifts the thrust bearing retainer and bearing. Be sure the puller button is on the end of the shaft so the shaft end is protected.

4. Turn the jackscrew of the puller until the bearing and retainer are drawn from the impeller shaft and the bearing plate. Caution: Hand wrenches only shall be used in turning the puller jackscrews to prevent cocking the retainer.

5. After removing both thrust bearings, the bearing plate can be removed after the oil drain connections and capscrews are removed from the bearing plate.

The impellers can now be removed. Use 7/8-14 eyebolts in the end of the impeller shafts. Lift out separately.

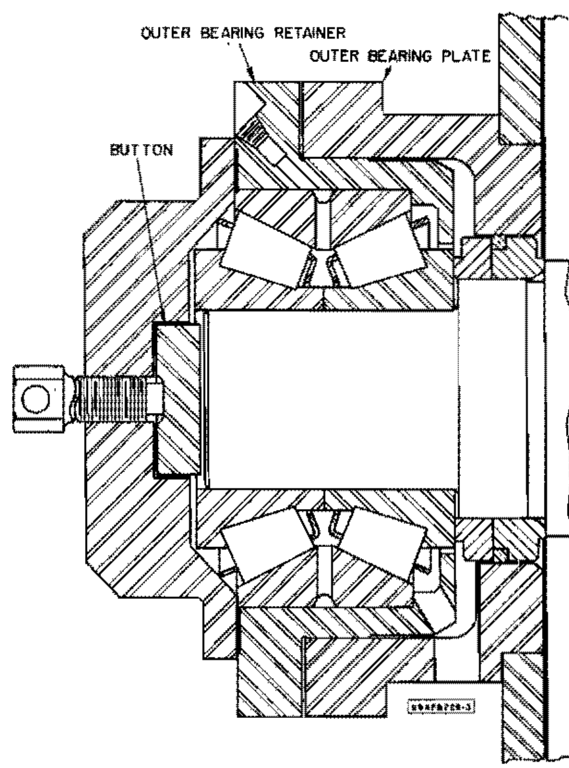
If it is necessary to remove the inner bearing plate for repair, stand blower erect and remove dowels and capscrews.

Blower Inspection and Repair After Disassembly

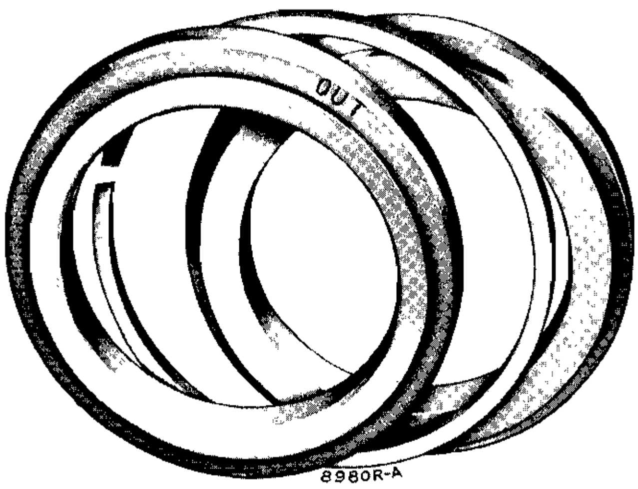
1. Inspect the seals on the impeller shafts, Illus. K12.

a. Check for ring groove binding. If binding is evident, inspect O.D. of rings. Scuffing will probably be evident. This inspection can reveal the cause for seal leakage.

b. Check the bearing plate bore. Be sure that it is not ridged from a ring that was



Illus. K11. Outer (Thrust) Bearing Puller
(For 12 Cyl. Blowers)



Illus. K12. Retainer and Seal Ring

bound on the shaft. During operation of the blower, this seal should remain stationary in the bore. Ridging is caused by a ring bound in the groove. If ridging is found, rebushing of the bore is necessary.

c. Check the retainer for groove wear. Use a new seal ring and a feeler gage. The groove ring clearance should be a maximum of .0095". If found worn, it should be replaced. The retainer puller is used to remove the seal ring retainers (single piece) or outer half of the two piece retainers.

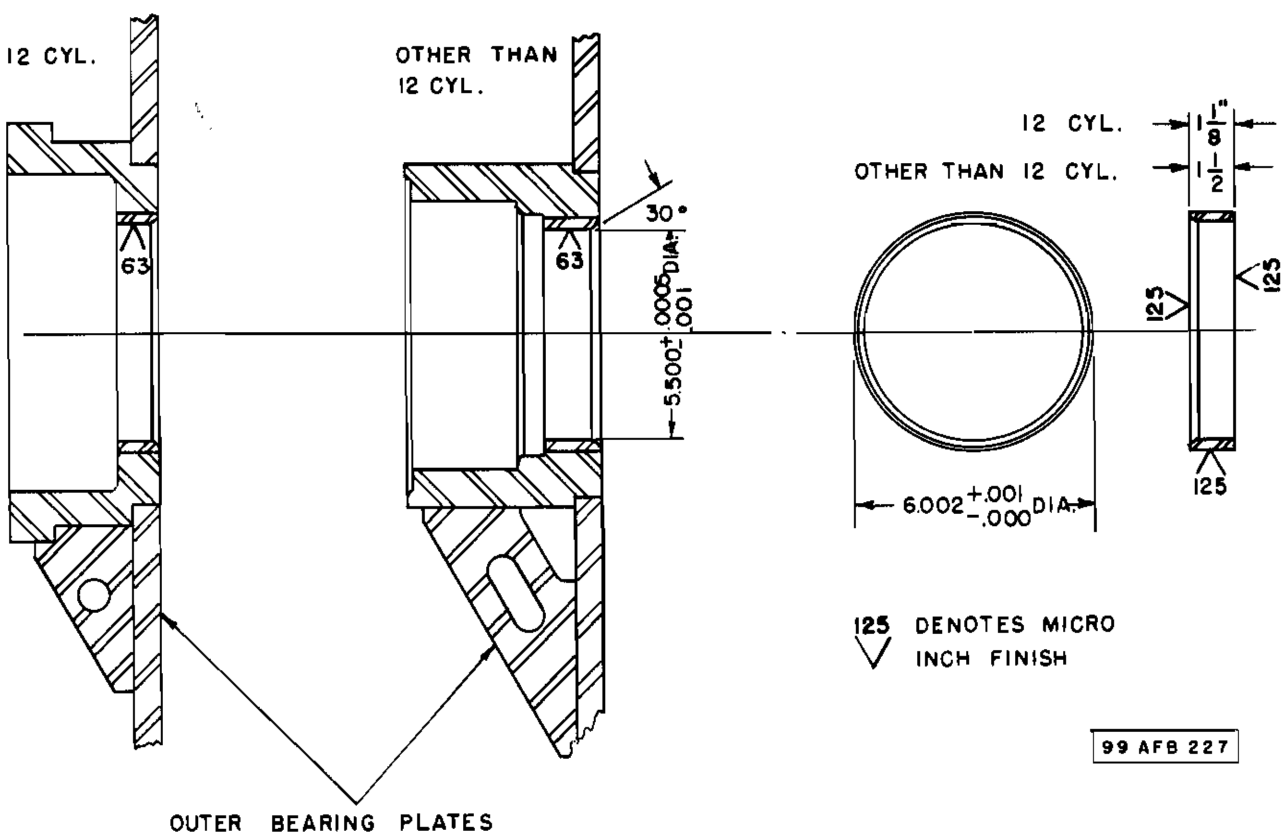
2. Check the thrust bearings for pitting and wear. Renew if necessary.

3. Remove the roller bearing outer races and bearings from the inner bearing plate. Be sure to identify their positions to avoid a mix up of bearing and locations. Check the bearings for wear by placing them on the inner race which is still in place on the impeller shafts. The bearing clearance should not be over .005" which can be determined by inserting feelers between the rollers and the race. The proper clearance can be determined where the maximum thickness feeler gage slides freely between the rollers and the race. If the bearing clearance is found to be excessive a new bearing must be applied.

Repair of Bearing Plate Seal Seat

Where ridging is found in the bearing plate bore, it is permissible to correct the seal ring bore in the bearing plate by bushing. There are certain precautions that must be taken to obtain the desired repair.

The exactness of the retainer bore must be concentric to the bearing bore and true to the



Illus. K13. Blower Bearing Plate Bushing Repair bearing plate. If not concentric and square with the adjacent bores, the seal will not function properly.

The bushing bore must meet the finish specification as shown in Illus. K13. Make bushings from 6-1/2 O.D. x 5-1/4 I.D. seamless steel tubing. Work bushing to meet the following dimensions before application.

O.D.	6.002 + .001 - .000
Width	1-1/8"
I.D.	5-1/4 to be finished after application

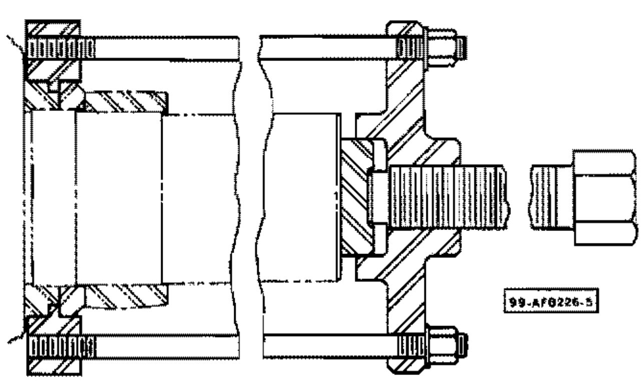
Machine bore in bearing plate to 6.000 + .001 - .000. Be sure the machining is done concentric to the bearing bore and true to the bearing plate. This gives a shrink fit of bushing to bore of .002 to .003". Freeze bushing in dry ice and apply.

After application of bushing in bearing plate, but before finish machining the bore, weld the bushing to the plate in the following manner: Drill three holes 1/4" dia. 3/16" deep equally spaced in bushing parting line to bore on the impeller side of the plate. Fill holes with weld.

Finish machine bore to 5.500 + .005 - .001. Bore to have RMS Micro inch finish of 63 max.

Removal of Inner Bearing Inner Race and Seal Ring Retainer

When it is necessary to remove either the inner race of the bearing or the seal ring retainer, it will be necessary to remove them as a unit. Use the puller tool (Symbol C-3427TD-A). The seal ring retainer serves as a puller support for the removal of the inner bearing inner race, Illus. K14. If the retainer is within limits, it may be reinstalled.



Illus. K14. Seal Retainer Puller

Installation of Seal Ring Retainer

The current retainers are a two-piece assembly having a collar and retainer. Previously a one-piece retainer was used. Either retainer may be used as they are interchangeable. Identical seal rings will be used in either type retainer.

The symbol of the retainers are:

12 Cyl. 2 piece (retainer CA12FB4509B)
(collar CA12FB4510A)
12 Cyl. 1 piece - CA12FB4509A
6-8-10 Cyl. 2 piece (retainer CAFB4509C)
(collar CAFB4510B)
6-8-10 Cyl. 1 piece - CAFB4509A

Single Piece Retainer

There is a light interference fit between the seal ring retainer and the impeller shaft. Heating by oil immersion at 200° F. is necessary. Where the immersion oil heater is set to 400° F. to 420° F., the retainer would only have to be immersed five to ten minutes before application. Be sure all fits are checked for burrs before application of the retainer.

Visually check the impellers and the housing bore for nicks or scratches. Clean up all marks found.

Two-Piece Retainers

Check retainers for burrs, also check for warped condition on a face plate. Be sure the shaft surface is clean before applying the retainer.

Install the inner portion of the retainer, the seal ring, and then the outer part of the retainer. Slight heating by oil immersion will allow the retainer assembly to be properly installed on the shaft.

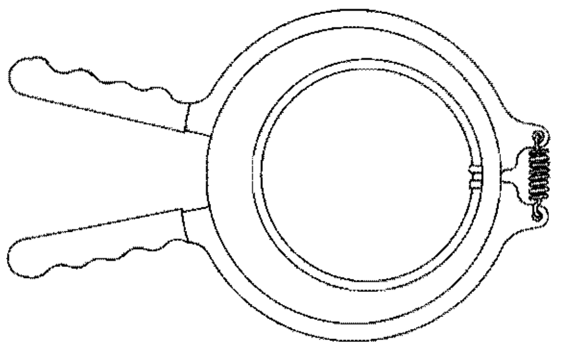
Application of Seal Rings

The retainer seal rings have a definite position in which to be installed. Be sure that the stamped "in" side of the ring is toward the impeller. This ring is sensitive to application inasmuch as if sprung or warped out of shape it will not seal properly. Be sure that the ring is not warped by setting it against a face plate.

When applying the ring in the single piece retainer, slide it into position in the groove of of the retainer with the ring expander, Illus. K15. Check the ring in the groove after application. Be sure the ring is free.

Assembly of the Blower

After all inspections have been made and



Illus. K15. Seal Ring Expander

corrections made where necessary, the blower can be assembled.

Prior to and upon disassembly of the blower all gaskets, shims and locations of bearings, etc. were checked for location and recorded. If the clearances were found correct, the blower clearances should repeat if the overhaul of the blower did not consist of part replacement that could dimensionally change the blower assemblies involved. Where the clearances were found incorrect at disassembly, the correction can be made at assembly, compensating for the amount of error and subtracting or adding shims from the original amount removed.

Application of Inner Bearing Plate

1. If inner plate was removed, install inner bearing plate using two new shim gaskets between bearing plate and housing. Note: Be sure dowels are in place before tightening bearing plate to housing. (This bearing plate is not normally removed from housing at overhaul.)

The blower housing will be resting on the outer side for the application of the inner bearing plate. Install outer race of inner bearings in their proper location in the inner bearing plate bores.

2. Set blower on stands with inner bearing plate down. (Use offset lifting bracket to facilitate handling.) Use care in handling the blower to prevent damage or distorting the housing.

If for any reason the initial clearances of a disassembled blower are not known or the overhaul has involved the blower dimensionally, the following procedure can be followed: Calculation of blower clearances to predetermine the shimming that will be necessary. This will eliminate the trial and error method.

Predetermining Impeller Total End Clearances (6-8-10-12 Cyl. Engine Blowers)

With impellers set in position and the outer bearing plate removed, determine amount of shim gaskets needed for total end clearances. The total end clearance would be the total of the running clearances. (Clearance values are for other than 12 cyl. blowers. Refer to page B3 for 12 cyl. clearances.) The running clearances are .021 minimum to .025 maximum on the outer end and .028 minimum to .032 maximum on the inner end. The total minimum clearance would be .021 plus .028 or .049". The total maximum clearance would be .025 plus .032 or .057". To find the actual clearance on the blower being repaired, measure with a depth micrometer the distance from the top end of the impeller lobes to the outer end of the housing.

Measure in several places and take an average. The answer obtained would be the total end clearance of the blower if the outer bearing plate was installed with no paper shim gaskets used. If this measurement does not fall between .049 and .057", the proper amount of shim gaskets will have to be applied to obtain the proper total clearance. At least one shim gasket must be used. This is a gasket as well as a shim. It is practical to attempt to obtain a total clearance that is as near as possible to .052 which is approximately the difference between .049 minimum and .057 maximum. This clearance will allow working tolerances.

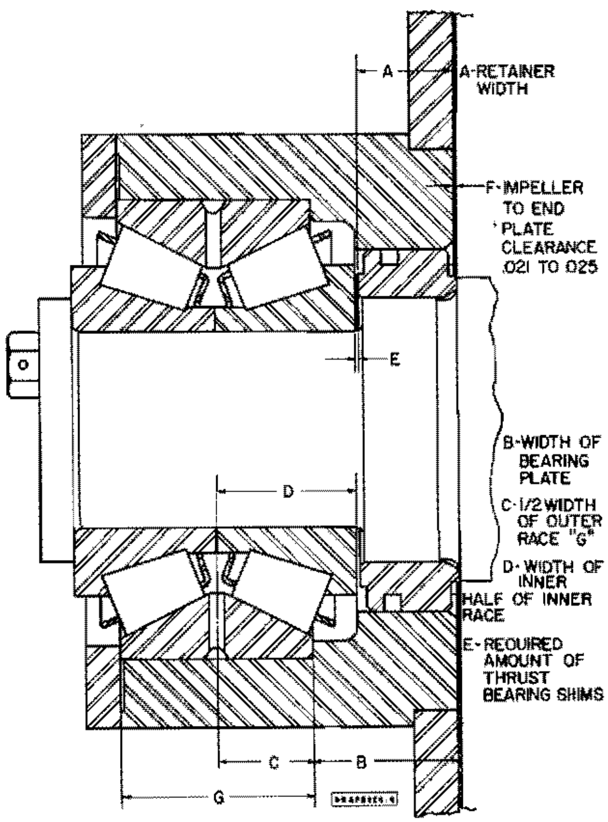
Predetermining Thrust Bearing Shims (6, 8 and 10 Cyl. Engines)

To distribute the total end clearances properly so the running clearances are within the proper tolerance, the thrust bearing must be checked and shimmed for proper positioning of the impellers. On the 12 cylinder blowers, the shimming is done under the flange of the thrust bearing adapter. The effect of the shimming remains the same on all blowers inasmuch as adding shims increases the outer end clearances and decreases the inner end clearances. The end clearances between the impellers and the bearing plate are .021 to .025 outer end and .028 to .032 inner end on other than 12 cylinder blowers.

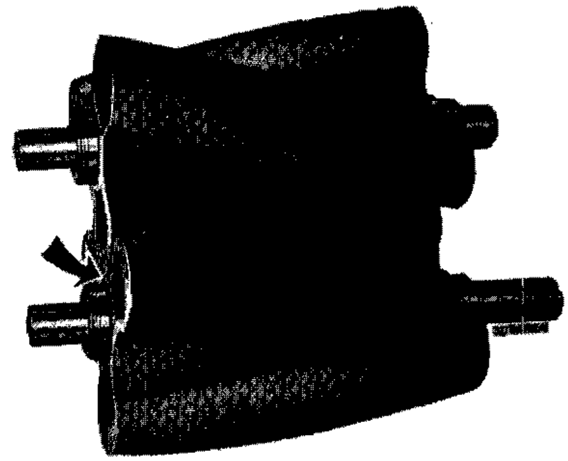
To determine the shimming of the thrust bearing that is required to distribute the total end clearances properly, the following procedure may be followed. On thrust bearing end of the impeller, determine the distance "A," Illus. K16, from the outside of the seal retainer to the impeller using a micrometer. Check around the seal in at least three places to be sure the reading is correct. (Note: Be sure there is no clearance between the seal retainer and the impeller.) Determine width of bearing plate bore "B" from inner side of end plate to bearing seating shoulder. Measure width of outer race and divide in two for "C." Measure width of inner half of the inner race as dimension "D." The actual impeller to end plate clearance "F" is calculated by adding the width of the bearing plate "B" to 1/2 the width of the outer race "C" and subtracting the sum of the retainer to impeller dimension "A" plus the width of the inner half of the inner race "D," (F = B + C - A + D). Thrust bearing shims "E" are determined from the actual end clearance "F." The difference between the actual end clearance "F" and the recommended outer end clearance of .021 to .025 is the amount of thrust bearing shims required.

Example:
Assume the actual end clearance "F" as calculated was .011". The outer end clearance is found by subtracting the calculated value of .011" from the mean value of .021" to .025" or .023". .023" minus .011" equals .012" steel shim required for proper outer end clearance of .023" mean.

From the total end clearance as previously determined which should be between .049" to .057" or a mean of .053" subtract the mean outer end clearance of .023" (.053 - .023 = .030).



Illus. K16. Thrust Bearing Shimming
For other than 12 Cyl. blowers.



Illus. K17. Blower Impellers

The result will be the inner end clearance which should be between .028" and .032" or a mean of .030".

Determining Thrust Bearing Shims
(12 Cyl. Engines)

The 12 cylinder engine blower outer bearing plate is designed so that the steel thrust bearing locating shims can be removed or changed without the removal of the thrust bearings or the bearing plate as on the 6, 8 and 10 cyl. blowers. Predetermining shim thickness is not required on 12 cylinder blowers.

Installation of Impellers

The impellers are ready to be set in the blower housing when the blower housing has been checked for burrs and cleaned and the seal retainers and rings have been installed on the impellers.

Install rings so that stamped mark "In" is toward the impeller. Set ring gap so that when impellers are set in plate in the housing, the gap is away from the mesh of the two impellers. Set impellers in housing so that matchmarks of the impellers coincide, Illus. K17.

Application of the Outer Bearing Plate

Place the proper amount of shim gaskets in place on the housing. Light oil will help to keep the gaskets flat.

Set outer bearing plate in place on housing. Be sure that the gap of the seal rings are away from the mesh of the lobes before setting plate on housing. Also be sure that the oil drain line fitting in bearing plate lines up with the tube fitting while bearing plate is being installed.

Install plate and line up dowels. Then secure end plate to housing.

At this point the total end clearances can be checked thru the suction opening with a feeler gage to assure that all parts are in proper position.

Application of the Thrust Bearings
(6, 8 and 10 Cyl. Engines)

Place proper amount of steel shims as previously used or calculated against retainers on impeller shafts.

Since there is a contact fit between the impeller shaft and the inner thrust bearing race, the inner roller assemblies of the bearing should be heated by immersion to approximately 200° F. to facilitate application. Note: Never heat the thrust bearing outer race. The fit of the inner race to shaft is light contact so moderate heating is sufficient. If the oil in the immersion heater is approximately 400° F., the bearing need only be left submersed about five to ten minutes.

Sectionally install the thrust bearing in place. When applying the outer race, it will be necessary to use a soft mallet or a piece of wood across the race to protect it while tapping it in place. Be sure no foreign particles gets in the bearing during this procedure.

After bearings have been installed, apply bearing retaining ring and secure. Install impeller shaft puller plates and tighten. The puller plates are used instead of the impeller shaft end plates for this process as the strain of tightening required to pull the blower shaft thru the contact fit of the bearing would be great enough to warp the shaft end plate. Be sure that the impeller shaft is pulled all the way in. When the position of the shaft is obtained, check inner and outer clearances of the impellers. If correct, remove puller plates and install shaft end plates and secure. Recheck clearances to be sure the shaft has not moved. Secure all nuts and bolts. Safety wire all capscrews, nuts and dowels using copper wire.

Application of Thrust Bearings
(12 Cyl. Engines)

Place bearing retainers in place in the end plate with .045" to .050" shims under the bolting flange. Secure bearing retainer to end plate.

Since there is a contact fit between the impeller shaft and the inner thrust bearing race, the inner roller assemblies of the bearing should be heated by immersion to approximately 200° F. to facilitate application. Note: Never heat the thrust bearing outer race. The fit of the inner race to shaft is light contact so moderate heating is sufficient. If the oil in the immersion heater is approximately 400° F., the bearing need only be left submersed about five to ten minutes.

Sectionally install the thrust bearing in place. When applying the outer race, it will be necessary to use a soft mallet or a piece of wood across the race to protect it while tapping it in place in the retainer. Be sure no foreign particles gets in the bearing during this procedure.

After bearings have been installed, apply bearing retaining ring and secure. Install impeller shaft end plates and tighten. Be sure that the impeller shaft is pulled all the way in. When the position of the shaft is obtained, check inner and outer clearances of the impellers. Add or subtract shims as necessary to give proper division of end clearances. Caution: These shims are half round. Be sure the same amount is under each side of each adapter bolting flange. It will be necessary to shim each impeller independently of the other.

Secure all nuts and bolts. Safety wire all capscrews, nuts and dowels using copper wire.

Air Test of Blower

It is recommended that the blower be air tested to determine proper application of the seals before the timing gears are secured.

Install covers with gaskets over openings in the blower housing. One cover should be provided with an accurate gage and an air inlet connection and valve.

With covers secured and no cover leakage noted, test blower as follows:

1. Allow air to enter blower until a pressure of 14-15 lbs. is reached on the gage. Do not use a higher pressure.

2. Shut off air and rotate impellers by hand. This should allow the rings to seat. No shocking of the shaft with a brass bar, etc. should be necessary to aid in locating and seating the rings. If the bore is rough, the ring seating can be hindered by not allowing the ring to slide into position. Shocking the ring into position for the air test will only give temporary correction. The seal rings may not remain in the shocked position when the blower is applied to the engine and result in leaky seals.

3. When pressure reaches 10 lbs., start timing bleed off of air thru the bearings. It should not take less than the seconds tabulated to bleed off air from 10 to 4 lbs. It is for this reason that an accurate gage must be used.

Blower	Time - Seconds
6 cyl.	175
8 cyl.	235
10 cyl.	260
12 cyl.	330

NOTE: The test should be run two times to be sure that all errors are eliminated.

4. If bleed off time is less than the seconds specified, it will be necessary to recheck the seal application.

The above test will determine if a seal ring is misapplied, warped or the bores are rough or out of round. The bleed off of air should be equal from all seals. An individual seal showing excessive leak off (noted by feel or sound) can be pointed out as the troublesome seal and correction made accordingly on the particular seal.

Precaution for Reassembly of Blower Gears

1. Heat gears to temperature of 400°-420°. Use oil immersion or oven heat. Never use open induction or flame.

2. Never use impact force on gears, etc. in installation. If the specified heat is used, they should go on easily.

3. Be sure all keys fit properly.

4. Be sure oil supply lines on the blower to the bearings are clean and tight.

5. Be sure all parts have been secured properly.

Installation of Timing Gears

Set blower in upright position for the remainder of the assembly. The top or driven gear is applied first after the following preparation.

1. Check key fit.
2. Check gear teeth for nicks.
3. Heat gear by oil immersion or in oven to approximately 400° for at least twenty minutes.

Install gear on shaft. Installed impeller shaft end plate in place, tighten and secure.

Allow gear to cool or cool by directing air hose on gear until hand can be held on the gear before applying driving gear and hub assembly.

Driving Gear and Flange Assembly

Prepare gear the same as for the driven gear. Check gear to flange for free fit.

Locate driven gear so the "O" matchmark will mesh with the marked driven gear tooth when the keyway engage the key. Caution: Be sure that the flange and gear are heated and applied as an assembly.

The assembly should slip on the shaft easily. Be sure the proper teeth are in mesh when the assembly is being installed. The flange and gear assembly should be heated by immersion or oven to approximately 400° for at least twenty minutes.

As soon as the assembly is in proper position on the shaft, slip spacer tool over the end of the shaft and tighten shaft end plate to hold gear hub in position while cooling.

Remove the shaft spacer after the assembly has cooled.

To determine if timing of impellers is correct, install and secure two fitted bolts in timing flange and secure. Check clearance between impellers as outlined below. If timing was incorrect or new gears were installed, the following procedure is applicable.

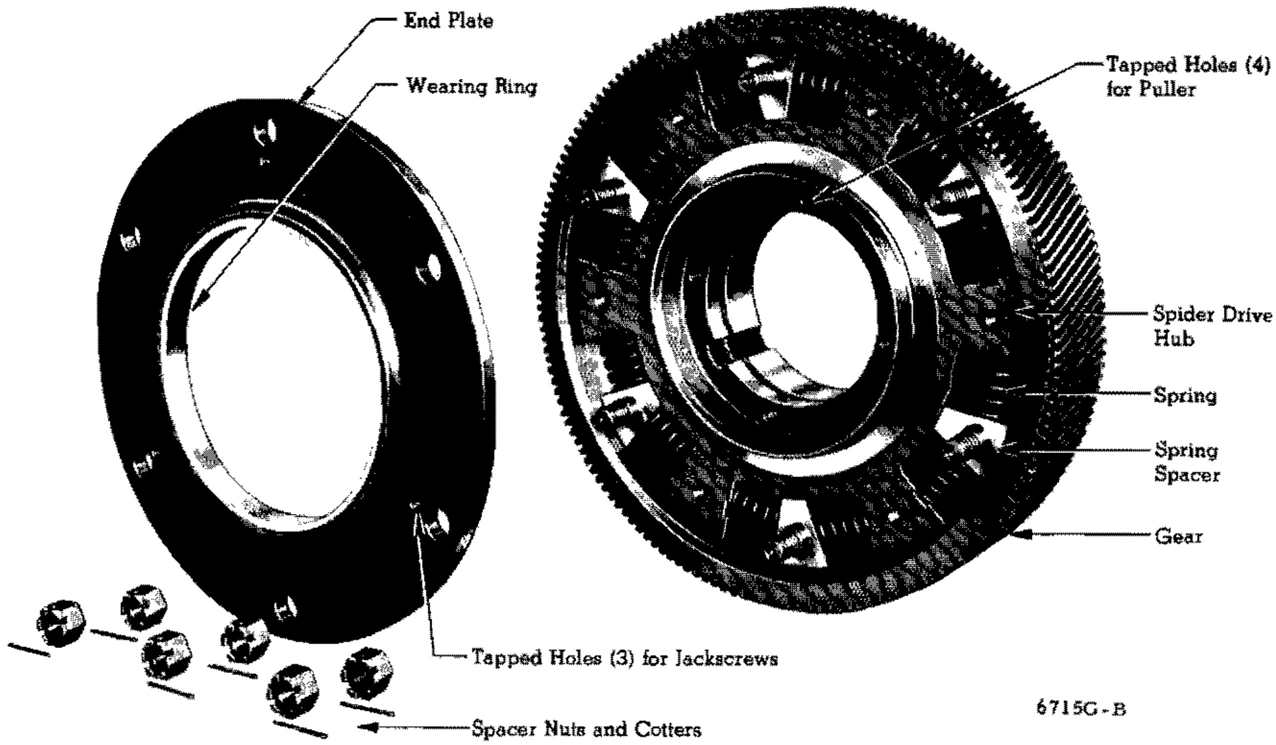
Timing the Impellers

If the timing must be reset, be sure the impeller clearances are equally divided. With the flange loose but in contact with the timing gear (no fitted bolts in place) insert a micarda strip between the impellers. The normal clearance between the impellers should be from .028 to .032 on all 6, 8, 10 and 12 cyl. blowers. It will be necessary to use various thickness micarda strips (.028, .030 and .032) to determine the maximum thickness strip which can be rolled between the impellers.

The thickness measurement of the maximum strip to be rolled thru freely is the clearance between lobes. When the maximum clearance point is found, lock the timing flange to the timing gear. This can be accomplished by using two bolts thru the fitted bolt holes in the flanges. Recheck the lobe clearance to determine the maximum clearance obtained with the timing flanges secured. The timing gear and flange must be reamed for oversize fitted bolts. Replacement bolts as furnished are .040 oversize. The original holes were reamed to .625 + .020 - .005. Recheck clearances after new fitted bolts have been installed.

Blower Drive Gear Pinion Application

Be sure the pinion gear being installed is the mate to the blower drive gear which is applied on the upper crankshaft of the engine to which the blower is to be installed.



Illus. K18. Blower Flexible Drive Gear

1. Check gear for burrs.
2. Check key fit.
3. Heat gear to approximately 400° for twenty minutes.
4. Apply gear.
5. Apply impeller shaft end plate and secure.

Blower Flexible Drive - Description

The blower flexible drive gear is mounted on the end of the upper crankshaft, and is shown in Illus. K18. It consists of a spider drive hub which is keyed to the crankshaft, a gear within which six spring spacers are bolted, with springs between the spacers and spider. The spring drive isolates the torsionals transmitted by the crankshaft. Both the end plate and the gear are equipped with brass wearing rings at their points of contact with the spider hub.

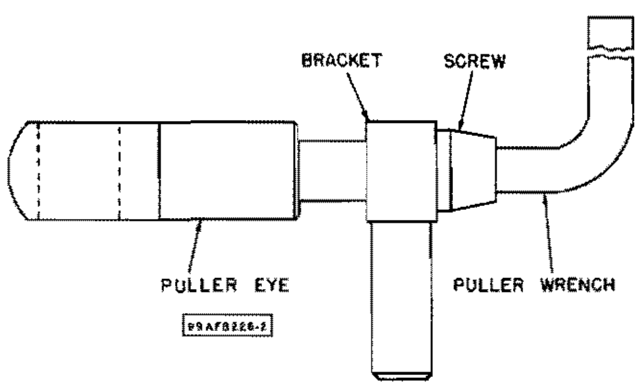
Servicing

The drive gear springs may be inspected without removing the gear from the crankshaft.

To disassemble the flexible drive gear, remove the nuts from the six spring spacers to free the end plate. Force the end plate from its fit in the gear by turning 1/2"-20 jackscrews into the three tapped holes, Illus. K18.

To remove the springs, install the tool, Illus. K19, over the spacer and into the hole in the spider. Tighten the tool to compress the springs on one side. This will free the springs on the other side so they can be removed. Back off the tension with the tool and remove the other sets of springs.

Early engines do not have the holes in the spider and require the following procedure to remove the springs. Force the hub around in one direction to release compression on half the springs, so that they can be lifted out. The hub can be forced by fitting a bolt and high nut between a spacer and the adjacent hub projection, and then turning the nut in the direction to push the hub from the spacer. Two bolts and nuts, at opposite positions, will be required. The bolts and nuts will act as jackscrews. When half the springs have been removed in this way, reverse the direction in which the hub is forced,



Illus. K19. Drive Spring Tool

and lift out the remaining springs.

The hub, and the spring spacers if necessary, can then be removed from the gear. The wearing rings can be removed and replaced if necessary.

Before reassembling parts, be sure that the oil holes in the hub are open. The parts should be clean and dry.

The flexible drive gear is assembled as follows: Replace the spring spacers and secure in place with the nuts on the back side. Drop the drive hub in place. Replace every other spring (each spring will be on same side of its adjacent spacer). On later engines, use the tool to force the hub around in one direction to compress the six springs already replaced to provide clearance for the remaining springs. On early engines, the hub can be forced by fitting a bolt and high nut between a spacer and hub projection, and using the bolt and nut as a jack against the spring compression. Use two bolts and nuts at opposite sides. In order to replace the remaining springs they must be compressed to their solid length by using a heavy "C" clamp. Then replace the end plate, nuts and cotters. Tighten the nuts to the torque value given in Chapter B.

To remove the drive gear, first remove the crankshaft end plate, which is held on by studs. Then, with the puller, remove the complete gear assembly as shown in Illus. K20.

To replace the blower flexible drive gear on the crankshaft, heat the assembly slowly in oil or in an electric furnace to about 320° F. temperature of the heating medium. Install the assembly to seat on the crankshaft, replace end plate and cool the assembly slowly with compressed air starting from the drive hub.

The blower flexible drive gear and the drive pinion are lapped together and furnished in sets.

Application of Blower to the Engine

The following points should be checked before attempting to install the blower:

1. Be sure the upper crankshaft has been applied and all main bearings and thrust bearing have been installed.

2. Be sure the contact surface on both blower and engine block have been cleaned.

3. Be sure the gear teeth are clean and free of burrs.

4. Be sure the proper block to blower gasket has been supplied. This is a .010 gasket. If a thicker gasket were used, the compression of the gasket during operation would reduce the blower drive to pinion clearance and gear trouble can be expected.

5. Be sure the blower drive and pinion gear are a matched set.

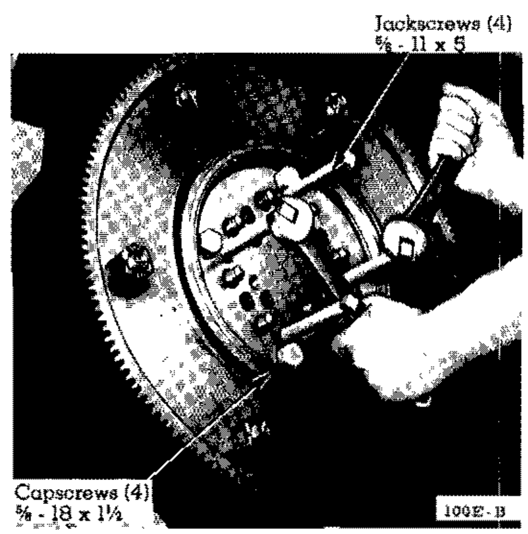
6. Be sure that the blower clearances are correct. When applying the blower to the block hold gasket in place on the blower with grease. Do not use Permatex or any other sealing compound.

Lift the blower by means of lifting eyebolts screwed into top of blower inlet opening bolting ring. One eyebolt on each side of ring. Be sure that the blower is level from side to side when lifted for application.

Lift blower in place on block. Be careful that the blower drive gear and pinion are not damaged when the blower is being guided to its place on the block. If the blower was previously used on an engine, the dowel holes will be reamed but may not necessarily be correct for the proper pinion and drive gear clearances. The blower may be positioned (while still hanging by the crane) so that one of the dowel holes line up and the dowel driven in place. The blower can then be lowered or raised until the proper backlash is reached and then the other hole rereamed and doweled if necessary.

> NOTE: Be sure the blower is tightened to the block in three places (top, center and bottom) on both sides before checking backlash. The backlash will change after tightening if the blower is not tightened properly when checked.

If a new blower is being applied, center the blower over the holes to be doweled as closely as possible and secure in place. Ream one dowel hole and install the dowel. Shift the blower for proper backlash. Ream the other



Illus. K20. Blower Drive Gear Puller

dowel and secure the blower to the cylinder block.

Replace the other parts in the reverse of the order of their removal. Be sure the oil supply piping is properly connected.

CHECKING BACKLASH

The blower pinion and drive gear backlash can be checked thru the top cover inspection cover if necessary. It is not necessary to remove the top cover to make the check but the check can be made readily when the cover is removed.

When installing a new flexible drive gear, the proper backlash must be maintained. Refer to Chapter B. This is determined by reassembling the blower with the original cylinder block dowels in place, then making the following check:

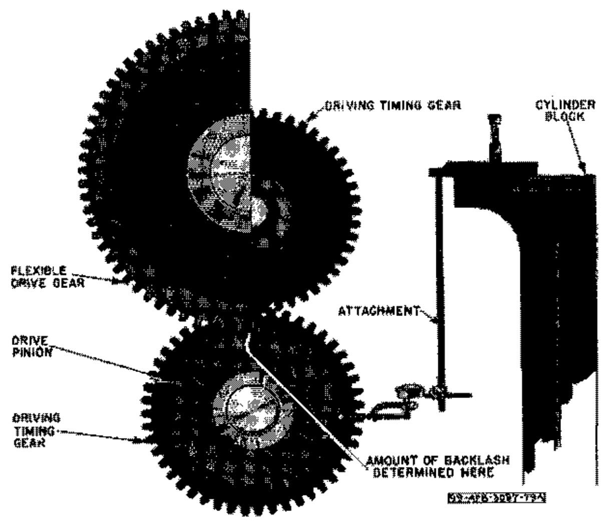
NOTE: Clamp the flexible drive gear solid so that a true reading will be obtained.

As shown in Illus. K21, when the top cover has been removed the indicator, attached to a surface gage block, may be clamped to the top flange of one side of the cylinder block. (When the backlash check is made thru the top cover inspection cover, it will be necessary to hold the gage block and indicator in position by hand instead of clamping.) Set the indicator attachment so that the ball point is in contact with a tooth of the blower drive pinion, or lower timing gear, and also so that the dial can be easily read. (Be sure the arrangement is at right angles so that an accurate reading will be obtained.)

From the other side of the engine, pull lightly on the driven timing gear until the teeth of the drive pinion are tight against the drive gear teeth. Set the indicator dial to zero.

Then push lightly on the driven timing gear until the pinion teeth are stopped by the drive gear teeth. The existing backlash will then be registered on the indicator.

If the required amount of backlash is not indicated, the blower must be reset with respect to the cylinder block to meet the requirements. This can usually be done by removing either dowel; then, raise or lower the blower (blower will be turning on dowel left in place) to meet backlash requirement. Then use an oversize dowel to relocate the blower to the block.



Illus. K21. Blower Drive Gear and Pinion - Backlash Check

CHAPTER L. FUEL SYSTEM

FUEL SUPPLY SYSTEM

Fuel Specification

Refer to Maintenance Bulletin "Diesel Fuel Oil Specification", Sec. 216A for the manufacturers recommendations.

Description

The fuel system consists of the supply, injection and drain systems. The supply system includes the oil tank, fuel pump, built-in supply pump (on early switcher engines), filters, emergency shutdown valve, gages and the necessary piping and fittings. The fuel supply pump (if used) is mounted on the exhaust end of the engine and is gear driven from the lower crankshaft. The motor driven pump is used for obtaining pressure in the supply system. Later engines use a motor driven fuel pump in place of the built-in fuel pump. Refer to Maintenance Bulletin "Fuel System," Sec. 216.

Operation

The pump draws fuel from the tank, thru a strainer and filters to the engine inlet. A pressure of 15 psi is built up and maintained in the fuel header. The relief valve maintains the pressure, allowing the fuel not used by the injection pumps to return to the tank.

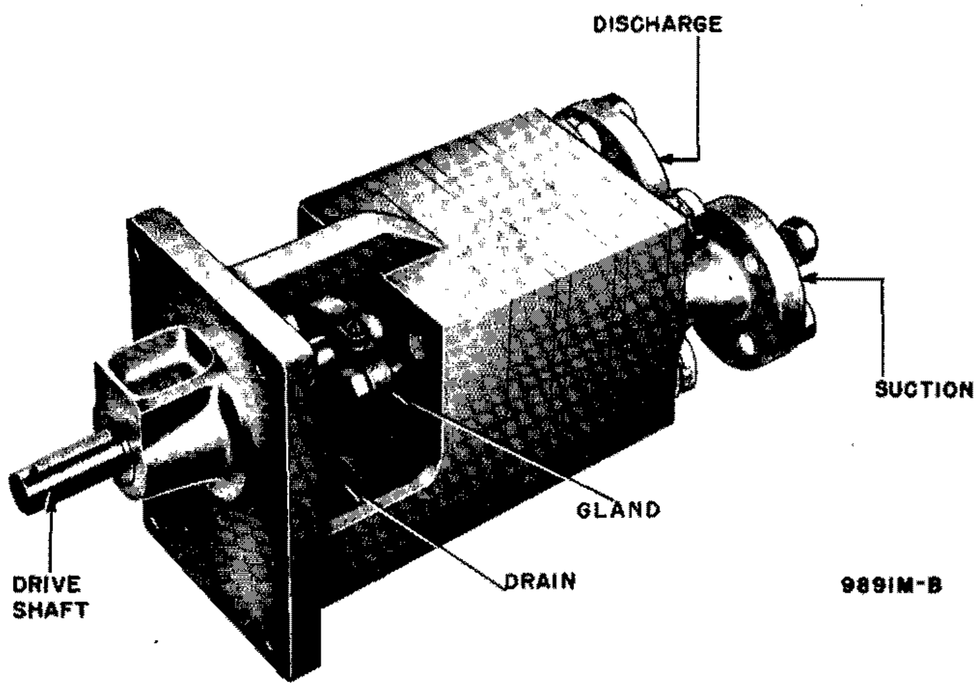
A by-pass relief valve is provided in the piping between the pump and the filter to protect the system in case of excessive clogging of the filter. Oil passing thru this relief valve is piped back to the fuel tank.

The fuel supply system should be checked for leakage after any parts have been replaced by running the fuel pump under normal pressure.

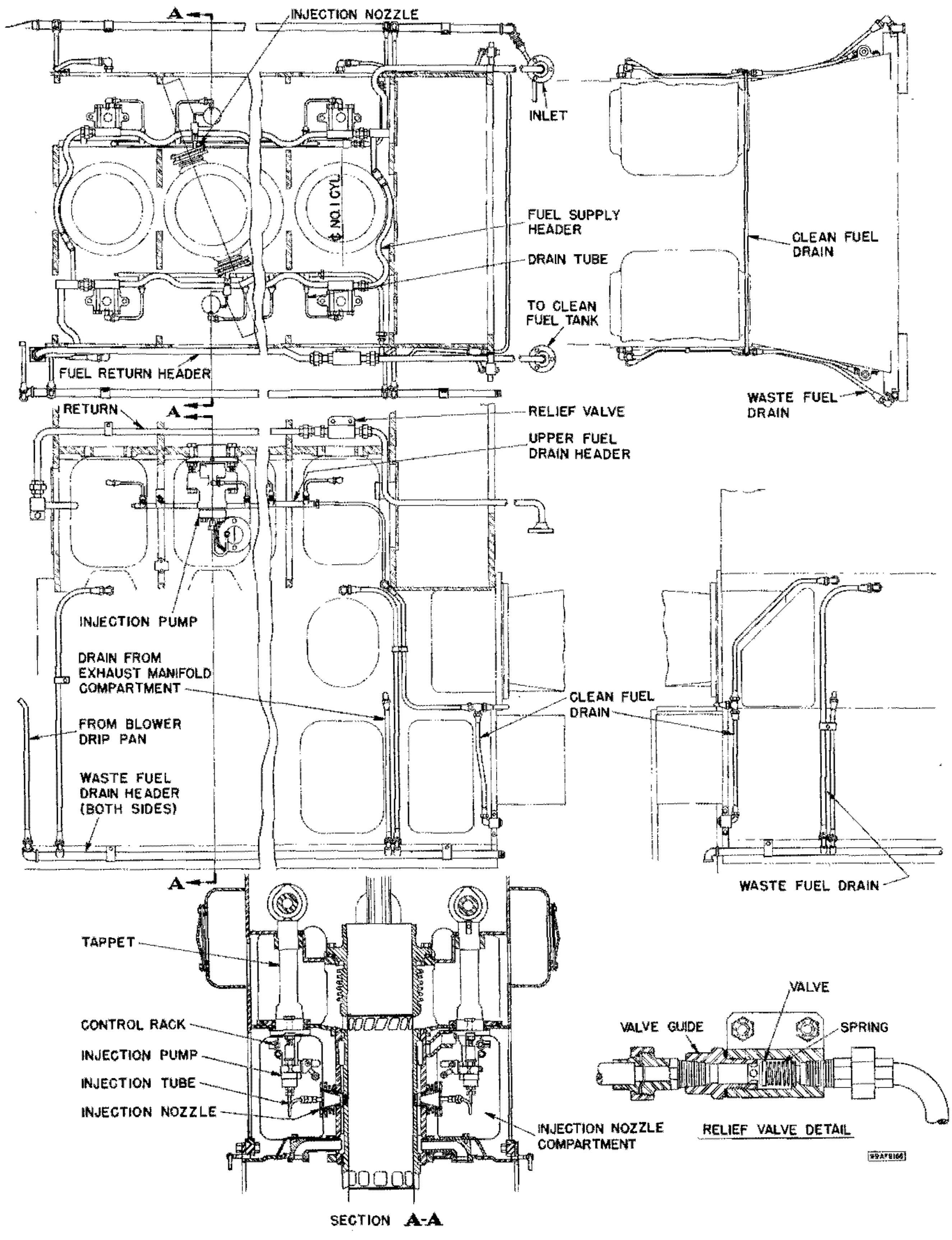
FUEL SUPPLY PUMP
(Engine Attached - Early Hood Type Locomotives)

The fuel oil supply pump, Illus. L1, is a positive displacement gear type pump. It will require no other attention than an occasional inspection. The packing gland should be tightened or packing replaced as found necessary.

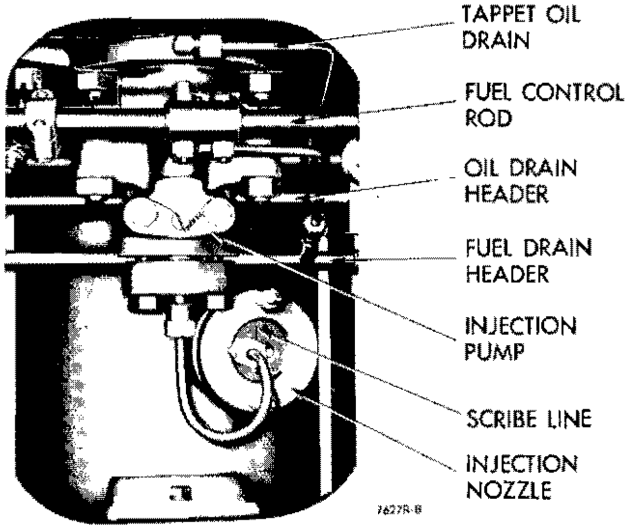
It is very important when installing packing that the rings are cut to the exact lengths. The joints should be alternated so that they do not come in line with each other. Leakage should be permitted thru the gland after the packing is first installed. The gland should be tightened in small increments while the engine is running, with several minutes between tightenings, in order to permit the packing to adjust itself to the shaft gradually. Use asbestos braided packing 5/16" thick, 3/4" inside diameter, 1-3/8" outside diameter.



Illus. L1. Fuel Oil Pump (Used on Early Hood Type Locomotive Engines)



Illus. L2. Fuel Injection and Drain System



Illus. L3. Injection Nozzle Compartment (Pintle Nozzle)

When the capacity of the pump drops off after an extended period of operation, the cause is most likely due to wear in the bearings, liner plates or pump gears. These can be replaced by using the following routine:

Disconnect pump from the engine and system. Remove the end plate, gasket, drive shaft nut, thrust washer, bearing plate and liner plate.

From the mounting bracket end, loosen the setscrew, and remove the gear and the gear key. Also remove the flinger, the packing gland, and the packing. The cylinder with shafts and gears can then be removed.

Mark the shafts to show gear positions. Take off the old gears and press on new ones to the marked positions.

Remove the sleeve bearings from the inner and outer bearing plates, and install new ones. In assembling, install with the oil groove in the bearing toward the pressure side of the pump.

Reassemble the pump in reverse of the disassembly procedure.

Data on the fuel supply pump will be found in Chapter B.

FUEL INJECTION SYSTEM

The fuel injection system consists of the injection pumps, nozzles and the connecting tubes. The pumps and nozzles are enclosed in the injection nozzle compartment and are located symmetrically with one pump and nozzle on each side of every cylinder.

Each injection pump receives fuel oil from the supply system at a fuel port. A measured quantity of fuel is delivered thru the injection tube to the nozzle. The injection pump control rod actuates the control racks of the pumps to regulate the amount of fuel to be delivered which is according to the governor requirements.

The fuel control rods on each side of the engine are connected by linkage to the governor at the exhaust end of the engine. The travel of the control rod in the full fuel direction is limited so that the engine cannot be overloaded. A stop screw with locknut is installed by the engine manufacturer on the cylinder block to stop the fuel control arm which connects the fuel control rods. The fuel control racks of the injection pumps regulate the amount of fuel delivered by the pumps to the nozzles. The excess fuel is returned to the supply header.

The injection pumps are operated thru tappet assemblies by individual cams on the camshafts. The two camshafts, located in the upper crankshaft compartment on each side of the cylinder block, are driven by a chain from the upper crankshaft at the exhaust end of the engine.

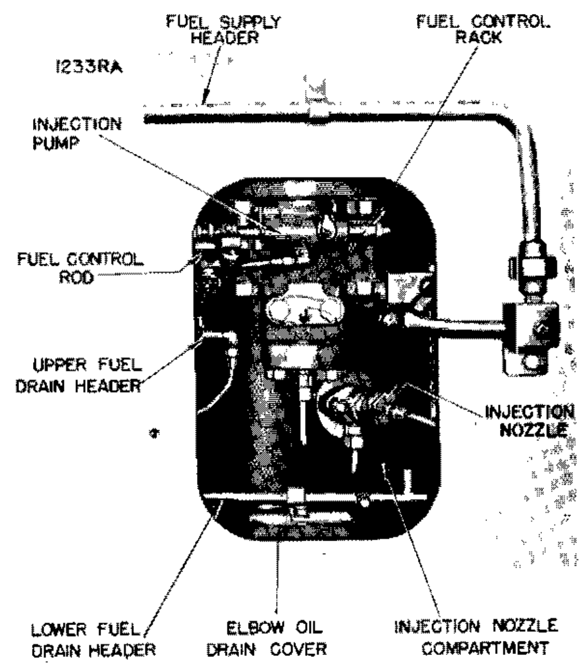
FUEL DRAIN SYSTEM

The fuel drain system, Illus. L2, has two functions:

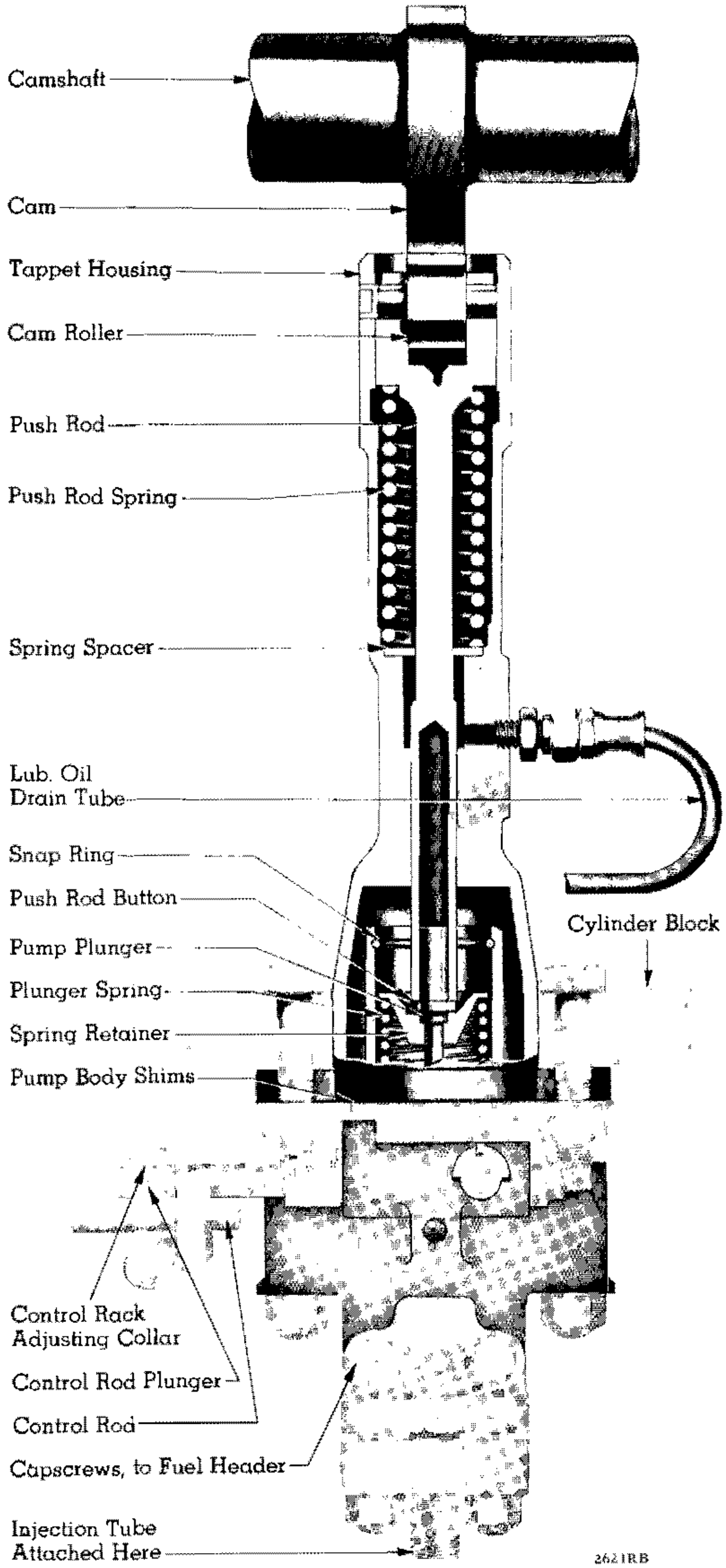
To return any clean unused fuel oil back to the fuel tank.

To collect any dirty fuel oil from the injection nozzle and exhaust manifold compartments on each side of the engine and conduct it to the waste fuel drains at the exhaust end.

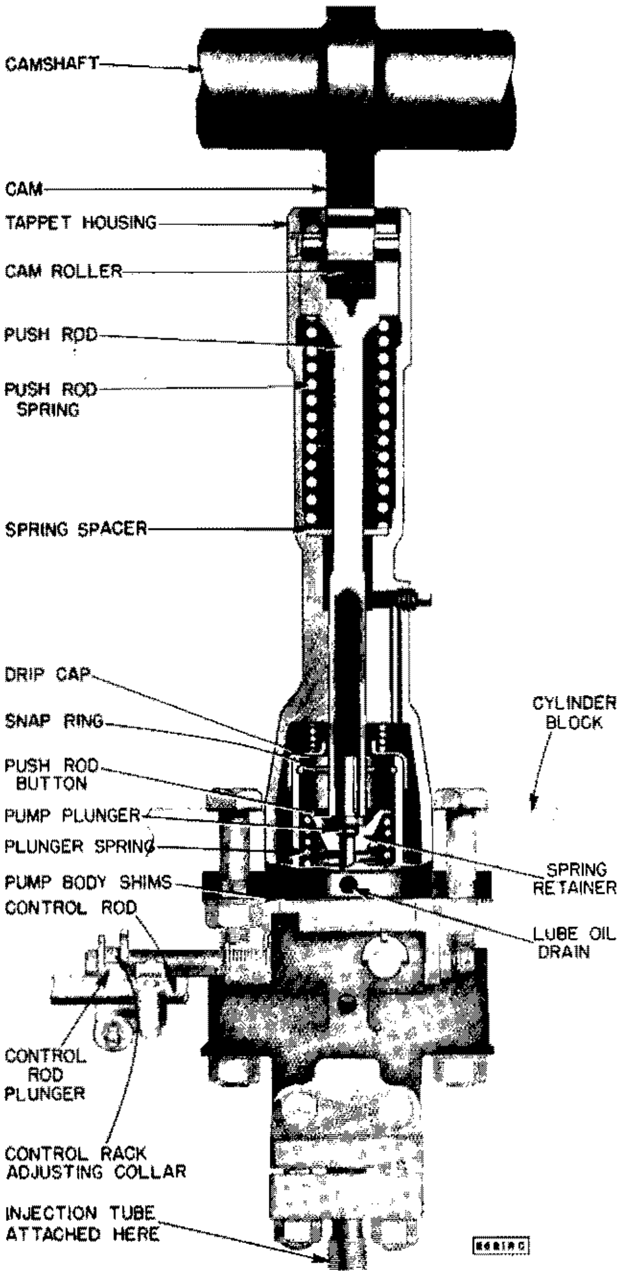
A fuel drain header is located in the injection nozzle compartment, Illus. L3, on each side of the engine. Fuel oil from the injection



Illus. L4. Injection Nozzle Compartment (F.M. & Co. Nozzle)



Illus. L5. Tappet Assembly (Drain Tube in Air Receiver)



Illus. L6. Tappet Assembly (External Drain Type)

pump drains into the upper drain header. Early engines with F. M. & Co. nozzles have an upper and lower fuel drain header. Fuel oil from the injection pump drains into the upper header. Leakage oil from the injection nozzles is piped to the lower drain header, Illus. 4.

The headers are interconnected and piped to the fuel tank.

INJECTION PUMP

Description

The injection pump plunger moves vertically in the pump barrel, delivering fuel thru the discharge valve and injection tube to the injection nozzle and into the combustion space. The injection pumps receive fuel from the engine header and deliver the fuel under a high pressure to the nozzles.

Each pump consists of a tappet assembly and a pump assembly, as shown in Illus. L5 or L6 and L7.

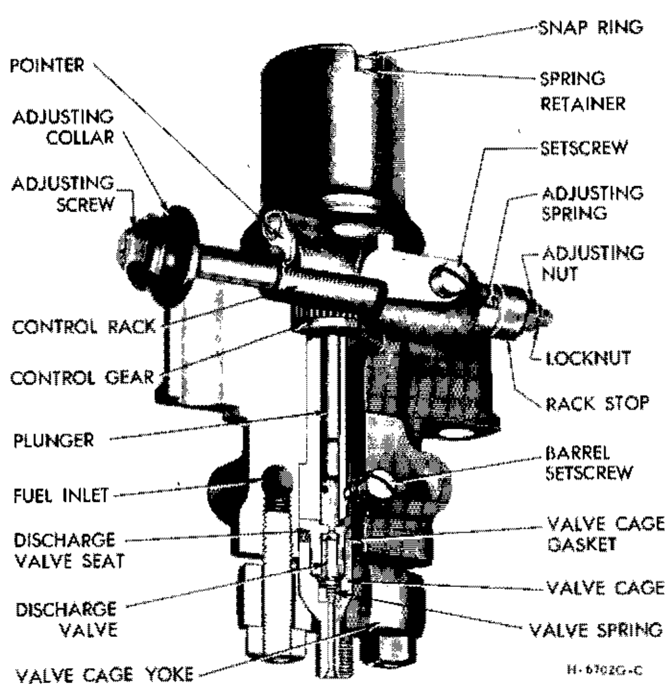
The tappet assembly transforms the rotary motion of the camshaft into reciprocating motion, and transmits this reciprocating motion to the pump proper. In the tappet assembly, the push rod spring holds the plunger cam roller against the cam, so that the plunger will follow the rise and fall of the cam.

In the pump assembly, the plunger spring acts thru its retainer to cause the pump plunger to follow the rise and fall of the push rod in the tappet assembly, Illus. L6 and L7.

Operation

The plunger stroke is constant, therefore, the space in the barrel under the plunger always admits an equal amount of fuel from the supply system. The amount of fuel delivered to the nozzle depends on the position of the helix on the plunger relative to the port in the pump barrel.

When the plunger is in its highest position, Illus. L8, the fuel port is uncovered and the pump barrel fills with fuel. The port is covered



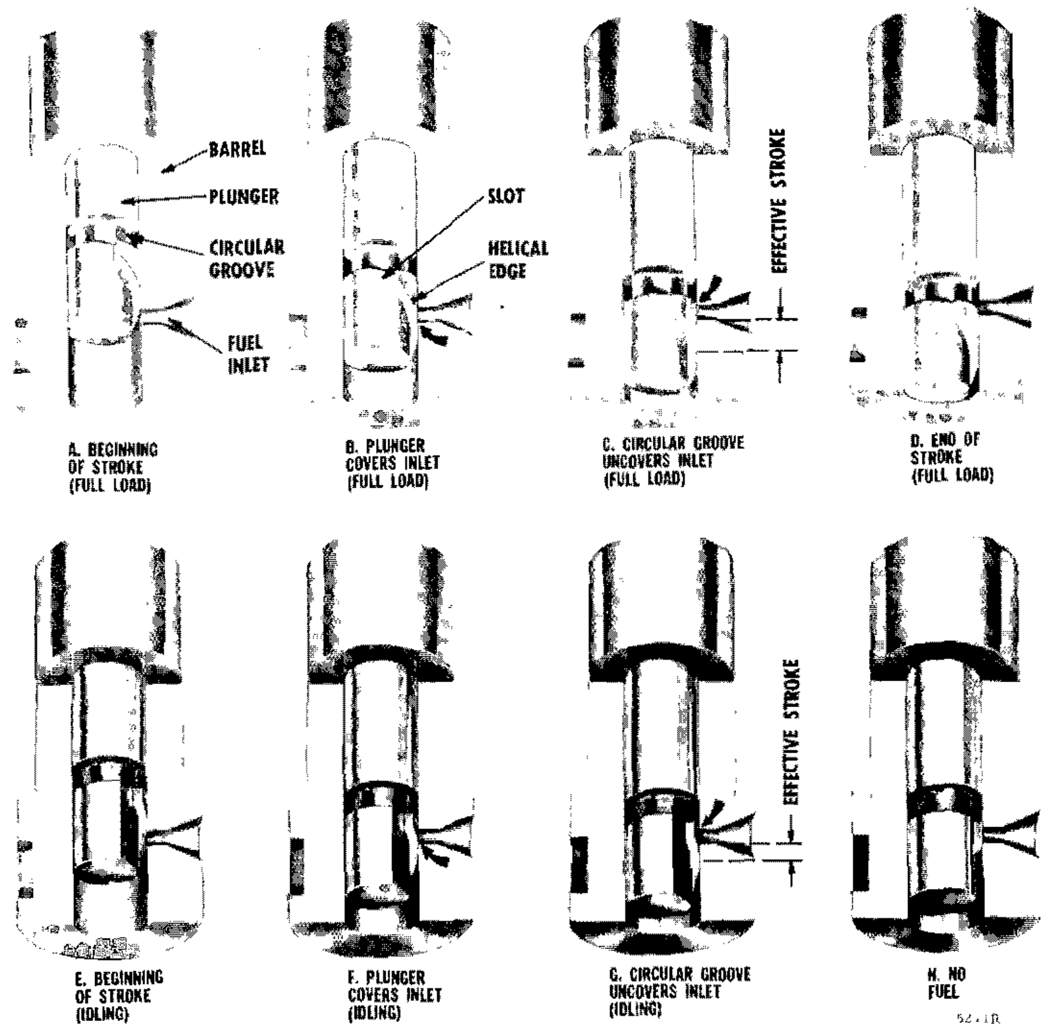
Illus. L7. Injection Pump Assembly

on the down stroke by the helix, and fuel is delivered to the nozzle until the recessed circular groove on the plunger uncovers the port.

Note from Illus. L8, that about a 1/4 turn changes the plunger position so that the effective stroke varies from "full load" to "no fuel" position. The effective stroke is that part of the plunger stroke during which the port is covered by the helix and fuel is injected.

When the plunger is in "stop" or "no fuel" position, the slot keeps the port uncovered during the entire stroke, thus by-passing all the fuel. In this position the effective stroke (measured fuel) is "O" and the by-pass stroke is maximum.

With the plunger turned so that the long end of the helical edge exactly coincides with the fuel inlet, the amount of fuel delivered is maximum. At "full load" the effective stroke, Illus. L8, is only a portion of the maximum stroke.

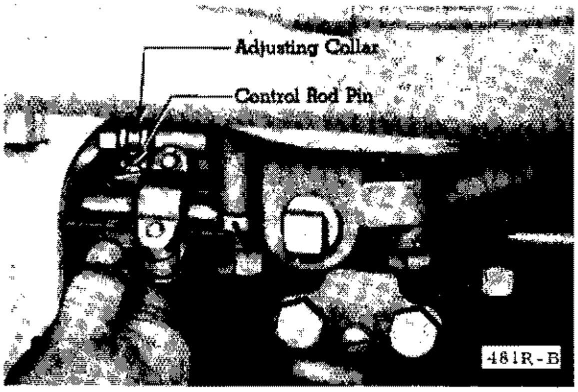


Views A, B, C, and D show the plunger in various stages of its stroke for "Full Load" position. Views E, F, and G show the plunger in "Idling" position. View H shows the plunger in "No Fuel" position.

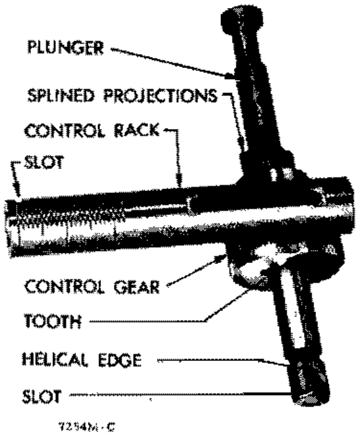
Injection begins when the plunger has fully covered the fuel inlet, as in views B and F. Injection ends when the circular groove begins to uncover the fuel inlet, as in views C and G. The arrows in views B and C indicate points at which the fuel port is covered and uncovered.

When the plunger is in the "No Fuel" position (View H) the slot keeps the port uncovered during the entire stroke, by-passing all the fuel.

Illus. L8. Approximate Fuel Injection Pump Plunger Positions



Illus. L9. Engaging Control Rod Pin



Illus. L11. Control Rack and Gear

An accurate check of the load balance can be obtained by inspecting the position of the injection pump control racks. On later engines with Woodward Type PG governors all the pumps on the engine should check at rack 8 when a 3/8 dimension is shown between the governor body and power piston. Refer to Table 1, Page L23, for settings of early engines. The pumps are calibrated so that each pump at the same rack setting delivers the same amount of fuel.

Priming and Cutout

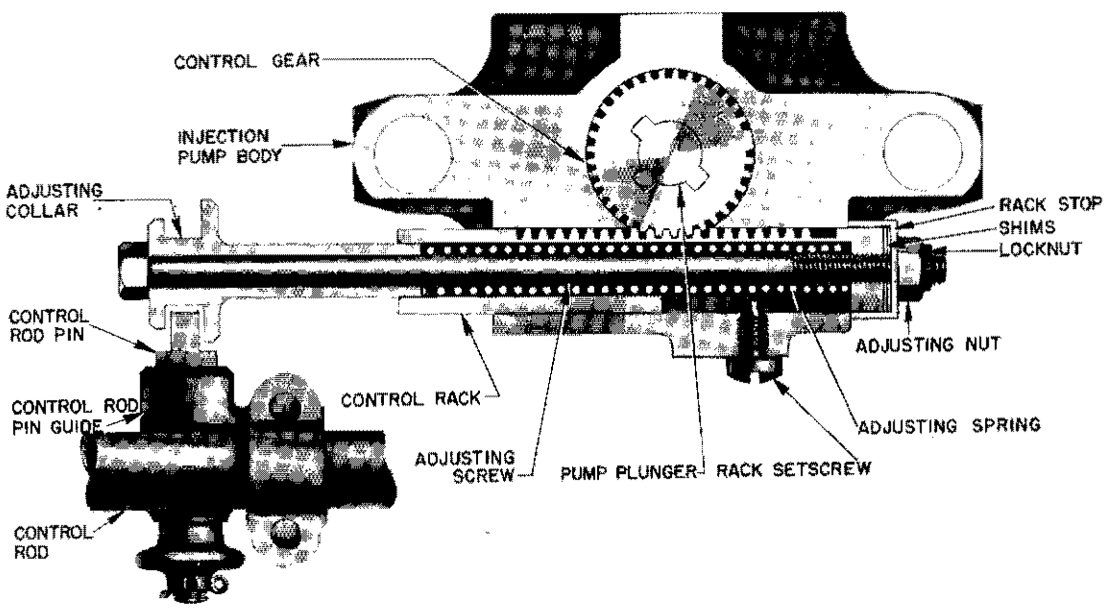
Any injection pump may be cut out or made inoperative by pulling the control rod pin, Illus. L9, out of the control rack adjusting collar, and moving the adjusting collar to the right ("O" rack) so that the plunger and collar will no longer be engaged.

CAUTION: THE GOVERNOR SHOULD NEVER BE DISCONNECTED FROM THE FUEL CONTROL LINKAGE WHILE THE ENGINE IS RUNNING NOR SHOULD THE ENGINE BE STARTED WITH THE LINKAGE DISCONNECTED. BEFORE STARTING THE ENGINE AFTER AN OVERHAUL OR WORKING ON THE INJECTION SYSTEM, CHECK THE ENGAGEMENT OF THE CONTROL ROD PINS AND LINKAGE TO THE GOVERNOR, Illus. **L10.**

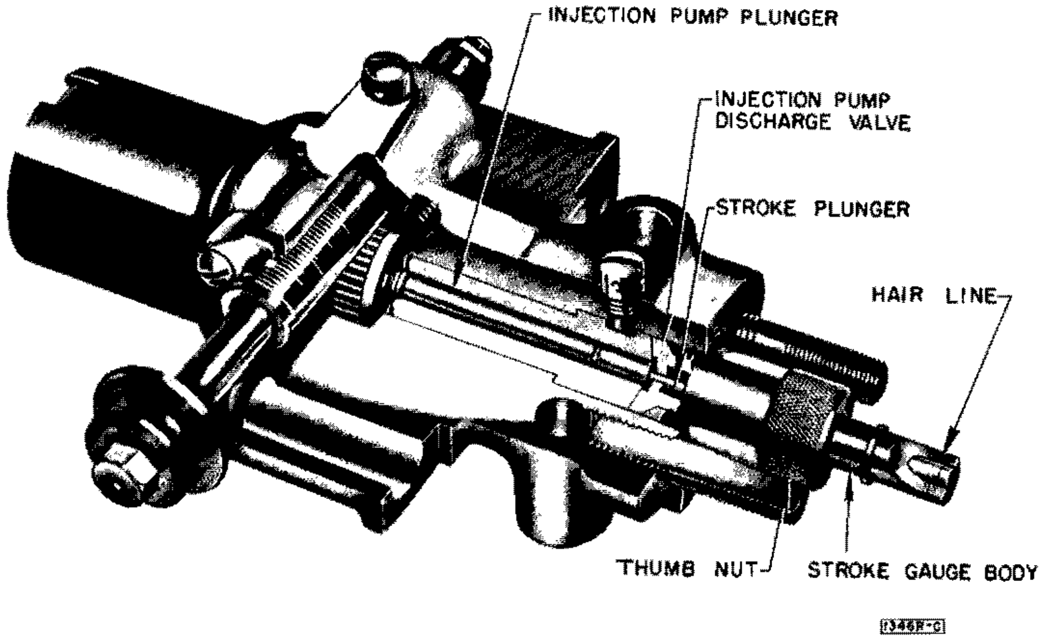
The injection pumps and nozzles are self-priming when replaced on the engine and connected to the fuel system. The motor driven fuel supply pump on later engines can be operated to fill the system.

Adjustment of Parts

The injection pump plunger, as previously explained, follows the rise and fall of the push



Illus. L10. Injection Pump Control



Illus. L12. Injection Pump Stroke Gage

rod in the separate tappet assembly. Correct timing of the beginning of injection depends upon when the helix on the plunger closes the fuel port. The amount of fuel injected depends upon the length of the plunger effective stroke . . . that part of the stroke between the closing and reopening of the fuel port by the helix. The effective stroke cannot be adjusted.

The correct vertical positioning the pump barrel in respect to the pump plunger is necessary to obtain the proper timing and assures the plunger being in the proper relation to the port. Shims are used between the pump body and the tappet assembly.

Part Replacement

The injection pump is a precision built assembly designed to give long trouble-free service. The manufacturer recommends that the injection pump be returned to the factory for proper servicing, setting and calibrating by persons specially trained in handling the precision parts. Contact the Locomotive Service Department.

Pump calibration is done so that all pumps on the engine deliver identical amounts of fuel at the same rack setting.

> CAUTION: THE CONTROL RACK POINTER SHOULD NOT BE REMOVED DUE TO DANGER OF LOSING THE ADJUSTING SHIMS. LOSS OF ANY OF THESE SHIMS WILL CHANGE THE CALIBRATION OF THE PUMP AND CAUSE OVER OR UNDER LOADING OF THE CYLINDER. IF THIS POINTER IS ACCIDENTALLY REMOVED AND THE ORIGINAL THICKNESS OF SHIMS WAS NOT RECORDED SO THAT THE SAME THICKNESS CAN BE DUPLICATED, THE PUMP SHOULD BE RETURNED TO THE FACTORY AND RECALIBRATED.

Injection Pump Difficulties

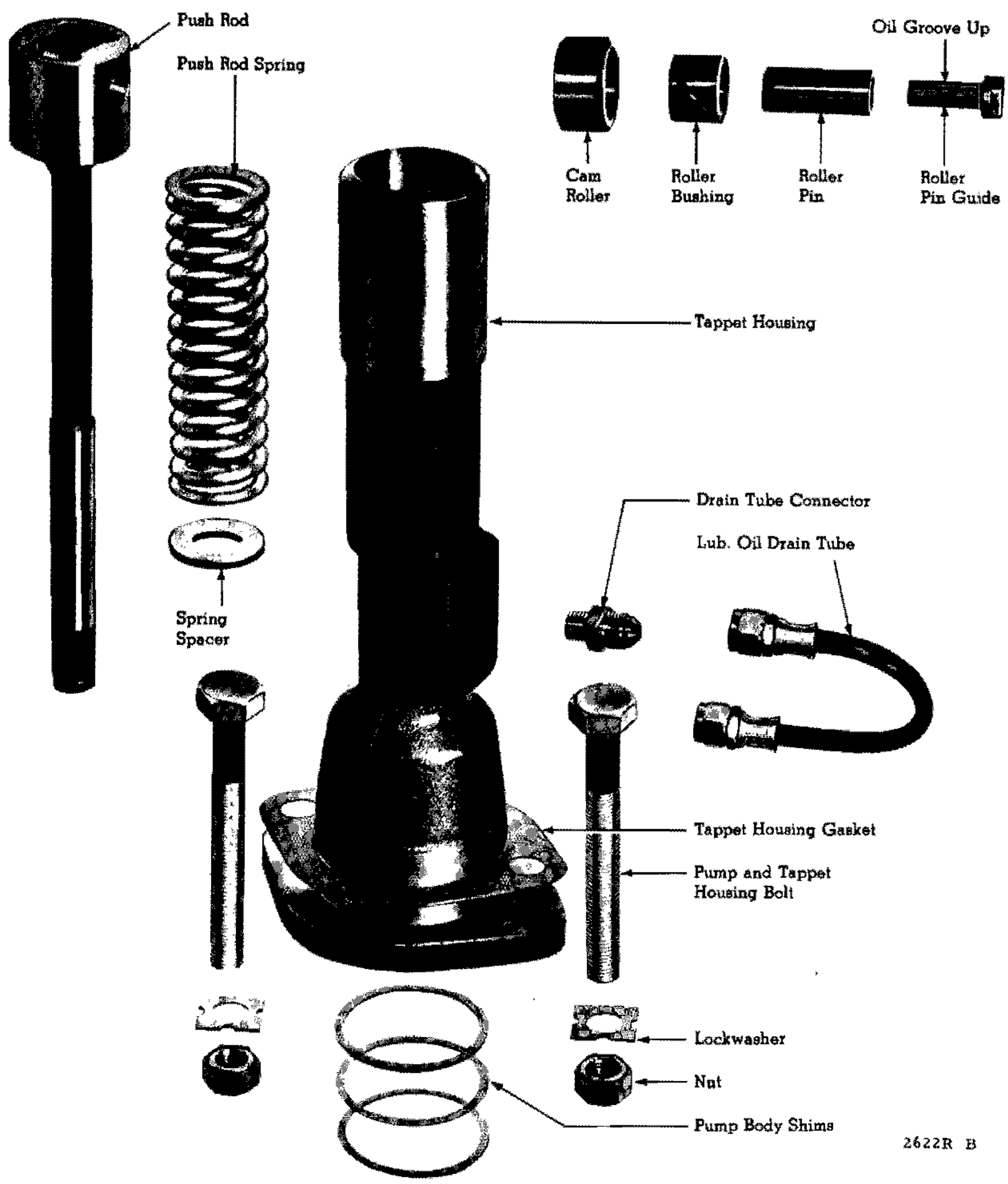
Fuel injection difficulties may develop from various causes, some of which may be traced to the injection pumps.

The operator can tell if a pump is discharging fuel by feeling the injection tube. If the pump is not delivering fuel, the cause is probably due to a misplaced gasket over the fuel port or to a stuck plunger. Water and foreign matter in the fuel will cause the plungers to stick.

Removal of Injection Pump from Engine

To remove the pump body, first disconnect the injection tube and the tube leading to the upper drain header. Then take out the capscrews holding the body to the fuel supply header. Pull the control rod pin out of engagement with the injection pump rack adjusting collar. Move the control rack toward the pump as far as possible to place it is "no fuel" position. Rotate the camshaft until the tappet cam roller, Illus. L5, is on low cam so as to relieve the spring pressure. Take off the nuts which hold the injection pump body to the tappet housing. The pump body will then be free to be removed downward from the engine. Be careful not to lose the pump body shims.

As previously stated, the fuel injection pumps should be returned to the manufacturer for part replacement.



Illus. L13. Injection Pump Tappet - Disassembled (Internal Drain Type)

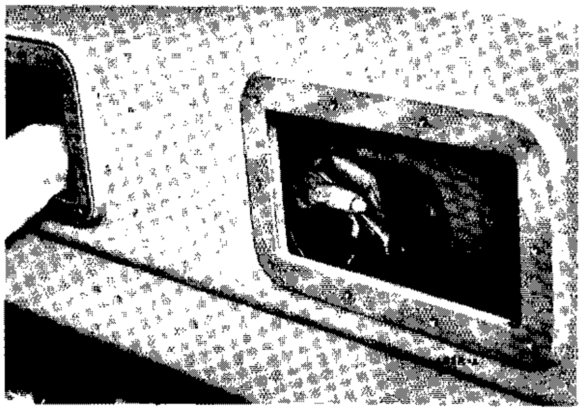
TAPPET ASSEMBLY

Removal

To remove the tappet assembly, Illus. L5 or L6, first bar the engine so that the cam adjacent to the tappet being removed is on low cam. Remove the injection pump.

Disconnect the external lubricating oil drain tube from the tappet housing, Illus. L3, or remove the internal drain tube and connector tube connector by reaching thru the air receiver inspection openings, Illus. L14.

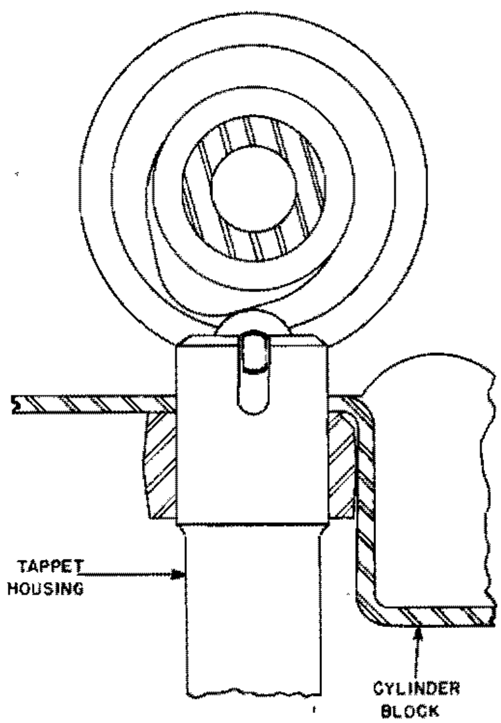
Remove one of the bolt nuts holding the tappet to the block. Loosen the other nut slowly. This will remove the remaining spring tension



Illus. L14. Disconnecting Tappet Oil Drain Tube

in the tappet. Be sure the spring tension is entirely removed before removing the nut.

Next, lower and withdraw the tappet housing from the engine while holding one hand against the fuel header so that the tappet housing base flange clears the fuel header. Should the tappet housing stick in the cylinder block bore reach thru the air receiver opening with a bar and tap the housing out. If the base flange will not clear the header by using this method, it will be necessary to remove the adjacent fuel header section. This can be done by taking out two capscrews in the first fuel header junction to the left of the tappet housing being removed



Illus. L15. Positioning Camshaft

and also the capscrews at the junction to the right of the housing; also remove the necessary header to pump capscrews. The section of fuel header can then be removed from the engine being careful not to lose the gaskets. In some instances enough additional clearance can be obtained by disconnecting the fuel header at one junction and holding it aside while lowering the tappet housing.

The roller assembly, push rod, spring and spacer are then removed as an assembly out of the tappet housing.

Disassemble and wash parts in non-inflammable solvent and dry. Inspect spring for cracks and roller and bushing for wear. Use new parts if necessary.

Dip all parts except the housing in lubricating oil. Replace spring spacer, spring and push rod in the housing. Put the roller bushing and cam roller in position. Insert roller pin and roller pin guide with the oil groove up as shown on Illus. L13.

Replacing

To replace the tappet assembly in the cylinder block, insert the assembly, roller end up, thru the hole in the block. The camshaft should be positioned so that the cam is near but not completely to high cam as shown, Illus. L15.

On engines previous to No. 968046, the lube oil drain tube opening at the side of the housing must be to the side leading to the nearest drain header connection.

Raise the tappet assembly up so that the nuts can be started. Use a pry lever to complete the lift of the tappet assembly into place in the cylinder block. Be sure no binding exists in the housing to block fit when prying the assembly into place. Move the pry lever up and down with short strokes so that free movement of the tappet assembly can be felt. This also permits the spring loaded tappet roller to locate itself in relation to the camshaft.

NOTE: The pry lever can be made up from bar stock or wood and should be installed as shown in Illus. L16.

The roller guide pin must be free in the tappet housing slot and lined up so that a clearance exists between the sides of the head of the guide pin and the slot in the housing. The clearance need not be equal on both sides but must be parallel. The guide pin will be free to move when the roller is correctly aligned to the camshaft.

Bar the engine so that the camshaft makes a full revolution. The roller must follow the cam with full contact and the guide pin must be free and not contact the sides of the housing slot during the rise and fall of the roller.

If these conditions are not met, loosen the nuts and shift the tappet assembly. Retighten the nuts and repeat the procedure until the conditions are as outlined above. Refer to Chapter B for torque limit.

REPLACING THE INJECTION PUMPS

Be sure the tappet cam roller is on low cam so as to remove the spring pressure.

Replace the shims that were taken from the injection pump body and assemble the pump to the tappet housing. Tighten the nuts evenly to the torque limits given in Chapter B.

Checking the pump vertical position is done with the aid of the injection pump stroke gage.

To use this gage, remove the injection tube and the pump discharge valve cage yoke, cage, valve and spring. Leave the valve seat and the cage gasket in place, Illus. L7.

Insert the plunger, Illus. L12, thru the hole in the discharge valve seat, with the beveled end of gage in such a position as to be easily seen. Tighten the thumb nut.

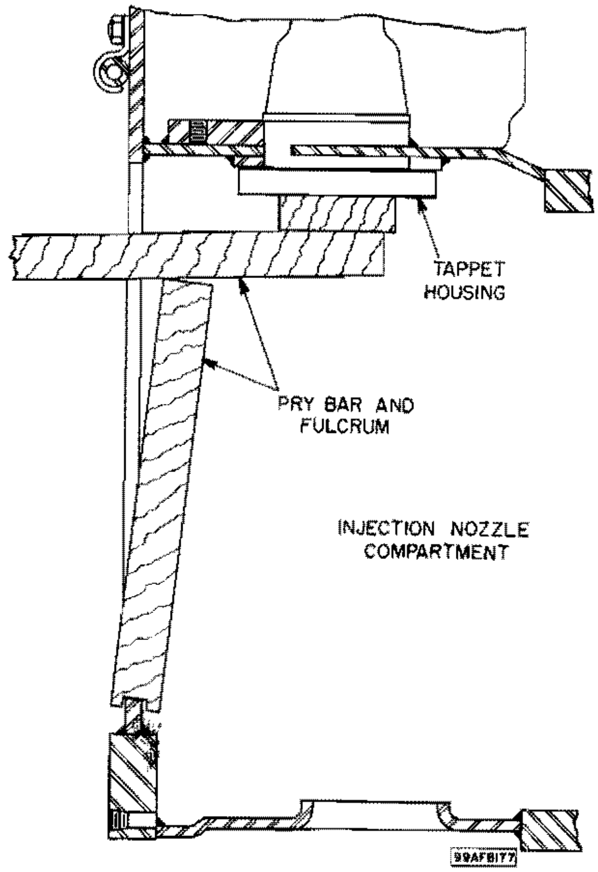
CAUTION: EXTREME CARE MUST BE TAKEN DURING THE FIRST REVOLUTION OF THE ENGINE AFTER THE INSTALLATION OF A DIFFERENT PUMP. THIS IS NECESSARY TO PREVENT DAMAGING THE PUMP BY THE CAM FORCING THE PUMP PLUNGER AGAINST THE DISCHARGE VALVE SEAT IF INSUFFICIENT SHIMS WERE USED BETWEEN THE PUMP AND TAPPET HOUSING. STOP BARRING THE ENGINE IF THE END OF THE STROKE GAGE PLUNGER EXTENDS MORE THAN .030" BEYOND THE STROKE GAGE BODY.

Bar the engine over slowly observing the travel of the stroke gage plunger until the plunger reaches the end of the downward stroke. The end of the stroke gage plunger should be flush with the end of the gage body ± .005".

If the plunger extends more than .005" beyond the end of the body, the pump body is too close to the tappet housing. Correct this by adding shims as necessary between these two sub-assemblies. Shims are provided in three thicknesses (.007, .0149", and .0598").

If the gage plunger does not come within .005" of the end of the gage body, the pump body is too far from the tappet assembly and is corrected by removing shims.

The pump body position can be set on the first attempt without guesswork, by using a dial



Illus. L16. Installing Tappet Assembly

indicator set up to read the exact shim thickness required. Clamp the indicator in place in a vertical position so that the indicator contact point bears on the end of the stroke gage body and will also bear on the stroke gage plunger as the engine is barred over.

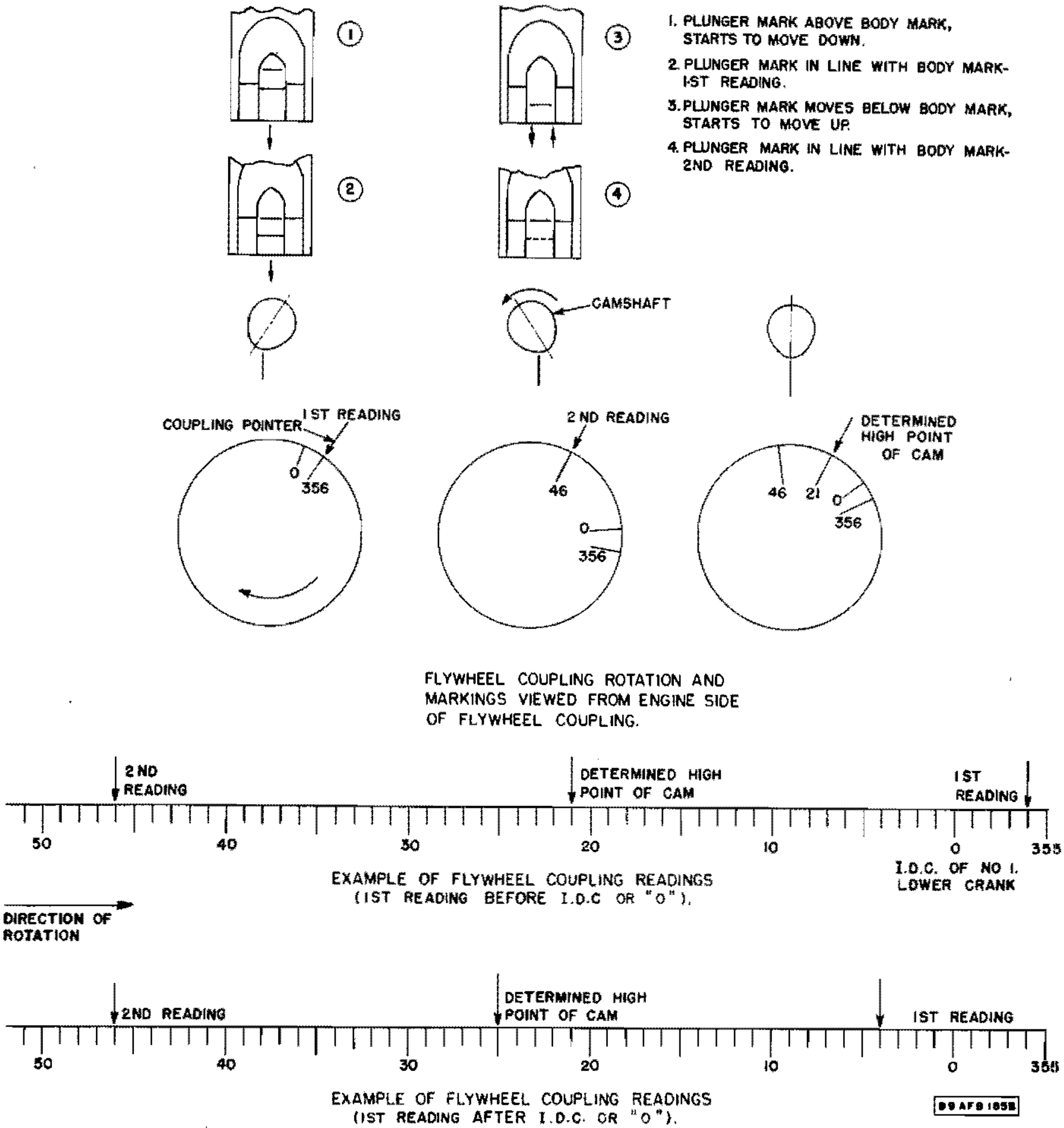
Bar the engine past high cam; the maximum indicator reading is the correct shim thickness to be used.

Attach the fuel header to the back of the pump with the two capscrews; be sure the gasket between the pump and the header is properly in place. Tighten to torque value given in Chapter B.

Connect the tube from the upper drain header and the injection tube to the discharge valve cage. Engage the control rod pin with the injection pump rack adjusting collar.

FUEL INJECTION TIMING

Fuel is injected into the combustion space near the end of the compression stroke. Proper timing for the beginning of injection is accomplished by setting the camshafts in correct relation to the lower crankshaft. The injection pump plungers will start their delivery stroke



Illus. L17. Graphic Procedure to Determine High Point of Cam

a certain number of degrees before the pistons reach the compression dead center. Refer to Illus. A2.

It is imperative that injection timing be set as accurate as possible, as errors in timing the engine greatly effect the performance of the engine and locomotive. After determining a timing setting, it is recommended the setting be rechecked before proceeding to the next step.

During the operations performed in setting injection timing, always bar the engine in the direction of rotation. If the setting is overrun, bar in reverse beyond the desired point and again come up to the desired setting. This is important as it takes up the slack of the timing chain always in the same direction.

The fuel injection timing is checked by using the following procedure:

Check the tension and condition of the timing chain. Refer to Chapter H. The proper relationship of the camshafts to the crankshafts will be maintained when the timing chain is correctly installed and the tension is as recommended.

Check the crankshaft timing. The lower crankshaft leads the upper. Refer to Chapter E for crank lead values. Install the plunger stroke gage on the No. 1 cylinder (opposite governor injection pump side).

As a starting point, bar the engine until pointer is at 15 to 20° before I.D.C. (340 to 345° coupling reading). In this position, the plunger line should be above the line on the barrel. Continue to bar the engine in the direction of rotation until the hairline on the stroke gage plunger lines up with the hairline on the gage barrel. Record the reading indicated by the coupling pointer.

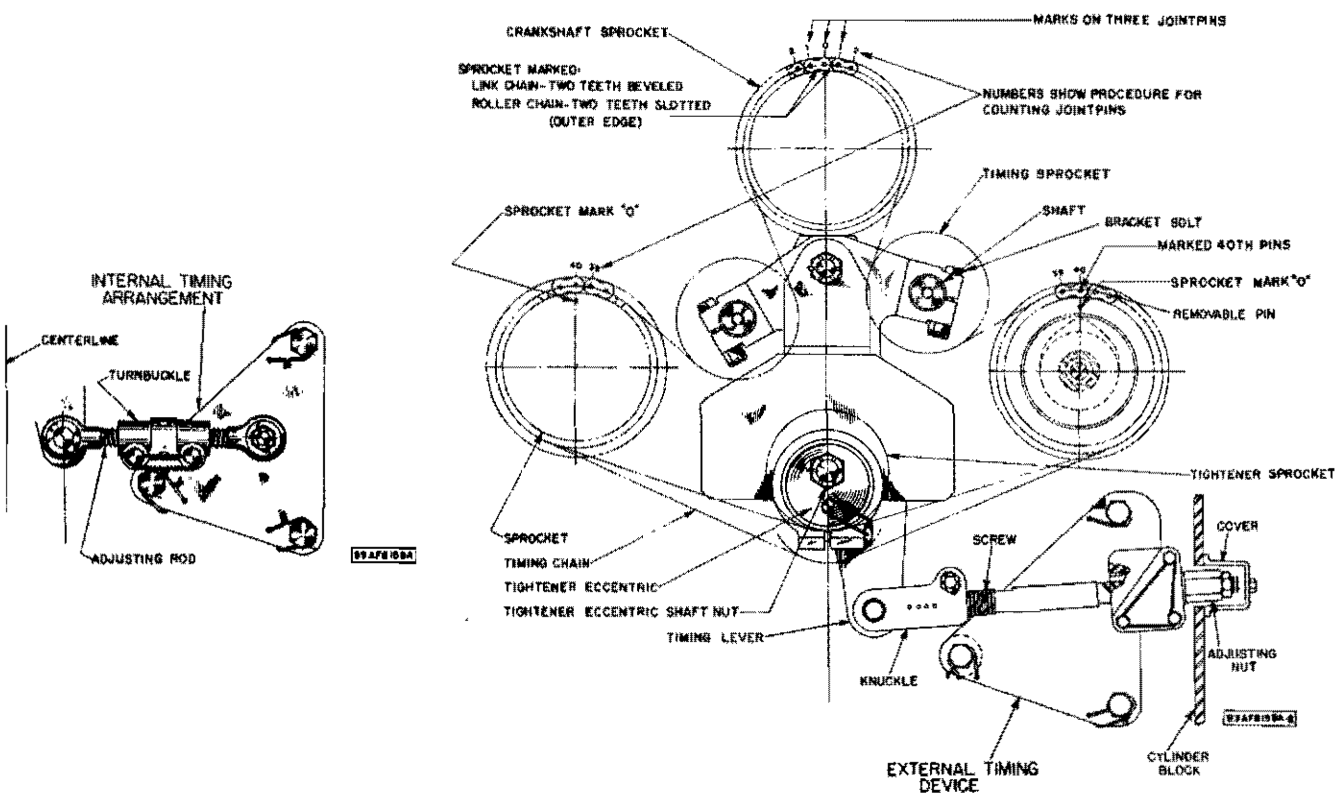
Continue to bar the engine in the direction of rotation until the plunger of the stroke gage moves down to the bottom of the stroke and returns to the position where the hairlines again line up. Record the flywheel coupling pointer reading.

The two flywheel coupling readings locate points on the camshaft lobe equal distance on either side of the high point of the cam, Illus. L17. It is necessary to find the center between these points with reference to inner dead center of the lower crankshaft or "O" on the flywheel coupling. The flywheel coupling markings are shown extended as a scale and are examples of typical coupling readings.

> NOTE: The high point of cam should be 22-1/2 ± 1/2° after I.D.C. No. 1 lower piston for engines with 12° crank lead and 19-1/2 ± 1/2° for engines with 15° crank lead.

If the flywheel coupling reading denoting high point of cam as determined is not within the specified limit, the timing of the camshaft (opposite governor side) must be changed in respect to the lower crankshaft.

The difference between the high point of cam as determined and the specified value will determine if the camshafts timing is early or late. If the determined value is less than the specified value, the timing is early; if greater, the timing is late. The difference between the values is the number of degrees to advance or



Illus. L18. Timing Lever Assembly

retard the camshafts.

NOTE: Early timing requires the rotation of the camshaft opposite the direction of rotation. Late timing requires the rotation of the camshaft in the direction of rotation.

To change the timing the required number of degrees, rotate the timing lever turnbuckle one turn for each degree in the direction as indicated below. Refer to Illus. L18.

Advance Timing (to make it earlier). Rotate turnbuckle clockwise, timing lever moves toward centerline.

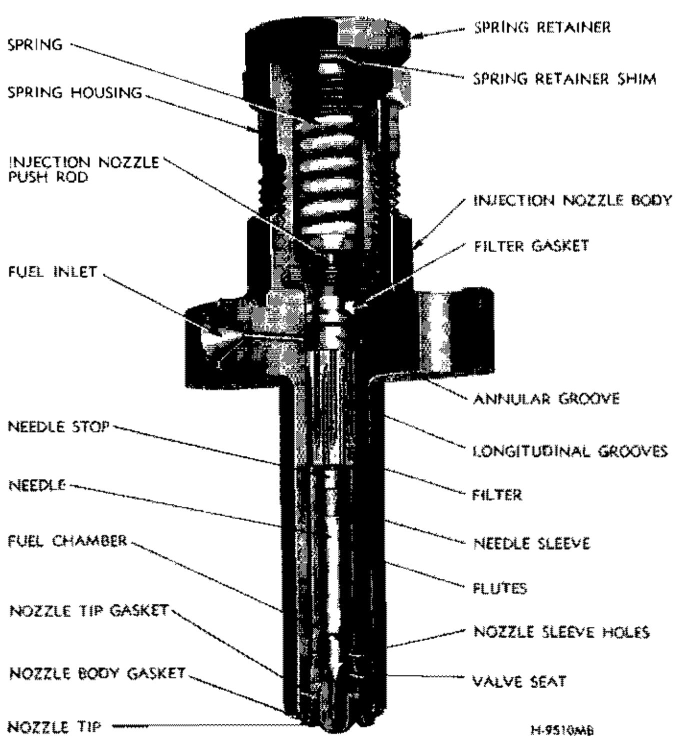
Retard Timing (to make it later). Rotate turnbuckle counterclockwise, timing lever moves away from centerline.

NOTE: On later engines an adjustable timing arrangement has been provided to enable timing adjustment to be made from outside the engine.

To change the timing, remove the cover plate and loosen the locknut. Rotate the timing adjusting nut in the direction as indicated. (One turn changes timing approximately 1-1/2°.)

Advance Timing (to make it earlier). Rotate nut counterclockwise.

Retard Timing (to make it later). Rotate nut clockwise.



Illus. L19. Injection Nozzle (F. M. & Co.)

Remove the stroke gage and install on the No. 1 cylinder (governor side) injection pump.

Proceed to check high point of cam for this pump using method as outlined above.

If the flywheel coupling reading denoting high point of cam as determined is not within the specified limit, the camshaft sprocket must be shifted in relation to the camshaft.

Slotted holes are provided in the camshaft sprocket for adjustment. Loosen the stud nuts and remove the dowels (when used). Be sure the sprocket is loose on the camshaft. If the timing is late, rotate the crankshaft opposite the direction of rotation the required number of degrees. Note the distance required to remove the slack in the drive.

INJECTION NOZZLE (F.M. & Co.)

Description

The differential pressure type fuel injection nozzle used on early engines consists of a needle, needle sleeve, nozzle tip, filter, push rod and spring. The injection nozzle needle sleeve is cooled by water flowing around the adapter from the cylinder liner. The water is admitted to the adapter water jacket thru a water passage or groove in the cylinder liner, Illus. L19.

Operation

On the down stroke of the injection pump plunger, fuel at high pressure enters the injection nozzle thru the injection tube and is forced thru the nozzle filter. This filter removes any foreign matter which has passed thru the main fuel filters and which might clog the small holes in the nozzle tip. See Illus. L22.

The filter built into this nozzle is extremely simple. The filter is a close fit in the nozzle body with a space of .0015" to .0035" allowed for the passage of fuel from one longitudinal groove to the other.

The longitudinal grooves are connected alternately with the annular groove. Thus the fuel entering this annular groove is forced thru the minute clearance between the filter and the nozzle body into the longitudinal grooves connected to the end of the filter.

The filtered fuel is forced on thru the flutes and holes in the needle sleeve and enters the chamber at the end of the needle. The fuel under pressure, acting against the face of the needle at the valve seat and at the shoulder lift the needle from its seat.

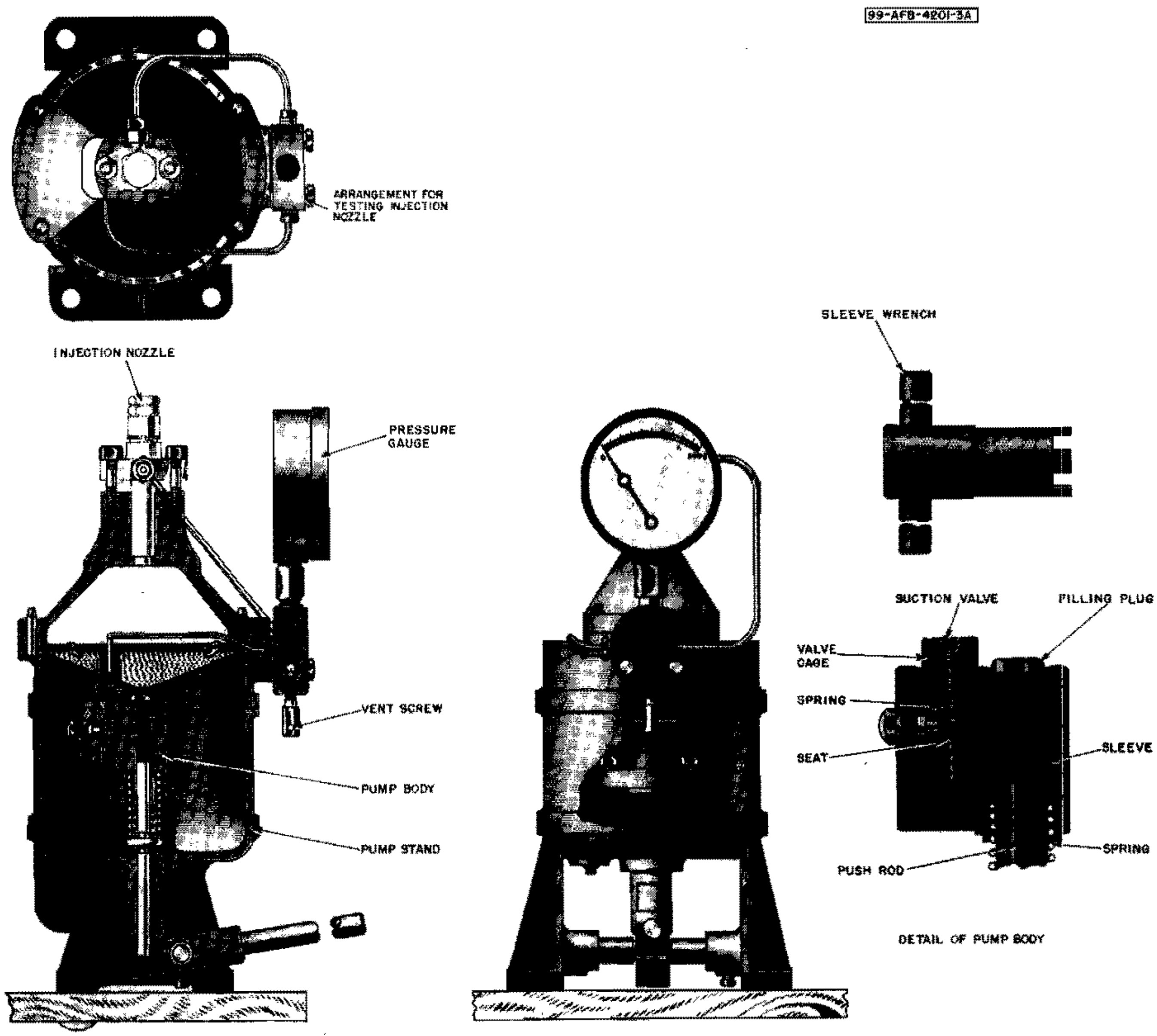
This action is counteracted by the spring thru the push rod. The fuel pressure will exceed the spring pressure and fuel will pass thru the holes in the nozzle tip and be injected into the combustion space of the cylinder in a fine spray.

The high pressure of the spring and fuel acting on the needle makes its action extremely fast. The needle is opened when the fuel pressure from the injection pump exceeds the spring load. It is closed when the fuel pressure drops below that required to hold it open. The differential pressures insure quick opening and closing of the needle and eliminate dribbling or leaking.

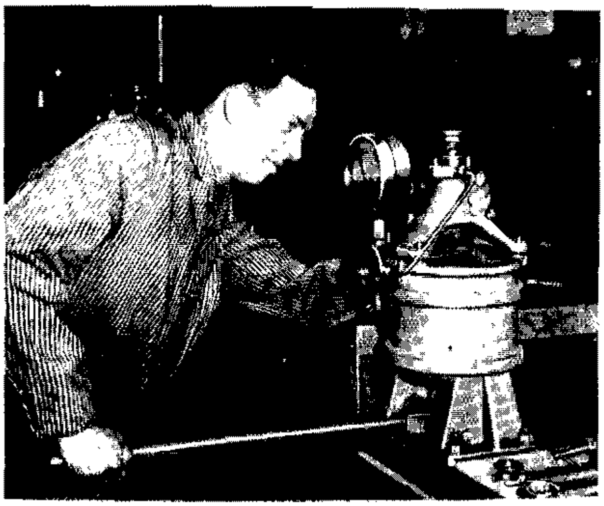
Removing Nozzle from Adapter

Disconnect the injection tube from the fuel injection pump and the drain tube to lower drain header. Take off the two nuts securing the injection nozzle body to the adapter collar. The nozzle should now be easily removable from the adapter. However, if it is inclined to stick, pry out the body gently until it is released from its seat in the adapter. Insert a bar or screwdriver between the nozzle body and the adapter collar.

The nozzle can then be removed for testing. Check the adapter in the cylinder liner from which the nozzle was taken. If the adapter is dirty, wipe away the carbon deposits. If the nozzle or adapter is dirty the probable cause is that the gasket between the nozzle body and adapter is leaking. Clean the nozzle and adapter and install a new gasket. Use graphite grease to paste the gasket to the seat. Be careful not



Illus. L20. Injection Nozzle Test Pump



Illus. L21. Testing F.M. & Co. Nozzle

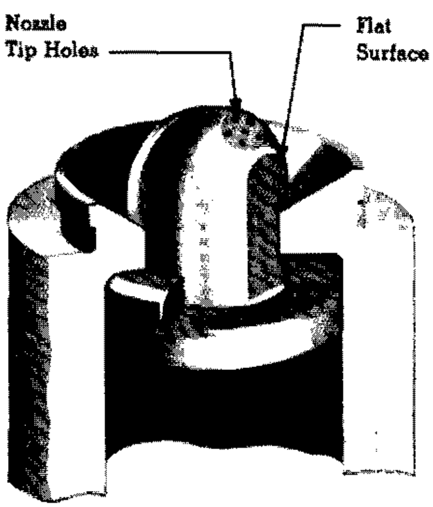
to injure the nozzle seat. If it is necessary to remove the adapter, see Chapter D.

Testing the Nozzle

When working under unfavorable conditions (dirty fuel), the injection nozzle may become dirty. If a nozzle is suspected of not functioning properly, it should be removed and tested on the test pump.

Set the nozzle into the pump, as shown in Illus. L20. Connect the oil supply tube from the pump pressure gage to the nozzle injection tube fitting, as shown. Operate the pump until the fuel is ejected from the nozzle in a fine spray.

Then pump with a slow, even stroke so that a continuous uniform popping occurs. While pumping slowly, the highest pressure indicated



Illus. L22. Injection Nozzle Tip

on the test pump gage is the pressure at which the needle valve opens.

The correct opening pressure is 3000 (+200, -000) lbs. Pressure readjustment is made by adding or removing spring retainer shims. Shims of .004", .0149", and .0299" are furnished. These will change the pressure approximately 100, 400 and 1000 lbs. respectively. Refer to Illus. L19.

If the pressure indicated on the gage is low it is possible that:

The spring setting is not correctly adjusted.
The needle valve is stuck partially open.
The spring is weak or broken.
Worn moving parts.

If the pressure indicated on the gage is high it is probable that:

The spring setting is high.
The holes in the tip are clogged.

CAUTION: KEEP HANDS AWAY FROM THE NOZZLE SPRAY AS THE OIL IS EJECTED WITH SUFFICIENT FORCE TO PUNCTURE THE SKIN AND MAY CAUSE BLOOD POISONING.

Testing for Leaky Needle Valve

Pump the pressure up to 2800 lbs. and hold this pressure momentarily. If drops of fuel collect at the nozzle tip, the needle valve leaks.

Part Replacement

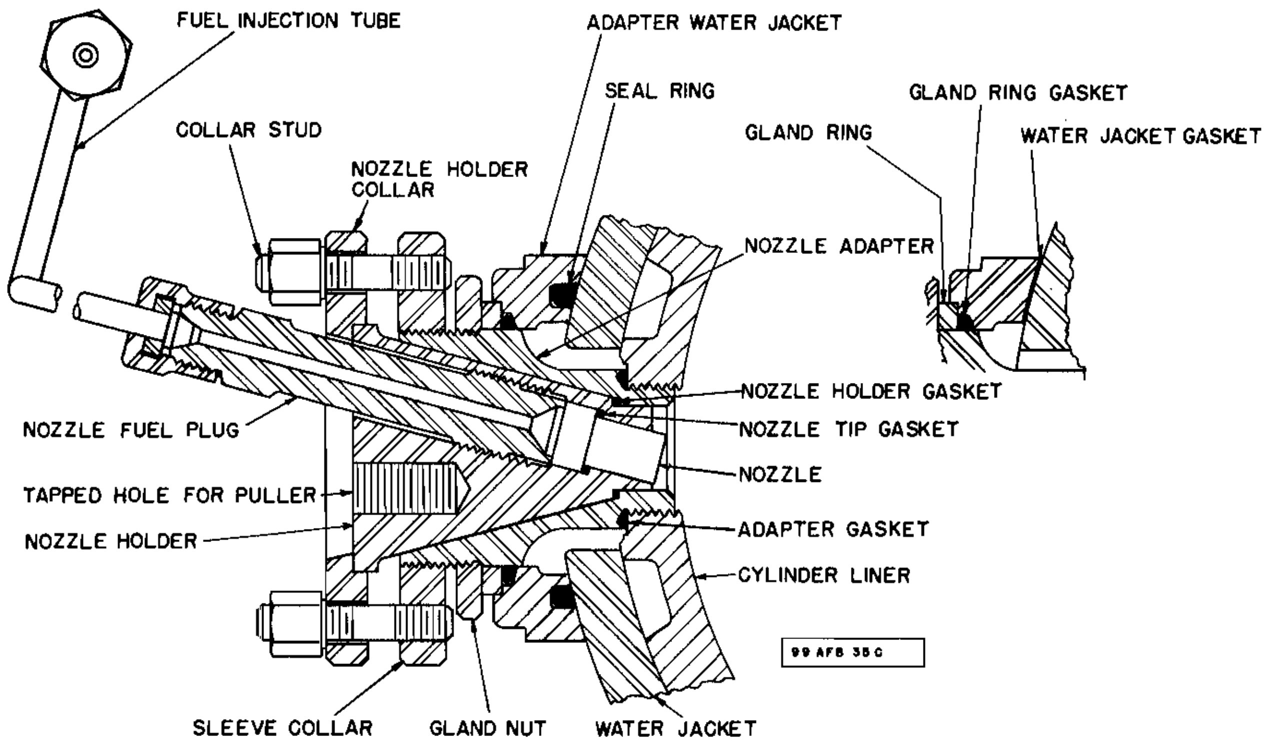
The injection nozzle is a precision assembly. The manufacturer recommends that the injection nozzle be returned to the factory for proper servicing by persons specially trained in handling the precision parts. The nozzle should not be disassembled in the field before returning it to the factory. Contact the Locomotive Service Department.

Care of Injection Nozzle Test Pump

The injection nozzle test pump will rarely require attention other than periodic testing of the pressure gage.

The sleeve wrench, Illus. L20, provided with the pump, is used for removing and replacing the pump sleeve.

For testing injection nozzles, the test pump should be filled with fuel oil to the level indicated. Care should be taken to use only clean, filtered oil of the same specifications as for the engine.



Illus. L23. Nozzle Assembly in Place in Cylinder

Cleaning the Nozzle Tip

The spray holes in the nozzle tip, Illus. L22, can be cleaned by soaking the nozzle in a solvent such as alcohol for several hours. Replace the nozzle in the test pump and flush out the holes. If the tip holes cannot be cleaned, replace the tip.

Replacing Nozzle in Adapter

Use a new injection nozzle body gasket. Line up the nozzle so that the flat is in a horizontal position with the fuel inlet down. Push the nozzle into the adapter. Replace the nuts on the two studs to hold the nozzle to its seat in the adapter. The nuts must be tightened evenly to 35-40 ft. lbs. torque to avoid distortion of the nozzle body; excessive tightening will damage the inner end of the adapter. Reconnect the tubing.

INJECTION NOZZLE (Pintle)

Description

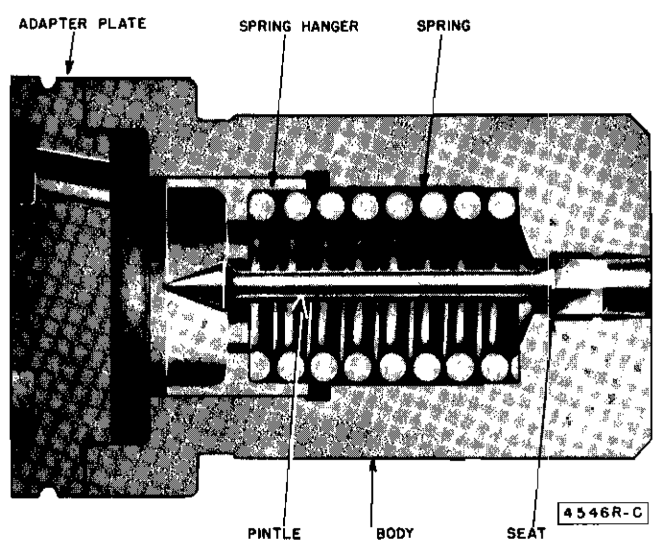
The pintle fuel injection nozzle is an outward opening, differential type nozzle which is hydraulically operated by fuel from the injection pump.

The nozzle assembly is held in place by the nozzle fuel plug as shown in Illus. L23.

The nozzle assembly contains all of the working parts of the nozzle. It is a replaceable unit and contains a pintle, spring hanger, adapter plate and spring all assembled in the nozzle body.

Operation

From the fuel injection pump, metered fuel under high pressure is delivered to the nozzle assembly. Here, the fuel passes thru holes in the adapter plate, and thru flow holes in the spring hanger to the valve seat. The pintle is



Illus. L24. Cross-Section of Nozzle Assembly

Illus. L25. Testing the Nozzle

held tightly on its seat in the body by the force of a spring acting on the spring hanger in which the other end of the pintle is fastened. Refer to Illus. L24.

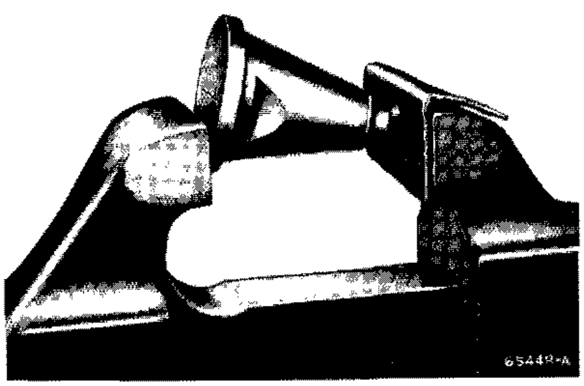
When the pressure of the fuel exerted on the pintle at the seat is sufficient to overcome the force of the spring, the pintle moves outward and the fuel flows past the seat.

After passing the seat, the high pressure fuel is applied on the increased pintle area which rapidly accelerates the outward movement of the pintle until it is stopped either by contact of the spring hanger with a shoulder in the spring cavity of the body, or its motion is arrested by a reduction in fuel pressure. The portion of the pintle adjacent to the outermost end is conical in shape, providing an increasing flow area between the diameter of the body bore and the pintle, as the pintle moves outward. The maximum outward movement of the pintle is controlled by a shoulder in the spring compartment of the body. The pintle will remain in the open position until the quantity of fuel metered by the pump is injected, then the fuel pressure will drop and the spring will return the pintle to its seat.

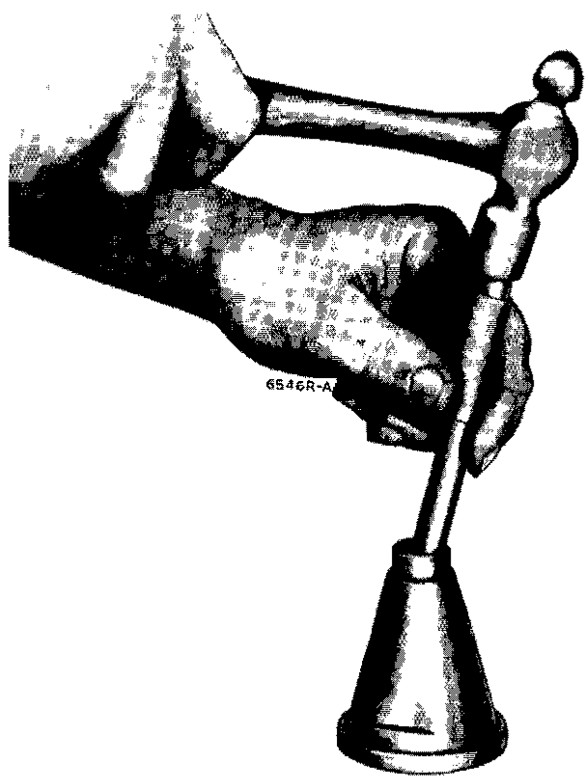
Servicing

The high velocity of the fuel flowing past the seat and orifice of the nozzle tends to cause erosion of the surfaces and edges, which will be rapidly accelerated if dirt particles are not properly filtered from the fuel. Consequently, ample filtration and frequent and careful cleaning of filter elements in the fuel system is essential for long and efficient life of the equipment.

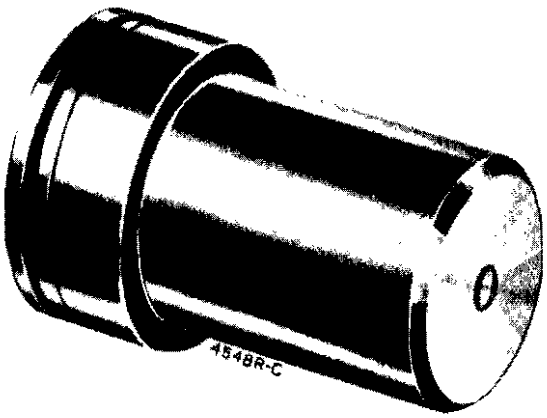
Unsatisfactory engine operation caused by defective nozzles is sometimes indicated by excessive exhaust smoke, by excessive fuel consumption, and/or by crankcase dilution. It should be borne in mind that other conditions may cause unsatisfactory operation with the same indications. Therefore, always check the nozzles in the hand test stand before deciding that they are the cause of the trouble.



Illus. L26. Pushing Nozzle from Holder



Illus. L27. Using Knock-out Tool



Illus. L28. Nozzle with Worn Pintle

Removal

Before disturbing the injection tube connections clean the connections with fuel oil and wipe dry with a clean cloth. The assembly may be removed with the puller assembly after removing the sleeve collar stud nuts and disconnecting the injection tube.

During the process of removal, do not strike the end of the nozzle assembly against any hard surface which may nick or otherwise damage the nozzle or body. Cover the open end of the injection tube to prevent entry of dirt. Cover the nozzle hole in the cylinder liner.

Testing

To test the nozzle assembly, first attach it to the test pump by connecting the test pump to the fuel inlet fitting of the nozzle assembly.

Prime the test pump by using very quick strokes of the handle until fuel is ejected from the nozzle. Refer to Illus. L25.

WARNING: Keep hands away from the nozzle spray as the oil is ejected with sufficient force to puncture the skin and may cause blood poisoning.

The purpose of a nozzle test stand is to measure the opening pressure and to observe the seat leakage and spray pattern.

To measure the valve opening pressure, push the operating handle downward and observe the pressure at which the valve opens.

The valve opening pressure of a new nozzle should be 1450 to 1650 psi. Always check a new nozzle for opening pressure before placing it in service. There is no method of adjusting the opening pressure on these nozzles. New nozzle should be returned to the manufacturer if the opening pressure is below 1450 psi. Nozzles which are checked after a period of use may have a minimum opening pressure of 1350 psi, (this pertains to nozzles stamped ADE10R11).

To measure seat leakage, bring the fuel pressure to 1300 psi for used nozzles or 1400 psi for new nozzles and observe the fuel leakage at the nozzle tip. A nozzle is considered satisfactory if the leakage is less than 8 drops per minute or if the seepage is slight. If the fuel appears to "run" out thru the body hole, or forms heavy drops of fuel that drip off the end of the pintle, the leakage would be considered excessive. No leakage should be noted between the nozzle and the holder parts during operation on the test stand.

To observe the spray pattern, operate the pump fairly rapidly (2 strokes per second) and observe the spray pattern. The spray should be uniform, cone shaped, finely atomized and free from "stringers" (side sprays). The cut-off (valve closing) should be sharp.

If fuel oil impurities have eroded or corroded the pintle or seat, the pattern will be made up of a coarse, non-uniform, irregular spray.

Removal of Nozzle from Holder

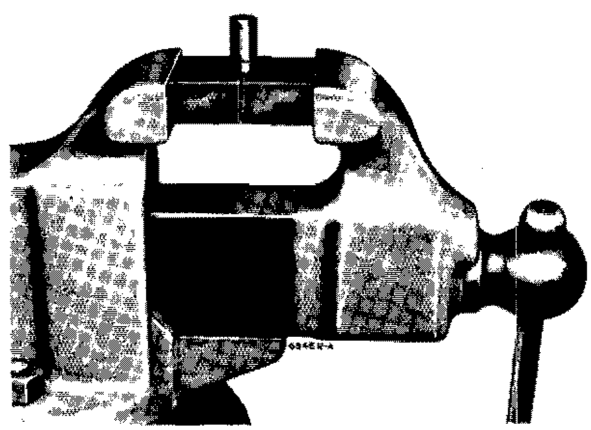
The following steps should be taken to remove the nozzle from the holder.

Remove fuel plug from holder.

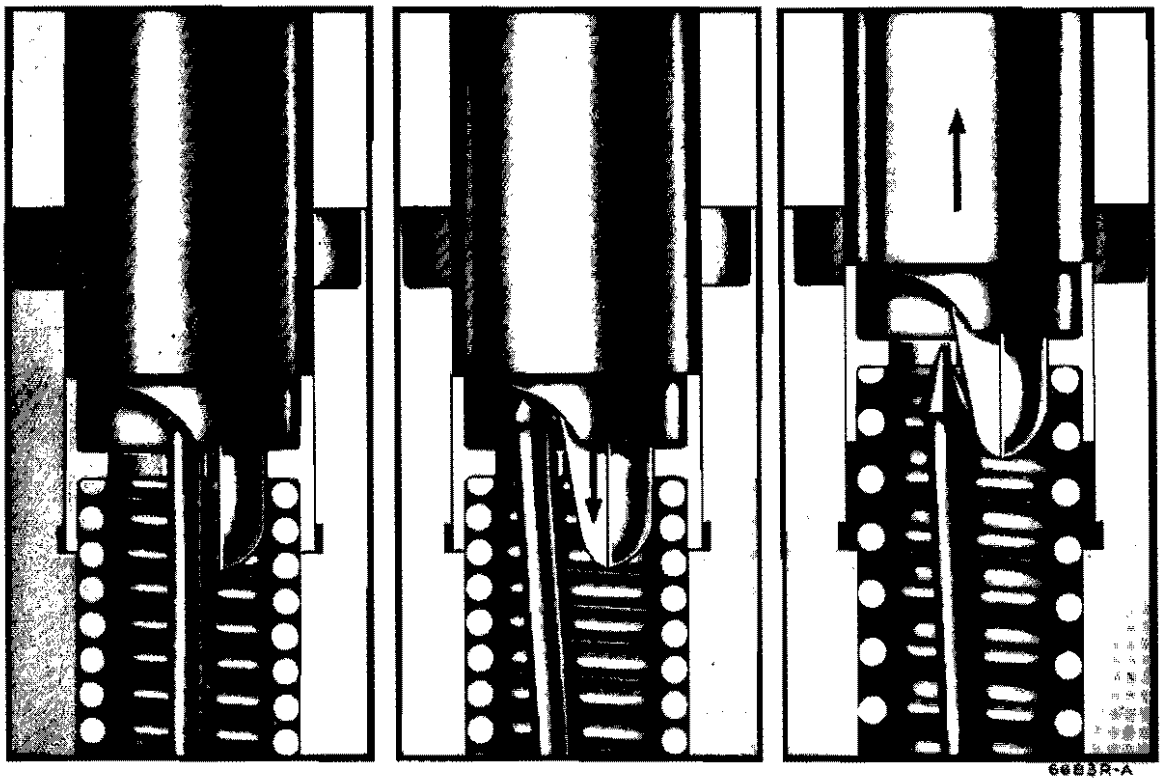
Place nozzle holder in vise (with copper jaws or wood blocks) and press nozzle in flush with end of holder, as shown in Illus. L26.

Use knockout tool, Illus. L27, to remove nozzle the rest of the way from the holder.

Care should be exercised so that the lapped faces between the nozzle and plug are not damaged. The copper gasket between the shoulder and nozzle holder should be removed if it appears to be damaged.



Illus. L29. Removing Adapter Plate



Illus. L30. Sequence of Tool Positions to Release Pintle

Disassembly, Inspection and Repair

The following steps should be taken to disassemble a nozzle.

Clean external parts of nozzle with clean cloth and solvent. Never use hard or sharp tools of any kind to clean end of nozzle. Serious damage may result to the surface of the pintle end.

> NOTE: If inspection of the nozzle prior to disassembly shows the end of the pintle depressed into the body in excess of .003", no attempt should be made to repair the nozzle as such a condition is indicative of excessive wear. The nature of the wear is such that it will nullify any reconditioning measures. Refer to Illus. L28.

Remove nozzle adapter plate with special clamping tool shown in Illus. L29.

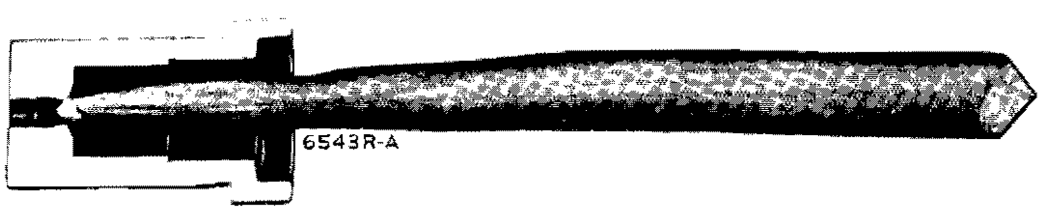
Place nozzle assembly in tool fixture and tap gently back and forth with a brass rod approximately 1/2" in diameter and 6" long until body is removed from adapter plate. DO NOT USE KNOCK-OUT TOOL FOR THIS OPERATION.

Remove pintle with nozzle assembly tool, No. TSE-7777 and the assembly plate No. TSE-7778. The tools are shown in position on Illus. L30 and L34. On nozzles ADE10R11B, it will be necessary to grind the pilot end of the tool to reduce the diameter approximately .020".

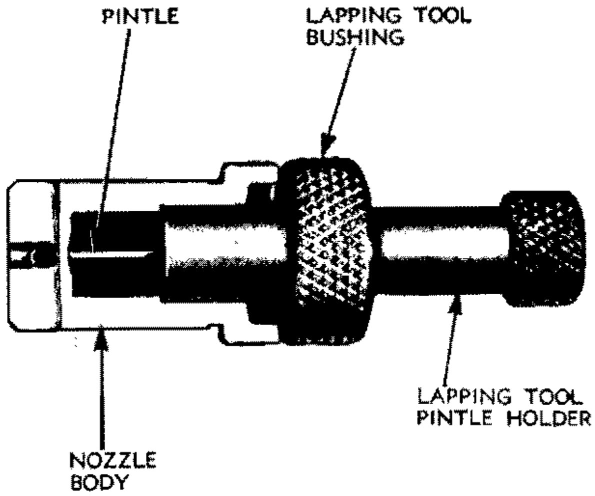
After the pintle has been removed from the body, wash parts in solvent and blow dry.

To correct the seat leakage, the pintle may be carefully lapped to the body seat. Apply fine lapping compound (American Bosch #BM 10007 or equivalent) to the pointed end of a wooden stick and apply on the body seat from the adapter plate end of the body, shown in Illus. L31.

It is important that no lapping take place



Illus. L31. Applying Lapping Compound



Illus. L32. Nozzle Lapping Tool

between the end of the pintle and the body orifice. The original factory clearance between these two parts must be maintained.

CAUTION: The pintle nozzle is a precision piece of equipment. It is possible when repairing a malfunctioning nozzle to overlap and widen the pintle seat contact. The process is to clean rather than lap. If the seat becomes too wide, it will slow the opening and cut off action of the nozzle and may allow cycling of the nozzle during operation of the engine. It is natural to assume that the opening pressure of a nozzle will increase when a nozzle is repaired but the increase should never bring the nozzle opening pressure above the limits of a new nozzle. Do not overlap a nozzle.

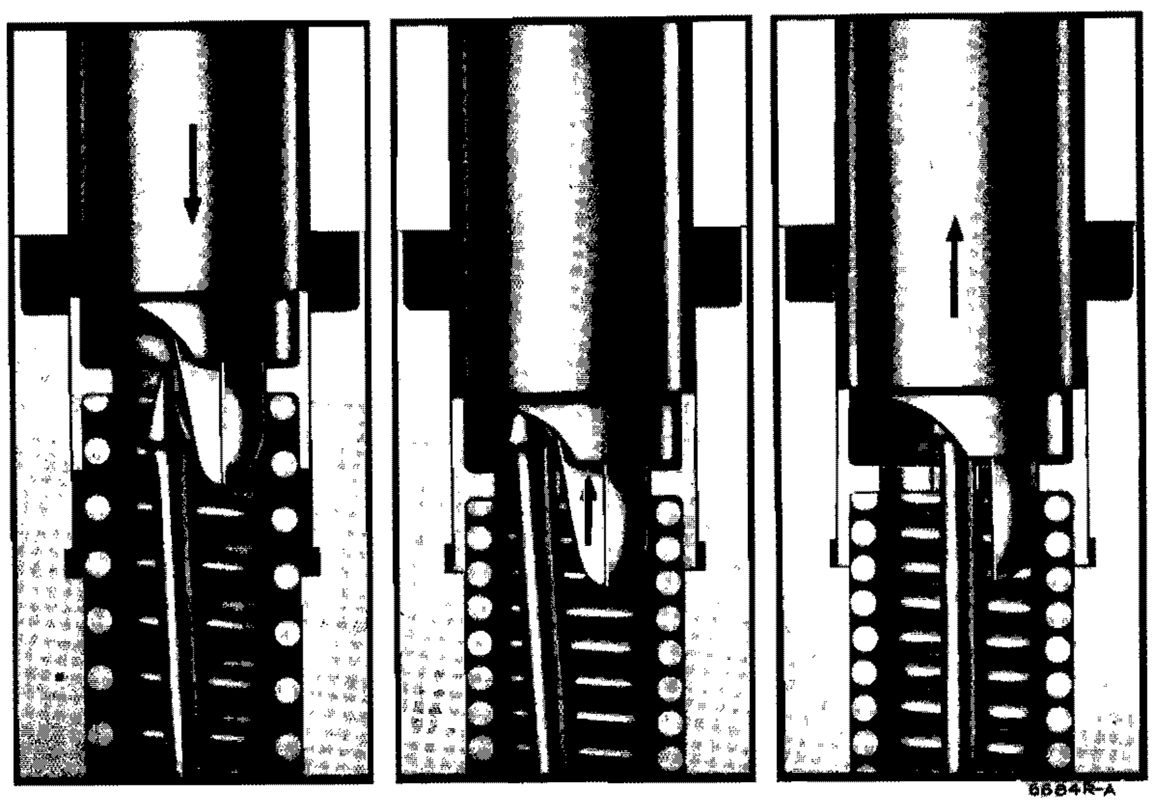
Install the lapping tool bushing into the nozzle body. Hold the pintle flush with the face of the nozzle body as the lapping tool holder is pushed onto the pintle, Illus. L32. Rotate the holder with a slight pull for approximately one minute to lap the pintle and body seats. Hold the bushing tight in the body while lapping. Thoroughly clean the pintle and body.

Reassembly of Nozzle

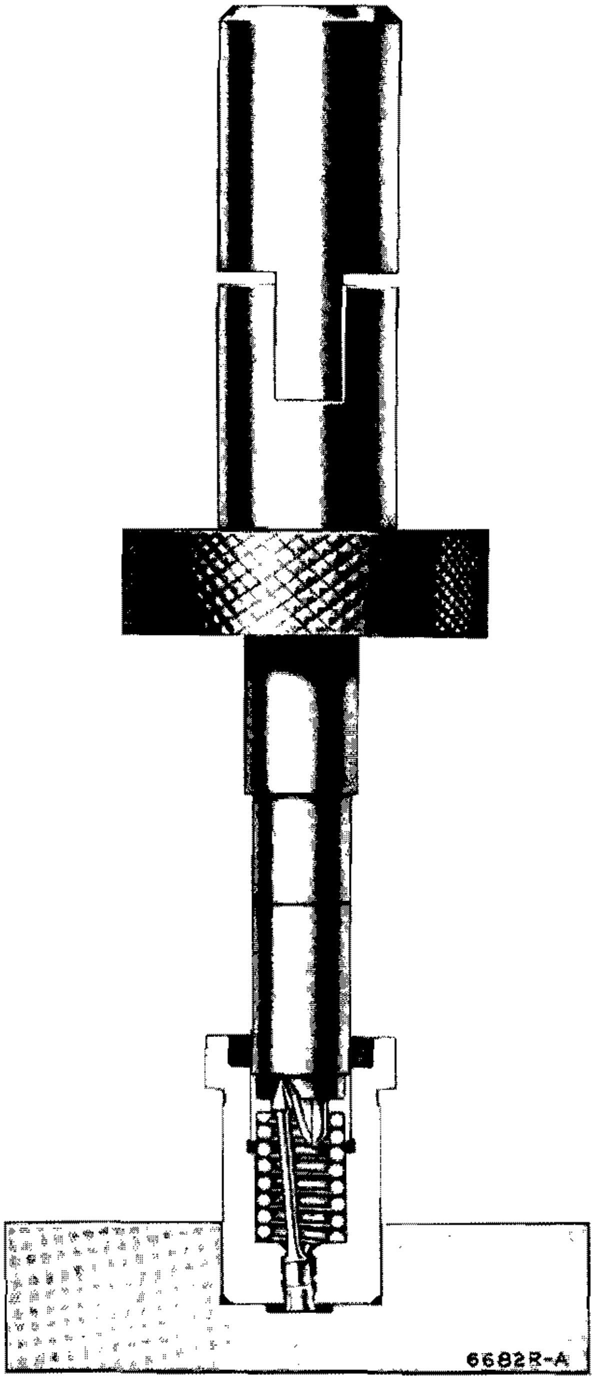
If all parts of the assembly appear to be in satisfactory condition, replace the pintle in the body. It should be free and should seat with the pintle end flush, or within .003" minus of the body face.

Reassemble the spring and spring hanger in the body making sure the hanger pintle stem seat is on the top. Use assembling tool to replace pintle in position as shown, Illus. L33 and L34.

Press adapter plate into body. For this operation, the body and adapter plate may be pressed in a vise between two blocks of wood. Never hammer the adapter into place, and at



Illus. L33. Sequence of Tool Positions to Replace Pintle



Illus. L34. Nozzle Assembly Tool in Position

all times protect the lapped surface from hard sharp objects.

In case the lapped surface on top of the nozzle adapter plate or the end of the fuel plug is damaged, they can be relapped separately on a lapping plate with medium or fine lapping compound. Never lap the adapter plate without first removing it from the nozzle body. This eliminates the danger of excessive lapping compound entering the inside of the nozzle.

Retesting the Nozzle

Refer to previous section "Testing" for procedure.

If the opening pressure is low, it may be caused by seat leakage. Seat leakage may be corrected by relapping. If the second lapping operation does not correct the leakage discard the nozzle.

Installation

When replacing the nozzle, the nozzle holder collar must be installed over the fuel plug before the plug is inserted into the nozzle holder adapter. Fit the collar on the studs as the nozzle holder is inserted into the adapter. Be sure that the scribed line is in a vertical position when the nozzle assembly is on the engine, Illus. L3. Also, the assembly must be installed so that the nozzle will spray to the right of the cylinder as viewed from each side of the engine.

Tighten the nozzle fuel plug to 40 ft. lbs. torque and the collar stud nuts to 35-40 ft. lbs. Hold the nozzle fuel plug with a wrench when tightening the fuel connection.

Storage

If a nozzle assembly is to be stored, proceed as follows:

1. Remove all carbon deposits.
2. Connect the nozzle assembly to the test pump which has been filled with a rust preventive compound such as "Tectyl No. 502."
3. Operate the test pump for a sufficient number of strokes to insure complete removal of all fuel oil from the nozzle and the substitution of the rust preventive.
4. Coat the exterior of the nozzle assembly with the rust preventive.
5. Wrap the nozzle in oil paper.

When a nozzle assembly has been in storage for a long time, it is possible some gumming of the rust preventive has occurred. Before installation of the nozzle in the engine, it should be connected to the test pump which has been filled with fuel oil, and the nozzle should then be thoroughly flushed with the fuel oil.

Test Stand Maintenance

Fuel oil supply should be changed at least every 30 days and fuel reservoir thoroughly cleaned out.

Fuel reservoir should always have a filter screen with a chamois skin directly beneath it for proper fuel filtering.

Check pressure gage every 30 days.

CYLINDER DUMMY PLUG (If used)

Each four hole liner is provided with two water cooled dummy plugs and adapters. These are used to fill openings in the cylinder liner. The same servicing and gasket replacement instructions apply to these plugs and adapters as to the injection nozzle adapters.

INJECTION PUMP FUEL CONTROL

Adjustments to the fuel control mechanism are made so that the load is balanced between the engine cylinders and that the engine will be supplied sufficient fuel as indicated by the governor. The adjustments are related to the correct setting of the governor and linkage.

Setting of Pumps

Refer to the following: -

A. Engines Using Type SI - Woodward Governor - Chapter Ma - Governing System

B. Engines Using Pneumatic - Hydraulic Woodward Governors - Chapter Mb and Md Governing System

C. Engines Using Electro-Hydraulic Woodward Governors - Chapter Mc - Governing System

D. 10 Cyl. Erie Built - Gen. Elec. Governors - Sec. 208.4 - Maintainer's Manual. Bulletin No. 2402.

SETTING FUEL CONTROL ARM STOP (TORQUE LIMIT) SCREW

a. Adjustment of the fuel control arm stop (torque limit) screw "E," Illus. L34, is made so as to provide a maximum rack setting for the injection pumps. These settings are specified in the "Load Limit" columns of Table 1.

b. Loosen the fuel control arm stop screw "E" to remove interference with the fuel control arm.

c. Disconnect the governor link lever from the governor and move up so that the rack position as read is higher than values shown in Table 1.

d. Lower the governor link lever slowly until the rack positions specified in the "Load Limit" column of Table 1 are reached.

e. When the setting is correct, turn the fuel control arm stop (torque limit) screw up against the fuel control arm and lock in place with the jam nut and seal.

SETTING LOW OIL PRESSURE SHUTDOWN (Early 6 Cyl. Engines Only)

With the engine in "no fuel" trip the overspeed stop. Adjust the control arm adjusting screw "D" on the fuel control arm to give a

TABLE 1 - For reference in checking Operating Conditions, the approximate settings of the injection pump racks are given in the following table.

Engine	*BHP Engine Output for Tractive Effort	** BHP Engine Output	Full Load Control Side	Full Load Opposite Control Side	Load Limit Total Rack Position
Offset Fuel Control Arm					
6 cyl.	1000	1075	7	7	15
6 cyl.	1200	1275	8	8	17
8 cyl.	1500	1620	7.7	7.3	16
8 cyl.	1600	1720	8	8	17
10 cyl.	2000	2120	8	8	17
10 cyl.	§Erie Built Locomotives				
12 cyl.	2400	2580	8	8	17
Center Pivot Fuel Control Arm					
6 cyl.	1200	1275	8	8	17
8 cyl.	1600	1720	8	8	17
10 cyl.	2000	2120	8	8	17
12 cyl.	2400	2580	8	8	17

* In addition engine will be pulling auxiliary horsepower.

§ Refer to Sec. 208.4 - Maintainer's Manual - Bulletin No. 2402.

** Refer to Maintenance Bulletin Sec. 206C for procedure to determine engine horsepower.

clearance of 1/32" between the piston rod and the adjusting screw. After adjustment is made, lock the jam nut.

SETTING FUEL CONTROL ARM TO CUT-OUT LEVER ADJUSTING SCREW

a. Set the governor to "full-fuel" position.
b. Trip the emergency stop push button. The fuel racks will then be in "no fuel" position.
c. Adjustment should be such that there will be 1/16" or less clearance between the fuel control arm adjusting screw "D" and the fuel cutout lever button.

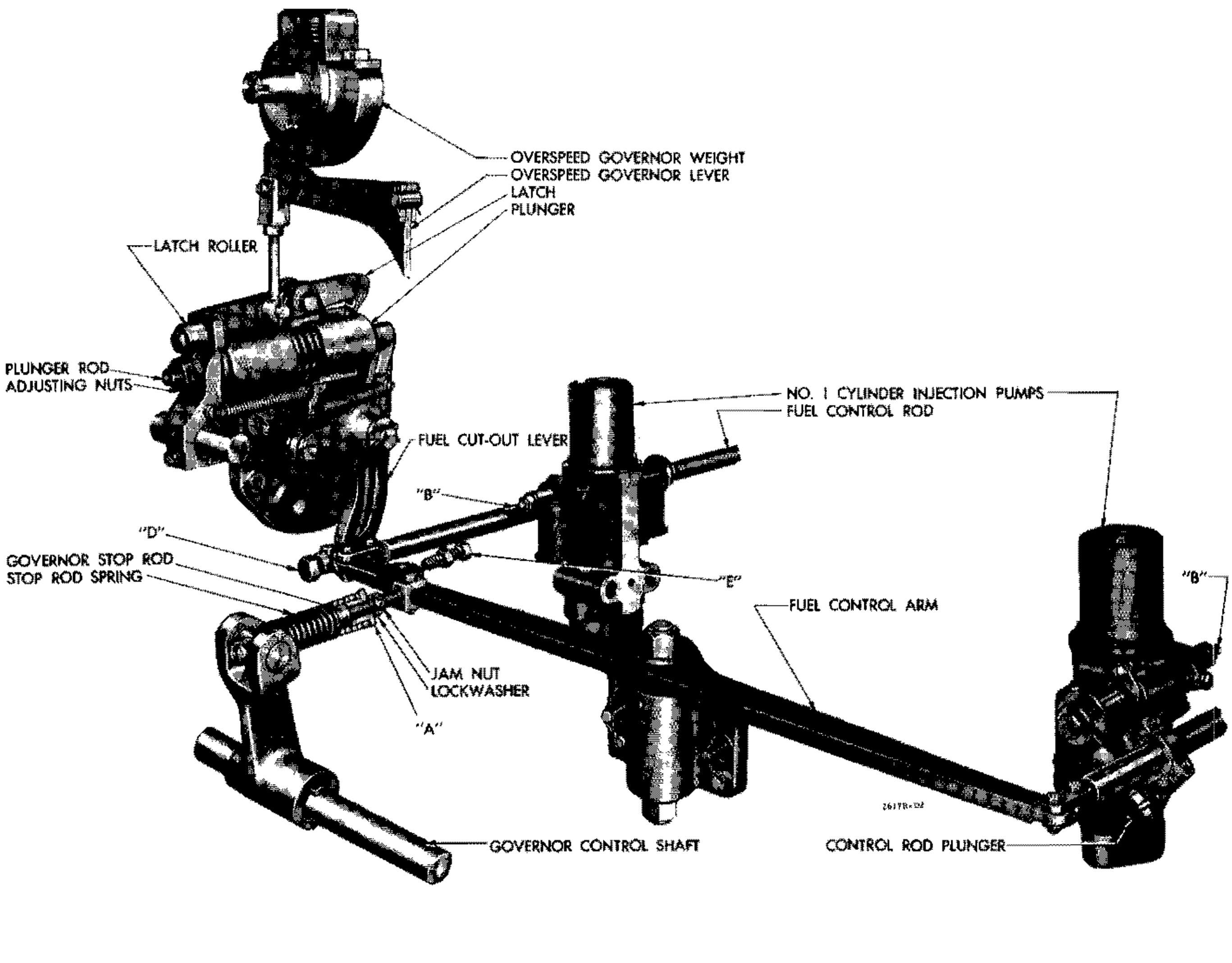
Set jam nut after making adjustment.

SETTING ENGINE SPEED

Idling (350 rpm for 6 cylinder engines with spring coupling vertical drive: 300 rpm for 6 cylinder engines with quill shaft vertical drive and all 8, 10, & 12 cylinder engines).

Full Speed (800 rpm for early 6 cylinder engines: 850 rpm for later 6 cylinder and all 8, 10 and 12 cylinder engines). Refer to Chapter Ma, Mb, Mc, or Md.

Refer to Bulletin 4401 "Electrical Equipment Manual" Sec. 414.1 for settings on the 10 Cyl. Erie Built Locomotives.



Illus. L35. Fuel Control Linkage Adjustment
Center Pivot Fuel Control Arm Shown
Offset Fuel Control Arm Used Previous to Engine No. 963984

CHAPTER Mc. GOVERNING SYSTEM

This Chapter is applicable to the following Electro-Hydraulic Woodward governors.

360310 governors have an adjustable load control cam and 30.5 ohm resistor pack.

360244 governor is a basic pneumatic-hydraulic 360373 governor with electric speed control pack.

360594 governor is the 360244 governor with straight link load control.

360595 governor is the 360310 governor with:

a. Straight link load control
b. Overriding solenoid controlled fast dump

360685 governor is the 360310 governor with:

a. 44 ohm resistor pack
b. Straight link load control
c. Overriding solenoid controlled fast dump

360964 governor is the 360310 governor with:

a. 44 ohm resistor pack
b. Straight link load control
c. Overriding solenoid controlled fast dump
d. Fuel servo stop
e. 12 Pt. Pyle National connector

360965 governor is the 360310 governor with:

a. 44 ohm resistor pack
b. Straight link load control
c. Overriding solenoid controlled fast dump
d. Fuel servo stop
e. 12 Pt. Pyle National connector
f. Fixed vane regulator timing orifice

360967 governor is the 360310 governor with:

a. Straight link load control
b. Overriding solenoid controlled fast dump
c. Fuel servo stop
d. 12 Pt. Pyle National connector

360975 governor is the 360310 governor with:

a. Straight link load control
b. Overriding solenoid controlled fast dump
c. Fuel servo stop
d. 12 Pt. Pyle National connector
e. Fixed vane regulator timing orifice

361108 governor is the 360310 governor with:

a. 44 ohm resistor pack
b. Straight link load control
c. Fuel servo stop
d. 12 Pt. Pyle National connector
e. Fixed vane regulator timing orifice

361210 governor is the 360244 governor with modification to:

a. Straight link load control
b. Fixed vane regulator timing orifice

361210 governor is the 360594 governor with modification to:

a. Fixed vane regulator timing orifice

361211 governor is the 360310 governor with modification to:

a. Straight link load control
b. Fixed vane regulator timing orifice
c. Overriding solenoid controlled fast dump

360211 governor is the 360595 governor with modification to:

a. Fixed vane regulator timing orifice

361212 governor is the 360685 governor with modification to:

a. Fixed vane regulator timing orifice

361513 governor is the 360310 governor with:

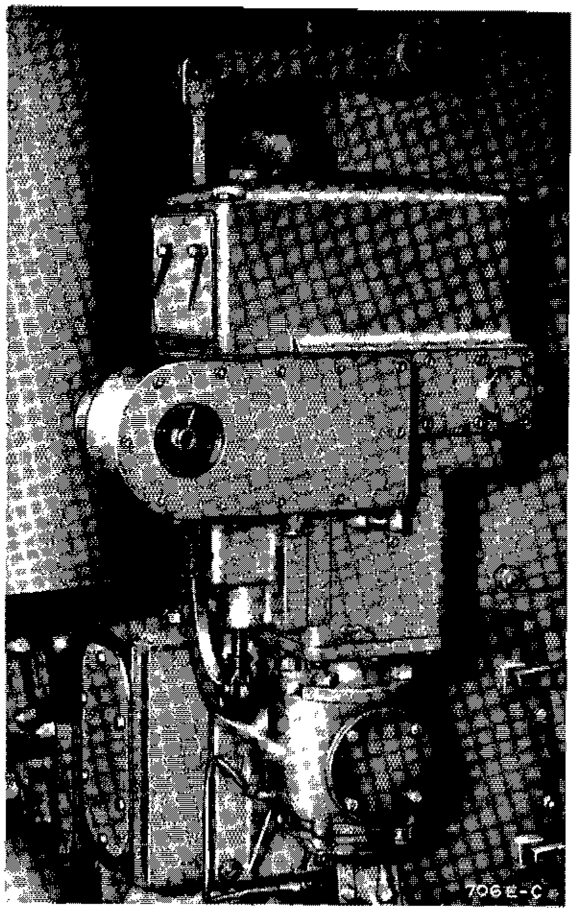
a. 10.7 ohm resistor pack
b. Straight link load control
c. Fixed vane regulator timing orifice
d. Load control pilot valve cutoff with 55 psi opening pressure
e. Maximum field start
f. Spring ballhead drive

Refer to the following Chapters and Bulletins for settings of other types of Governors.

Chapter Ma. Type SI Woodward Governor
Chapter Mb. Pneumatic-Hydraulic Woodward Governor (Early Types - previous to 360686)
Chapter Md. Pneumatic-Hydraulic Woodward Governors (360686 and later types)
Bulletin 2402 and 4401 for the General Electric Governor

GENERAL

The Electro-Hydraulic governors are normally isochronous (that is, if the engine is not overloaded, it maintains the same speed regardless of load, except at the instant the load changes) with auxiliaries added for load control, low oil pressure shutdown, and hydraulic



Illus. Mc1. Governor Installed on Engine

speed control, controlled thru an arrangement of electrical solenoids. The governors are temperature compensated to limit the speed droop to 5 rpm for 100° F. temperature rise of governor oil.

For purpose of designation, the front of the governor is the end having the indicating plate and power piston assembly. All descriptive instructions referred to in this instruction assume that the observer views the governor with the indicating plate and power piston assembly to the viewer's left, and the shutdown device to the back, away from the viewer. This is the actual manner in which the unit is installed on the engine.

INSTALLATION

When the governor is installed on the engine, particular care should be exercised to see that the drive connection to the engine is aligned properly. Bolt the governor to the governor drive base, making sure the gasket is in place. The linkage from the governor to the fuel system must be aligned properly. Friction or lost motion must be eliminated. Before mounting, make certain that the Unibal bearing in the governor end of the "J" bar moves freely. The pin must slide freely into the "J" bar and governor clevis without any prying or additional alignment; if it does not, check the engine overspeed reset lever to see that it is engaged. After connecting the governor, check the power piston gap and fuel control mechanisms as outlined under "Engine Adjustments." Connect the oil pressure line to the oil pressure shutdown device.

Plug in electrical receptacle for the governor control apparatus.

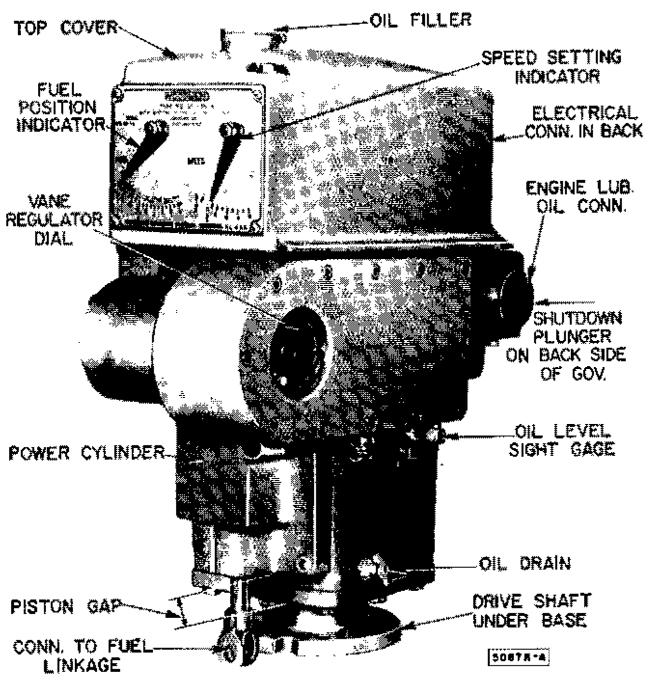
Fill the governor with a good grade of SAE 30 oil for ordinary temperature conditions.

> NOTE: Governors with fixed load regulator timing orifice are calibrated using SAE 30 oil. A switch to lighter or heavier oil should only be made when the rate of vane servo movement, under normal operating temperatures (engine warmed up), varies appreciably from the normal rate. (The normal rate is 7 seconds increase, minimum to maximum field, and 14 seconds decrease, maximum to minimum field.) The increase rate should not vary more than ± 2 seconds from normal and the decrease rate not more than ± 4 seconds from normal.

Governors with external load regulators (360244, 360594, etc.) modified by adding the fixed orifice should use SAE 40 oil except under extreme cold conditions. The normal rate is 9 seconds increase, minimum to maximum field, and 18 seconds decrease, maximum to minimum field, with 140°SAE 40 oil. The increase rate should not vary more than ± 2 seconds and the decrease rate not more than ± 4 seconds from normal.

The oil must not contain additives which are used to free up rings, remove carbon, etc., unless a non-foaming additive is also present. The oil should not foam or sludge excessively when agitated, or form a gummy deposit when heated. Use clean new oil or filtered oil. All containers must be clean and be rinsed with a light grade fuel oil or kerosene before using.

Keep the governor oil level between lines in the oil gage when the engine is running. Oil may be added to the governor thru the oil filler cup. Add the oil slowly to avoid over-filling. Oil level above or below the lines on the gage, when running, will cause aeration of the oil resulting in a hunting condition.



Illus. Mc2. Front and Left Hand Side View of Governor

ENGINE ADJUSTMENT

(Applicable to engines previous to engine No. 963984 with OFFSET fuel control arm, Illus. Mc4.)

Injection Pump Overtravel Check

It is important that injection pumps with rack stops have proper overtravel for satisfactory governor operation. Overtravel can be checked with the pump on or off the engine. Press the rack stop, Illus. Mc3, against the pump body and note the maximum rack reading. The maximum rack reading must be 8-3/4 rack or hunting is likely at full load (8 rack) operation. The 3/4 rack overtravel must be maintained.

If the maximum rack reading is not 8-3/4 rack, remove the collar and shim as required to 8-3/4 rack. The collar must be square to the pump body and not bind the rack.

Fuel Control

The adjustment procedure is started with the governor connected to the fuel control mechanism and the governor power piston in the "No Fuel" position.

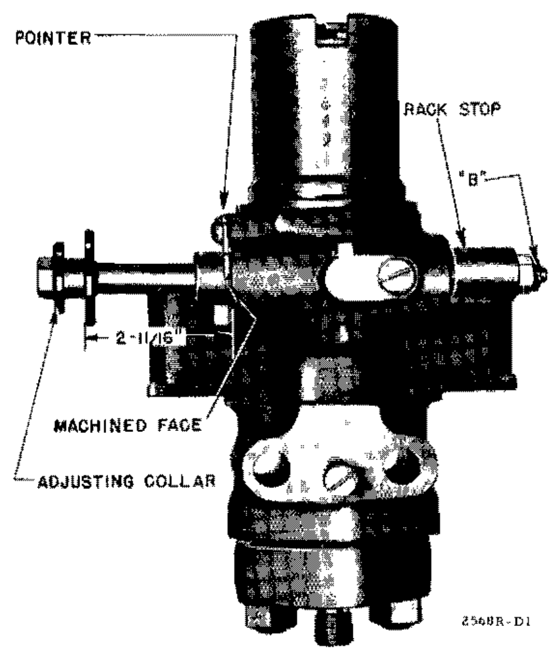
It is important that fuel rack adjustments be made very carefully as a slight error can cause hunting at full load.

Raise the governor power piston by means of the governor power piston jack (Illus. Mc6, No. 32) until a 3/8" dimension is reached between the governor body and governor piston rod coupling. Use a gage. This is important.

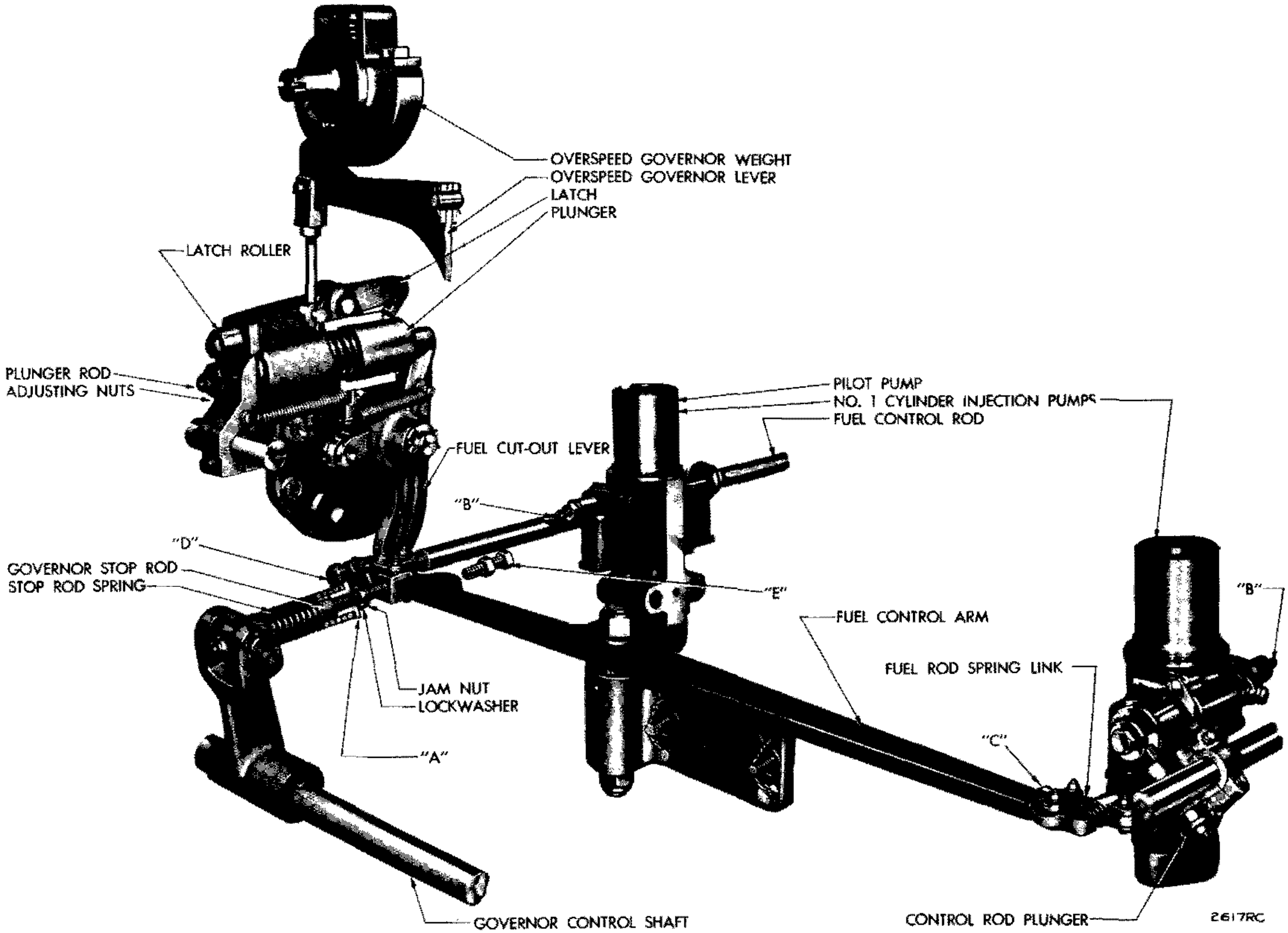
Check the fuel control linkage for binding and check each injection pump rack for sticking. Also be sure the torque limit screw "E," Illus. Mc4, is not limiting the rack travel to less than 17 total rack reading. (All units other than 1000 and 1500 HP units.)

Set the No. 1 injection pump on the opposite governor side of the engine so a 2-11/16" measurement is obtained between the inner face of the control rack adjusting collar and the body of the pump adjacent to the pointer. This dimension is shown in Illus. Mc3. Bend out the ears of the square lockwasher located on the governor stop rod adjustment inside the exhaust end cover on the opposite governor side. Loosen the jam nut and turn the hexagonal head screw "A" in or out on the threaded adjusting rod end. When a 2-11/16" measurement is obtained, tighten the jam nut, and bend down the ears of the square lockwasher. Adjust the No. 1 pump on the opposite governor side to rack 8 by turning the adjusting screw "B" in Illus. Mc3.

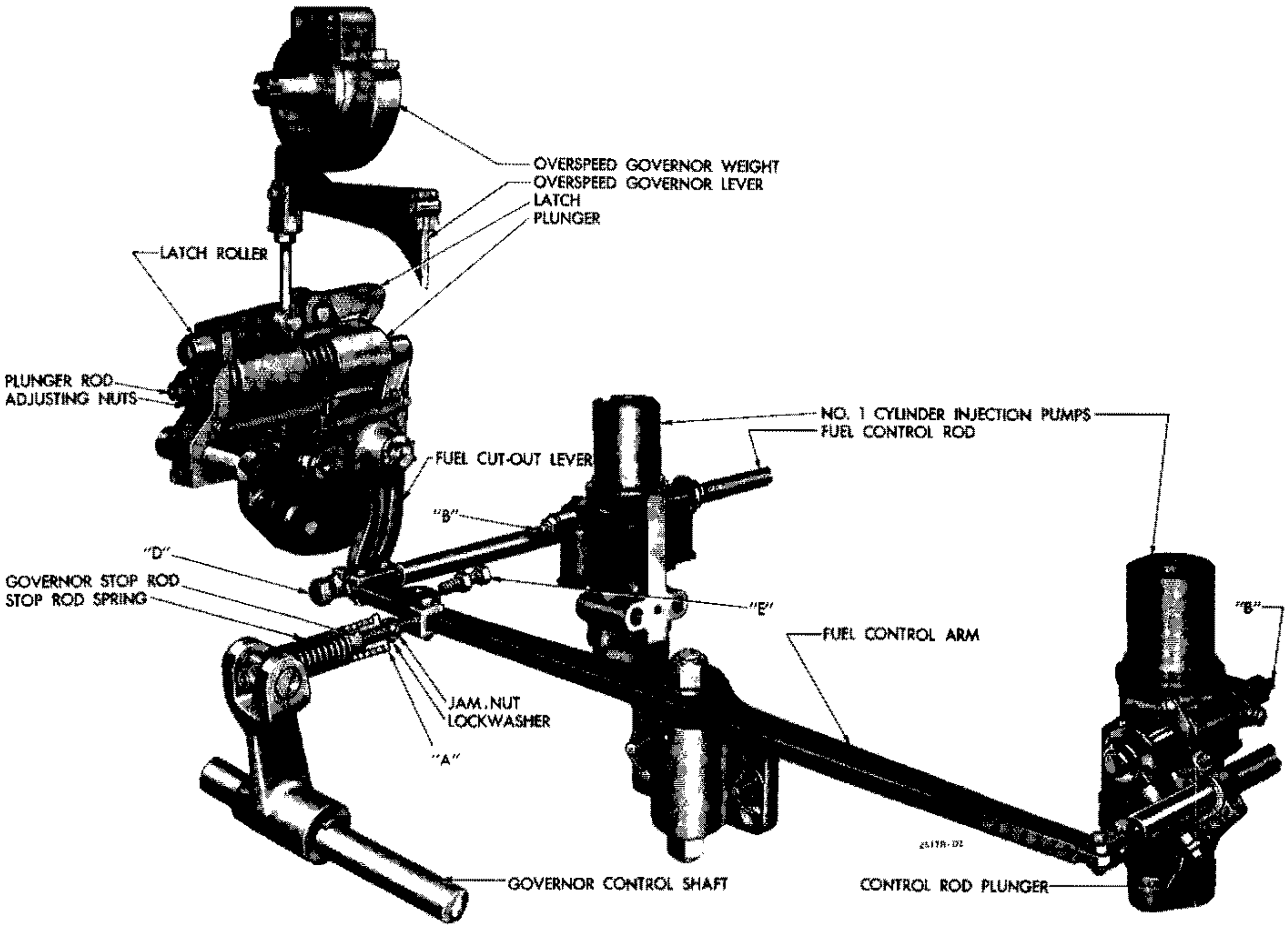
Set the No. 1 injection pump on the governor side so a 2-11/16" measurement is obtained between the inner face of the control rack adjusting collar and the body of the pump, turning the fuel rod link adjusting screw "C" in Illus. Mc4 to obtain the 2-11/16" distance. The fuel rod link adjusting screw is part of the fuel rod



Illus. Mc3. Fuel Injection Pump Adjustments



Illus. Mc4. Fuel Control Linkage Adjustments - OFFSET Fuel Control Arm Shown
(Refer to Illus. Mc5 for CENTER PIVOT Fuel Control Arm)



Illus. Mc5. Fuel Control Linkage Adjustments
(CENTER PIVOT Fuel Control Arm)

spring link which connects the fuel control arm to the control rod on the governor side of the engine. When this setting has been made, adjust the pump to rack 8 by turning the rack adjusting screw "B" in Illus. Mc3.

Adjust all the pumps to rack 8. Be sure the rack collar is not turned when the rack is adjusted.

Reduce the rack position on the pumps by means of the power piston jack. As the No. 1 governor side pump reaches the zero position, the No. 1 opposite governor side pumps should be at approximately 3-1/4 rack.

With the governor in the "At Rest" position, check the rack position on both sides of the engine. Racks on the governor side will read zero, racks on the opposite governor side should be from 3/4 to 1 rack.

Injection Pump Overtravel Recheck

Jack the governor power piston to the end of travel. (On governors with internal fuel stops, 5/16" power piston gap corresponds to 8-3/4 fuel rack.)

Check the pump racks. Each pump should be at 8-1/2 rack. If pumps are not at 8-1/2 rack, adjust the torque limit screw "E," Illus. Mc4, to give 8-1/2 rack on each side or a total of 17 rack (all units other than 1000 and 1500 hp units). Refer to Chapter L for complete settings.

Disengage the control rod plunger from the adjusting collar and check settings of rack stop. With the rack stop against the pump body, the rack should read 8-3/4. To adjust the rack stop, remove the collar and shim as required to read 8-3/4 rack. Be sure the collar is square to the body and does not bind the racks.

If settings have been made on a cold engine, the adjustments should be rechecked after the engine has been brought up to temperature. Also, check for correct full engine speed before readjusting full load governor piston gap and fuel rack setting.

ENGINE ADJUSTMENT

(Applicable to Engine No. 963984 and all thereafter with CENTER PIVOT fuel control arm, Illus. Mc5.)

Injection Pump Overtravel Check

It is important that injection pumps with rack stops have proper overtravel for satisfactory governor operation. Overtravel can be checked with the pump on or off the engine. Press the rack stop, Illus. Mc3, against the pump body and note the maximum rack reading. The maximum rack reading must be 8-3/4 rack or hunting is likely at full load (8 rack) operation. The 3/4 rack overtravel must be maintained..

If the maximum rack reading is not 8-3/4 rack, remove the collar and shim as required to 8-3/4 rack. The collar must be square to the pump body and not bind the rack.

Fuel Control

The adjustment procedure is started with the governor connected to the fuel control mechanism and the governor power piston in the "No Fuel" position.

It is important that fuel rack adjustments be made very carefully as a slight error can cause hunting at full load.

Raise the governor power piston by means of the governor power piston jack (Illus. Mc6, No. 32) until a 3/8" dimension is reached between the governor body and governor piston rod couplings. Use a gage. This is important.

Check the fuel control linkage for binding and check each injection pump rack for sticking. Also be sure the torque limit screw "E," Illus. Mc5, is not limiting the rack travel to less than 17 total rack reading. (All units other 1000 and 1500 hp units.)

Set the No. 1 injection pump on both sides of the engine so a 2-11/16" measurement is obtained between the inner face of the control rack adjusting collar and the body of the pump adjacent to the pointer. This dimension is shown in Illus. Mc3. Bend out the ears of the square lockwasher located on the governor stop rod adjustment inside the enhaust end cover on the opposite governor side. Loosen the jam nut and turn the hexagonal head screw "A" in or out on the threaded adjusting rod end. When a 2-11/16" measurement is obtained, tighten the jam nut, and bend down the ears of the square lockwasher.

When this setting has been made, adjust the No. 1 pump on both sides of the engine to rack 8 by turning the rack adjusting screw "B," Illus. Mc3.

Adjust all the pumps to rack 8. Be sure the rack collar is not turned when the rack is adjusted.

With the governor in the "At Rest" position, check the rack positions on both sides of the engine. All racks should read approximately zero.

Raise the governor power piston by means of the power piston jack so racks are at 3 or above. Trip the overspeed. All racks should read zero. If racks do not read zero, adjust screw "D," Illus. Mc5, until racks read zero.

Injection Pump Overtravel Recheck

Jack the governor power piston to the end of travel. (On governors with internal fuel stops, 5/16" power piston gap corresponds to 8-3/4 fuel rack.)

Check the pump racks. Each pump should be at 8-1/2 rack. If pumps are not at 8-1/2 rack, adjust the torque limit screw "E," Illus. Mc5, to give 8-1/2 rack on each side or a total of 17 rack (all units other than 1000 and 1500 hp units). Refer to Chapter L for complete settings.

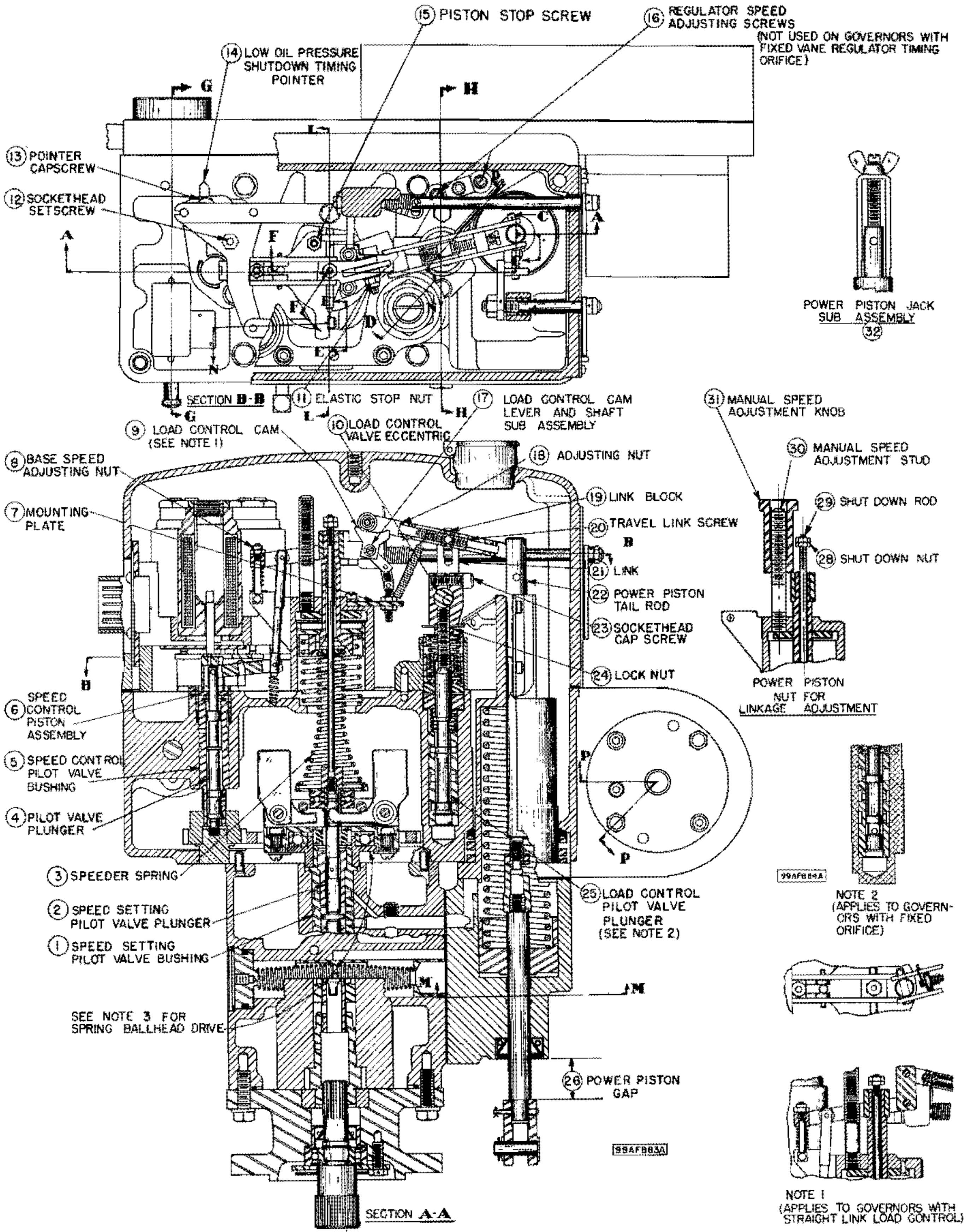
Disengage the control rod plunger from the adjusting collar and check settings of rack stop. With the rack stop against the pump body, the rack should read 8-3/4. To adjust the rack stop, remove the collar and shim as required to read 8-3/4 rack. Be sure the collar is square to the body and does not bind the racks.

If settings have been made on a cold engine, the adjustments should be rechecked after the engine has been brought up to temperature. Also, check for correct full engine speed before readjusting full load governor piston gap and fuel rack setting.

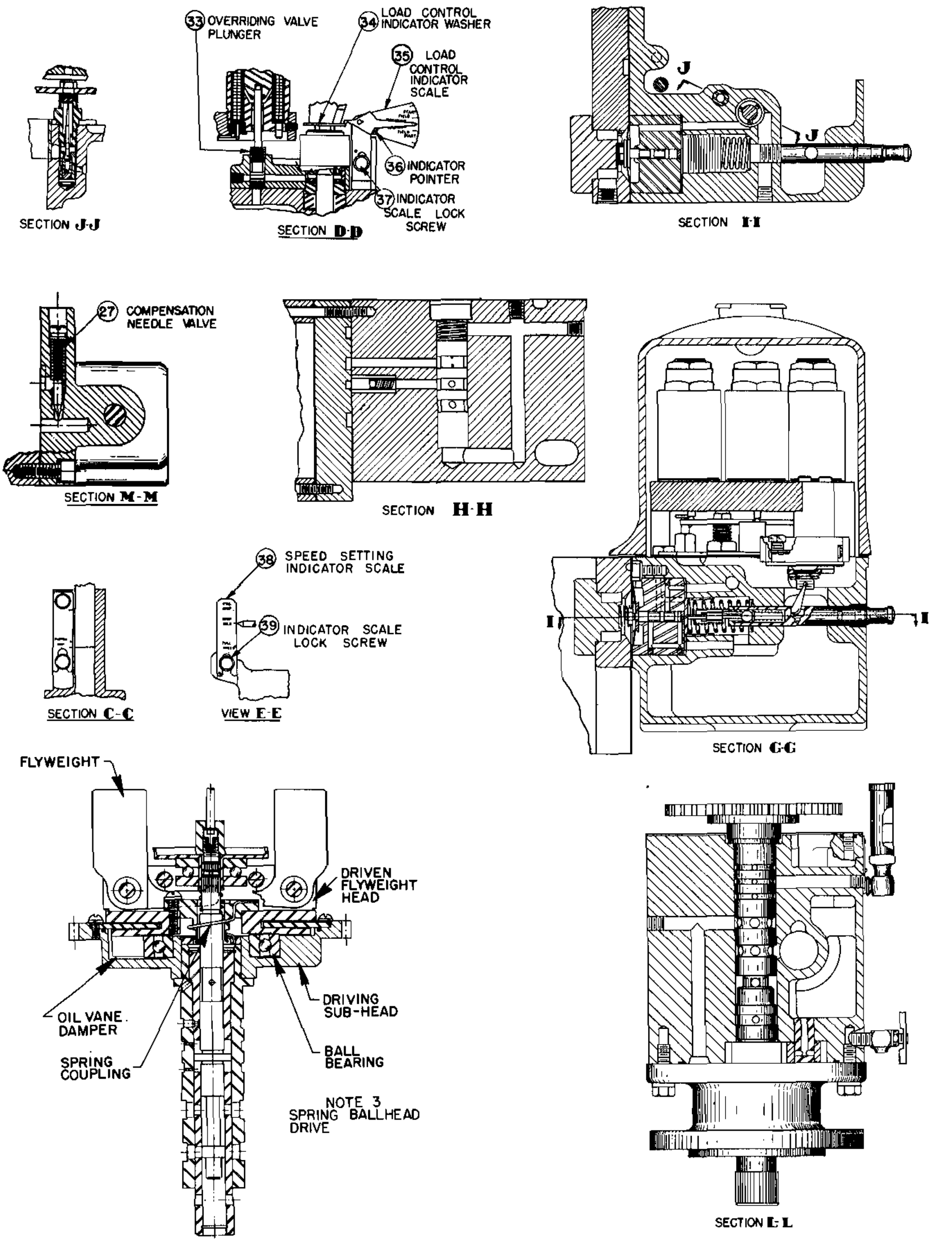
ATTENTION: The governor has been set at the factory, but should occasions arise when setting is necessary, the following procedures should be observed.

GOVERNOR SETTING (Preliminary)

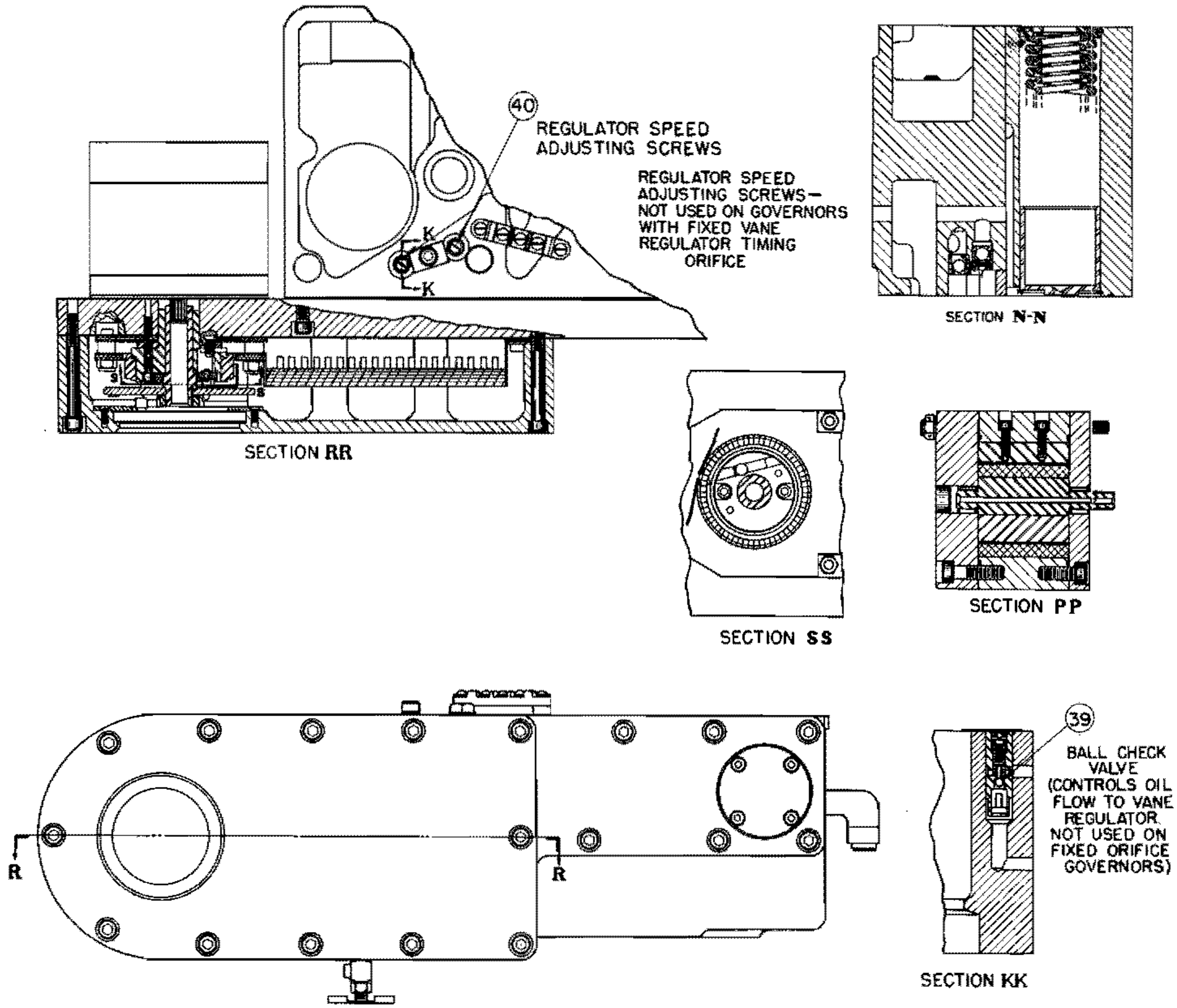
Remove the governor cover with care to prevent possible damage to the cover gasket. Place a bolt along the edge nearest the viewer to prevent oil from running down the side of the governor. The head of the bolt will be in the open portion above the power piston assembly and the body of the bolt will be along the edge of the governor. If desired, a scale may be used instead of the bolt. Start the engine and bleed the air from the governor. With a new governor or a governor that has been drained or cleaned, all the air must be bled from the governor. Loosen the 1/8" pipe plug near the plate on the viewers side of the governor several turns and allow oil to flow freely. Also loosen the compensating needle valve (Illus. Mc7, Ref. 27)



Illus. Mc6. Main Cross-section of Governor



Illus. Mc7. Cross-section of Governor - Auxiliary Views
(Refer to Illus. Mc6 for sectional view of governor)



Illus. Mc8. Cross-section of Governor - Auxiliary Views (Refer to Illus. Mc6 for sectional view of governor)

several turns and allow the engine to surge freely for 30 seconds to work out any air in the governor passages. This is important. The compensating needle is in the power piston mounting pad and is located on the side away from the viewer.

After all the air is out of the system, tighten the 1/8" pipe plug and reset the governor compensating needle until all hunt has been eliminated. The hunt is usually eliminated when the compensating needle is between 1/4 and 1/2 turn open; however, the opening should be as great as possible, without producing hunting.

The adjustment of the compensating needle should be made with the governor oil temperature as close as possible to the normal operating temperature of approximately 140-160° F. If settings are made under conditions warmer than normal, excessive idle speed undershooting may occur with cold oil. The governor may hunt with hot governor oil if compensation is adjusted with the governor colder than normal.

ENGINE SPEED SETTING

In setting the engine speed for the various throttle or controller positions, it is necessary to have an accurate tachometer in order to be able to check the engine speed exactly. The governor oil should be hot before starting the adjustment. Make sure that all necessary safety precautions are taken prior to setting engine speeds. The engine overspeed trip must be in proper operation.

In setting the engine speeds, throttle manipulation is necessary; sequence of manipulations in setting engine speed follows:

1. With the engine running and on the line, energize all the solenoids (ABCD) by placing the throttle in position No. 6. Check to see that all the solenoids are energized with the throttle in this position.

2. Adjust the engine speed to 692 plus or minus 4 rpm by adjusting the base speed adjusting nut (Illus. Mc6, Ref. 8). Screwing the base speed adjusting nut up increases engine speed; screwing the nut down decreases engine speed. The nut is located between solenoids "B" and "C" to the right of center of the governor speed or spring servo.

Since all solenoids are energized in throttle position No. 6, the triangular plate upon which the solenoids impart action rests on an even plane. The fulcrum controlling the speeder servo pilot valve rests on the under side of the triangular plate. The base speed adjusting nut adjusts the relationship between the speeder servo and the balance point of the speeder servo pilot valve.

By de-energizing one solenoid at a time, the angle of the triangular plate changes so that its relation to the fulcrum point changes. Various positioning of the solenoid plungers caused by energizing the solenoids in various sequences impart action upon the triangular plate which controls the positioning of the speed control pilot valve plunger and bushing (Illus. Mc6, Ref. 5). The plunger and bushing position the top end of the speeder spring and control the force exerted by the speeder spring; the force exerted by the speeder spring determines the engine speed required to center the governor main pilot valve. Consequently an error in speed will uncenter the governor main pilot valve plunger and cause the power piston to move in a direction to correct the speed error.

3. Placing the throttle in throttle position No. 8 will energize solenoids A, B and C. With the throttle in this position, bring the speed up to 850 plus or minus 4 rpm by turning the adjusting screw on "D" solenoid. Turn the adjusting screw on "D" solenoid up to increase speed.

4. Move the throttle to position No. 7 and adjust the engine speed to 766 plus or minus 4 rpm with the adjusting screw on "A" solenoid. Turn the adjusting screw on "A" solenoid down to increase speed. In position No. 7, coils "B"

THROTTLE POSITION	ENGINE RPM	GOVERNOR SOLENOIDS				ADJ. STEPS	SPEED ADJ.	1.14 RATIO GOV. RPM	TOLERANCE RPM ENG., GOV.
		A	B	C	D				
Off	0				X		Shutdown Nuts	0	
Idle	300					5	C Solenoid	343	± 4
1	300					5	C Solenoid	343	± 4
2	376	X						433	± 15
3	454			X				522	± 15
4	536	X		X		4	B Solenoid	612	± 4
5	613		X	X	X			702	± 15
6	692	X	X	X	X	1	Fulcrum Nut	792	± 4
7	766		X	X		3	A Solenoid	881	± 4
8	850	X	X	X		2	D Solenoid	971	± 4

A = 1 B = 4 C = 2 D = -2 Speed Increase per Throttle Step Approximately 80 ± 4

Speed Setting Chart

and "C" are energized.

5. Proceeding, move the throttle to position No. 4 and adjust the speed to 536 plus or minus 4 rpm with the adjusting screw on "B" solenoid. Turn adjusting screw on "B" solenoid down to increase speed. With the throttle in position No. 4, solenoids "A" and "C" are energized.

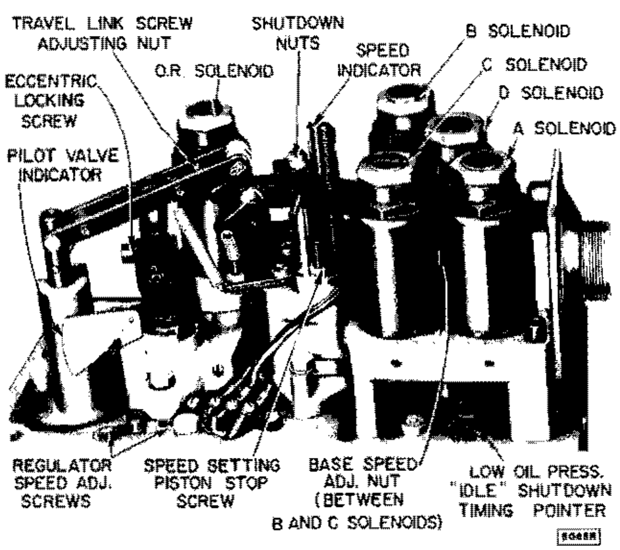
6. Move throttle into throttle position marked "Idle" and adjust the speed to 300 plus or minus 4 rpm with the adjusting screw on "C" solenoid. Turn adjusting screw on "C" solenoid down to increase speed.

7. Check the engine speeds with the throttle in positions 2, 3, and 5. The engine speeds at these points should come within plus or minus 15 rpm of 376, 454, and 613 rpm respectively. In some cases these speeds can be brought within the limits by shifting the basic throttle speeds within the tolerance. If any of the speeds in throttle positions 2, 3, or 5 are outside the 15 rpm tolerance, a new speeder spring (Illus. Mc6, Ref. 3) should be installed.

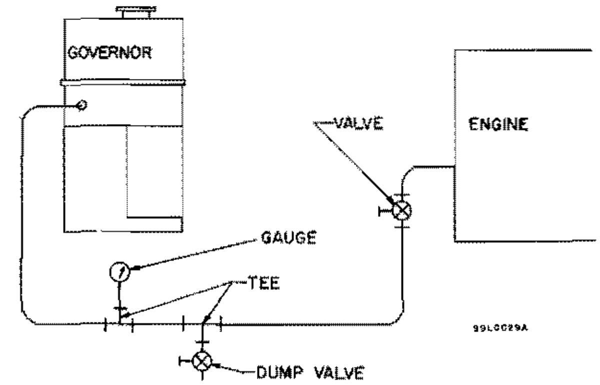
8. Tolerances for the final engine speed settings are: Idle and throttle positions 4, 6, 7, and 8 - plus or minus 4 rpm, positions 2, 3, and 5 - plus or minus 15 rpm.

9. Start with the throttle in idle position, move up to throttle position No. 8 and then back down to idle in single steps. Engine speeds going up should check with speeds going down within 2 rpm; if not, find source of friction and correct.

10. With the throttle in idle position, set the shutdown nuts (Illus. Mc6, Ref. 28) to have 1/32" clearance on the end of the piston, with all slack out.



Illus. Mc9. Top View of Governor (Early governor with adjustable load control cam shown)



Illus. Mc10. Test for Low Oil Pressure Shutdown

11. Move the throttle to shutdown. The governor should close off entirely. Return the throttle to the idle position and turn the stop screw (Illus. Mc6, Ref. 15) in the top of the speeder spring power cylinder down until it contacts the piston, back it off one and one-half turns, (3/64") and lock tightly.

12. With the throttle in the idle position, quickly move the throttle to throttle position No. 8. Record the time required for the engine speed to reach 850 rpm. This should be from 5 to 8 seconds.

13. Set scale (Illus. Mc7, Ref. 38) on speeder spring power cylinder so that 300 rpm engine speed corresponds to idle engine speed. Scribe a line at 650 rpm and full speed.

14. After completion of other tests, put the governor cover in place and recheck speeds. Make corrections until speeds are correct with the cover in place.

LOW OIL PRESSURE SHUTDOWN

The low oil pressure shutdown device is incorporated in the governor to provide complete protection against low oil pressure in the engine.

This device is equipped with a timing port which will permit starting of the engine with no oil pressure, and allow sufficient time for oil to flow through the engine before acting to shut down the engine due to no oil pressure or low oil pressure.

The timing adjustment is incorporated in the bushing (Illus. Mc6, Ref. 5) controlled by the pointer-lever (Illus. Mc6, Ref. 14). Timing for idle shutdown is from 45 to 60 seconds. That is, if an oil pressure failure occurs, the engine shuts down after a 45 to 60 second period at engine "idle." This setting has been marked by a center punch mark to coincide with the pointer at original setting.

Moving the pointer in a counterclockwise direction increases the time delay of shutdown at engine idle.

Above 400 rpm engine speed, the speed setting beam moves to a position to nullify the timing. This setting is made by adjusting the setscrew. (Illus. Mc6, Ref. 12.) At 400 rpm or over the engine shutdown is instantaneous.

To test the operation of the device, disconnect the engine oil pressure line from the governor. Make up a test outfit to bridge this gap as shown in Illus. Mc10. The test unit will contain a valve and two tees, with suitable tubing connections. This equipment should be so assembled that the oil coming from the engine flows first through the valve, then through the two tees and finally into the governor engine oil pressure connection. For convenience, the piping, the tees, and the valve should be arranged in a circular coil. The unit can then be connected to the governor and to the engine oil line with a minimum of distortion of the engine oil line.

Fit the tee closest to the governor with a gage. This gage will register engine oil pressure. The other tee is fitted with a dump valve. With the dump valve closed and the in-line valve open, the gage will show engine oil pressure as impressed on the oil shutdown device. Closing the in-line valve traps the oil pressure to the governor. Opening the dump valve in the first tee dumps the oil pressure. With the test valve combination, all settings can be made fairly accurately.

Close the dump valve and open the in-line valve. Start the engine and run it at idle or 300 rpm. The engine should not shut down. Open the dump valve slightly to establish a small leak, and then slowly close the in-line valve. The engine should shut down in 45 to 60 seconds when the gage registers from 3 to 6 psi.

Again close the dump valve and open the in-line valve. Run the engine at a speed greater than 400 rpm. Open the dump valve slightly, and slowly close the in-line valve. When the engine oil pressure has been reduced to 14 to 18 psi by manipulating the valves, the engine should shut down immediately.

If engine shutdown does not occur at 3 to 6 psi oil pressure when running at idle, and 14 to 18 psi when running over 400 rpm, the error will probably be found due to manufacturing tolerances in the springs. The speed setting piston spring has the greatest share in determining the above oil pressure.

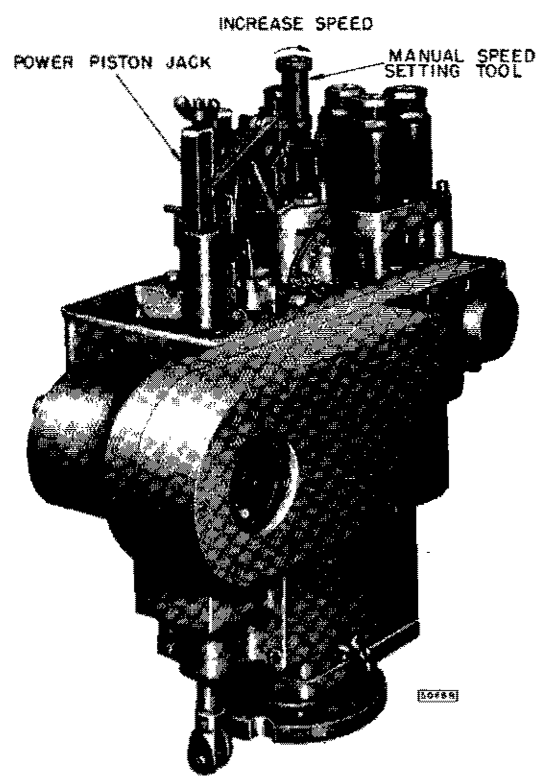
LOAD CONTROL PILOT VALVE LAP CHECK

The pilot valve assembly is the device that hangs from the link block. (Illus. Mc6, Ref. 19.)

Before lapping the valve, check to see that the eccentric setting is not more than 20° from a horizontal plane and that the link block (Illus. Mc6, Ref. 19) is set centrally over the valve. These two conditions will facilitate making adjustments for minimum field start (maximum field start on 361513 governors) and full load conditions. Also set the overriding solenoid for 1/16" travel (2 turns from the full down position).

With the generator field or "LOCO-RUN" cut out and the engine running with the throttle in the 5th or 6th notch, the vane regulator will be in maximum field position. Lift the pilot valve by hand to make the vane regulator move counterclockwise or to "minimum field." Release the pilot valve slowly and allow the vane regulator to move clockwise toward "maximum field." Stop the vane regulator approximately in mid-travel by manually controlling the pilot valve. The position of the pilot valve at which no motion is imparted to the vane regulator is called "lap" or "O" position. With the pilot valve held in the lap position, check the indicator pointer to see that it is exactly centered.

If the indicator does not accurately indicate the balanced or "lap" position of the load control



Illus. Mc11. Application of Governor Tools pilot valve, adjust the indicator scale (Illus. Mc7, Ref. 35) by loosening the screw (Illus. Mc7, Ref. 37) and sliding the indicator scale to the proper position to indicate "O" position. Tighten the screw and recheck the pilot valve lap position.

VANE REGULATOR TIMING SETTING

(Applies to 360244 and 360594 and other governors with external load regulators not rebuilt with fixed orifice for load regulator timing.)

With the engine operating under the same conditions as for the Pilot Valve Lap Check and with the governor oil at approximately 160° F., check the vane regulator timing. The regulator should move from minimum to maximum field (clockwise) in 5 seconds with hot oil or 7 seconds with cold oil, and from maximum to minimum field (counterclockwise) in 10 seconds with hot oil or 15 seconds with cold oil.

View the vane regulator from the commutator side when checking the arm movement rotation.

Adjust the rate of movement by the screws (Illus. Mc6, Ref. 16). The adjusting assembly is located in the lower left hand corner when viewing the governor from the top as shown in Illus. Mc9. The adjusting screws provide a means of adjusting the timing of the regulator. To increase the rate of oil flow in decrease excitation direction, turn the screw located on the left of the adjusting assembly in a clockwise direction. Turn the other screw located on the right of the adjusting assembly clockwise to increase flow in the increase excitation direction. The adjusting assembly is located on the forward part of the governor, on the power piston block assembly. The screw nearest the engine control the "maximum" time. The screw furthest from the engine the "minimum to maximum" time.)

VANE REGULATOR TIMING SETTING

(Applicable to 360310, 360595, 360685, 360964, 360967, and other governors with integral load regulator, but not equipped with fixed orifice for load regulator timing.)

With the engine operating under the same conditions as for the Pilot Valve Lap Check and with the governor oil at approximately 160° F., check the vane regulator timing. The regulator should move from minimum to maximum field (clockwise) in 5 seconds with hot oil or 7 seconds with cold oil, and from maximum to minimum field (counterclockwise) in 10 seconds with hot oil or 15 seconds with cold oil.

View the vane regulator from the commutator side when checking the arm movement rotation.

Adjust the rate of movement by the screws (Illus. Mc6, Ref. 16). The adjusting assembly is located at the lower left hand corner when viewing the governor from the top as shown in Illus. Mc9. The adjusting screws provide a means of adjusting the timing of the regulator. To increase the rate of oil flow in decrease excitation direction, turn the screw located on the left of the adjusting assembly in a clockwise direction. Turn the other screw located on the right of the adjusting assembly clockwise to increase flow in the increase excitation direction.

Provision is made to return the vane regulator from the maximum to minimum field in 2 to 3 seconds when the overriding solenoid is energized on governors with controlled fast dump. The rate of movement is not adjustable (not affected by the adjusting screws) and is accomplished by a wide bottom land on the load control pilot valve plunger uncovering a large port in the bushing. See Note 2 of Illus. Mc6.

In adjusting normal maximum to minimum timing, it is very important that the pilot valve plunger be raised only enough to bring the pointer to minimum field mark on the scale. If the plunger is raised further, and the governor is equipped with the overriding solenoid controlled fast dump, the large port in the bushing is uncovered causing a 3 second return to minimum field.

ADJUSTMENT OF OVERRIDING SOLENOID

To adjust the solenoid screw the plunger stop plug all the way in after first loosening the locknut at the top of the solenoid. With the coil de-energized, back out the plunger stop plug until the overriding valve plunger (Illus. Mc7, Ref. 33) operates freely. The adjustment of the solenoid is approximately 2 turns (1/16" travel) from the full down position.

FULL LOAD SETTING

After the pilot valve has been lapped, the full load adjustment can be checked and corrected if required. With the engine shut down, apply the governor tools. Jack up the power piston with the use of the power piston jack (Illus. Mc6, Ref. 32) until a 3/8" power piston gap is reached. The power piston jack is the yoke-like device with a thumb screw attachment; the jack mounts on top of the power piston.

Turn the manual speed adjusting tool (Illus. Mc6, Ref. 31) until full engine speed is recorded on the speed indicator (Illus. Mc7, Ref. 38). The manual speed adjusting tool screws on to the manual speed adjusting stud and is used to depress the speeder servo piston.

When the above two conditions are met, the load control pilot valve pointer (Illus. Mc7, Ref. 36) must be balanced at "O" position. If it is not, loosen the Allen head capscrew (Illus. Mc6, Ref. 23) in the pilot valve assembly and adjust the eccentric (Illus. Mc6, Ref. 10) by means of a screwdriver until the pointer shows "O" position.

MINIMUM FIELD START SETTING

(See "Maximum Field Start" applicable to 361513 governors)

With the engine running at idle speed (with cooling fan off and compressor unloaded) measure the power piston gap. The measured gap should be within range of 58/64 to 66/64 inches.

Stop the engine and jack up the power piston to the gap determined above. If this gap is not known, use 60/64 inch. Also use the manual speed setting tool to set the speed indicator pointer to "idle." Then check the load control pilot valve pointer. The pointer should be at minimum field. If the pointer is not at minimum field, turn the travel link screw (Illus. Mc6, Ref. 20) until the load control pilot valve pointer indicates minimum field.

> NOTE: Early governors could not be set all the way to minimum field due to the fact that the link (Illus. Mc6, Ref. 21) may strike the upper link spreader block when the overriding solenoid functions. 3/32 toward minimum field was specified for the early governors. (The 3/32 reading is not an actual scale measurement. The distance between the graduations is considered as 1/8 inch and is derived from the movement of the pilot valve plunger. In reality the "3/32" is 3/4 the distance toward minimum field.)

Inasmuch as the minimum field start setting is not independent of other settings, the full load setting should be rechecked after the minimum field start setting has been made. It may be necessary to adjust both the load control pilot valve eccentric as well as the block to secure the specified conditions.

The governor is set at the factory for idle speed minimum field start with a power piston gap of 60/64 inch. An increase of 3/64 inch or more to the piston gap when set at 60/64 inch and minimum field will tend to cause the vane servo to move to maximum field.

MAXIMUM FIELD START SETTING
(Applicable to 361513 governors)

With the engine running at idle speed (with cooling fan off and compressor unloaded) measure the power piston gap. The measured gap should be within range of 58/64 to 64/64 inches. If the gap is not known, use 60/64 inch.

Stop the engine and jack up the power piston to the gap determined above. Also use the manual speed setting tool to set the speed indicator pointer to "idle." Then check the load control pilot valve pointer. The pointer should be at maximum field. If the pointer is not at maximum field, turn the travel link screw (Illus. Mc6, Ref. 20) until the load control pilot valve pointer indicates maximum field.

Inasmuch as the maximum field start setting is not independent of other settings, the full load setting should be rechecked after the maximum field start setting has been made. It may be necessary to adjust both the load control pilot valve eccentric as well as the block to secure the specified conditions.

The governor is set at the factory for idle speed maximum field start with a power piston gap of 60/64 inch.

RELOCATING THE PILOT VALVE

In remote cases extreme adjustments might have to be made to the travel link screw in setting the Minimum (or Maximum) Field Start Adjustment and to the eccentric in setting the Full Load Adjustment. The extreme adjustments can be avoided by relocating the pilot valve setting which will give a minimum amount of adjustment to the eccentric and travel link screw.

Start relocating the pilot valve by raising the pilot valve until the nut on the threaded portion of the pilot valve shows at the opening of the pilot valve cage. Do not lift the pilot valve too high as the control land of the upper seat will contact the lip of the upper oil seal and may cut the rubber rings. Unlock the locknut (Illus. Mc6, Ref. 24) under the indicator washer (Illus. Mc7, Ref. 34), and with an open end wrench turn the lower nut that protrudes from the opening either to the right or left, as required to satisfy the determined extreme conditions. (This nut is not shown in Illus. Mc6; however, it is located directly below the locknut.)

After relocating the pilot valve, lock the locknut.

If the pilot valve has been relocated, the pilot valve will then have to be lapped again as explained under Pilot Valve Lap Check.

Reset the travel link screw for minimum (or maximum) field start and the eccentric for full load as explained previously. Since the pilot valve was relocated due to the extreme adjustments needed in setting the travel link screw and the eccentric, the travel link screw and the eccentric should now need only a small adjustment.

LOAD CONTROL CAM SETTING

(Applies to 360310 and 360244 and other governors with the load control cam instead of the straight link.)

The load control cam (Illus. Mc6, Ref. 9) should be set, so that the engine will develop full torque from 650 rpm to 850 rpm. (The full torque speed of 650 rpm is approximate and from the "Speed Setting Chart" would indicate this range as 613 to 692 rpm.)

With the engine shut down, jack up the power piston to a 3/8" gap. While turning the manual speed adjusting tool to get full engine speed, pause when the speed indicator pointer reaches 650 rpm. Check the position of the arm of the load cam. The arm should be horizontal. If it is not, loosen the nuts above and below the mounting plate (Illus. Mc6, Ref. 7) and adjust them so that the cam arm comes to a horizontal position. After this adjustment is made, move the speed servo to full engine speed.

With the power piston in full load position, the load cam must be adjusted to give the following relationship. When the speed servo is moved from the "full engine speed" position to the 650 rpm position, the load control pilot valve indicating pointer must not move more than 1/32" from the "O" position. The pointer, however, must start to move away from the "O" position as the speed servo is moved below 650 rpm.

The cam can be adjusted by loosening the nut (Illus. Mc6, Ref. 11) on the shaft located on the cam mounting assembly. Loosen the nut very slightly to prevent slipping of setting and lightly tap the cam into position until the above described relationship is obtained. When that relationship has been established, the cam is set correctly and the nut can be tightened.

As the cam setting may affect the full load setting and minimum field start setting, they should be rechecked. After the full load and minimum field start settings are rechecked, recheck the cam setting.

When the cam, full load, and minimum field start settings are all set, wire the travel link screw (Illus. Mc6, Ref. 20) to prevent loss of setting.

FINAL PRECAUTIONS

Remove the governor power piston jack and manual speed adjusting tool and store them above the power piston assembly.

The position of the fuel indicating actuating pins must be checked. The pin is located just below the point where the floating lever assembly is hinged at the top of the tail rod. The normal position of the pin when properly connected is to the back of the governor or toward the engine. The governor mechanically limits the engine to 2nd or 3rd notch when the pin is improperly positioned.

Apply the cover to the governor making sure that the gasket is square and unbroken, and that pointers on the front of the cover are engaged with the inner linkage. Bolt the cover down and check the oil level.

TOOLS

Allen Wrench - 3/32"
Allen Wrench - 1/8"
Allen Wrench - 5/32"
Allen Wrench - 5/16"
Open End - 15° Box Wrench - 5/16"
Open End - 15° Box Wrench - 11/32"
Open End - 15° Box Wrench - 7/16"
Open End - 15° Box Wrench - 3/8"
Open End - 15° Box Wrench - 5/8"
Open End - 15° Box Wrench - 1-1/16"
Long Nose Pliers - 6"
Screwdriver - 8"
Spintite Wrench - 11/32"
Waldes Truarc Snap Ring Pliers - #1
Waldes Truarc Snap Ring Pliers - #3
"T" Handle Wrench
T-14675 Fixture
Load Control Pilot Valve Adjusting Wrench
Power Piston Seal Installing Sleeve
Steel Rule with 1/64" Graduations - 6"

CHAPTER Md - GOVERNING SYSTEM

This Chapter is applicable to the following Pneumatic-Hydraulic Woodward governors.

360686 governors have integral load regulator, straight link load control, amphenol plug, 35-45 ohm resistor pack and fast dump.

360963 governor is the 360686 governor with the Pyle National connector and fuel servo stop.

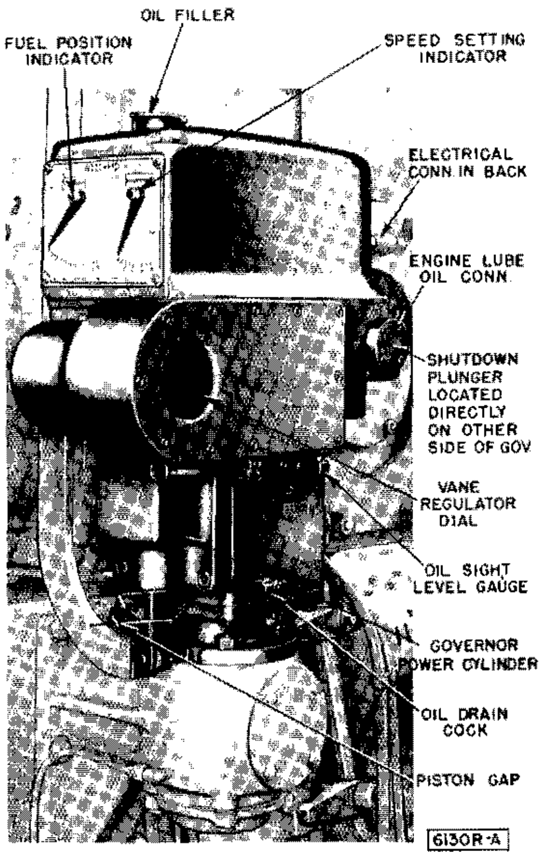
360966 governor is the 360963 governor with fixed vane regulator timing orifice.

361213 governor is the 360686 governor with modification to fixed vane regulator timing orifice.

361690 governor is the 360966 with 55 psi load control cutoff valve and spring ballhead drive.

Refer to the following Chapters and Bulletins for settings of other types of Governors.

Chapter Ma. Type S1 Woodward Governors
Chapter Mb. Pneumatic-Hydraulic, Woodward Governors (Early Types - previous to 360686)
Chapter Mc. Electro-Hydraulic, Woodward Governors
Bulletin 2402 and 4401 for the General Electric Governors



Illus. Md1. Governor Installed on Engine

GENERAL

The Pneumatic-Hydraulic governors are hydraulic governors, normally isochronous, with auxiliaries added for load control, low oil pressure shutdown, and pneumatic control of speed. The governors are temperature compensated to limit the speed droop to 5 rpm per 100° F. temperature rise of governor oil.

For purpose of designation the front of the governor is the end having the indicating plate and power piston assembly. All descriptive instructions assume that the observer views the governor with the indicating plate and power piston assembly to the viewer's left, and the shutdown device to the back, away from the viewer. This is the actual manner in which the unit is installed on the engine, Illus. Md1.

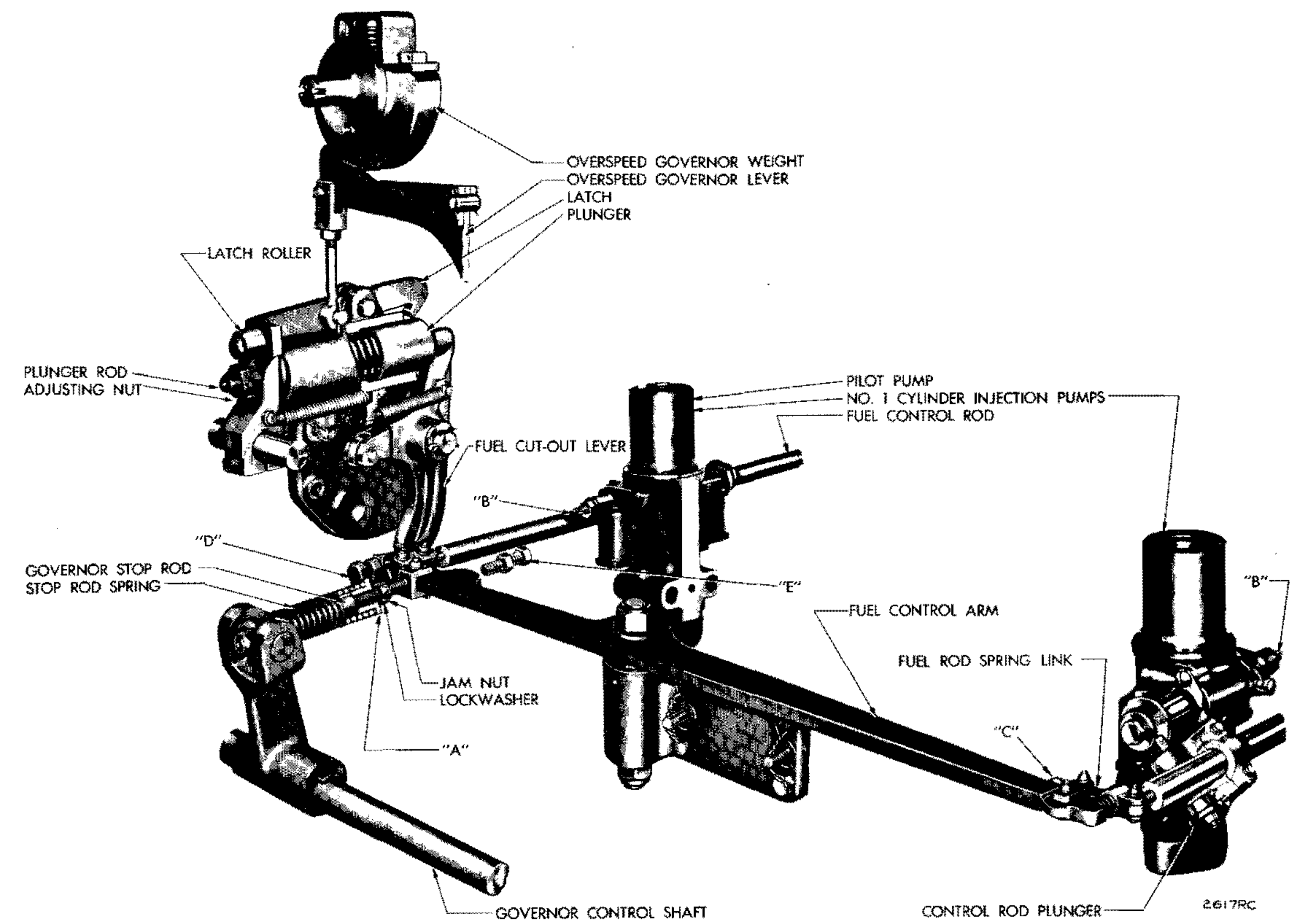
INSTALLATION

When the governor is installed on the engine, particular care should be exercised to see that the drive connection to the engine is aligned properly. Bolt the governor to the governor drive base, making sure the gasket is in place. The linkage from the governor to the fuel system must be aligned properly, friction or lost motion must be eliminated. Before mounting, make certain that the Unibal bearing in the governor end of the "J" bar moves freely. The pin must slide freely into the "J" bar and governor clevis without any prying or additional alignment; if it does not, check the engine overspeed reset lever to see that it is engaged. After connecting the governor, check the power piston gap and fuel control mechanisms as outlined under "Engine Adjustments." Connect the oil pressure line to the oil pressure shutdown device.

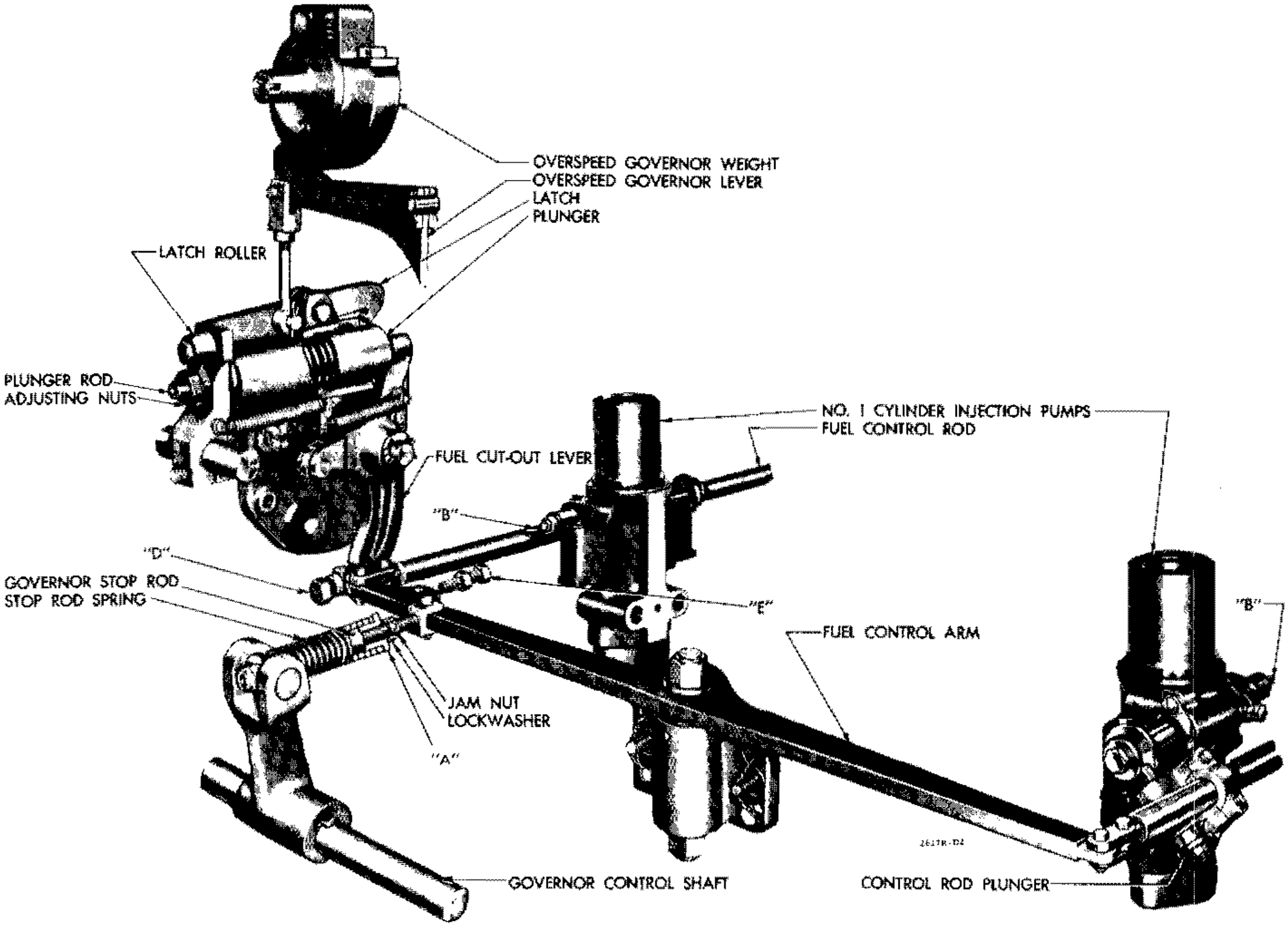
Plug in electrical receptacle for the governor control apparatus.

Fill the governor with a good grade of SAE 30 oil for ordinary temperature conditions.

NOTE: Governors with fixed load regulator timing orifice are calibrated using SAE-30 oil. A switch to lighter or heavier oil should only be made when the rate of vane servo movement, under normal operating temperatures (engine warmed up), varies appreciably from the normal rate. (The normal rate is 7 seconds increase, minimum to maximum field, and 14 seconds



Illus. Md2. Fuel Control Linkage Adjustments - OFFSET Fuel Control Arm Shown
(Refer to Illus. Md3 for CENTER PIVOT Fuel Control Arm)



Illus. Md3. Fuel Control Linkage Adjustments
(CENTER PIVOT Fuel Control Arm)

decrease, maximum to minimum field.) The increase rate should not vary more than ± 2 seconds from normal and the decrease rate not more than ± 4 seconds from normal.

The oil must not contain additives which are used to free up rings, remove carbon, etc., unless a non-foaming additive is also present. The oil should not foam or sludge excessively when agitated, or form a gummy deposit when heated. Use clean new oil or filtered oil. All containers must be clean and should be rinsed with a light grade fuel oil or kerosene before using.

Keep the governor oil level between lines in the oil gage when the engine is running. Oil may be added to the governor thru the oil filler cup. Add the oil slowly to avoid over-filling. Oil level above or below the lines on the gage, when running, will cause aeration of the oil resulting in a hunting condition.

ENGINE ADJUSTMENT

(Applicable to engines previous to Engine No. 963984 with OFFSET fuel control arm, Illus. Md2.)

Injection Pump Overtravel Check

It is important that injection pumps with rack stops have proper overtravel for satisfactory governor operation. Overtravel can be checked with the pump on or off the engine. Press the rack stop, Illus. Md4, against the pump body and note the maximum rack reading. The maximum rack reading must be 8-3/4 rack or hunting is likely at full load (8 rack) operation. The 3/4 rack overtravel must be maintained.

If the maximum rack reading is not 8-3/4 rack, remove the collar and shim as required to 8-3/4 rack. The collar must be square to the pump body and not bind the rack.

Fuel Control

The adjustment procedure is started with the governor connected to the fuel control mechanism and the governor power piston in the "No Fuel" position.

It is important that fuel rack adjustments be made very carefully as a slight error can cause hunting at full load.

Raise the governor power piston by means of the governor power piston jack (Illus. Md5, No. 15) until a 3/8" dimension is reached between the governor body and governor piston rod coupling. Use a gage. This is important.

Check the fuel control linkage for binding and check each injection pump rack for sticking. Also be sure the torque limit screw "E," Illus. Md2, is not limiting the rack travel to less than 17 total rack reading.

Set the No. 1 injection pump on the opposite governor side of the engine so a 2-11/16" measurement is obtained between the inner face of the control rack adjusting collar and the body of the pump adjacent to the pointer. This dimension is shown in Illus. Md4. Bend out the ears of the square lockwasher located on the governor stop rod adjustment inside the exhaust end cover on the opposite governor side. Loosen the jam nut and turn the hexagonal head screw "A" in or out on the threaded adjusting rod end. When a 2-11/16" measurement is obtained, tighten the jam nut, and bend down the ears of the square lockwasher. Adjust the No. 1 pump on the opposite governor side to rack 8 by turning the adjusting screw "B" in Illus. Md4.

Set the No. 1 injection pump on the governor side so a 2-11/16" measurement is obtained between the inner face of the control rack adjusting collar and the body of the pump, turning the fuel rod link adjusting screw "C" in Illus. Md2 to obtain the 2-11/16" distance. The fuel rod link adjusting screw is part of the fuel rod spring link which connects the fuel control arm to the control rod on the governor side of the engine. When this setting has been made, adjust the pump to rack 8 by turning the rack adjusting screw "B" in Illus. Md4.

Adjust all the pumps to rack 8. Be sure the rack collar is not turned when the rack is adjusted.

Reduce the rack position on the pumps by means of the power piston jack. As the No. 1 governor side pump reaches the zero position, the No. 1 opposite governor side pumps should be at approximately 3-1/4 rack.

With the governor in the "At Rest" position, check the rack position on both sides of the engine. Racks on the governor side will read zero, racks on the opposite governor side should be from 3/4 to 1 rack.

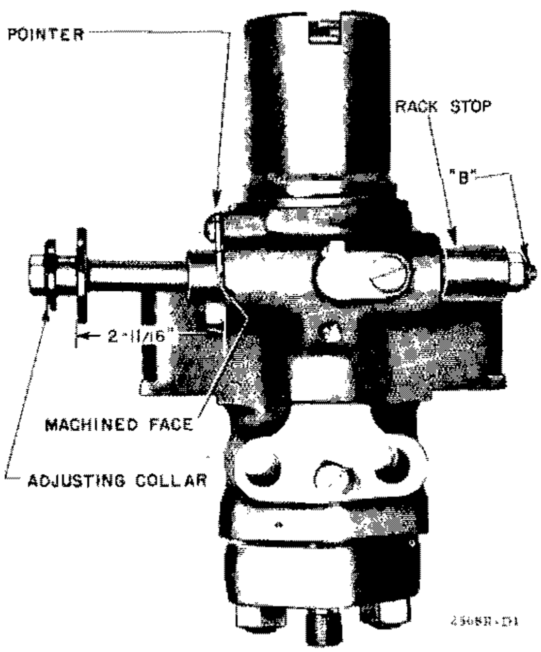
Injection Pump Overtravel Recheck

Jack the governor power piston to the end of travel. (On governors with internal fuel stops, 5/16" power piston gap corresponds to 8-3/4 fuel rack.)

Check the pump racks. Each pump should be at 8-1/2 rack. If pumps are not at 8-1/2 rack, adjust the torque limit screw "E," Illus. Md2, to give 8-1/2 rack on each side or a total of 17 rack. Refer to Chapter L for complete settings.

Disengage the control rod plunger from the adjusting collar and check settings of rack stop. With the rack stop against the pump body, the rack should read 8-3/4. To adjust the rack stop, remove the collar and shim as required to read 8-3/4 rack. Be sure the collar is square to the body and does not bind the racks.

If settings have been made on a cold engine, the adjustments should be rechecked after the engine has been brought up to temperature. Also, check for correct full engine speed before readjusting full load governor piston gap and fuel rack setting.



Illus. Md4. Fuel Injection Pump Adjustments

ENGINE ADJUSTMENT

(Applicable to Engine No. 963984 and all thereafter with CENTER PIVOT fuel control arm, Illus. Md3.)

Injection Pump Overtravel Check

It is important that injection pumps with rack stops have proper overtravel for satisfactory governor operation. Overtravel can be checked with the pump on or off the engine. Press the rack stop, Illus. Md4, against the pump body and note the maximum rack reading. The maximum rack reading must be 8-3/4 rack or hunting is likely at full load (8 rack) operation. The 3/4 rack overtravel must be maintained.

If the maximum rack reading is not 8-3/4 rack, remove the collar and shim as required to 8-3/4 rack. The collar must be square to the pump body and not bind the rack.

Fuel Control

The adjustment procedure is started with the governor connected to the fuel control mechanism and the governor power piston in the "No Fuel" position.

It is important that fuel rack adjustments be made very carefully as a slight error can cause hunting at full load.

Raise the governor power piston by means of the governor power piston jack (Illus. Md5, No. 15) until a 3/8" dimension is reached between the governor body and governor piston rod coupling. Use a gage. This is important.

Check the fuel control linkage for binding and check each injection pump rack for sticking. Also be sure the torque limit screw "E," Illus. Md3, is not limiting the rack travel to less than 17 total rack reading.

Set the No. 1 injection pump on both sides of the engine so a 2-11/16" measurement is obtained between the inner face of the control rack adjusting collar and the body of the pump adjacent to the pointer. This dimension is shown in Illus. Md4. Bend out the ears of the square lockwasher located on the governor stop rod adjustment inside the exhaust end cover on the opposite governor side. Loosen the jam nut and turn the hexagonal head screw "A" in or out on the threaded adjusting rod end. When a 2-11/16" measurement is obtained, tighten the jam nut, and bend down the ears of the square lockwasher.

When this setting has been made, adjust the No. 1 pump on both sides of the engine to rack 8 by turning the rack adjusting screw "B," Illus. Md4.

Adjust all the pumps to rack 8. Be sure the rack collar is not turned when the rack is adjusted.

With the governor in the "At Rest" position, check the rack positions on both sides of the engine. All racks should read approximately zero.

Raise the governor power piston by means of the power piston jack so racks are at 3 or above. Trip the overspeed. All racks should read zero. If racks do not read zero, adjust screw "D," Illus. Md3, until racks read zero.

Injection Pump Overtravel Recheck

Jack the governor power piston to the end of travel. (On governors with internal fuel stops, 5/16" power piston gap corresponds to 8-3/4 fuel rack.)

Check the pump racks. Each pump should be at 8-1/2 rack. If pumps are not at 8-1/2 rack, adjust the torque limit screw "E," Illus. Md3, to give 8-1/2 rack on each side or a total of 17 rack. Refer to Chapter L for complete settings.

Disengage the control rod plunger from the adjusting collar and check settings of rack stop. With the rack stop against the pump body, the rack should read 8-3/4. To adjust the rack stop, remove the collar and shim as required to read 8-3/4 rack. Be sure the collar is square to the body and does not bind the racks.

If settings have been made on a cold engine, the adjustments should be rechecked after the engine has been brought up to temperature. Also, check for correct full engine speed before readjusting full load governor piston gap and fuel rack setting.

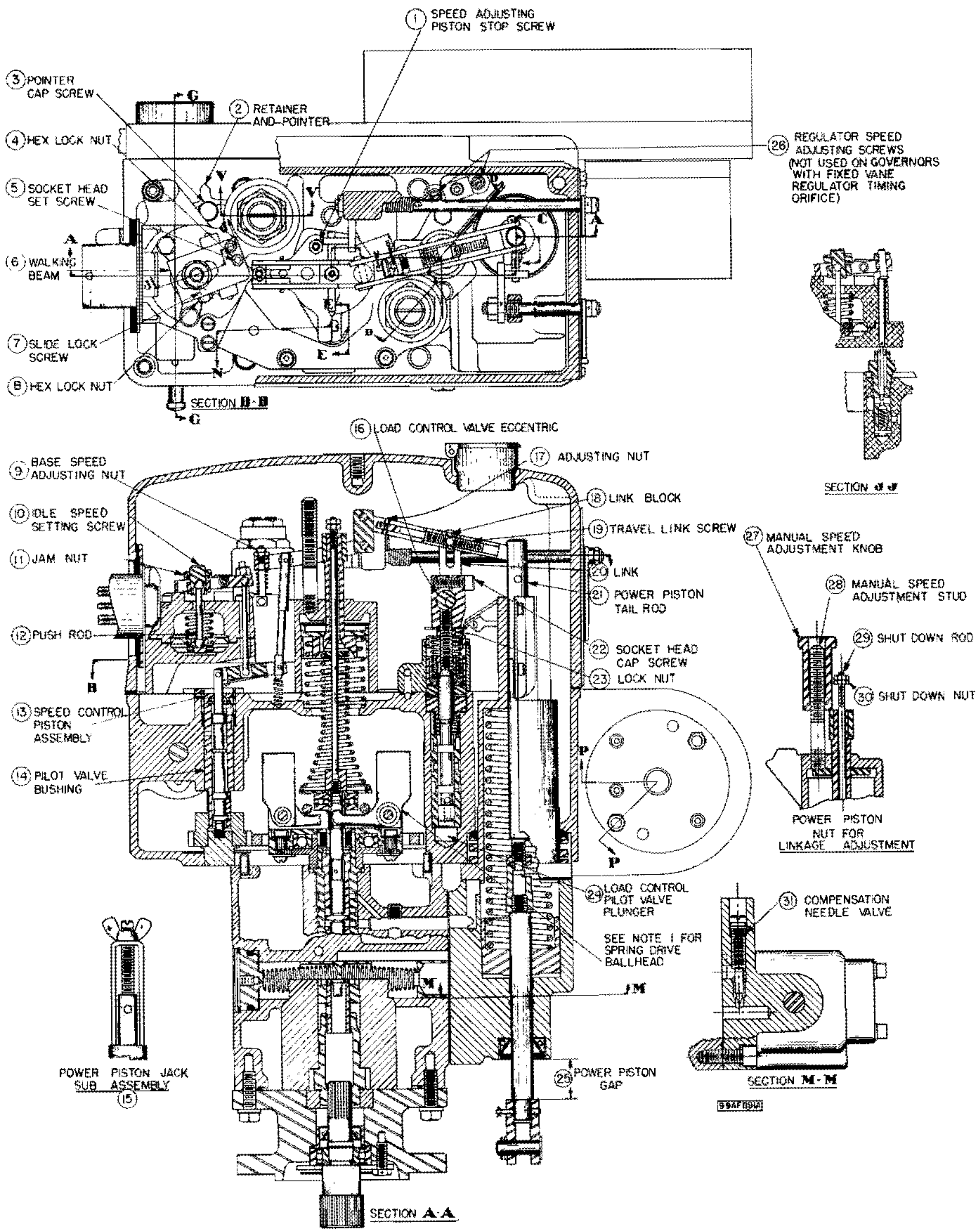
ATTENTION: The governor has been set at the factory, but should occasions arise when setting is necessary, the following procedures should be observed.

GOVERNOR SETTING (Preliminary)

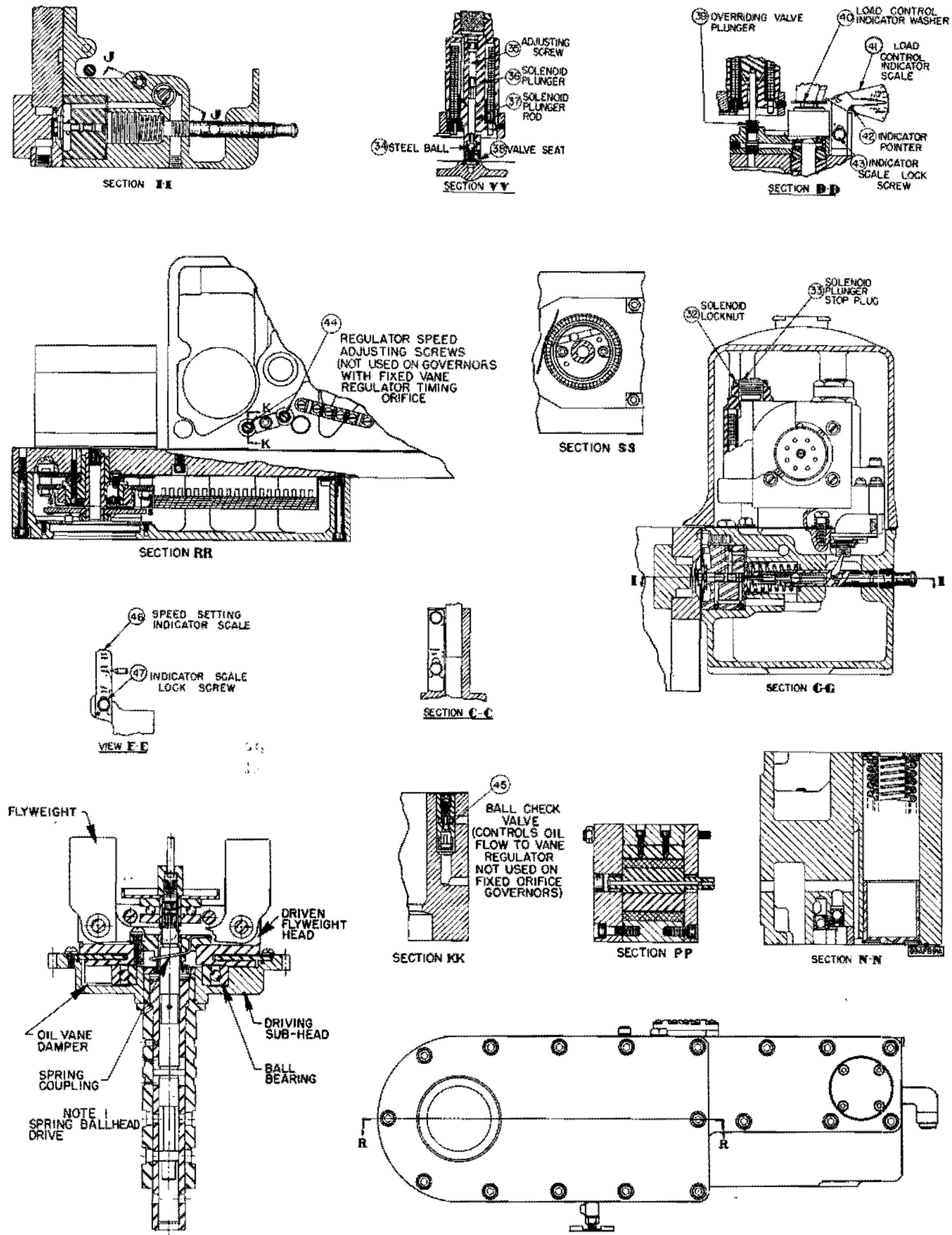
Remove the governor cover with care to prevent possible damage to the cover gasket. Place a bolt along the edge nearest the viewer to prevent oil from running down the side of the governor. The head of the bolt will be in the open portion above the power piston assembly and the body of the bolt will be along the edge of the governor. If desired, a scale may be used instead of the bolt. Start the engine and bleed the air from the governor. With a new governor or a governor that has been drained or cleaned, all the air must be bled from the governor. Loosen the 1/8" pipe plug near the plate on the viewers side of the governor several turns and allow oil to flow freely. Also loosen the compensating needle valve (Illus. Md5, Ref. 31) several turns and allow the engine to surge freely for 30 seconds to work out any air in the governor passages. This is important.

After all the air is out of the system, tighten the 1/8" pipe plug and reset the governor compensating needle until all hunt has been eliminated. The hunt is usually eliminated when the compensating needle is between 1/4 and 1/2 turn open; however, the opening should be as great as possible, without producing hunting.

The adjustment of the compensating needle



Illus. Md5. Main Cross-section of Governor



Illus. Md6. Auxiliary Cross-section of Governor should be made with the governor oil temperature as close as possible to the normal operating temperature of approximately 140-160° F. If settings are made under conditions warmer than normal, excessive idle speed undershooting may occur with cold oil. The governor may hunt with hot governor oil if compensation is adjusted with the governor colder than normal.

ENGINE SPEED SETTING

With an accurate tachometer, check the engine idle speed. If the engine speed is not at idle rpm, adjust the idle speed by means of governor base speed adjusting locknut (Illus. Md5, Ref. 9) until the desired engine rpm is reached. Screwing the nut "up" increases engine speed - screwing the nut "down" decreases engine speed. This locknut is located to the right of the center of the governor, in front of the speed setting beam (Illus. Md5, Ref. 6). The speed setting beam is the teeter-totter device behind the electrical connection. Make sure that the speed setting beam is free and rests on its stop in the idle position. Check that the push rod (Illus. Md5, Ref. 12) does not touch screw (Illus. Md5, Ref. 10) in the speed setting beam. Such contact would tend to keep the speed setting beam off of its "idle" position. With the beam tightly against the right stop, the idle speed can be accurately set.

> CAUTION: When adjusting only the engine idle speed, the full speed must also be rechecked as any change in the base speed setting nut affects the entire speed range.

Full engine speed is obtained by depressing the speed setting beam manually against the left speed setting beam stop. An Allen setscrew (Illus. Md5, Ref. 5) and locknut (Illus. Md5, Ref. 4), located in the speed setting beam on a centerline to the left of the fulcrum, are used for full speed adjustment. Check the engine speed while the speed setting beam is held tightly against the left hand stop. If the engine speed is low, screw the Allen setscrew out. If the engine speed is high screw the Allen setscrew in, making sure to hold the beam depressed against the left stop with the setscrew against the stop. After the full engine speed is set, lock the Allen setscrew locknut and recheck the full engine speed. After the speeds have been accurately set, run the engine at idle speed; loosen the locking screw (Illus. Md6, Ref. 47) and adjust the speeder servo position scale (Illus. Md6, Ref. 46) until the "idle" marking line come exactly under the pointer. Run the engine up to full speed and note whether the pointer comes opposite the "full speed" marking. If it does not, scribe a line on the scale at the pointer level and use this as the "full speed" line. Establish a similar line for 650 rpm engine speed.

LOW OIL PRESSURE SHUTDOWN

The low oil pressure shutdown device is incorporated in the governor to provide complete protection against low oil pressure in the engine.

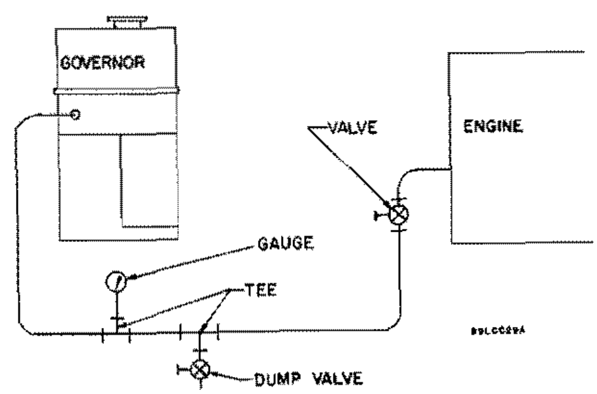
This device is equipped with a timing port which will permit starting of the engine with no oil pressure, and allow sufficient time for oil to flow thru the engine before acting to shut down the engine due to no oil pressure or low oil pressure.

The timing adjustment is incorporated in the bushing (Illus. Md5, Ref. 14) controlled by the pointer-lever (Illus. Md5, Ref. 2). Timing for idle shutdown is from 45 to 60 seconds. That is, if an oil pressure failure occurs, the engine shuts down after a 45 to 60 second period at engine "idle." This setting has been marked by a center punch mark to coincide with the pointer at original setting.

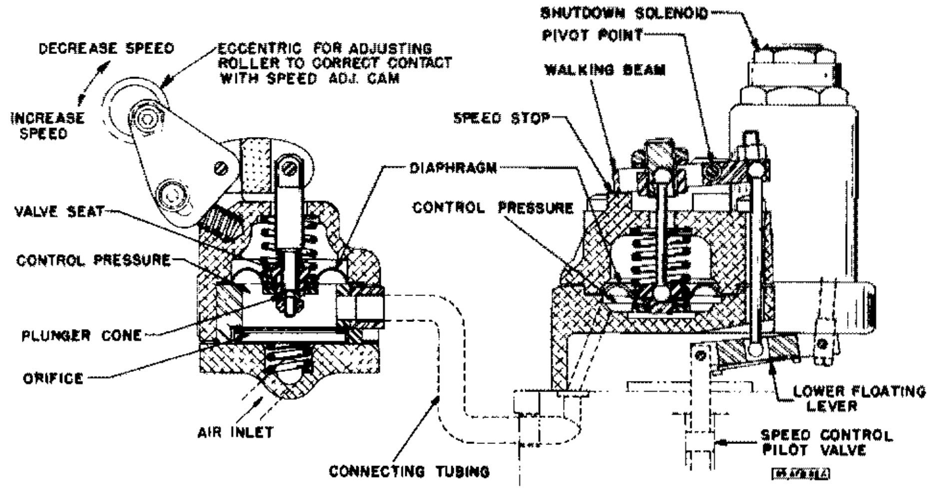
Moving the pointer in a counterclockwise direction increases the time delay of shutdown at engine idle.

Above 400 rpm engine speed, the speed setting beam moves to a position to nullify the timing. This setting is made by adjusting the setscrew, (Illus. Md5, Ref. 5). At 400 rpm or over the engine shutdown is instantaneous.

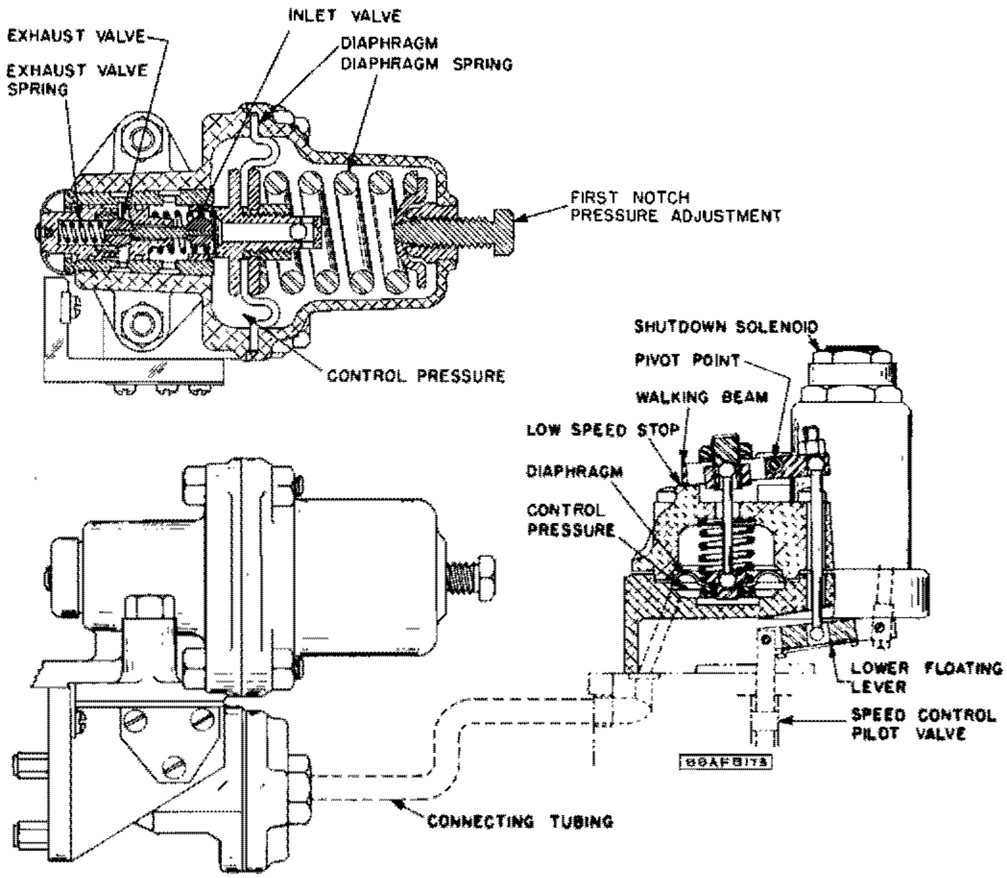
To test the operation of the device, disconnect the engine oil pressure line from the governor. Make up a test outfit to bridge this gap as shown in Illus. Md7. The test unit will contain a valve and two tees, with suitable tubing connections. This equipment should be so assembled that the oil coming from the engine flows first thru the valve, then thru the two tees and finally into the governor engine oil pressure connection. For convenience, the piping, the tees, and the valve should be arranged in a circular coil. The unit can then be connected to



Illus. Md7. Test for Low Oil Pressure Shutdown



Illus. Md8. Transmitter and Receiver Portions of Throttle and Governor - Woodward Governor Transmitter for Cutler-Hammer Throttle



Illus. Md9. Transmitter and Receiver Portions of Throttle and Governor - Westinghouse Air Brake Transmitter for 3-A2E-U Throttle

the governor and to the engine oil line with a minimum of distortion of the engine oil line.

Fit the tee closest to the governor with a gage. This gage will register engine oil pressure. The other tee is fitted with a dump valve. With the dump valve closed and the in-line valve open, the gage will show engine oil pressure as impressed on the oil shutdown device. Closing the in-line valve traps the oil pressure to the governor. Opening the dump valve in the first tee dumps the oil pressure. With the test valve combination, all settings can be made fairly accurately.

Close the dump valve and open the in-line valve. Start the engine and run it at idle or 300 rpm. The engine should not shut down. Open the dump valve slightly to establish a small leak, and then slowly close the in-line valve. The engine should shut down in 45 to 60 seconds when the gage registers from 3 to 5 psi.

Again close the dump valve and open the in-line valve. Run the engine at a speed greater than 400 rpm. Open the dump valve slightly, and slowly close the in-line valve. When the engine oil pressure has been reduced to 14 to 18 psi by manipulating the valves, the engine should shut down immediately.

If engine shutdown does not occur at 3 to 5 psi oil pressure when running at idle, and 14 to 18 psi when running over 400 rpm, the error will probably be found due to manufacturing tolerances in the springs. The speeder spring has the greatest share in determining the above oil pressures.

ADJUSTMENT OF OVERRIDING AND SHUT-DOWN SOLENOIDS

The solenoids are of the fixed armature type and the adjustable armature type.

The solid armature type does not have an internal adjustment. To adjust the solenoid, screw the plunger stop plug (Illus. Md6, Ref. 33) in all the way, after first loosening the lock-nut (Illus. Md6, Ref. 32). With the coil de-energized, back out on the plunger stop plug until the device actuated by the solenoid operates freely. The adjustment on the solenoid is approximately 2 turns (1/16" travel) from the full down position. This type of solenoid is used on the overriding solenoid.

The adjustable armature type has an adjustment to set a desired overtravel. To set the overtravel, remove the plunger stop plug (Illus. Md6, Ref. 33) and the locknut (Illus. Md6, Ref. 32) from the solenoid case. Loosen the adjusting screw about 3 turns. Hold the solenoid plunger firmly against the lower seats and adjust the adjusting screw, turning it in, until it contacts the solenoid plunger rod (Illus. Md6, Ref. 35) and is snug against the pin. This pin contacts the steel ball (Illus. Md6, Ref. 34) to hold it on its seat (Illus. Md6, Ref. 38), thereby controlling the electrical shutdown feature when the solenoid is energized. While the setscrew is snug against the pin, loosen the hold on the solenoid plunger and turn the adjusting screw in 1/4 turn more. Reapply the plunger stop plug and locknut to the solenoid case and turn the plunger stop plug down snugly. Back the plunger stop plug out 1-1/2 turns and lock the locknut. Care should be exercised when removing the plunger to prevent the loss of any of the washers. This solenoid is only used for the shutdown assembly.

LOAD CONTROL PILOT VALVE LAP CHECK

The pilot valve assembly is the device that hangs from the link block. (Illus. Md5, Ref. 18.)

Before checking the lap position of the valve, check to see that the eccentric setting is not more than 20° from a horizontal plane and that the link block is set centrally over the valve. These two conditions will facilitate making adjustment for minimum field start and full load conditions. Also set the overriding solenoid for 1/16 travel (2 turns from the full down position).

With the generator field cutout, interlocks EF, EFR, P1 and P2 blocked open, to keep the governor overriding solenoid de-energized, and the engine running with the throttle in the 5th or 6th notch, the vane regulator will be in maximum field position. Lift the pilot valve by hand to make the vane regulator move counterclockwise or to "minimum field." Release the pilot valve slowly and allow the vane regulator to move clockwise toward "Maximum field." Stop the vane regulator in approximately mid-travel by manually controlling the pilot valve. The position of the pilot valve at which no motion is imparted to the vane regulator is called "lap" or "O" position. With the pilot valve held in the lap position, check the indicator pointer to see that it is exactly centered.

If the indicator does not accurately indicate the balanced or "lap" position of the load control pilot valve, adjust the indicator scale (Illus. Md6, Ref. 41) by loosening the screw (Illus. Md6, Ref. 43) and sliding the indicator scale to the proper position to indicate "O" position. Tighten the screw and recheck the pilot valve lap position.

VANE REGULATOR TIMING SETTING

NOTE: The following settings do not apply for governors with fixed regulator timing orifice.

With the engine operating under the same conditions as for the Pilot Valve Lap Check with the overriding solenoid properly adjusted and with the governor oil at approximately 160° F., check the vane regulator timing. The regulator should move from minimum to maximum field (clockwise) in 5 seconds with hot oil or 7 seconds with cold oil, and from maximum to minimum field (counter-clockwise) in 10 seconds with hot oil or 15 seconds with cold oil.

View the vane regulator from the commutator side when checking the arm movement.

Adjust the rate of movement by the screws

(Illus. Md6, Ref. 44). The adjusting assembly is located at the lower left hand corner when viewing the governor from the top. The adjusting screws provide a means of adjusting the timing of the regulator. To increase the rate of oil flow in decrease excitation direction, turn the screw located on the left of the adjusting assembly in a clockwise direction. Turn the other screw located on the right of the adjusting assembly clockwise to increase flow in the increase excitation direction.

Provision is made to return the vane regulator from the maximum to minimum field in 1 to 3 seconds when the overriding solenoid is energized.

The rate of movement is not adjustable (not affected by the adjusting screws) and is accomplished by a wide bottom land on the load control pilot valve plunger uncovering a large port in the bushing.

In adjusting normal maximum to minimum timing, it is very important that the pilot valve plunger be raised only enough to bring the pointer to minimum field mark on the scale. If the plunger is raised further the large port in the bushing is uncovered causing a 3 second return to minimum field.

FULL LOAD SETTING

After the pilot valve has been lapped, the full load adjustment can be checked and corrected if required. With the engine shut down, apply the governor tools. Jack up the power piston with the use of the power piston jack (Illus. Md5, Ref. 15) until a 3/8" power piston gap is reached. The power piston jack is the yoke-like device with a thumb screw attachment; the jack mounts on top of the power piston.

Turn the manual speed adjusting tool (Illus. Md5, Ref. 27) until full engine speed is recorded on the speed indicator (Illus. Md6, Ref. 46). The manual speed adjusting tool screws on to the manual speed adjusting stud and is used to depress the speeder servo-piston.

When the above two conditions are met, the load control pilot valve pointer (Illus. Md6, Ref. 42) must be balanced at "O" position. If it is not, loosen the Allen head capscrew (Illus. Md5, Ref. 22) in the pilot valve assembly and adjust the eccentric (Illus. Md5, Ref. 16) by means of a screwdriver until the pointer shows "O" position.

MINIMUM FIELD START SETTING

With the engine running at idle speed (with cooling fan off and compressor unloaded) measure the power piston gap. The measured gap should be within range of 58/64 to 63/64 inches.

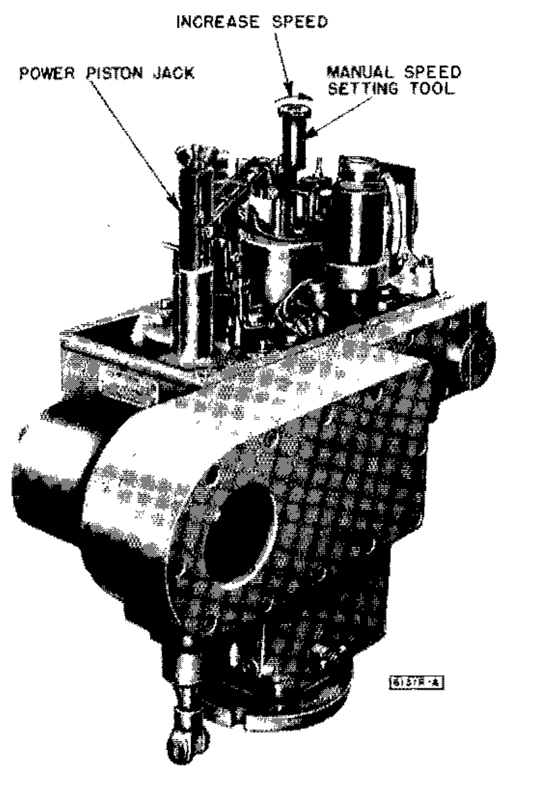
Stop the engine and jack up the power piston to the gap determined above. If this gap is not known, use 60/64 inch. Also use the manual speed setting tool to set the speed indicator pilot valve pointer. The pointer should be at minimum field. If the pointer is not at minimum field, turn the travel link screw (Illus. Md5, Ref. 19) until the load control pilot valve pointer indicates minimum field.

Inasmuch as the minimum field start setting is not independent of other settings, the full load setting should be rechecked after the minimum field start setting has been made. It may be necessary to adjust both the load control pilot valve eccentric as well as the block to secure the specified conditions.

The governor is set at the factory for idle speed minimum field start with a power piston gap of 60/64 inch. An increase at idle of 3/64 inch or more to the piston gap (which is determined at idle by individual engine characteristics) will tend to cause the vane servo to move to maximum field at idle with the overriding solenoid de-energized.

THROTTLE-GOVERNOR COORDINATION ADJUSTMENT

Previous adjustments, under ENGINE SPEED SETTING, have set the engine speed for idle and full speed. The next step is to adjust the throttle to the governor so that these speeds



Illus. Md10. Application of Governor Tools

Table 1 - THROTTLE PRESSURES

	Westinghouse Air Brake Throttle 3-A2E-U Type	Cutler-Hammer Throttle with Woodward Governor Transmitter
Idle	Less than 12 psi (not critical)	Less than 10 psi (not critical)
First Notch	14-15 psi	14-15 psi
Full	55-65 psi	55-60 psi

will be obtained at the proper throttle positions. Refer to Illus. Md8, and Md9, for views of the transmitter and receiver portions of the throttle and governor.

NOTE: Cutler-Hammer throttles must be pre-set before installation as the adjustments are not accessable when installed. Westinghouse Air Brake throttles can be adjusted after installing.

If available, apply a gage to the throttle air line. This can conveniently be connected to the tee in the line at the throttle-reverser assembly. The gage should preferably be one having one pound graduations on its scale.

Check the control air pressure: see that it is 80 pounds.

Check the range of throttle pressures as listed in the table below. The full open throttle pressure may vary to some extent, depending on the tolerance, cam accuracy and spring variations. However, it should be within the limits of the table.

Adjustments adapt the governor to the throttle and are to be used only when the throttle pressures are correct and the governor is out of adjustments. Readjustment should not be necessary on new governors which are factory preset.

After the correct throttle adjustment is obtained, move the throttle from idle to the first notch, watching the engine speed closely. Should an increase in speed be noted when the throttle is moved from idle to first notch with correct throttle pressure, loosen adjusting nut (Illus. Md5, Ref. 11) and back out the screw (Illus. Md5, Ref. 10) until the engine speed drops to idle and then turn it in until the speed is just on the verge of rising.

Check the accuracy of the adjustment by advancing the throttle very slightly from "first notch." By the time the throttle has been moved approximately 1/2" out of the first notch, the speed should begin to rise slightly. If the throttle can be advanced further than 1/2" without causing this tendency to rise, the screw (Illus. Md5, Ref. 10) may not have been screwed in quite far enough.

Move the throttle to the full open position. Press down the left end of the speed setting beam manually. There should be no increase in engine speed when this is done.

If the engine speed does increase, return the engine to idle speed. Loosen the locknut (Illus. Md5, Ref. 8) and the locking screw (Illus. Md5, Ref. 7) on the inner side of the speed setting beam. Also loosen slightly the adjusting nut (Illus. Md5, Ref. 11). The block containing the screw (Illus. Md5, Ref. 10) is now free to move horizontally in the slot in the speed setting beam. Move the block slightly toward the fulcrum, and lock it in place. Then readjust the screw (Illus. Md5, Ref. 10) so the speed is again just on the verge of rising. Lock the adjusting nut (Illus. Md5, Ref. 11). Open the throttle to the full throttle position and check the adjustment. If engine speed increase is still obtained when the left end of the speed setting beam is depressed, repeat the adjustment.

If the engine speed does not increase when the left end of the speed setting beam is pressed down, either on the first trial or after the adjustment has been made, the reduced throttle action should be checked.

With the engine at full speed and the handle in the "full throttle" position, reduce the throttle slowly until the engine speed drops slightly. At this point, check the gage in the throttle line and the distance the throttle has been moved from the full open position. If the gage pressure has dropped more than 3 lbs. from the full throttle reading or the throttle movement has exceeded 1/4" to 3/8", return the engine to idle and loosen the adjusting nut (Illus. Md5, Ref. 11). Move the block containing the screw (Illus. Md5, Ref. 10) away from the fulcrum. Readjust screw so that the engine speed is on the verge of rising with the throttle in the "first notch." Recheck and readjust if necessary. After all settings for engine speeds have been satisfied, lock the speed setting beam adjustment by tightening the setscrew (Illus. Md5, Ref. 7) and the locknut (Illus. Md5, Ref. 8).

As a final step, check the engine speed at full throttle. It should be the same as initially set. If the engine does not come up to speed, it is probable that an "over-correction" has been made and that the block has been moved too far from the fulcrum in making the adjustment.

When screw (Illus. Md5, Ref. 10) is moved closer to the fulcrum of the speed setting beam, the range is decreased. That is, it will require less pounds of air pressure, or less throttle movement. When the screw is moved further away from the fulcrum of the speed setting beam, the range is increased.

It can be seen that the adjustments made by moving the block toward or away from the fulcrum of the speed setting beam are necessarily a "cut-and-try" proposition and that "over-corrections" in either direction are possible.

RELOCATING THE PILOT VALVE

In remote cases extreme adjustments might have to be made to the travel link screw in setting the Minimum Field Start Adjustment and to the eccentric in setting the Full Load Adjustment. The extreme adjustments can be avoided by relocating the pilot valve setting which will give a minimum amount of adjustment to the eccentric and travel link screw.

Start relocating the pilot valve by raising the pilot valve until the nut on the threaded portion of the pilot valve shows at the opening of the pilot valve cage. Do not lift the pilot valve too high as the control land of the upper seat will contact the lip of the upper oil seal and may cut the rubber rings. Unlock the locknut (Illus. Md5, Ref. 23) under the pointer plate (Illus. Md6, Ref. 40), and with an open end wrench turn the lower nut that protrudes from the opening either to the right or left, as required to satisfy the determined extreme conditions. (This nut is not shown in Illus. Md5, however, it is located directly below the locknut.)

After relocating the pilot valve, lock the locknut.

If the pilot valve has been relocated, the pilot valve will then have to be lapped again as explained under Pilot Valve Lap Check.

Reset the travel link screw for minimum field start and the eccentric for full load as explained previously. Since the pilot valve was relocated due to the extreme adjustments needed in setting the travel link screw and the eccentric, the travel link screw and the eccentric should now need only a small adjustment.

FINAL PRECAUTIONS

Remove the governor power piston jack and manual speed adjusting tool and store them above the power piston assembly.

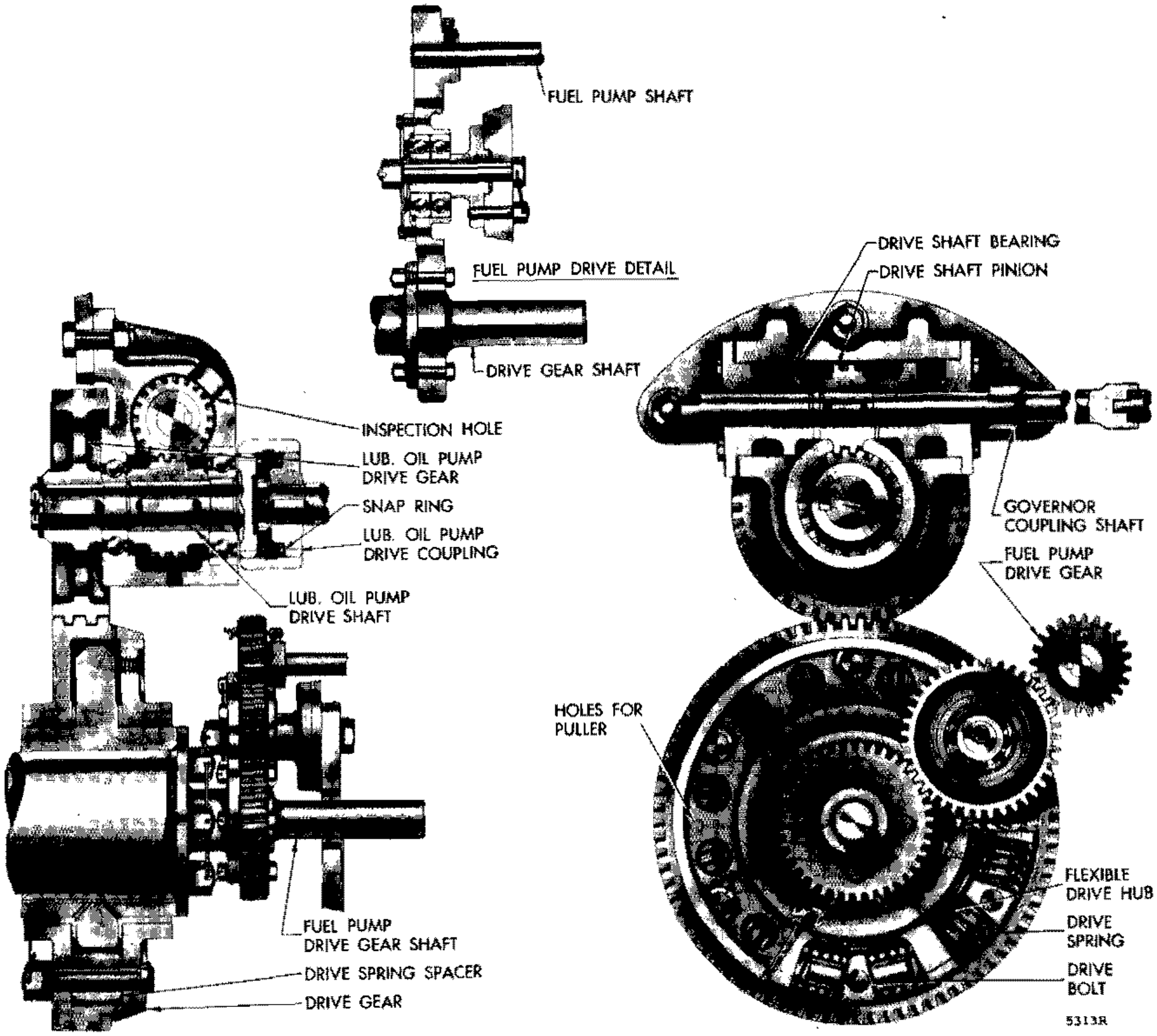
The position of the fuel indicating actuating pins must be checked. The pin is located just below the point where the floating lever assembly is hinged at the top of the tail rod. The normal position of the pin when properly connected is to the back of the governor or toward the engine. The governor mechanically limits the engine to 2nd or 3rd notch when the pin is improperly positioned.

Apply the cover to the governor making sure that the gasket is square and unbroken, and that pointers on the front of the cover are engaged with the inner linkage. Bolt the cover down and check the oil level.

TOOLS

Allen Wrench - 3/32", 1/8", 5/32", 5/16"
Open End - 15° Box Wrench - 5/16"; 11/32", 7/16", 3/8", 5/8", 1-1/16"
Long Nose Pliers - 6"
Screwdriver - 8"
Spintite Wrench - 11/32"
Waldes Truarc Snap Ring Pliers - #1, #3
"T" Handle Wrench - 3/8"
T-14675 Fixture
Shutdown Nut Wrench and Gage
Power Piston Seal Installating Sleeve
Steel Rule with 1/64 Graduations - 6"
Load Control Pilot Valve Adjusting Wrench

CHAPTER N. FLEXIBLE DRIVE - GOVERNOR AND ATTACHED PUMPS



Illus. N1. Flexible Drive for Governor and Attached Pumps
(Fuel pump drive used only on early "Hood" Type Locomotives)
(Gear drive used instead of coupling drive on 12 cyl. lub oil pump)

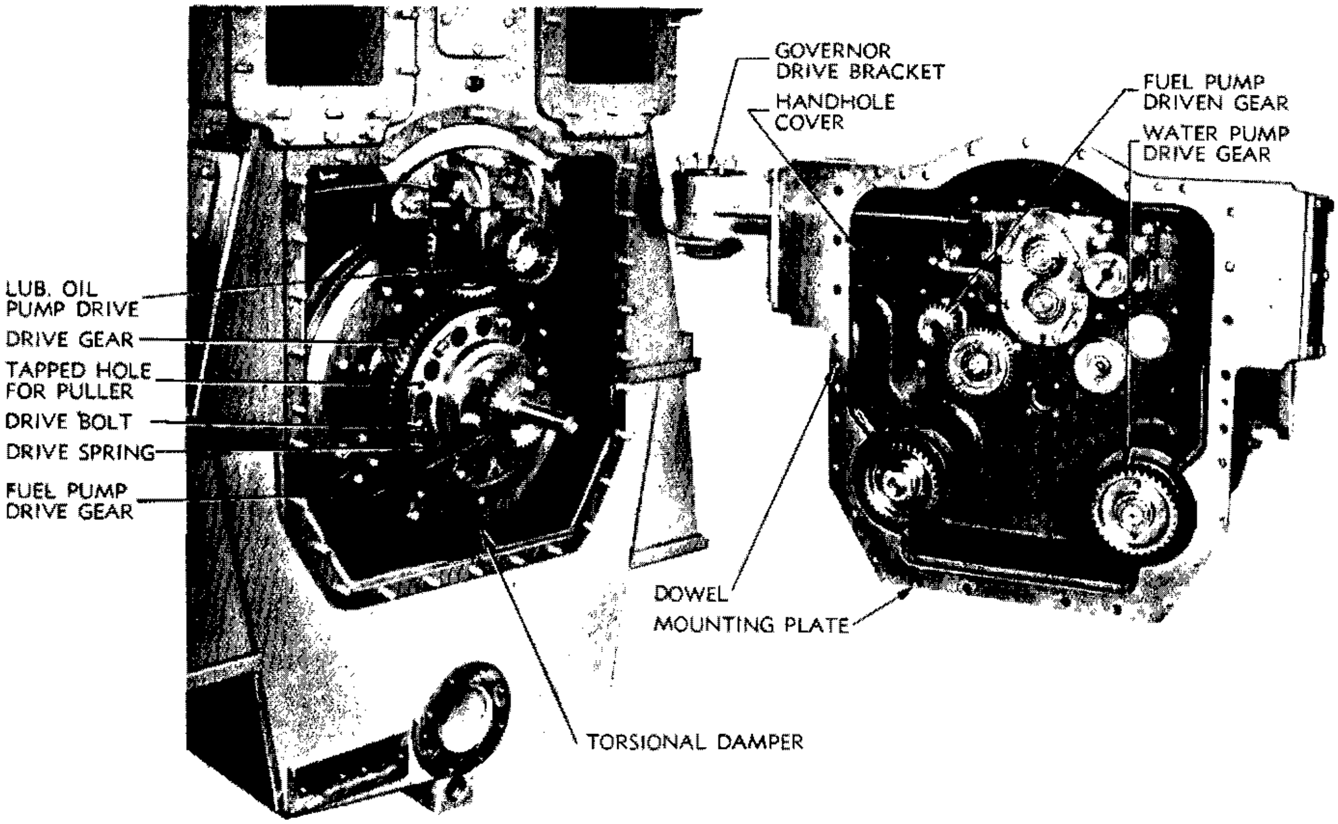
DESCRIPTION

The water circulating pump, lubricating oil pump and the governor are driven from the lower crankshaft thru a flexible gear drive. Early engines except the 10 cyl. Erie Built Locomotive have an engine driven fuel pump. In this drive (Illus. N1 and N2) power is transmitted thru springs which isolate the torsionals transmitted by the lower crankshaft. The circulating water pump is driven directly from the flexible gear. (Early engines were equipped with two water pumps.) The fuel pump drive gear and idler gear in turn rotate the fuel pump driven gear. (Not used on 10 cyl. Erie Built and all later engines.) The upper lubricating oil pump impeller on the 6, 8 and 10 cylinder engines is driven by means of an internal gear coupling. The lower impeller on the 12 cylinder pump is gear driven.

A helical gear, mounted on the lubricating oil pump drive shaft, meshing with a mating gear on the governor drive gear shaft drives the governor coupling shaft. The governor coupling shaft in turn drives the governor or tachometer-generator thru a bevel gear drive.

SERVICING

To disassemble the flexible drive, disconnect the piping to and from the lubricating oil



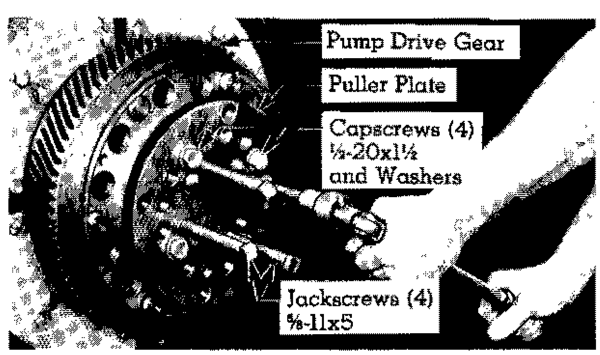
Illus. N2. General View of Flexible Drive
(Fuel oil pump drive used only on early "Hood" Type Locomotives)
(Gear drive used instead of coupling drive on 12 cyl. lub oil pump)

and water pumps. Disconnect the tubing and linkage leading to the governor and governor bracket. Remove the handhole cover on the control side of the pump mounting plate and the stud nuts holding the governor bracket. The governor bracket assembly and governor are then removed. The handhole is provided for reaching thru and holding the governor coupling shaft in place while removing the governor bracket. Remove the pumps from the pump mounting plate. After taking off the stud nuts and dowel nuts, the pump mounting plate can be removed.

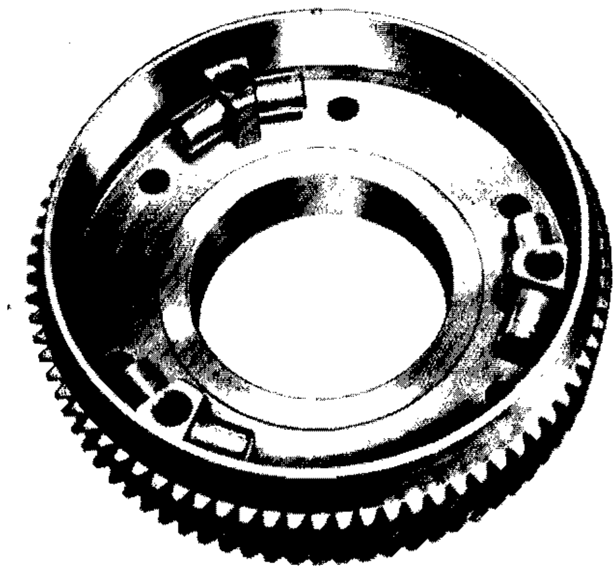
Remove the fuel pump drive gear shaft from the end of the lower crankshaft (if used). Install the drive gear puller (Illus. N3) on the flexible drive hub using the tapped hole provided. This puller can be purchased from the engine manufacturer. Tightening the puller jackscrews will withdraw the complete flexible drive from the crankshaft.

Remove the nuts from the drive bolts and drive out the bolts. By using three 1/2"-20 capscrews in the three holes in the spring retainer force the spring retainer from its fit in the drive gear. The drive hub, drive springs and spring spacers can then be separated from the drive gear.

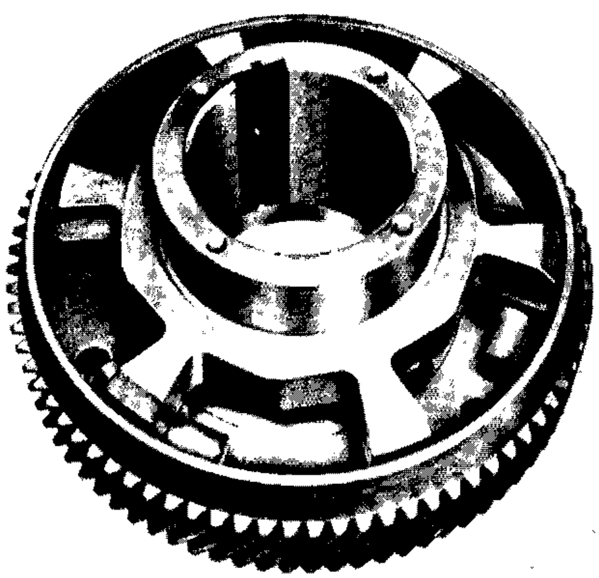
The wearing bushings which are pressed into the spring retainer and drive gear should be cleaned, inspected and renewed if necessary. The drive springs should also be inspected and replaced if broken. Before reassembling the parts clean all oil from the surfaces and allow the parts to dry. This will make it easier to reassemble the parts. Check the oil holes in the drive hub and gear to be sure they are open. Place the gear open side up on a bench. Then place three of the spring spacers in the gear (Illus. N4) to temporarily support the drive hub in place. The spacers should be between adja-



Illus. N3. Drive Gear Puller



Illus. N4. Spring Spacers in Gear

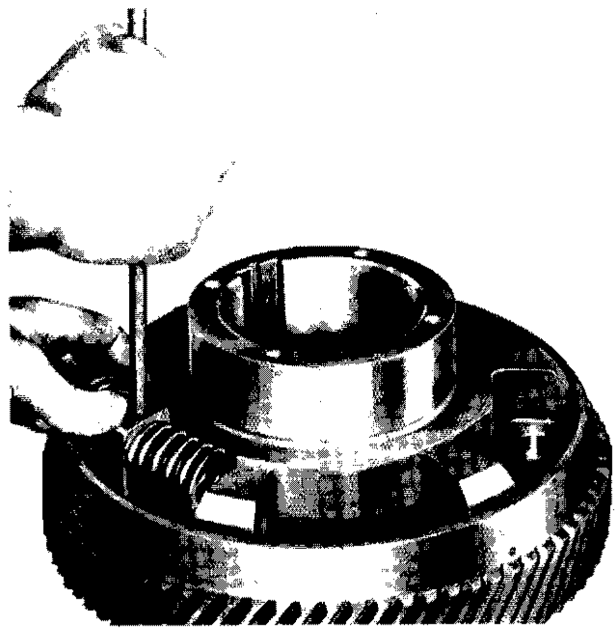


Illus. N5. Drive Hub in Place

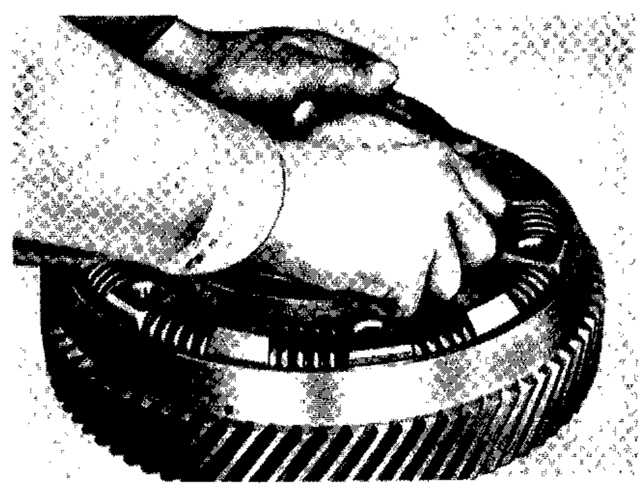
cent bolt holes as shown in the illustration. Place the drive hub in place on the spacers, Illus. N5. The lugs must be between adjacent bolt holes. Then place two drive springs in place on one of the remaining spacers. Place the spacer and springs between two drive hub lugs and force in place with a bar inserted thru the spacer and gear holes as shown in Illus. N6. Tap down further with a soft hammer. Replace the next spacer and springs by the same method at a position directly opposite to the first one replaced. Then replace the remainder, sliding out the spacers used as blocks. Force the assembly down as shown in Illus. N7; replace spring retainer, bolts and nuts, Illus. N8, being sure the bolt holes and matchmarks are aligned. Use a soft hammer to drive the bolts in place. Tighten to torque value given in Chapter B.

ASSEMBLY

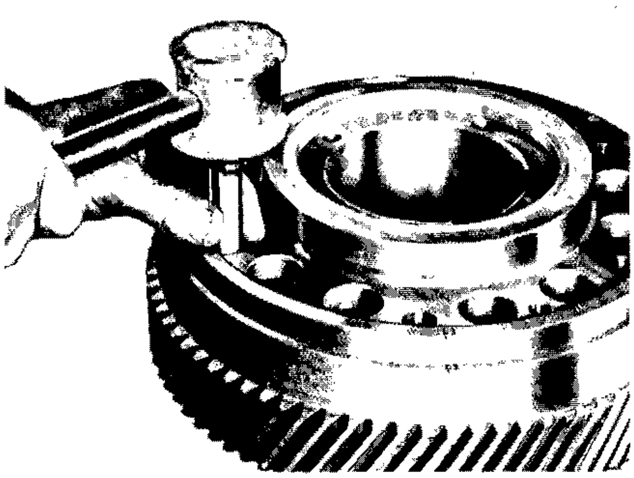
Rotate the engine crankshaft until the keyway in the crankshaft is at the top. Check the keyway in the flexible pump drive hub and fit key in the crankshaft. Apply white lead and light oil to the



Illus. N6. Forcing Springs and Spacer in Place



Illus. N7. Forcing Assembly Down



Illus. N8. Tapping Bolt in Place

flexible pump drive hub, oil groove and keyway.

Heat the flexible pump drive slowly in oil (or in an electric furnace) to about 320° F. temperature of the heating medium. The hole in the flexible drive hub should then be about .007" oversize.

Install flexible drive to seat properly on the crankshaft. Replace the fuel pump drive gear shaft (or end plate) on the end of the crankshaft while the flexible gear assembly is still hot. Cool slowly with compressed air, starting at the hub. Lift the pump mounting plate back in place on the dowels. A cover is provided on the upper opposite control side of the plate for reaching thru while guiding the lubricating oil pump internal gear drive coupling in place. Secure the mounting plate, replace pumps and test pump drives for free movement. Replace governor, governor bracket, linkage and tubing.

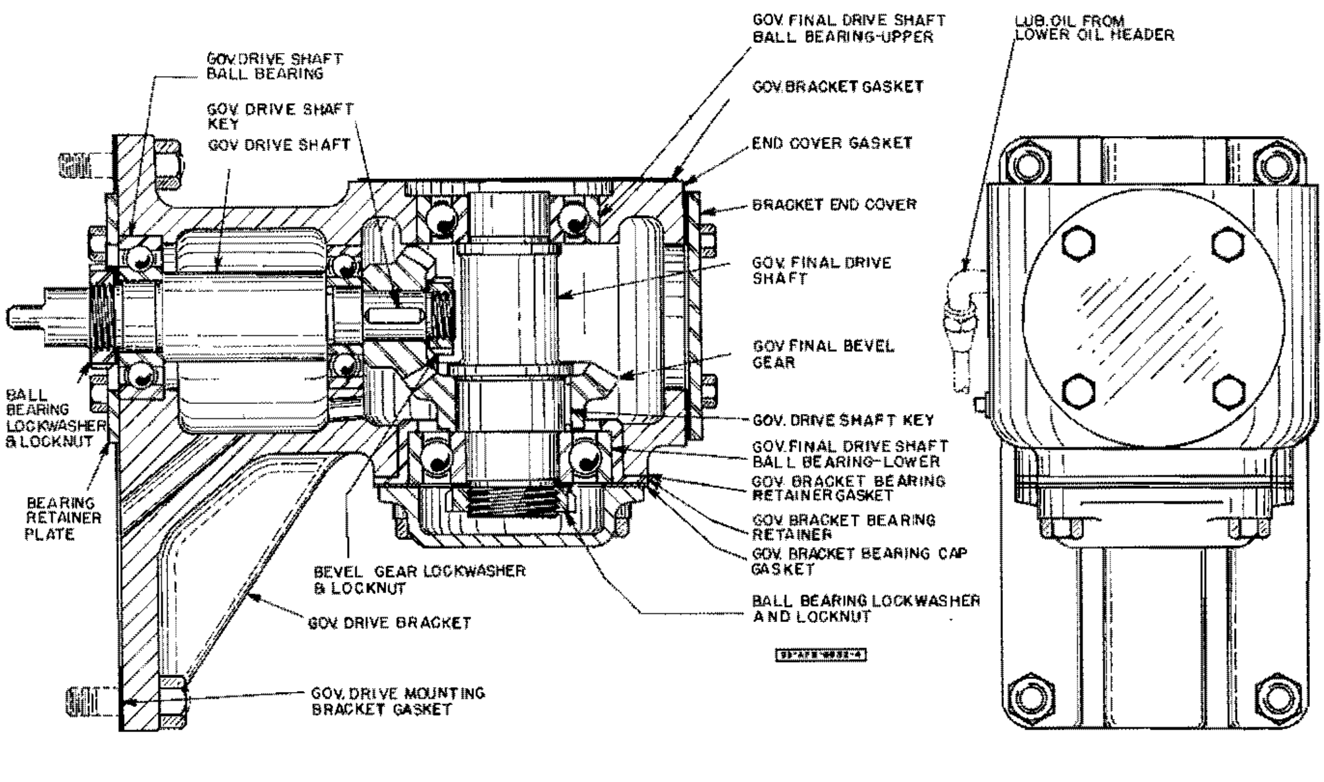
If a new pump mounting plate is to be used, it must be dowelled to the cylinder block so that the proper backlash between mating gears will be provided. Likewise if a new lubricating oil pump drive bracket is to be used it must be fitted to the cylinder block with new fitted bolts. For information regarding correct gear backlash, refer to Chapter B.

GOVERNOR DRIVE

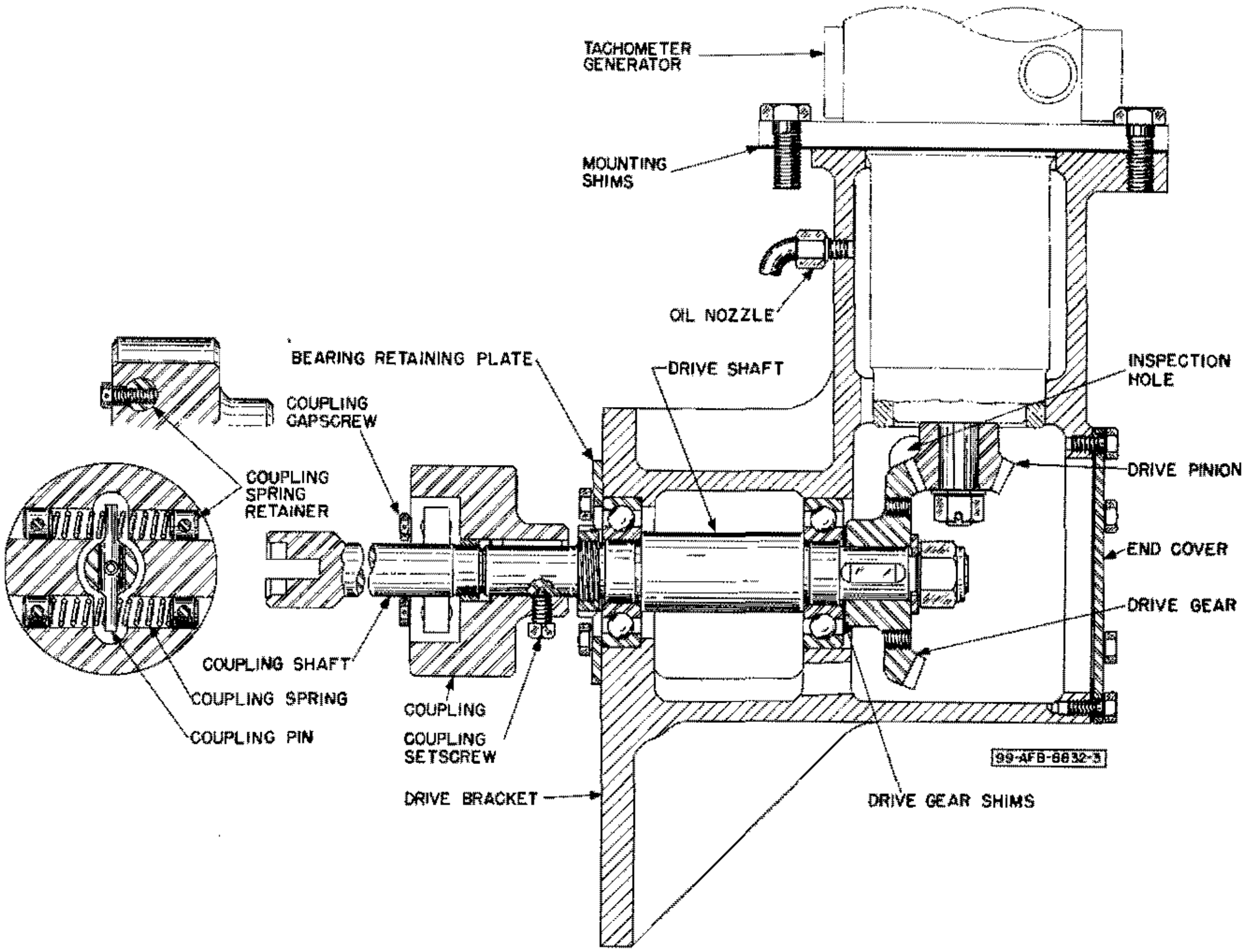
Engines with Woodward Governors

The governor drive, shown in Illus. N9, transmits power from the flexible pump drive, to rotate the governor.

The governor coupling shaft is designed so as to provide for any vibration or misalignment which may occur. The ball bearings and gears of the governor drive are lubricated from the engine pressure system. These bearings and the gears should be inspected periodically for wear, and be replaced if necessary.



Illus. N9. Governor Drive (Woodward Governor)



Illus. N10. Tachometer-Generator Drive - 10 Cyl. Erie Built Locomotives (Used on engines up to but not including No. 882199.)

Engines with Electric Governor

The tachometer-generator drive, shown in Illus. N10, transmits power from the flexible drive to rotate the tachometer-generator. The tachometer-generator drive is bevel gear driven. The tachometer-generator furnishes current to actuate the electric governor pilot valve.

The tachometer-generator drive, shown in Illus. N11, transmits power from the flexible drive to rotate the tachometer-generator. The tachometer-generator is direct driven. The tachometer-generator furnishes current to actuate the electric governor pilot valve.

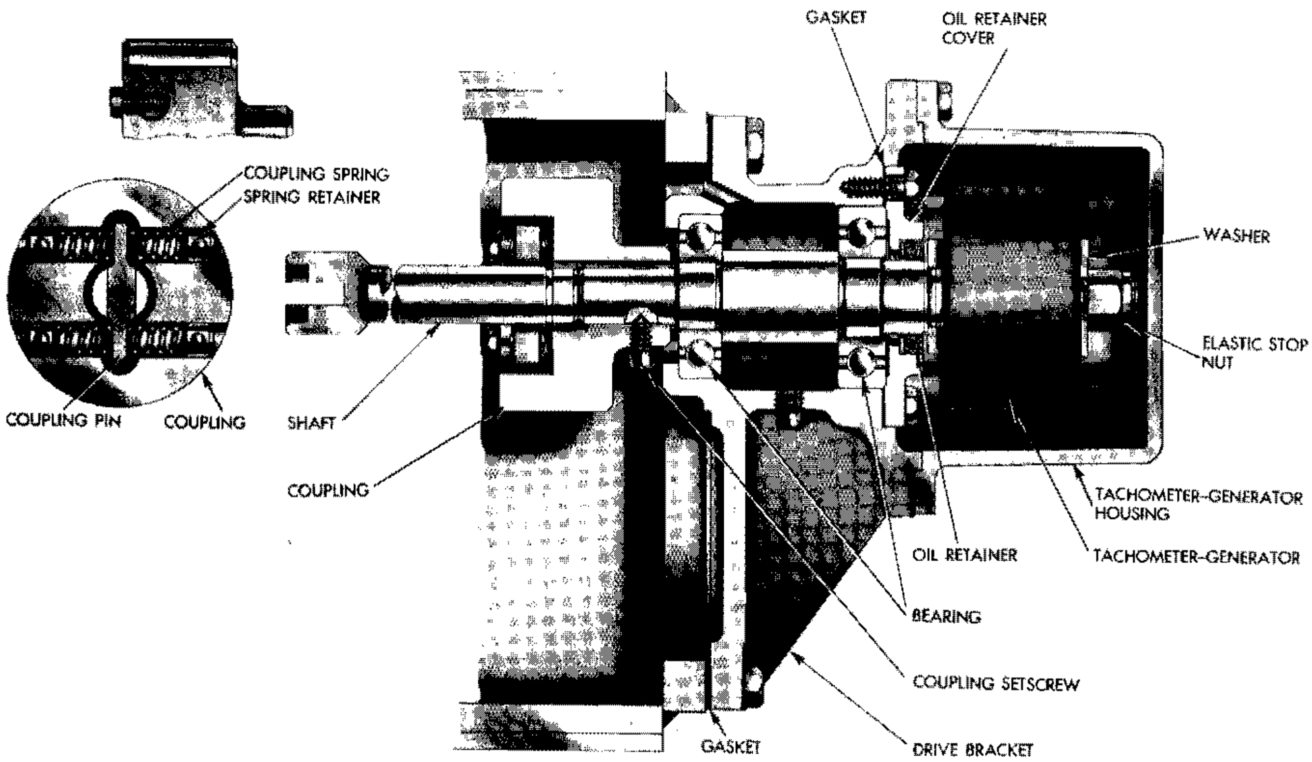
The coupling and shaft are designed so as to provide for any vibration or misalignment which may occur. The bearings and gears are lubricated from the engine pressure system. The bearings and gears should be inspected periodically for wear and should be replaced, if necessary.

SERVICING

Engines with Woodward Governors - Illus. N9

To inspect or replace bearings, the governor must first be removed. To remove the governor disconnect the necessary linkage, and oil lines. Then remove the nuts holding the governor drive bracket to the pump mounting plate. Take off the handhole cover on the pump mounting plate and hold the governor coupling shaft in place while removing the drive bracket assembly. The bearings on the final drive shaft can be taken off after removing the bearing cap and bearing locknut. The bearings on the governor drive shaft can be removed after taking off the two locknuts, retainer plate and bevel drive gear.

When reassembling, insert bearings and shafts in their proper places. Reassembly is



Illus. N11. Tachometer-Generator Drive
Used on 10 Cyl. Erie Built Locomotives starting with No. 882199 but not including No. 927599.
Used on General Electric equipped "Train Master" and "General Purpose" units.

the reverse of the disassembly procedure.

Early 10 Cyl. Erie Built Locomotives with Electric Governor - Illus. N10.

To inspect or replace bearings, remove the tachometer-generator after removing the necessary tubing and leads. Then remove the nuts holding the drive bracket to the pump mounting plate. Take off the handhole cover on the pump and hold the coupling shaft in place while removing the drive bracket assembly and the coupling shaft. Remove the coupling setscrew. The coupling and coupling shaft can then be removed from the assembly. The coupling can be disassembled after first removing the coupling capscrews.

The bearings on the drive shaft can be removed after taking off the locknut and retaining plate at one end and the end cover, "Elastic Stop" nut, washer, bevel drive gear and shims at the other end.

Before reassembling the parts, check the coupling springs for cracks and replace, if necessary. Reassembly is the reverse of the disassembly procedure.

Later 10 Cyl. Erie Built Locomotives and Units with Electric Governor - Illus. N11.

To inspect or replace bearings, remove the following parts in the sequence named. First, remove the tachometer-generator housing. This will permit the removal of the "Elastic Stop" nut, washer, tachometer-generator and bearing cap. Then remove the nuts holding the drive bracket to the pump mounting plate. Take off the handhole cover on the pump mounting plate and hold the coupling shaft in place while removing the drive bracket assembly and the coupling shaft. Remove the coupling setscrew. The coupling and coupling shaft can then be removed from the assembly. The coupling can be disassembled after first removing the coupling capscrews. The bearings on the drive shaft can now be removed.

Before reassembling the parts, check the coupling springs for cracks and replace, if necessary. Reassembly is the reverse of the disassembly procedure.

CHAPTER P. LUBRICATING SYSTEM - PISTON COOLING

DESCRIPTION OF THE EXTERNAL SYSTEM

The engine lubricating oil pump draws oil from the sump in the engine subbase and forces it thru the cooler and filter. Leaving the cooler and filter, the oil is piped to the engine, where it enters the lower lubricating oil header thru an inlet fitting. (Later locomotives also have strainers.)

For a more complete description of the external parts of the lubricating oil system refer to the "Engineman's Manual."

DESCRIPTION OF ENGINE PRESSURE SYSTEM

The engine is equipped with a pressure lubrication and piston cooling system which supplies a continuous flow of oil to all surfaces requiring lubrication, and to the pistons for cooling. After engine lubrication and piston cooling, the oil drains to the engine subbase.

The engine pressure system consists of a positive pressure gear pump, an upper and lower oil header built into the cylinder block and connections to bearings and other points requiring lubrication. (The 12 cylinder engine has an upper and two lower oil headers.)

Illus. P2 shows how lubricating oil is circulated thru the engine.

Entering the lower lubricating oil header from the inlet near the front end, the oil flows thru the lower header toward the blower end. There, a vertical pipe carries the oil to the upper header.

Thru supply pipes from both lower and upper headers, oil is forced to each main bearing, thru the crankshaft passages to each crankpin bearing. From each crankpin bearing, oil passes thru the drilled passage in the connecting rod to the piston pin bearings and to the piston for cooling. The surfaces between the thrust bearing shells, and the crankshaft flanges are lubricated by means of grooves in the thrust bearing shells.

The cooling oil from each lower piston is discharged into the subbase. Oil from each upper piston is discharged into the upper crankcase. This oil then drains to each end and down to the subbase.

The two camshafts receive lubrication from the upper oil header. The oil flows into and fills the hollow camshafts from a connection at the front end. (Refer to Illus. H2.) Small openings at each bearing allow oil to reach the bearing surface. Lubrication for the timing chain is supplied from an opening in the end of each camshaft and from the excess oil from the No. 1 main bearing. The lubricating oil from the openings in the ends of the camshafts flows out thru drilled holes in the camshaft sprocket plate and the overspeed governor shaft.

The oil that sprays from the timing chain and splashes from the upper pistons provides lubrication for the bearings of the idler sprockets and the control mechanism.

Flexible pump drive parts receive lubrication thru a hole in the crankshaft and thru longitudinal grooves in the torsional damper spider hub.

The torsional damper weights receive lubrication thru drilled holes in the spider hub which are aligned with the longitudinal grooves.

Oil from the upper crankcase enters the tappet housing and lubricates the tappet assembly. The excess oil is drained thru tubes to a return header which conducts the oil to the front end compartment.

The blower drive gears are lubricated by a spray of oil from a nozzle which branches from the pipe connecting the upper and lower oil headers. Openings in the drive gear spider furnish lubrication for the two wearing rings. Oil is brought to these openings from the drive end main bearing by means of a drilled hole in the upper crankshaft.

Two oil tubes are connected at the drive end of the upper oil header. One tube supplies lubricating oil to the inner blower bearings, and timing gears. The other line supplies oil to the outer blower bearings.

The upper and lower vertical drive gear and pinion are lubricated by oil from a nozzle. An additional tube, leading from the connecting piping between the upper and lower oil headers, supplies oil to the lower bearing housing thereby lubricating the lower roller and thrust bearing.

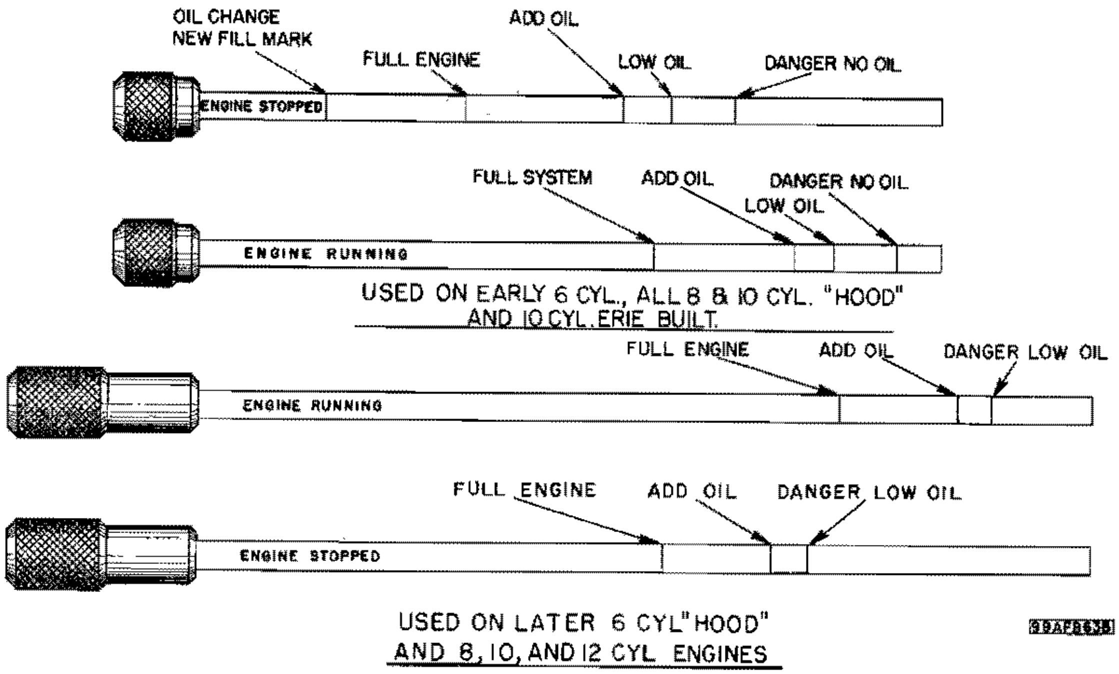
OIL USE AND CHANGE

Refer to Maintenance Bulletin "Locomotive Lubrication" Sec. 203 for general specifications and recommended oil change periods.

An oil level gage dip stick is provided for measuring the oil level (Illus. P1). Each side of the oil level gage is calibrated. One side is marked "ENGINE STOPPED" and the other side "ENGINE RUNNING."

The dip stick may be read either with the engine running or stopped. Care must be exercised so that the correct side is read.

When the system is being filled for the first



Illus. P1. Oil Level Gage

time, oil should be added until the level reaches the "FULL ENGINE" mark on the "ENGINE STOPPED" side of the dip stick. After the engine has been run and the oil distributed thru the system the level will be at the "FULL MARK."

Lubricating oil need not be added until the oil level has reached the "ADD OIL" mark. Oil should then be added until the level is at the "FULL ENGINE" mark depending on whether the engine is running or stopped.

When changing lubricating oil drain the entire system completely. After properly cleaning the system, add oil to the proper gage mark level.

OIL CONSUMPTION PROBLEMS

There are many reasons which may cause an engine to use an excessive amount of lube oil. Some of the factors that enter into the problem of high lube oil consumption are:

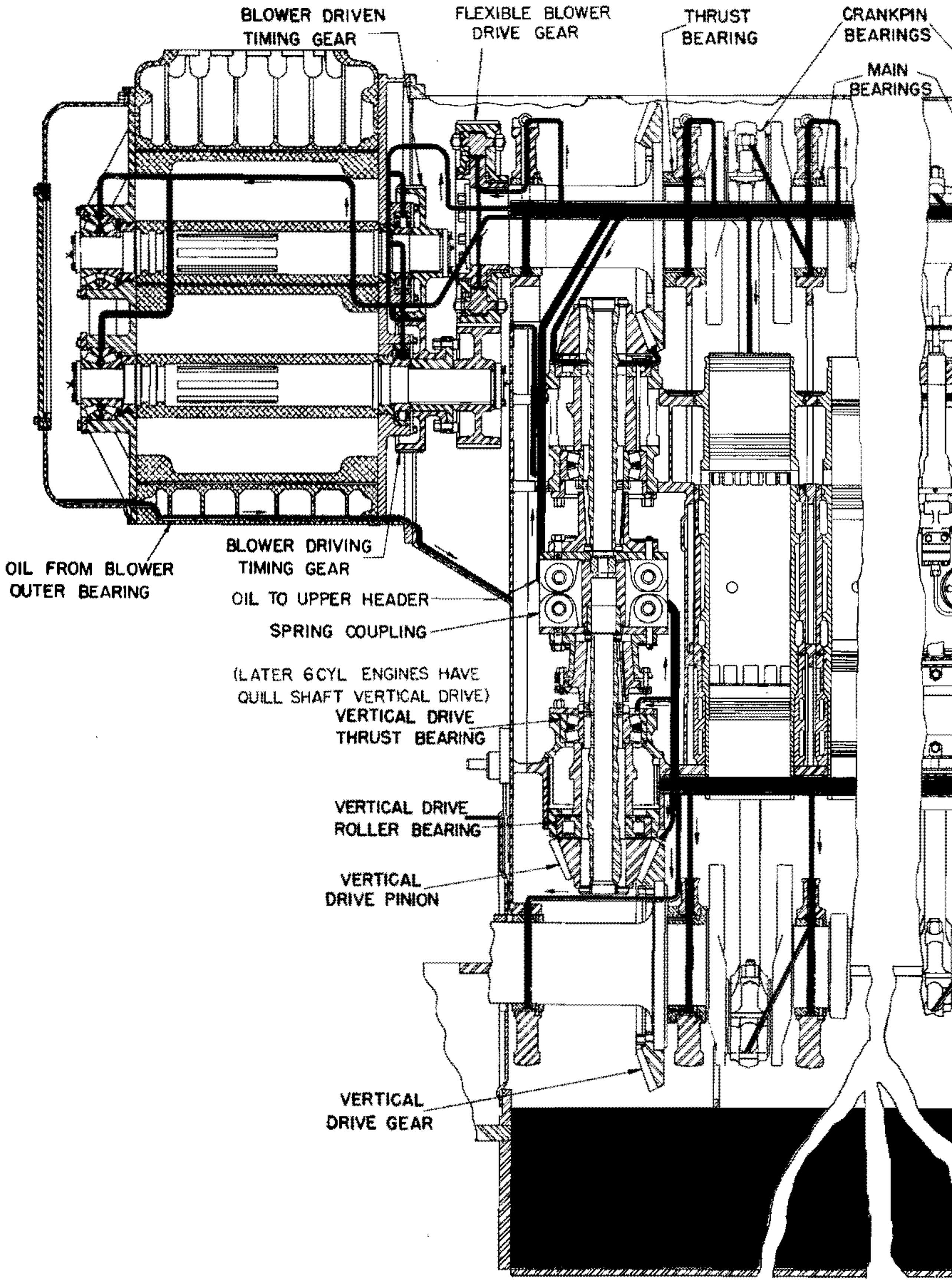
1. Oil ring abuse through handling
   a. Edges being nicked because of improper protection in storage
   b. Allowing rings to be damaged while handling in shop
   c. Overstretching and distorting rings when applying
2. Dirty liners damaging or nicking the rings.
3. Ring compressor being nicked or distorted
4. Ring expanders missing from oil control ring
5. Improper liner application
6. Improper liner surface control at time of deglazing
7. Engine temperature low
8. Engine oil leaks
9. Plugged air intake filters
10. Overfilling the crankcase

Most of these conditions are obvious and can be corrected by stringent control and insistance that maintenance personnel observe proper standards of care. Others are less evident, but can be determined by proper trouble-shooting.

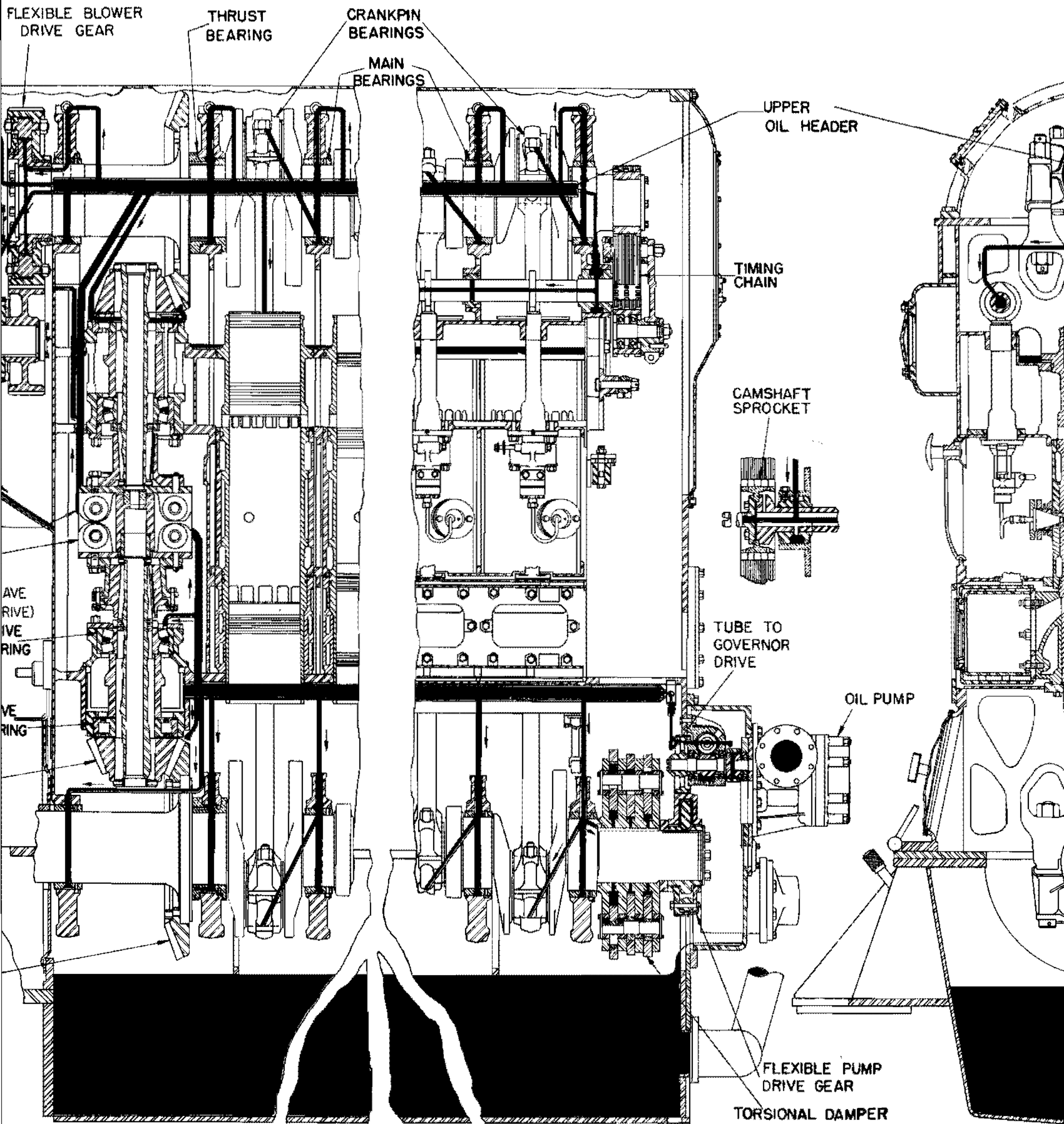
Overfilling the crankcase is a common occurrance in the field, yet is infrequently recognized as an important contributor to high lube oil consumption. Engine smoke problems, as well as heavy port carbon, can result from too much oil in the crankcase. The splashing of the lube oil due to the connecting rods dipping into the oil, deposits an excessive quantity of oil on the cylinder walls and increases the oil control problem. This action also overburdens the oil separator.

PRELUBRICATION OF THE ENGINE

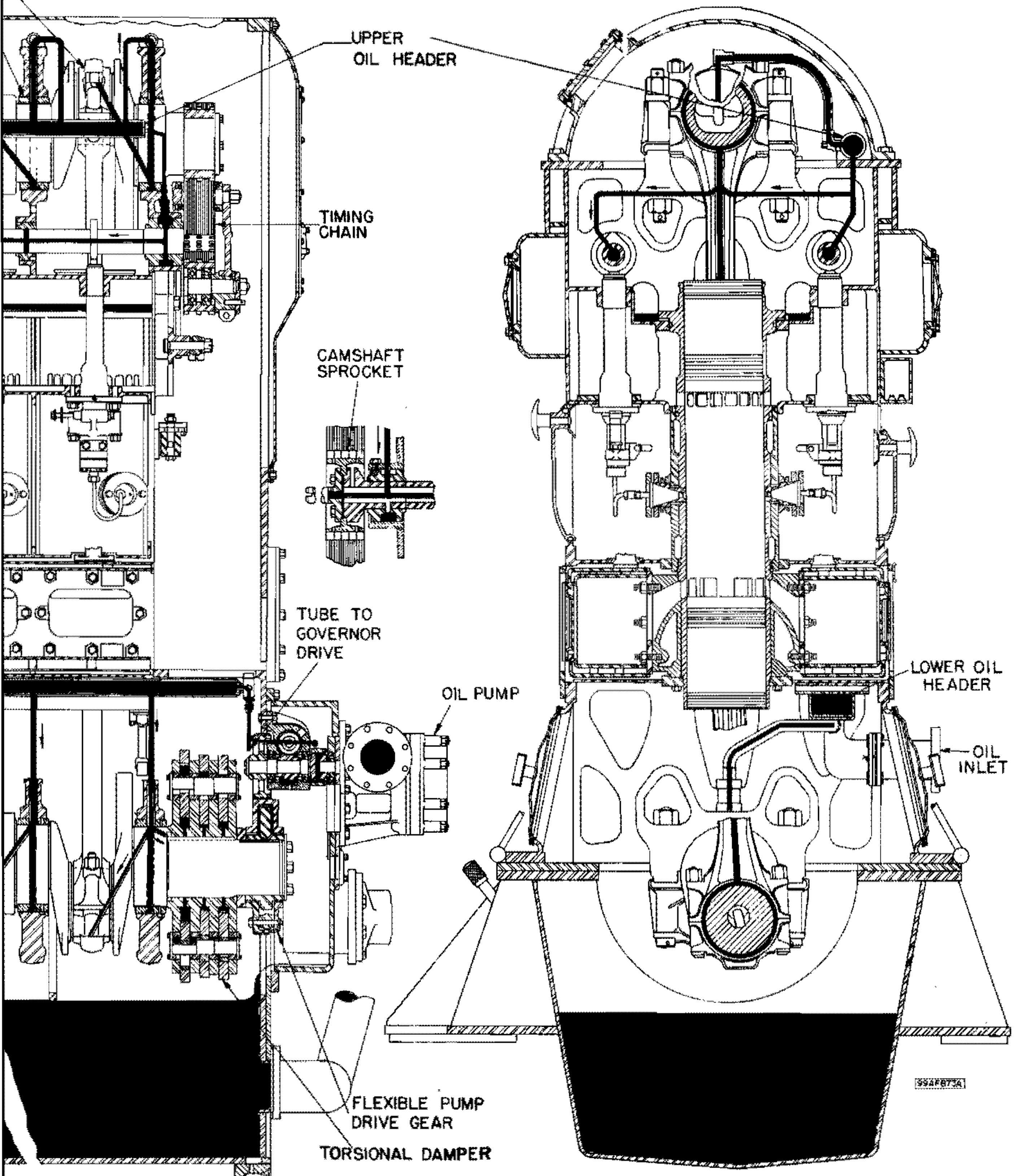
Prelubrication of an engine or charging the oil system is beneficial in that it prevents failures that could occur due to the lag of oil pressure at the engine when the oil system was



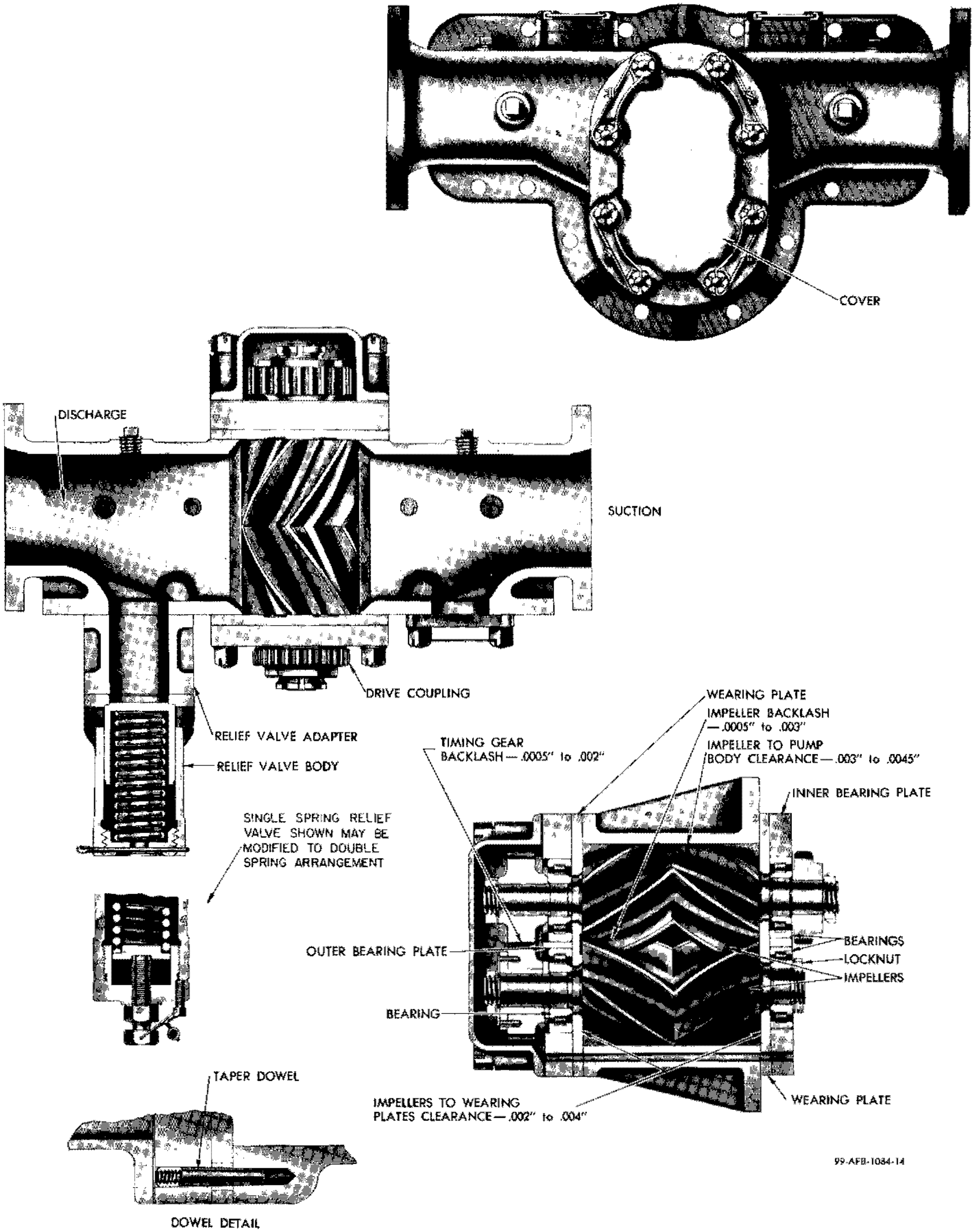
Illus. P2 Lubricating Oil Circula



Illus. P2 Lubricating Oil Circulating in the Engine



ting in the Engine



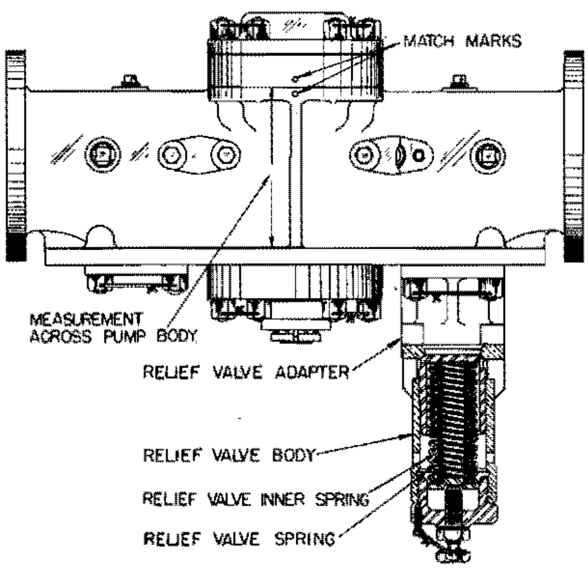
Illus. P3. Lubricating Oil Pump (Early Engines) previously drained. When the system is charged, the oil flow through the engine is almost immediate upon starting. Prelubrication supplies oil through the engine so that assurance is obtained that all parts are being lubricated and that no excessive leakage through gaskets or improperly applied parts exists. This is especially important where major overhaul work has been done on the engine. When an engine has been shut down for a long period of time, prelubrication prevents starting the engine on dry bearings. This also applies when putting a new locomotive into service or when the locomotive has been out of service for an extended period. The benefits of prelubrication can be nullified, however, if cleanliness is not heeded. Clean oil, clean supply lines, and a clean pump must be assured before prelubrication is attempted. When connections are made to prelubricate an engine, be sure the hook-up is made so that the oil passes through the strainer before it reaches the engine.

LUBRICATING OIL PUMP DESCRIPTION

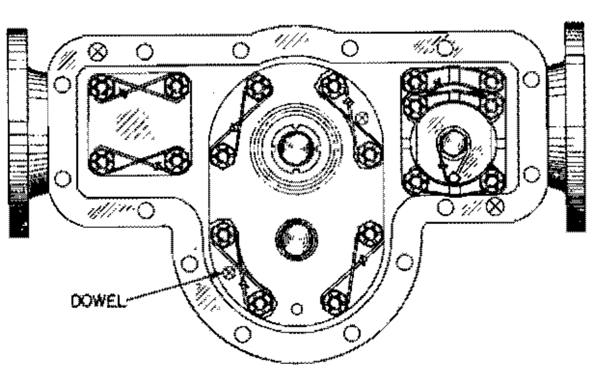
The lubricating oil pump is shown on Illus. P3, P4, and P5. The impellers are of the herringbone gear type. The pump is mounted on the pump mounting plate at the exhaust end of the engine, and is driven, thru gears and a flexible drive, by the lower crankshaft.

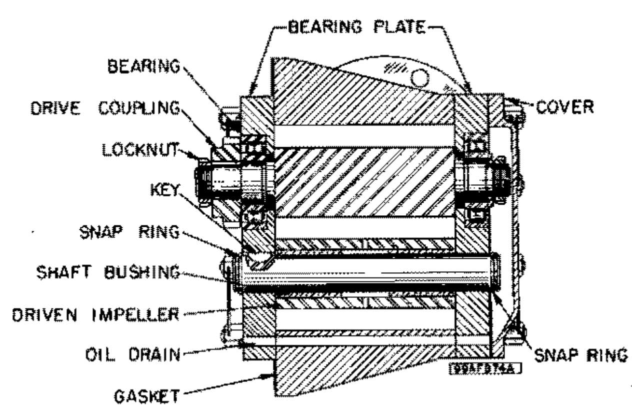
> NOTE: The lubricating oil pump on early engines have ball bearings and timing gears driving the driven impeller. Later 6, 8, and 10 cyl. engines have ball bearings on the driven impeller. The 12 cylinder engines have bushings at the ends of both impellers.

The bearings and timing gears are lubricated by oil flowing from the pump thru openings in the wearing plates (early engines). The driver impeller bearings and the driven im-



	BACKLASH	CLEARANCE
IMPELLERS	.005	
DRIVEN IMPELLER SHAFT TO BUSHING		.005 TO .0065
DRIVEN IMPELLER BUSHING TO IMPELLER		.001 TO .0025
IMPELLER TO HOUSING		.008 TO .011





Illus. P4. Lubricating Oil Pump (Later 6, 8, and 10 Cyl. Engines) peller bushing are lubricated by oil passing thru an opening in the bearing plate and by holes thru the driven impeller to the bearing (on later 6, 8, and 10 cyl. engines). The bushings on the impellers of the 12 cyl. pump are lubricated by a line from the lower oil header.

APPLICATION

In order to determine the proper pump to be used on an engine, the following information is tabulated.

No. of Cyl.	G.P.M. at Full Engine Speed	Pump Body Symbol	Measure-ment (Across pump body)
6	235	C-AFB1084H	5-1/16
8	300	C-AFB1084J	6-1/2
10	350	C-AFB1084K	7-1/2
12	425	C-A12FB1084B	9-5/16

SERVICING

The impellers may be examined by removing the discharge pipe and barring the engine. The outer bearings and timing gears (if used) may be examined by removing the cover.

The lubricating oil pump should be removed periodically and disassembled for inspection of parts.

Disconnect the piping and remove the pump from the engine.

The following procedure should be used depending on the pump in service.

Applicable to Early Engines

Remove the pump cover and the timing gear locknuts and lockwashers. Pull the timing gears. The same puller yoke is used as shown in Illus. Q6. Remove the timing gear keys.

Pull the taper dowels (5/16"-24 puller thread) from the outer bearing plate and inner bearing plate.

Remove the nuts holding the inner bearing plate in place. Then force the impellers from the outer bearings by jacking evenly against the timing gear ends of the impeller shafts. The outer bearings will stay in place in the bearing plate.

Remove the locknuts and lockwashers from the drive coupling end of the impeller shafts. Then pull the drive coupling using the puller yoke mentioned previously. Remove the drive coupling key. The impeller may now be forced from the inner bearings by jacking evenly against the drive coupling end of the impeller shafts. The inner bearings will stay in place in the bearing plate.

Carefully check the parts for damage and wear, especially the bearings and impellers.

Disassemble the valve and check the valve seat for pitting. If the seat is pitted, it can be corrected by machining on a 5° greater angle than the valve body seat. Lightly lap valve to seat. Extreme care must be used when lapping valve to seat. Excessive lapping will increase the width of the contact surface which will hinder the action of the valve. The valve and seat should have thin line contact.

Assemble valve with double springs and spring retainer. Check all parts for burrs. Be sure valve works freely. Pumps with double spring relief valve arrangement are stamped with double x (xx) letters on the front edge of the right hand flange of the pump (when facing the exhaust end of the engine).

Test valve as shown in Illus. P6, and set opening pressure at 80 to 85 psi and lock. Make up a flange with 1/4" P.T. opening and secure to pump side of relief valve with gasket between relief valve and flange. Install gage next to flange with a valve to shut off the test medium (air, water or oil).

Assemble valve to pump. Be sure that valve to pump contact surfaces are clean. This is a metal to metal contact and a good fit is required to prevent leakage.

Reassemble the pump in reverse of the disassembly procedure.

In reassembling the parts, see Illus. P3 for the clearance and backlash between parts. Clearances given are maximum and minimum. When assembling the pump, minimum clearances shown are desired and must be held as close as practically possible by fitting in such a manner that parts still come within specifications.

Make sure that the cover gasket is assembled in the correct position so as not to obstruct the oil return hole at the bottom of the pump. The slot in the gasket must be aligned with the drilled oil return hole in the bearing plate and pump body.

The dowelling for locating the lubricating oil pump body to the pump mounting plate on early engines is not jig located; if a different pump than the original is installed, the original dowelling cannot be used.

However, on later engines, the dowelling is jig located at the factory. Redowelling will not be necessary when pump replacement is made. The old, individually located, dowels were 1/2" diameter; the new, jig located, dowels are 5/8" diameter.

All replacement pumps furnished by the

factory will have jig located dowel holes. Therefore, if the pump mounting plate on the engine is not furnished with jig located doweling, it will be necessary to re-dowel the pump mounting plate with the required jig. (Contact the Locomotive Service Department.)

In replacing the pump on the pump mounting plate, it will be necessary to guide the coupling drive in place by putting a hand thru the inspection cover opening at the corner of the pump mounting plate. The dowels should relocate the pump so that there will not be any binding of drive. Before pulling nuts up tight, check alignment of coupling. Tighten nuts to torque value given in Chapter B.

Replace piping connections.

Applicable to Later 6, 8, and 10 Cyl. Engines

Remove the pump cover, locknut and lockwasher from the driver impeller, and the snap ring from each end of the driven impeller shaft.

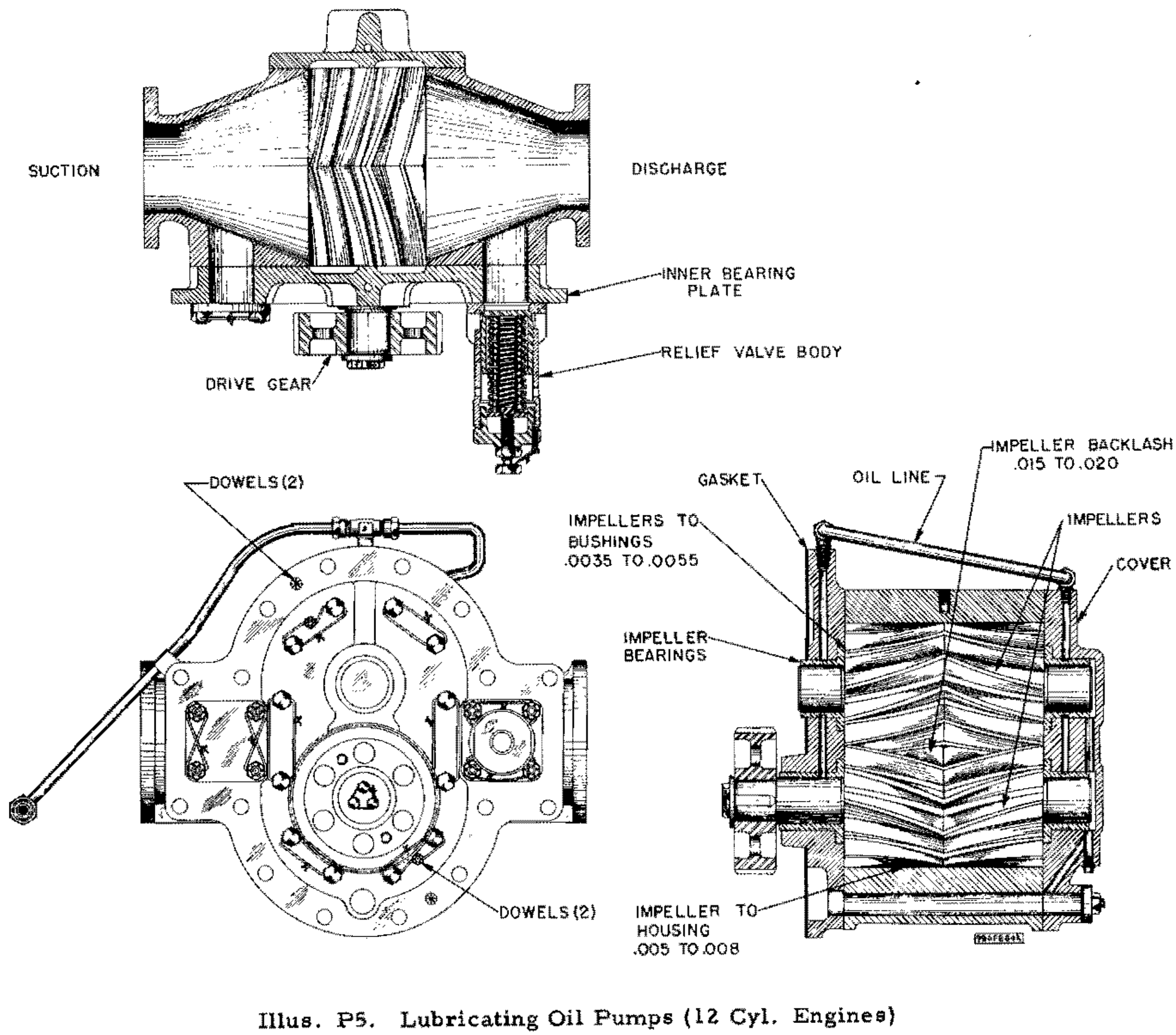
Pull the dowels from the inner and outer bearing plates. Remove the nuts holding the inner bearing plate in place. With the puller yoke, Illus. Q6, jack against the driven impeller shaft until the shaft is free. Using the puller yoke, jack the driver impeller shaft from the outer bearing plate.

Remove the locknut and lockwasher from the drive coupling and pull the coupling using the puller mentioned.

Remove the key. Use the puller and jack against the driver impeller shaft and push the shaft out of the inner bearing plate. The bearings will stay in place in the bearing plates.

Remove the impellers and bushing from the driven impeller.

Check the parts for damage and wear especially the bearings and impellers.



Illus. P5. Lubricating Oil Pumps (12 Cyl. Engines)

Disassemble the valve and check the valve seat for pitting. If the seat is pitted, it can be corrected by machining on a 5° greater angle than the valve body seat. Lightly lap valve to seat. Extreme care must be used when lapping valve to seat. Excessive lapping will increase the width of the contact surface which will hinder the action of the valve. The valve and seat should have thin line contact.

Assemble valve with double springs and spring retainer. Check all parts for burrs. Be sure valve works freely. Pumps with double spring relief valve arrangement are stamped with double x (xx) letters on the front edge of the right hand flange of the pump (when facing the exhaust end of the engine).

Test valve as shown in Illus. P6, and set opening pressure at 80 to 85 psi and lock. Make up a flange with 1/4" P.T. opening and secure to pump side of relief valve with gasket between relief valve and flange. Install gage next to flange with a valve to shut off the test medium (air, water or oil).

Assemble valve to pump. Be sure that valve to pump contact surfaces are clean. This is a metal to metal contact and a good fit is required to prevent leakage.

Reassemble the pump in reverse of the disassembly procedure.

In reassembling the parts, see Illus. P4 for the clearances between parts. Clearances given are maximum and minimum. When assembling the pump, minimum clearances shown are desired and must be held as close as practically possible by fitting in such a manner that parts still come within specifications.

Make sure that the cover gasket is assembled in the correct position so as not to obstruct the oil return hole at the bottom of the pump. The slot in the gasket must be aligned with the drilled oil return hole in the bearing plate and pump body.

In replacing the pump on the pump mounting plate, it will be necessary to guide the coupling drive in place by putting a hand thru the inspection cover opening at the corner of the pump mounting plate. The dowels should relocate the pump so that there will not be any binding of drive. Before pulling nuts up tight, check alignment of drive. Tighten nuts to torque value given in Chapter B.

Replace piping connection.

Applicable to 12 Cyl. Engines

Pull the dowels and remove the nuts from the inner bearing plate and from the outer cover.

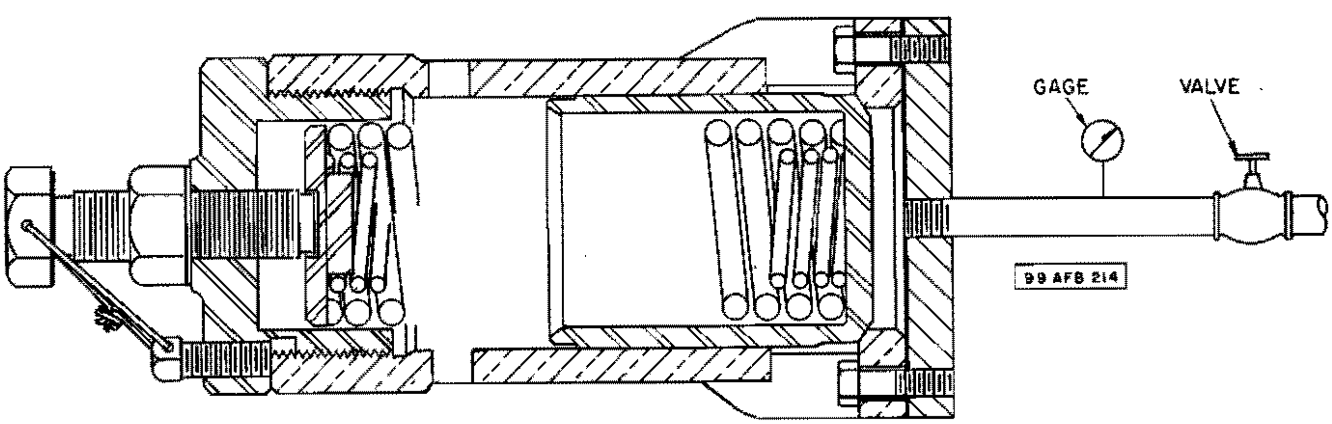
Remove the capscrews and retaining plate and the drive end of the impeller shaft. Pull the drive gear using the puller, Illus. Q6.

Remove the inner bearing plate and outer cover.

Check the parts for wear and damage especially the bearings and impellers. The bearings can be replaced if excessively worn. Pull the bearing and press in new bearings.

Disassemble the valve and check the valve seat for pitting. If the seat is pitted, it can be corrected by machining on a 5° greater angle than the valve body seat. Lightly lap valve to seat. Extreme care must be used when lapping valve to seat. Excessive lapping will increase the width of the contact surface which will hinder the action of the valve. The valve and seat should have thin line contact.

Assemble valve with double springs and spring retainer. Check all parts for burrs. Be sure valve works freely. Pumps with double spring relief valve arrangement are stamped with double x (xx) letters on the front edge of the right hand flange of the pump (when facing



Illus. P6. Testing Pump Relief Valve

the exhaust end of the engine).

Test valve as shown in Illus. P6, and set opening pressure at 80 to 85 psi and lock. Make up a flange with 1/4" P.T. opening and secure to pump side of relief valve with gasket between relief valve and flange. Install gage next to flange with a valve to shut off the test medium (air, water or oil).

Assemble valve to pump. Be sure that valve to pump contact surfaces are clean. This is a metal to metal contact and a good fit is required to prevent leakage.

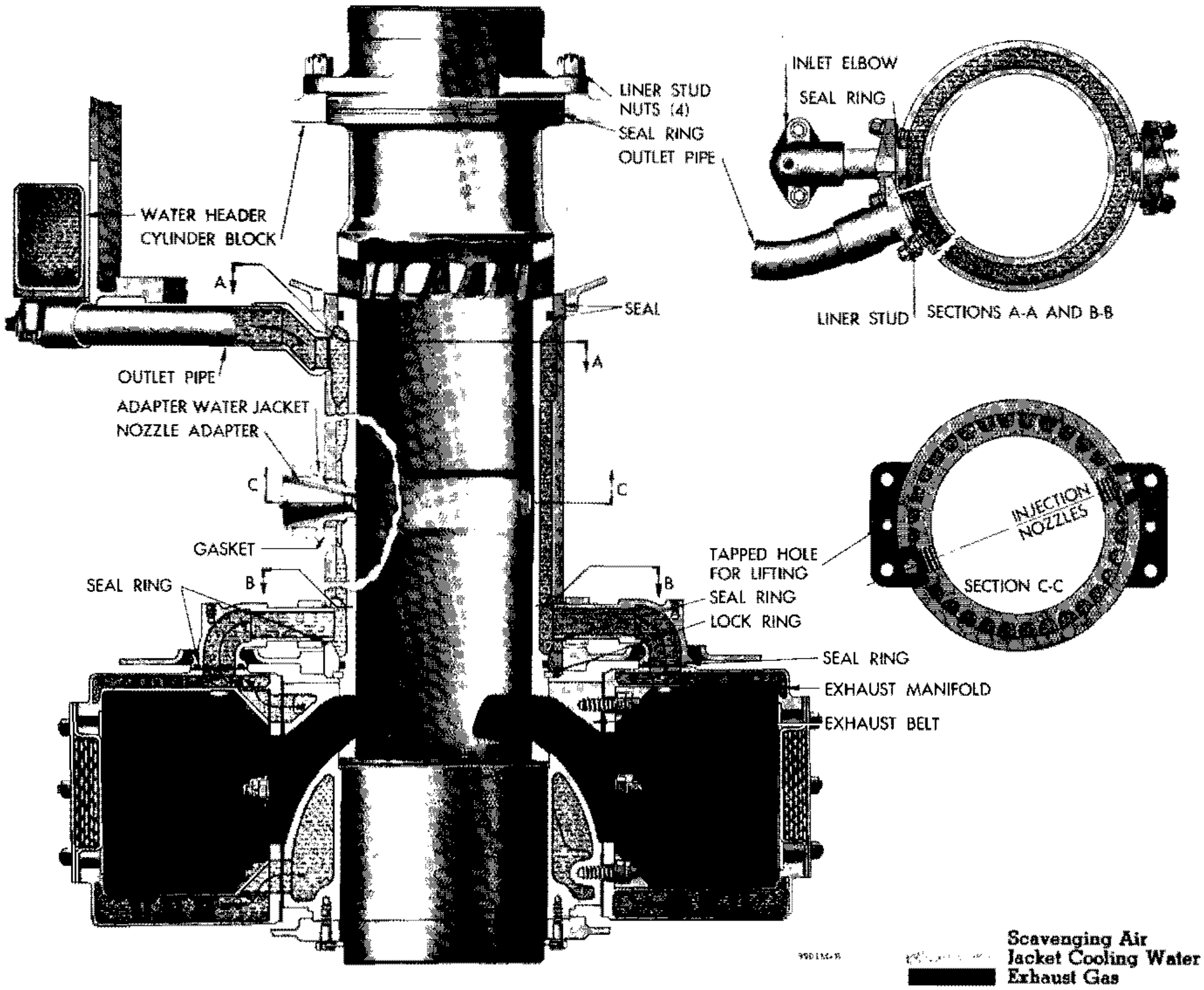
Reassemble the pump in reverse of the disassembly procedure.

In reassembling the parts, see Illus. P5 for the clearances between parts. Clearances given are maximum and minimum. When reassembling the pump, minimum clearances shown are desired and must be held as close as practically possible by fitting in such a manner that parts still come within specifications.

In replacing the pump on the mounting plate the dowels should relocate the pump so that drive gear has the correct backlash. Before pulling nuts up tight, check alignment and free movement of the drive. Tighten the nuts to torque value given in Chapter B.

Replace piping connections.

CHAPTER Q. COOLING SYSTEM



Illus. Q1. Water Passages thru the Engine
(As viewed from the exhaust end)

DESCRIPTION - EXTERNAL SYSTEM

The engine is cooled by circulating water thru its passages. This water circulates in a closed system consisting of the engine cooling system, piping, supply tank and radiators.

Only clean water which is properly treated for scale and corrosion should be used in the system. A thin layer of dirt or scale on the cylinder walls will act as an insulator, tending to cause overheating and possible damage to the engine.

Refer to Maintenance Bulletins "Cooling Systems" Sec. 218 Series, for complete description of external system and water treatment procedure.

WATER PASSAGES THRU THE ENGINE

On locomotives with exhaust elbows, the jacket cooling water enters the engine thru an inlet in each exhaust elbow. The water then flows thru passages which form a cooling jacket surrounding the elbows. The water then enters the exhaust manifold water jackets extending the full length of the manifold. On locomotives with individual exhaust snubbers, the cooling water enters directly into the exhaust manifold water jacket.

Exhaust passages thru the exhaust belts and the lower part of the liner are cooled by the jacket water travel thru the exhaust belts. The water enters from the exhaust manifold at openings at the lower side of the belts and returns to the manifolds at openings near the top.

As shown in Illus. Q1, the water flows from the exhaust manifolds to inlet elbows on each side of the cylinders. These elbows conduct the water to the space between the cylinder liner and its jacket. Ribs on the cylinder liner direct the water upward, to cool the liner. Water passages also lead to the water jackets around the injection nozzles.

Upon reaching the top of the liner jacket, the water flows out of the cylinder water space thru an outlet pipe which leads to the water header. This header extends along the opposite governor side of the cylinder block, just below the air receiver. Its outlet flange is at the exhaust end of the engine.

LUBRICATING OIL COOLING WATER SYSTEM (Two Pump System - Early Engines)

The lubricating oil is cooled by an oil cooler which is cooled in turn by the cooling water system. The oil cooling water is cooled by radiators and the air cooling systems.

The lubricating oil cooling water pump discharges water thru the oil coolers where the water cools the lubricating oil. After leaving the oil cooler, the water flows thru the radiators where it is cooled. From the radiators, the water flows back to the water tank and to the pump to repeat its cycle.

SUGGESTIONS TO THE OPERATOR

No restrictions should be allowed in the cooling systems.

The engine system should be subjected to 50 lbs. hydrostatic pressure after any parts have been replaced and reconnections made. The water test applies to the engine only. Use pump or hydrant pressure and block off the inlet and outlet; also the cab heaters. Observe all connections for possible leakage.

WATER PUMPS - JACKET WATER (and Lubricating Oil Cooling Water Pump on Early Engines)

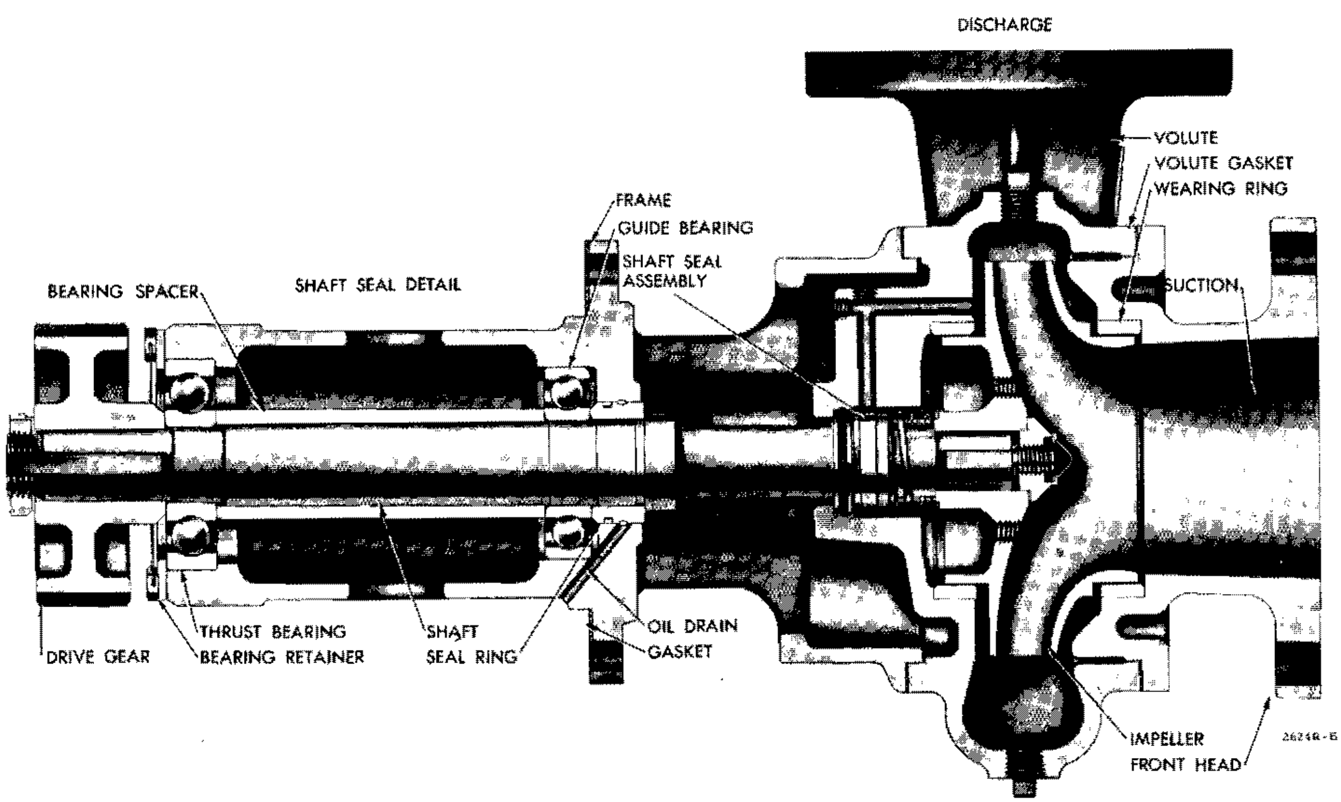
DESCRIPTION

The built-in circulating water pump is of the centrifugal type. Refer to Illus. Q2.

This pump is gear driven from the lower crankshaft thru a flexible drive gear. The pump is attached to the pump mounting plate at the exhaust end of the engine.

The shaft and impeller assembly rotates on ball bearings and has a carbon seal at the volute end.

Lubricating oil reaches the pump bearings from the exhaust end compartment thru openings in the pump frame and is distributed by the bearings spacer. Leakage of oil to the outside is prevented by the oil seal ring.



Illus. Q2. Water Pump

SERVICING

The following inspections may be made without completely disassembling the pumps:

The seal may be inspected after removing the front head and impeller.

The wearing rings, Illus. Q2, are pressed into the volute and the front head and are replaceable. Original clearance is .030". Replace rings when wear increases to about twice the original clearance.

The oil seal ring, Illus. Q2, should be replaced when leakage is noticed.

SHAFT SEALS

The shaft seals prevent water in the volute from leaking out along the pump shaft.

The shaft seal is a precision product and must be handled with care. Take particular care not to scratch the lappedfaces on the sealing seats.

It is recommended that the complete assembly be replaced rather than replacing individual parts.

A new shaft seal assembly can be installed after the front head and impeller have been removed. Two types of mechanical seals are used. Pumps with the "Garlock" seals are marked with an "X".

Crane Seal (Exposed Spring) - Illus. Q3

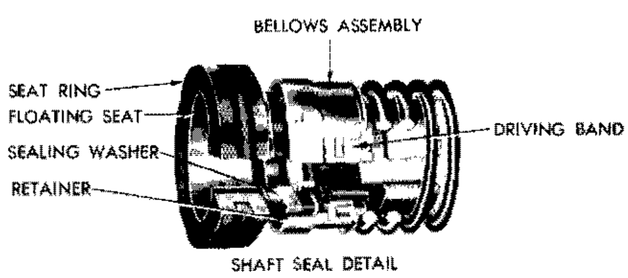
First, remove the spring. The pressure upon the bellows will then be removed, allowing the bellows to expand and free itself from the shaft. Then remove the bellows assembly. A suggestive method for the removing of the bellows assembly would be to fashion two hooks made of strong steel wire as shown in Illus. Q4. These hooks can then be used to hook the retainer and pull the assembly out.

CARE SHOULD BE TAKEN WHEN PULLING THE BELLOWS ASSEMBLY OUT SO AS NOT TO DAMAGE THE CARBONSEAL.

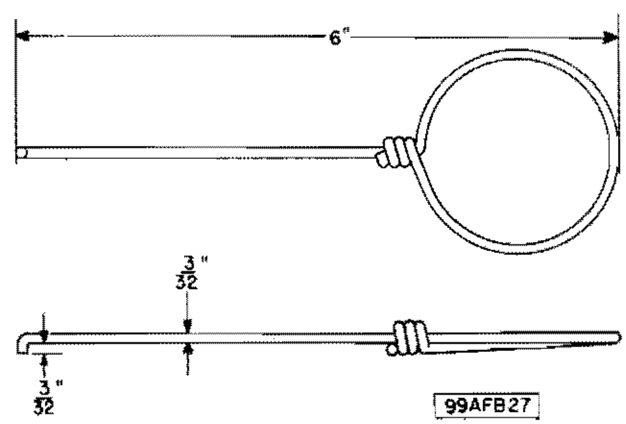
A SLOW EVEN FORCE SHOULD BE EXERTED WHEN PULLING THE ASSEMBLY OUT WITH THE TWO HOOKS. ALSO, BE SURE TO BEND THE END OF THE WIRE OVER ONLY 3/32" WHEN FORMING THE HOOK SO IT WILL NOT OVERLAP AND DAMAGE THE FACE OF THE SEALING WASHER.

Remove the seat ring and floating seat by using two bars (1/4"x3/8") with the ends bent 45° and inserted thru the openings in the frame. Pry and tap evenly from both sides with the bent ends bearing on the floating seat as shown in Illus. Q5. The new assembly is installed as follows: Place the new rubber seat tight against the shoulder of the floating seat. The rounded outer edge should be positioned so that it will be against the volute shoulder to facilitate insertion. Wipe the lapped sealing face of the floating seat perfectly clean and oil the face with clean, light oil. Oil the outer surface of the seat ring with light oil and push the assembly into the cavity using a smooth sleeve with an I.D. of about 1-17/32" and wall thickness of 1/4" as shown in Illus. Q6, which will make contact on the outer edge of the floating seat. not on the lapped sealing face. This will also insure locating the floating seat squarely to the shaft.

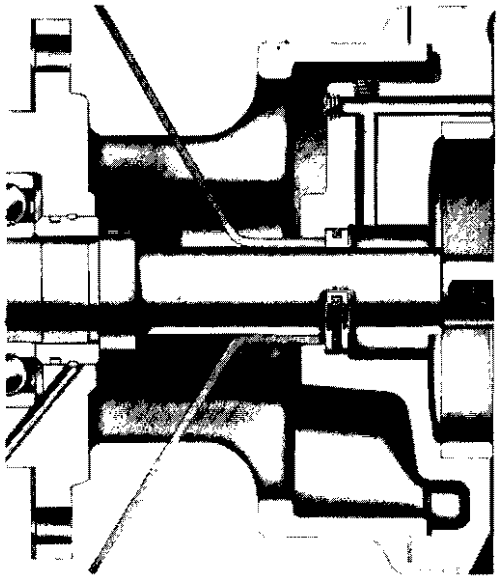
Wipe the lapped sealing face of the sealing washer perfectly clean and oil the face with clean, light oil. If the sealing washer is loose in the retainer shell, paste it in with a small quantity of grease. Place the sealing washer, bellows assembly and spring on the shaft and slide the complete assembly in as far as it will go. Be sure the sealing washer is in the proper position. The notches on the edge of the sealing washer should mate with the lugs on the retainer. Also check the spring to make sure it is seated properly on the spacer before sliding the



Illus. Q3. "Crane" Shaft Seal



Illus. Q4. Bellows Assembly Puller



Illus. Q5. Removing Seat and Seal Ring

assembly in. Install the impeller with new seal washer, making sure that the spring seats properly on the impeller hub. Replace the impeller nut.

Garlock Seal (Enclosed Spring) - Illus. Q7.

After removal of the front head and impeller, remove the spacer. The stationary seat, vibration ring and mechanical seal are removed using two bars (1/4"x3/8") with the ends bent 45° and inserted thru the openings in the pump frame. Pry and tap evenly from both sides with the bent ends bearing on the stationary seat. The bars would be used in the same manner as shown in Illus. Q5.

The new seal is assembled as follows:

The shaft and counterbore in the pump housing must be smooth and free of score marks.

Remove protective coating from face of stationary seat. Lubricate vibration ring O.D. With vibration ring on stationary seat, slide unit into counterbore. Wipe seal face with soft clean cloth to remove dirt that may have collected. Remove protective coating from face of seal unit and lubricate shaft and slide seal unit into place.

Slide spacer ring into place. Install impeller shaft gasket impeller and lock in place with nut.

DISASSEMBLING THE WATER PUMP

Matchmark the volute and front head so that the front head can be replaced in its original position. Then remove the front head. To loosen it, tap it lightly with a soft hammer.

Remove the nut and washer from the impeller end of the shaft. Then remove the impeller as shown in Illus. Q8. Be careful not to damage the impeller edges. Be sure the puller button is in place. Remove the impeller seal washer.

The shaft seal is now removed. For the removal of the shaft seal, refer to the instructions under "Shaft Seals."

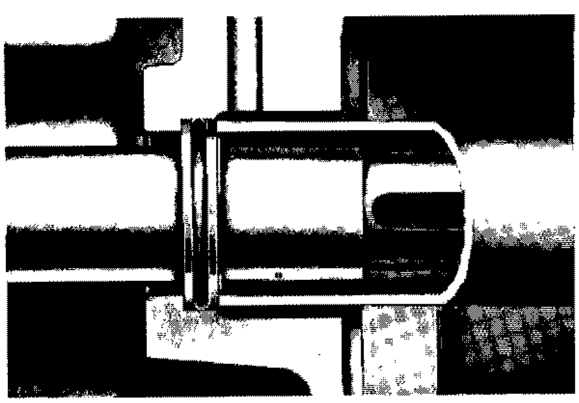
Matchmark the volute and frame so that the volute can be replaced in its original position. Then remove the volute.

Pry up the lockwasher at the gear end and remove the locknut with a spanner wrench.

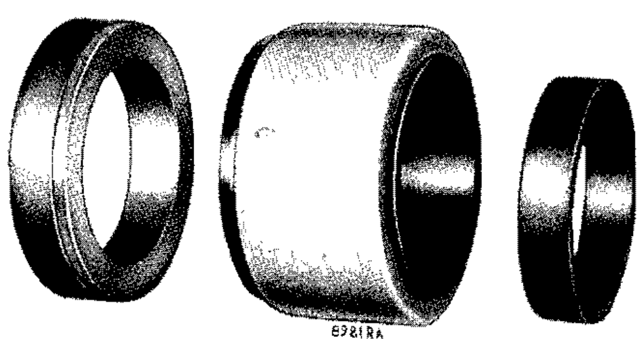
Remove the drive gear with the puller as shown in Illus. Q8.

Remove the bearing retainer plate from the drive gear end of the pump frame.

Next, remove the pump shaft with bearings in place thru the drive gear end of the pump frame. Tapping the impeller end of the shaft will free the bearings of the frame. Protect the end of the shaft. The bearings and oil retainer



Illus. Q6. Replacing Seat and Seal

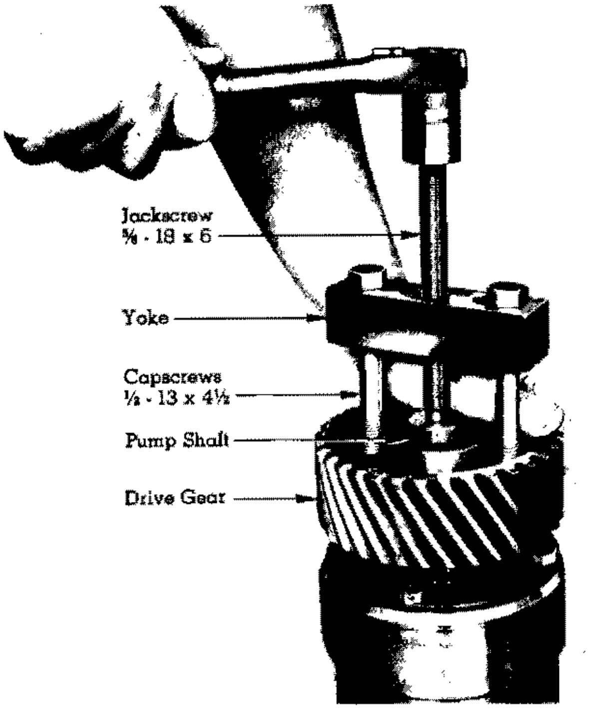


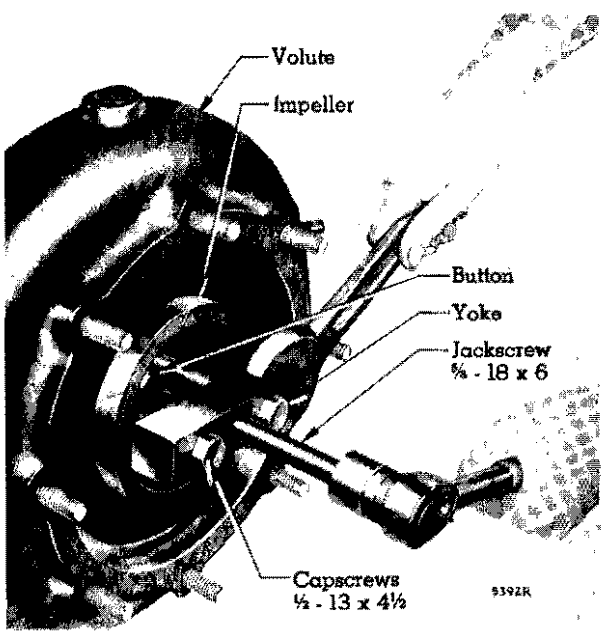
Illus. Q7. "Garlock" Shaft Seal

are removed after the shaft assembly has been removed from the frame.

REASSEMBLING THE WATER PUMP

Put the oil retainer with seal ring in place in the pump frame. The seal ring can be compressed into the frame bore by looping a wire around the ring and pulling the ends to compress the ring into the bore.





Illus. Q8. Gear and Impeller Puller

Set the frame on its volute end. Wash both bearings in clean fuel oil. Insert the shaft guide bearing, tapping it evenly and gently until it rests against the oil retainer.

Insert the bearing spacer so that it rests on the inner race of the guide bearing.

With the bearing number facing out, insert the thrust bearing into the top of the frame. Force the bearing evenly into place against the bearing spacer. Then replace the bearing retainer plate.

Set the pump on its drive gear end, and insert the shaft. Force the shaft into place until the shoulder is against the oil retainer. Protect the impeller end of the shaft.

Replace the volute on the pump frame, lining up the matchmarks.

The shaft seal assembly is now inserted. Instructions are given under "Shaft Seals."

With the shaft seal assembly in place, replace the impeller. Be sure the seal washer is in place. Start the impeller onto the shaft by tapping the inner hub face with a lead hammer. Then press into place until the impeller rests snugly against the shaft sleeve. Replace the impeller nut and washer.

Replace the front head, lining up the matchmarks previously made.

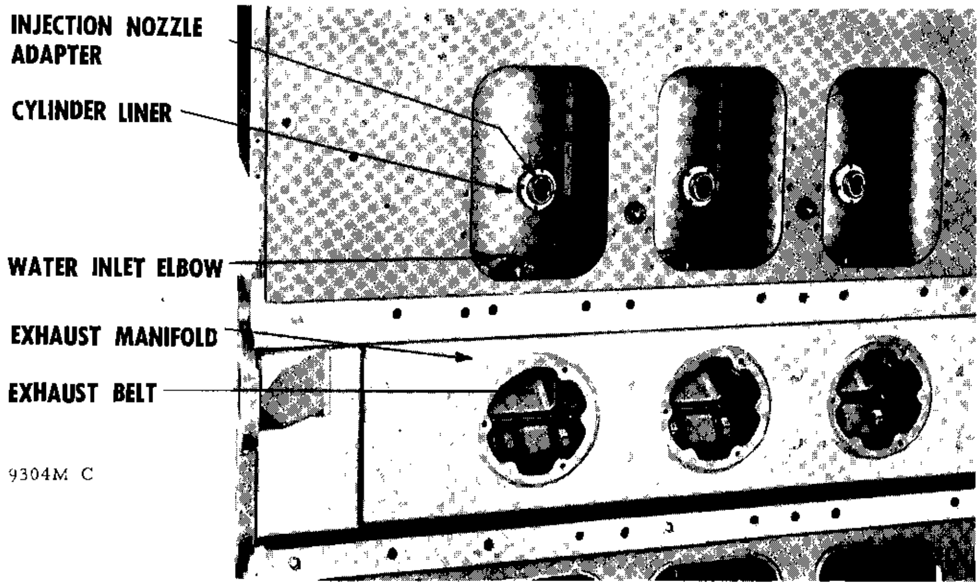
Paint the drive gear bore with white lead, and replace the gear on the shaft. Replace the lockwasher and locknut on the drive gear. Be sure the locknut is sufficiently tightened so that the drive gear, bearing inner races, bearing spacer, oil retainer and shaft shoulder are all tightly in place without end clearance between adjacent parts. Check this condition by reaching thru the frame opening and turning the bearing spacer. If the spacer turns independently of the shaft, it is an indication that end clearance exists which must be corrected by tightening the drive gear locknut.

INSTALLING THE WATER PUMP

Install the pump to mounting plate, check the backlash of the drive gears.

The pump mounting plate is aligned at the factory using two water pumps to determine location of mounting plate. The mounting plate does not require realignment when replacing a water pump.

CHAPTER S. EXHAUST SYSTEM



Illus. S1. Cylinder Liner and Exhaust Manifold in Position

DESCRIPTION

The exhaust system conducts the gases from the exhaust ports to the atmosphere. The hot gases flow out of the cylinder liner when the lower piston uncovers the exhaust ports. The gases enter individual exhaust belts connected to the exhaust manifolds, which are mounted in the cylinder block on each side of the engine. The gases pass on into the elbows or silencer at the front end of the engine and on to the atmosphere.

Cooling water enters the engine thru the inlet at the exhaust elbows (or at the silencer) and flows into the water jacket of the exhaust manifolds. The water then flows thru the water jacket of the manifolds and exhaust belts, thereby cooling the exhaust passages.

Drain tubes are provided in the exhaust elbows or silencer to drain any condensation that may collect in the manifolds, elbows or silencers. These drains must be kept clean to prevent the accumulation of foul weather moisture and condensation. If these drains are not clean the collected moisture will be carried out the stack at higher throttle notches and be deposited on the top of the locomotive and tracking cars.

The cooling water passages of the engine can be drained by draining the jacket water cooling system. Refer to Maintenance Bulletins "Cooling Systems," Sec. 218 Series.

Illus. S2 shows the relationship of the exhaust manifolds, belts and cylinder block.

Openings in the exhaust manifolds at each cylinder are provided for the inspection of the piston rings and liners and also for cleaning purposes. Covers are used on these openings.

REMOVING EXHAUST MANIFOLD

To remove an exhaust manifold for inspection or repair, first drain the jacket water system.

Remove outside connections (exhaust elbows, or silencer, fuel drain piping and cylinder liner inlet elbows).

The exhaust manifold cover plate (stress plate) is attached to the cylinder block with fitted bolts and dowels. Remove the nuts from the dowels and pull the dowels. Remove the nuts from the fitted bolts and drive the bolts back flush with the plate.

Then remove the cover plate being careful not to damage the threads on the bolts.

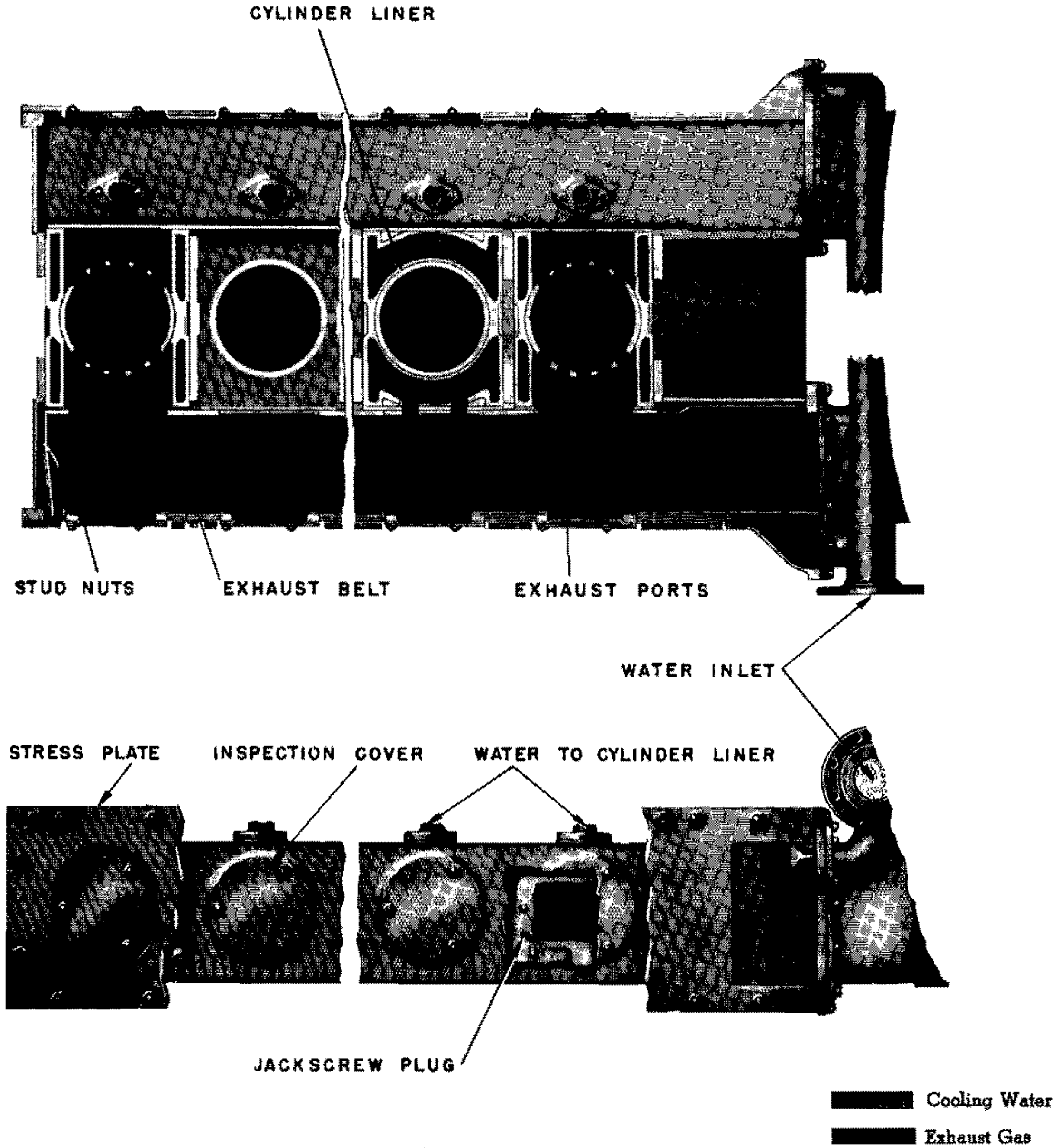
Next remove the inspection cover plates.

The nuts from the exhaust belt to manifold studs are then removed. The washers may be left on the studs but caution should be exercised so that the washers are not lost. Also remove the capscrews holding the manifold outlet flange to the cylinder block.

Then take out the brass plugs which protect the jackscrew holes in each manifold. There are two plugs in each of certain cylinders. These plugs are located as follows:

6 cyl. engine-cylinders No. 1, 3 and 6
8 cyl. engine-cylinders No. 1, 3, 6 and 8
10 cyl. engine-cylinders No. 1, 3, 6, 8 and 10
12 cyl. engine-cylinders No. 1, 3, 6, 8, 10 and 12

Into these holes insert lubricated round



Illus. S2. Exhaust System

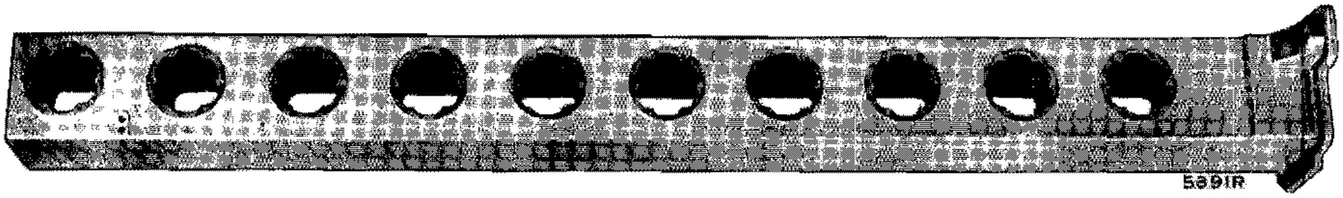
point hardened setscrews (1/2"-13x1-1/2" long or longer), turning them in until they contact the exhaust belt surface. Then, beginning at one end and working toward the other, tighten the setscrews in turn. Return to the starting point and repeat. Continue until, due to the action of the setscrews, the manifold breaks away from the gasketed joint between the belt and manifold. Remove the manifold from the exhaust manifold compartment of the cylinder block. Clean all gasketed surfaces. Care should be exercised so that the manifold is not damaged.

After making any repairs to the manifold, test the manifold water jacket to 50 lbs. hydrostatic pressure.

INSTALLING EXHAUST MANIFOLD

When installing the exhaust manifold and elbow or silencer, always use new gaskets on cleaned surfaces. Mike the exhaust belt gaskets and select for uniform thickness.

Place the exhaust belt gasket on the exhaust belt studs and grease the manifold side. Do not use any gasket sealing compound on either side. The gaskets must be installed with the large holes at the bottom. If the gaskets are inverted, the sealing area is cut down at the top and leaks can be expected.



Illus. S3. Exhaust Manifold for 10 Cyl. Engine

Place the manifold into the manifold compartment and align so that the outlet flange is properly positioned with the mating surface on the end of the cylinder block. Replace (not securely) two nuts at each end and center of the manifold.

Install the capscrews and tighten to pull the outlet flange to the cylinder block. Do not tighten securely.

Install the exhaust belt stud nuts on the No. 1 cylinder. Alternately tighten the capscrews and stud nuts to the torque limits given, Chapter B.

Replace and tighten the exhaust belt stud nuts on the remaining cylinder in order, starting at No. 2 cylinder.

Replace the manifold cover plate by placing it on the extended ends of the fitted bolts. Next, replace the dowels, drive the fitted bolts in place and tighten the nuts securely.

Then replace remaining parts.

Another hydrostatic test should be made of the engine jacket water system to check for leaks at the exhaust belt and water connections to the cylinder liner. The 50 lb. test applies to the engine only and not to the external piping. Use pump or hydrant pressure and block off inlet and outlet. Check connections and make necessary reconnections.

Refill the jacket water cooling system.

Refer to Maintenance Bulletin Sec. 206B for inspection and retightening program for an overhauled unit.

EXHAUST BELTS

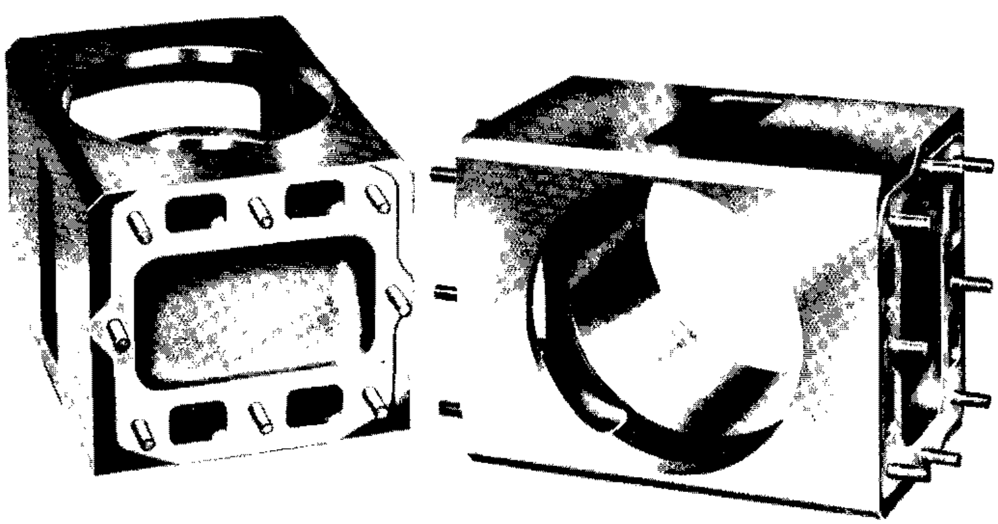
The exhaust belt can be removed from the cylinder block after an exhaust manifold and the included cylinder liner have been removed. However, if more than one-half of the exhaust belts are to be removed, it is advisable to remove both manifolds.

Capscrews pass up thru the lower cylinder block deck into the bottom of each individual exhaust belt (Illus. D1). Remove these capscrews, and then lift the belt from the recess in the cylinder block and withdraw it from the engine.

Replacement is as follows: Clean and check the recessed fit in the cylinder block for burrs also check the surface of the exhaust belt. Place the exhaust belt in the proper position in the cylinder block. Snug up the bottom capscrews.

Refer to "Installing Exhaust Manifold" for remaining reassembly outline.

After the manifolds are installed and secure, tighten the exhaust deck to belt capscrews to the torque value given, Chapter B.



Illus. S4. Exhaust Belt

CHAPTER U. MISCELLANEOUS TOOLS

Special Tools

Servicing of this engine as outlined in the preceding Chapters of these instructions is recommended with the tools listed in the following table. These tools are specially designed for the particular function and considerable time will be saved by their use. They are available from the engine manufacturer. Any tools or group of tools for a certain sub-assembly may be ordered. Tools marked with a § symbol are combination tools.

§ Blower - Drive Pinion Puller
- Timing Gear and Flange Puller
- Thrust Bearing Puller
- § Bearing Plate and Top Cover Eyebolt (1/2"-20)
- § Gear and Flexible Pump Drive Gear Puller (Same plate used with either puller)
- Lifting Plate (6-8-10 Cyl.)
- Lifting Plate (12 Cyl.)
- Impeller Shaft Spacer (6-8-10 Cyl.)
- Impeller Shaft Spacer (12 Cyl.)
- Impeller Clearance Checking Strips (.028, .030, .032)
- Seal Retainer Puller
- Seal Ring Expander

Connecting Rod Bolt Nut Ratchet Wrench and Socket

Crankpin Lapping Tool

Crankshaft - Lead Gage
- Sprocket Puller
- Thrust Face Tool

§ Flexible - Pump Drive Gear and Blower Gear Puller (Same plate used with either puller)
- Blower Drive Gear Spring Compressor

(F.M. & Co. Nozzle)

Injection Nozzle - Test Stand
- Filter Puller
- Needle Grinding Tool
- Tip Cleaning Tool
- Adapter Wrench
- Adapter Gland Nut Wrench

(Pintle Nozzle)

Injection Nozzle - Test Stand
- Holder Removing Tool
- Cap Removing Tool
- Tip Plate
- Pintle Removing Tool
- Pintle Knockout Tool
- Lapping Tool
- Adapter Wrench
- Adapter Gland Nut Wrench

Injection Pump Discharge Valve Seat Puller
- Plunger Stroke Gage

Lubricating Oil - Pump Gear Puller
- Pump Gear Puller (12 Cyl. engine)
- Pump Relief Valve Grinder

Main Bearing - Wrench
- Wrench - Light
- Wrench - Power
- Shell Removing Tool (Plain)
- Shell Removing Tool (Thrust)
- Lapping Tool (Crankshaft in place)
- Lapping Tool (Crankshaft removed)
- Cap Checking Gage
- Cap Press Mandrel
- (Thrust) Saddle Tool

Piston Inserting and Removing Tools
Platform Hanger
Timing Chain Sprocket Bearing Puller
§ Top Cover and Blower Bearing Plate Eyebolt
Torsional Damper - Spider Puller
- Bushing Removing Tool
- Wedge Block Tool
- Spider Bushing Removing Tool

Vertical Drive - Thrust Bearing Puller
- Roller Bearing Puller
- Coupling Hub Puller
- Adjusting Flange Removing Tool
- Pinion Shaft Eyebolt
- Thrust Bearing Locknut Wrench
- Coupling Hub Locknut Wrench
- Taper Dowel Inserting Tool

Water Pump Gear and Impeller Puller

STANDARD TOOLS

The following tools are furnished as standard equipment with each engine:

Barring Tool

Governor Jackscrew

CHAPTER X. INSTALLATION

When installing the engine the equipment should be correctly aligned to insure proper operation. Refer to Chapter E for information on alignment of crankshaft coupling and for fitting the various types of main generators.

Illustrations show the relative location of the engine external parts and the distances required for removal of certain parts when necessary. It is suggested that these dimensions be checked when the engine is installed.

Clean out all piping before making final hook up to the engine.

Inspect and tighten all piping connections on the engine.

Be sure all parts of the engine move freely by turning the engine over several times with the barring device. Do not start the engine until it is certain no parts are binding.

Replacement "Pool" engines are furnished complete with subbase less governor, silencer and nozzles.

The engine and subbase should be removed or replaced as a unit to facilitate alignment.

Refer to Maintenance Bulletin Sec. 206A for Inspecting and Testing Overhauled Units.

Refer to Maintenance Bulletin Sec. 206B for Inspecting and Retightening program for overhauled unit.

A

B

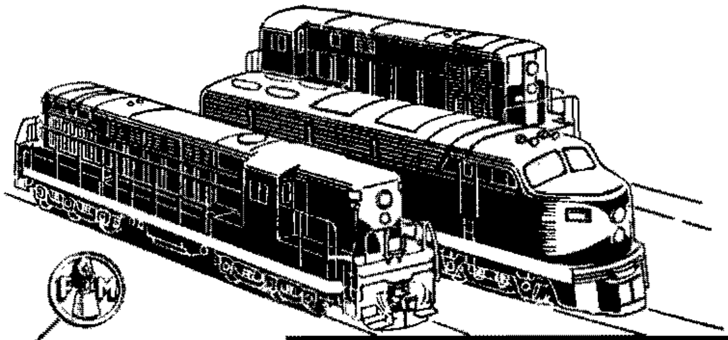
C

C (cont.)

D

E

F



FAIRBANKS, MORSE & CO.
Railroad Division
Diesel Locomotive Service Dept.
Beloit, Wisconsin

FAIRBANKS-MORSE

DLSD Bulletin A-43A
Nov. 15, 1957

DIESEL LOCOMOTIVE SERVICE DEPARTMENT BULLETIN

Supersedes Bulletin A-43A of 7/26/57

Subject: Application and Servicing of Monofilar Torsional Damper

Monofilar type torsional dampers are used on latest production engines and service replacement. The damper is easier to maintain as it has fewer parts which do not require heat fit of individual parts. Special tools for maintenance are not required. The damper has a longer wear life.

The dampers are completely interchangeable with the pendulum type damper. A special retainer plate is provided with the 12 cylinder upper damper.

This bulletin is also intended as a supplement to the Engine Service Manual Sec. 308 and should be filed under Chapter E.

TORSIONAL DAMPERS

Description

Lower Damper

A monofilar type torsional damper is mounted on the lower crankshaft at the control end of the engine to eliminate torsional vibrations at critical speeds.

The damper, Illus. 1, as used on 12 cylinder engines, consists of a spider fitted with weights. Each weight is located and free to move in or out on a weight pin. Lubrication is furnished to the damper pins and weights by the lockplates collecting oil from along the sides of the spider. The damper for the 8 and 10 cylinder is similar to the 12 cylinder damper. The six cylinder damper has only three pin positions.

Upper Damper

A monofilar type torsional damper is mounted on the upper crankshaft at the control end of the engine to eliminate torsional vibrations at critical speeds. This damper is used only on the 12 cylinder engine.

The damper, Illus. 2, is of the same design as the lower damper, except the weights are narrower.

Maintenance

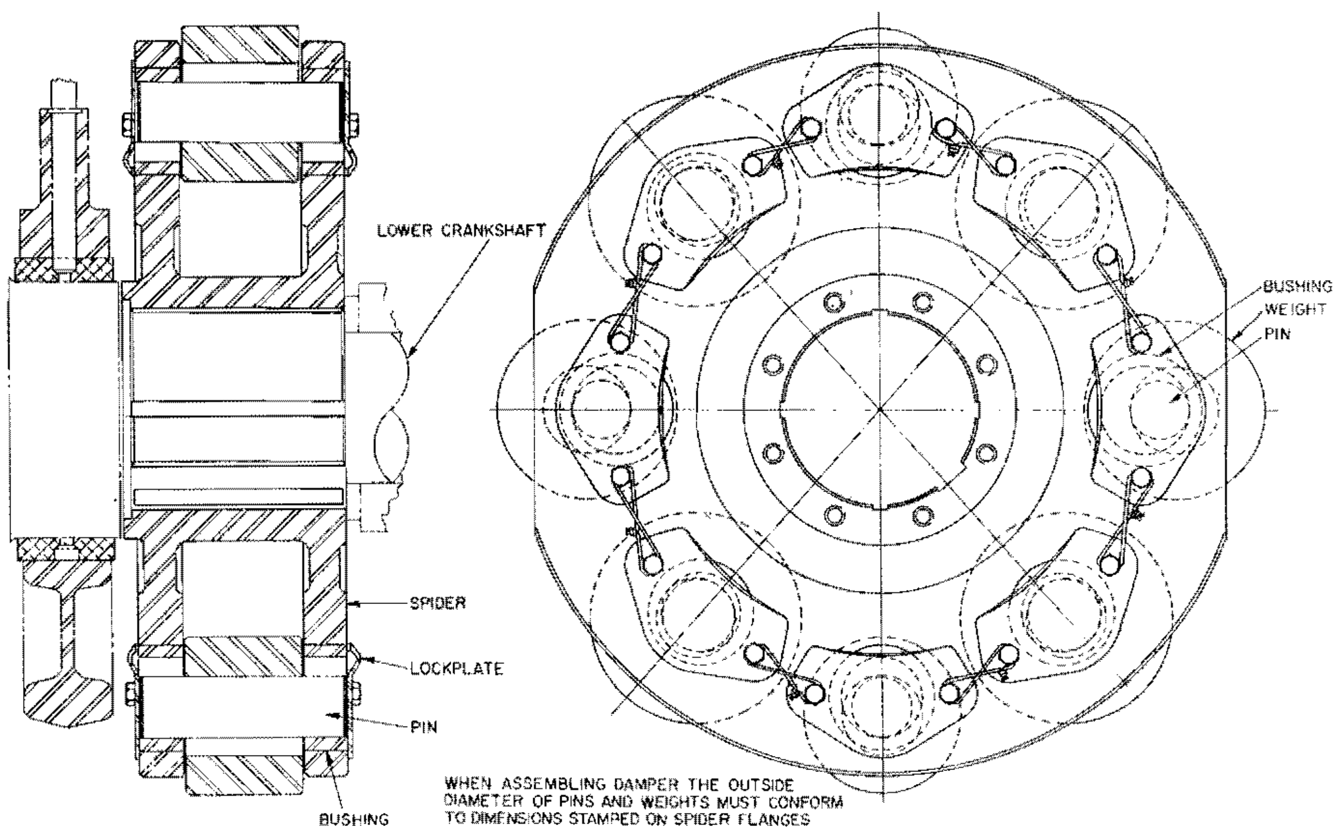
Lower Damper

1. Inspection of the lower damper pins and bushings must be made at regular periods as outlined in Maintenance Bulletin Sec. 206 to assure trouble free operation of the damper.

2. Remove crankcase inspection cover located next to the governor. There are eight nuts securing the cover.

3. Remove the inspection cover on the pump mounting plate.

4. Reach in along outer side of the damper and remove the lockwire and lockplate from the weight position aligned with the crankcase inspection opening.



Illus. 1. Monofilar Torsional Damper - Lower 12 Cyl. Engines

5. Use a magnet to remove the pin.

6. Remove the weight and bushings.

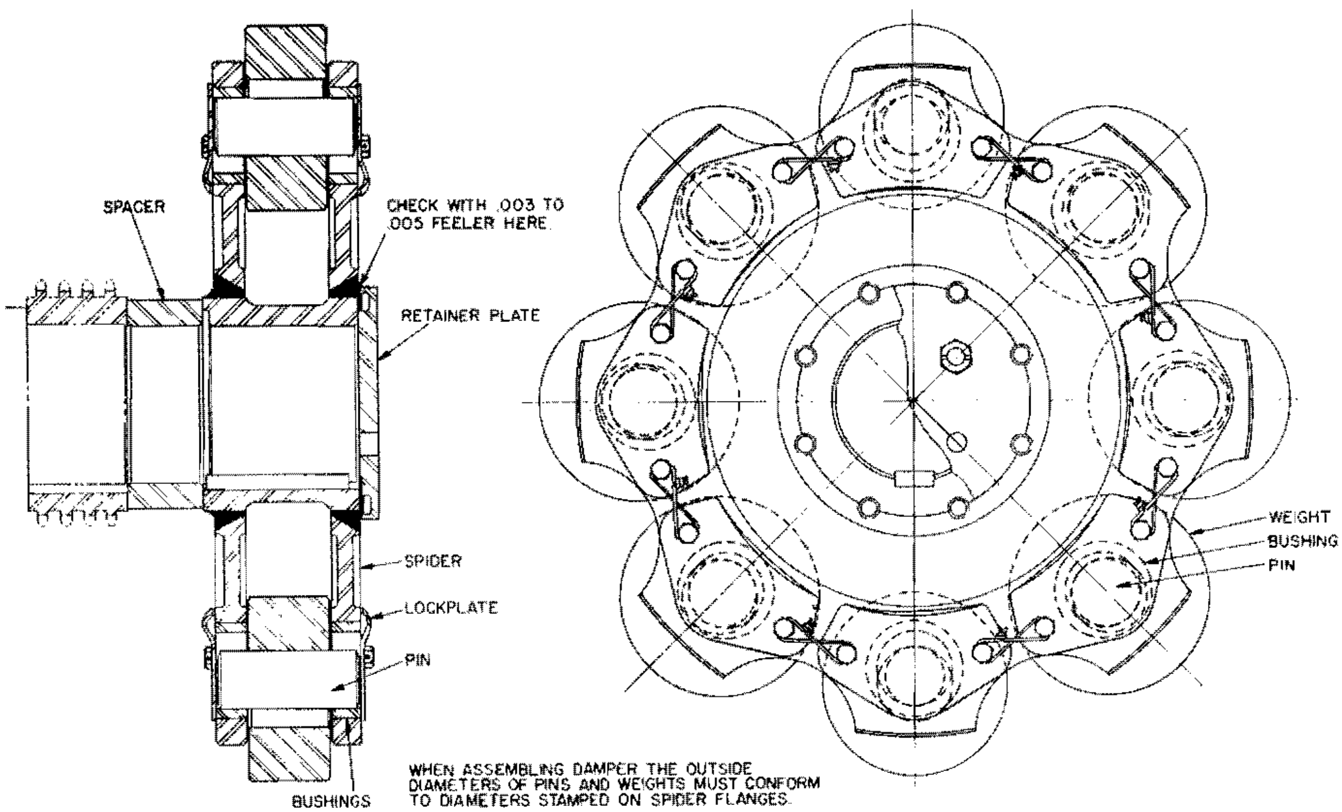
7. Carefully note the position of the pin, weight and bushing as it is removed. If inspection of these parts discloses that they can be reused, the weight, bushings and pin must be returned to their original location in the spider. Also the parts must not be turned end for end. In use, these parts had become "worn-in" and the reversal of parts would require a new "wear-in" which could materially shorten the life of the weight, pin and bushings.

8. Visually inspect the pin and bushings for pitting and fretting conditions. Inspect the lockplate for wear on the pin side.

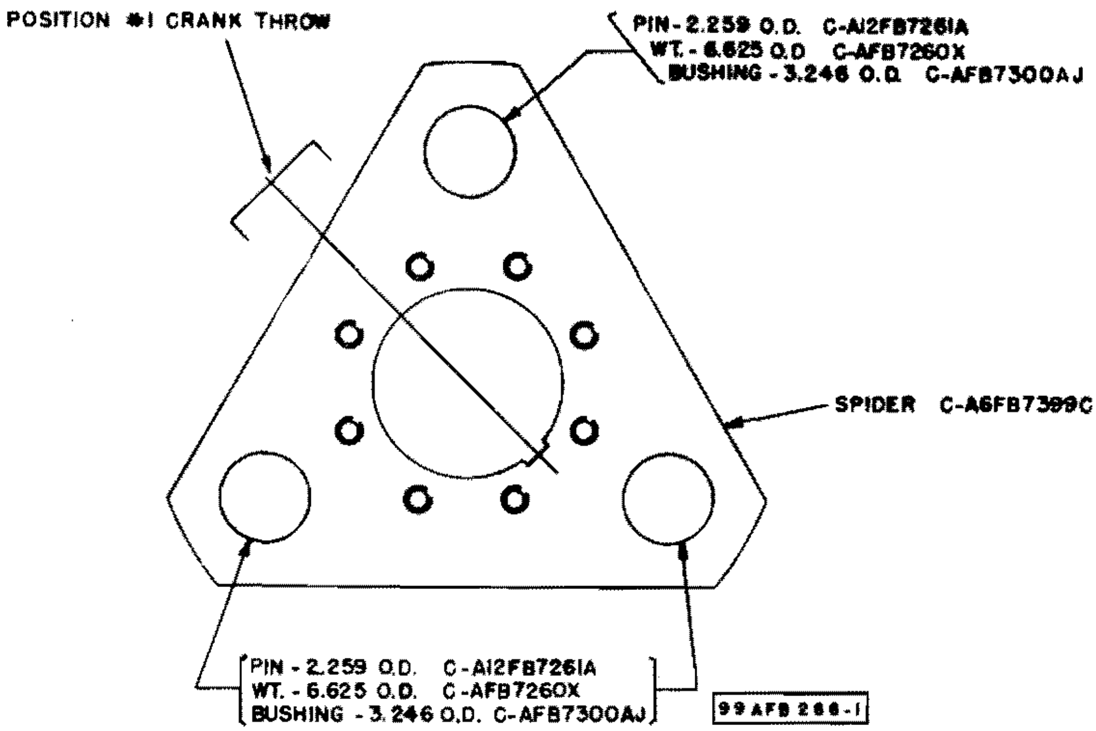
9. Check the pin for wear with a micrometer. Check the diameter at several points as the wear may not be uniform. If the diameter reaches the limit shown in the "Wear Limit Chart," a new pin must be used.

10. Check the I. D. and O. D. of the bushings for wear. Refer to the Wear Limit Chart.

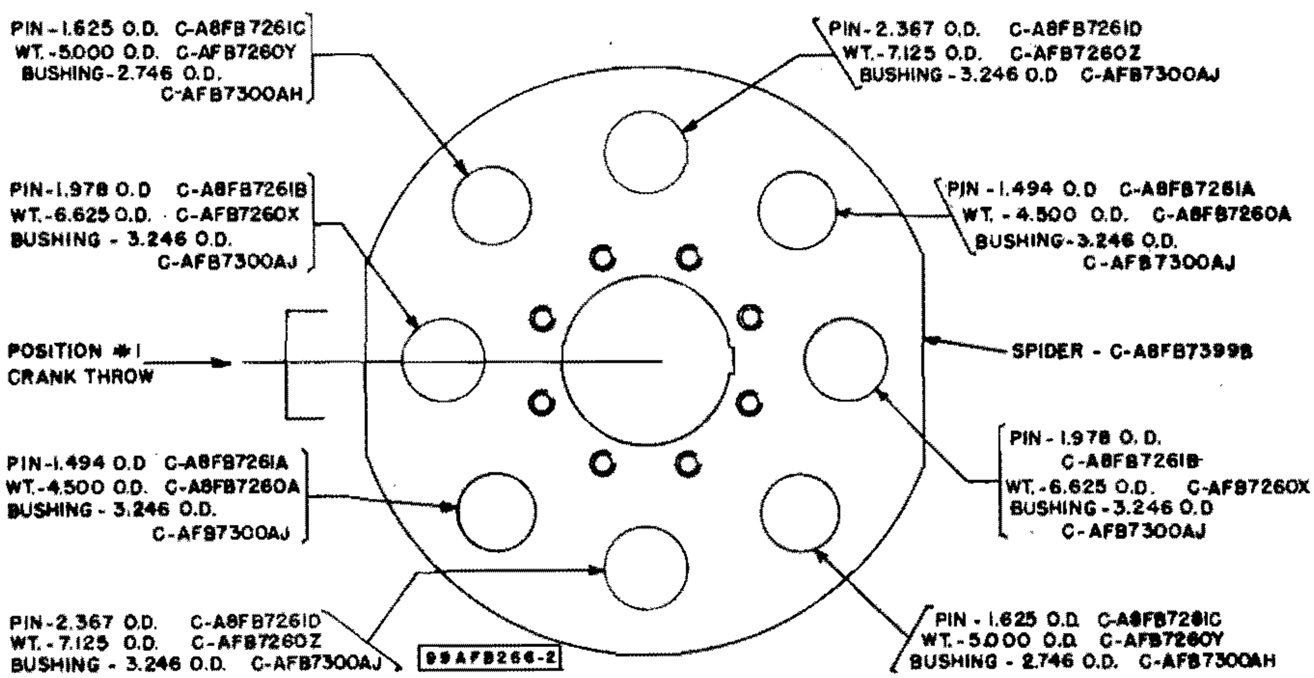
11. Carefully check the I. D. of the weights for slight wear indentations. If the bore reaches the limit shown in the "Wear Limit Chart," the weights must be replaced.



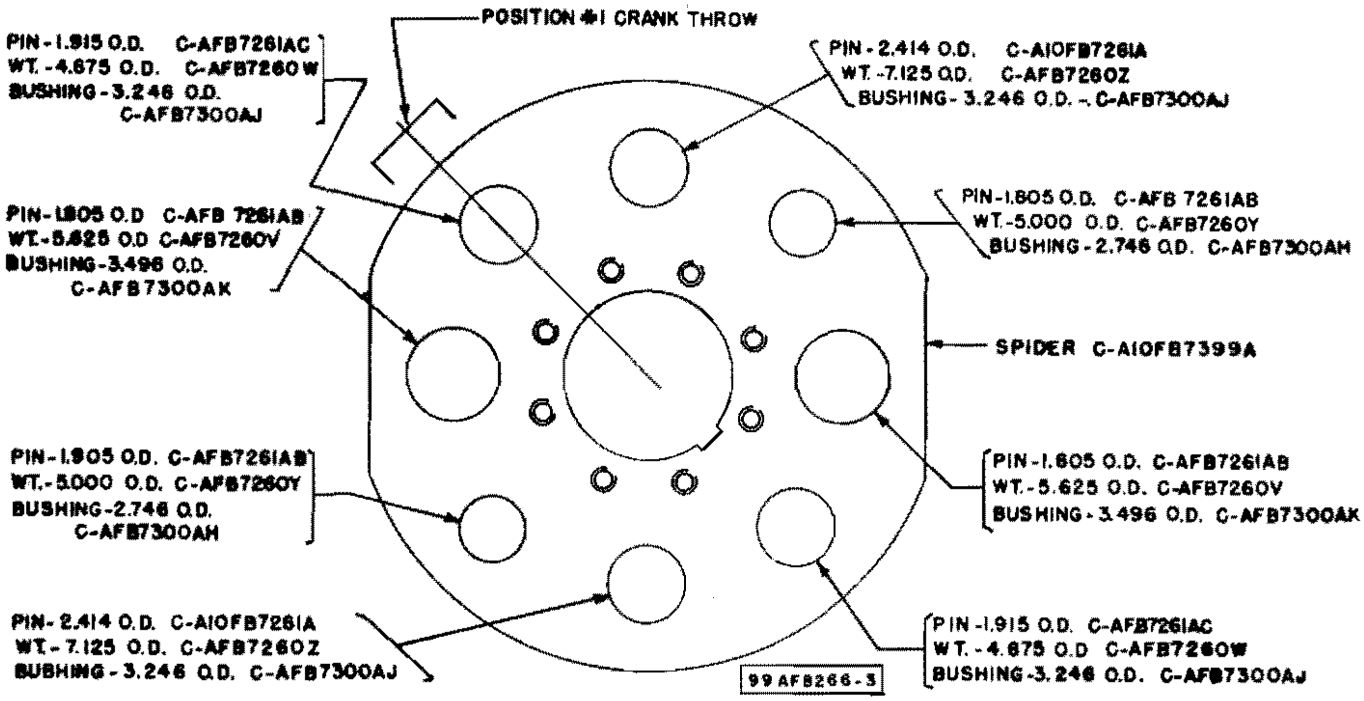
Illus. 2. Monofilar Torsional Damper - Upper - 12 Cyl. Engines



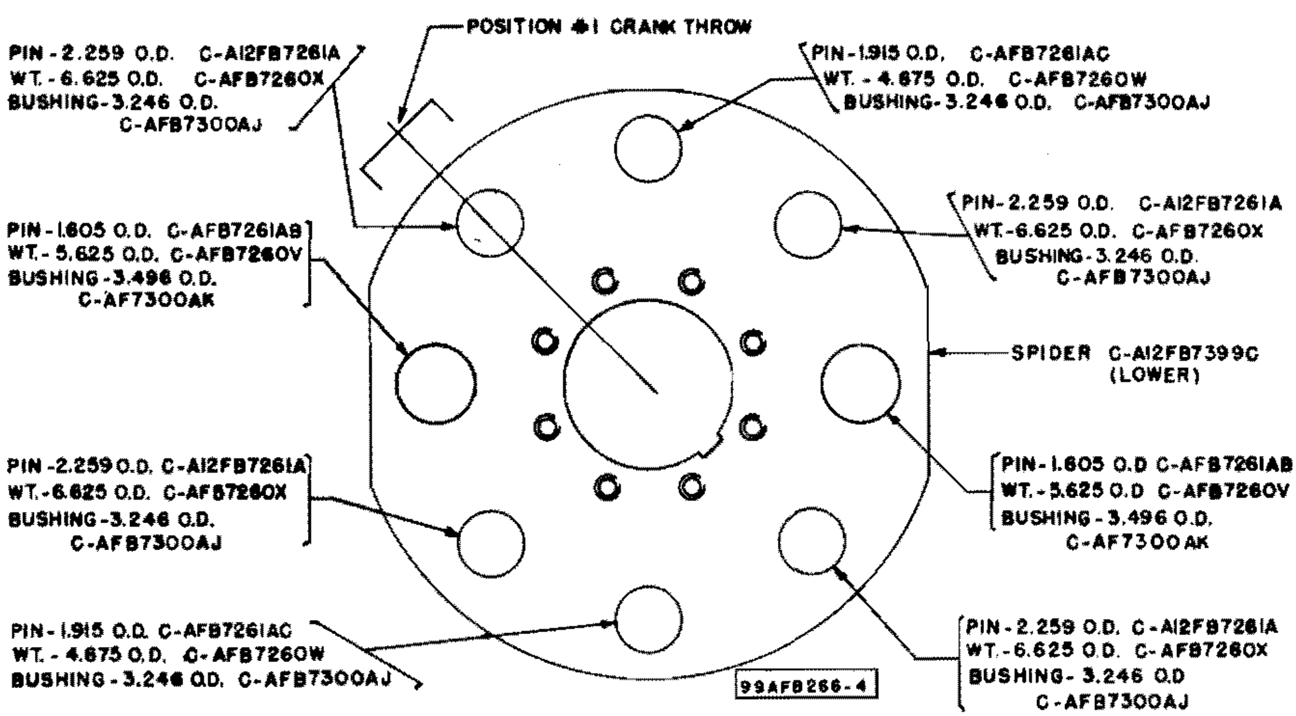
Illus. 3. Pin, Weight and Bushing Location - 6 Cyl. Damper



Illus. 4. Pin, Weight and Bushing Location - 8 Cyl. Damper



Illus. 5. Pin, Weight and Bushing Location - 10 Cyl. Damper



Illus. 6. Pin, Weight and Bushing Location - 12 Cyl. Lower Damper

12. Replacement of a worn or damaged bushing requires replacing the other bushing in the affected pin position regardless of condition.

13. After inspection determines the parts as usable, install the bushings, weight and pin to the exact position from which removed.

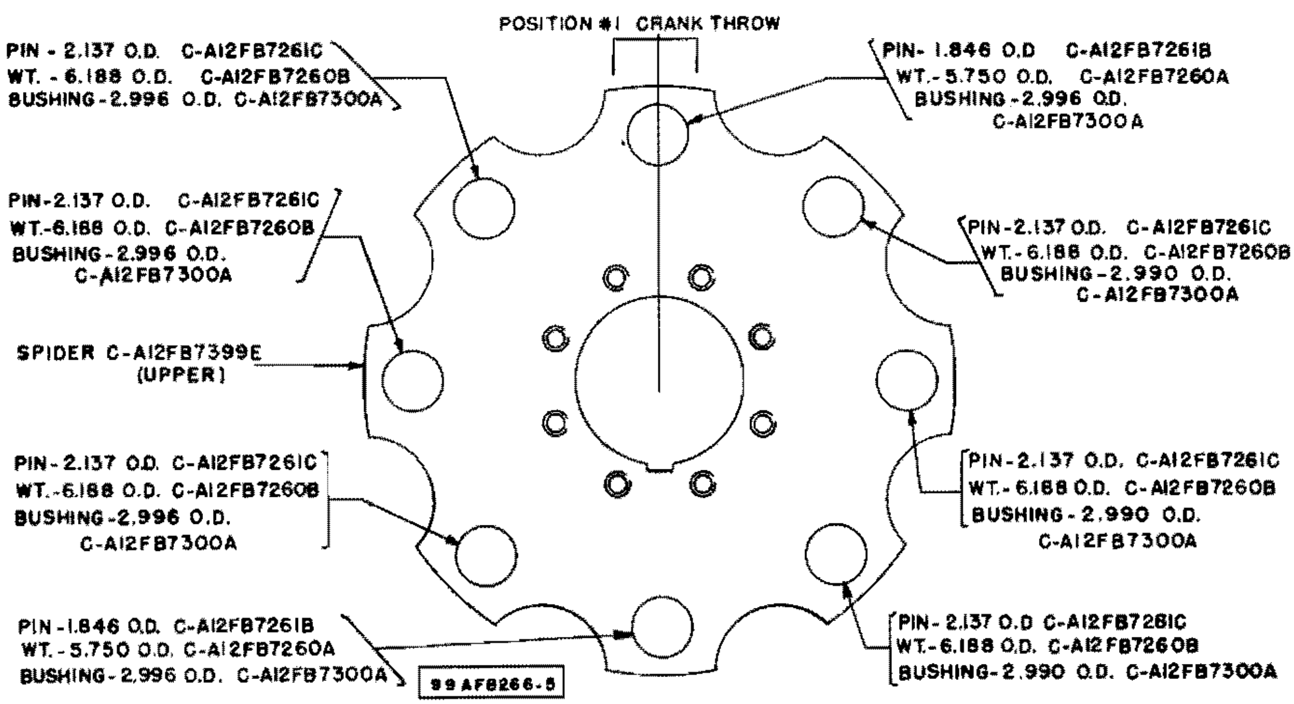
Extreme caution must be taken when replacing parts to be sure that the parts are replaced in the proper hole in the spider. The O.D. of the pin and weight is stamped on the spider. The O.D. of the weight and pin must be determined by measurement and installed according to the stamped dimensions on the spider. Refer to Illus. 3 thru 7. Bushings are to be selected and installed according to the dimensions shown in the illustration.

14. Replace lockplate and lockwire.

15. Bar the engine to position the next weight, inspect and reassemble until each position has been inspected.

Upper Damper

1. The upper damper should be inspected at the same periods as apply for the lower damper. (It is assumed the damper will be inspected while the upper crankshaft is out of the engine.)



Illus. 7. Pin, Weight and Bushing Location - 12 Cyl. Upper Damper

2. Remove the lockplates from both sides of the damper. Inspect the inner surface. If wear is shown, install new lockplates when reassembling the damper.

3. Remove the pins, weights and bushings.

4. Arrange parts in systematic order so that parts being replaced may be returned to their original location and position.

5. Inspect the pins, weight and bushings in accordance with procedure outlined for inspecting lower damper parts. The same recommendations for replacement of parts apply.

Reassembly

1. Reassemble by replacing the bushings, weights, pins and lockplates.

2. Replace parts removed to make the inspection.

Removing Spider - Lower Damper

1. Remove the lube oil pumps from the pump mounting plate.

2. Remove the governor and bracket from the pump mounting plate.

3. Remove the water pump and the pump mounting plate.

4. Remove the pump and governor drive bracket from the cylinder block.

5. Use the puller and remove the pump drive gear.

6. Install the puller to the damper spider and tighten down the jackscrew.

7. Use white lead or oil on the jackscrew.

8. If available, steam may be used to facilitate removal. Do not use an open flame. Start heating at the circumference, keeping strain on the puller. Two 5/8-18 N.F. tapped holes are provided in the damper spider for lifting eyebolts to facilitate handling the spider.

Installing Spider

1. To reinstall the spider, heat the assembly slowly in oil (or an electric furnace) to about 320° F. temperature of the heating medium.

> NOTE: The damper must be correctly installed on the crankshaft. Be sure the undercut at the hub is toward the engine, also the tapped puller holes must be on the side away from the engine.

2. Lifting means should be provided for placing the spider in position.

3. Rotate the engine crankshaft until keyway is at the top.

4. Check the keyways in crankshaft and spider, and fit key in crankshaft.

5. Apply white lead and oil to the surface of the crankshaft where the damper is to be installed.

6. Install the spider to seat on the crankshaft. Do not damage the damper by excessively pounding to seat.

7. Cool slowly with compressed air starting at the center.

8. Reassemble flexible pump drive.

9. Reconnect governor and replace covers and connections removed in preliminary procedure.

Upper Damper

10. The upper damper is installed using a procedure similar to that outlined for lower dampers.

11. Use the old retainer plate or make up a plate to pull the damper into place. Remove the plate.

12. Apply the proper retainer plate. Tighten the stud nuts to 165-175 ft.lbs. torque.

a. Check with a feeler gage between the spider and plate.
b. A .003" to .005" feeler gage should fit evenly around the plate.

WEAR LIMITS

Torsional Damper - Monofilar Type	Max. Wear Limit No Less Than	Max. Wear Limit No More Than
(6 Cyl. Engines)		
Bushing 3.246 OD (ID		2.511
Bushing 3.246 OD (OD	3.2435	
Pin OD	2.255	
Weight (6.625 OD) ID		2.511
Spider Bushing Bore - 8 Holes		3.260
(8 Cyl. Engines)		
Bushing 3.246 OD (ID		2.511
Bushing 3.246 OD (OD	3.2435	
Bushing 2.746 OD (ID		2.011
Bushing 2.746 OD (OD	2.7335	
Pin OD	1.490	
Pin OD	1.621	
Pin OD	1.974	
Pin OD	2.363	
Weight (4.500 OD) ID		2.511

	Max. Wear Limit No Less Than	No More Than
(8 Cyl. Engines - con't)		
Weight (5.000 OD) ID		2.011
Weight (6.625 OD) ID		2.511
Weight (7.125 OD) ID		2.511
Spider Bushing Bore - 2 Holes		2.760
Spider Bushing Bore - 6 Holes		3.260
Torsional Damper (10 Cyl. Engines)		
Bushing 3.246 OD (ID		2.511
Bushing 3.246 OD (OD	3.2435	
Bushing 2.746 OD (ID		2.011
Bushing 2.746 OD (OD	2.7335	
Bushing 3.496 OD (ID		2.761
Bushing 3.496 OD (OD	3.4935	
Pin OD	1.801	
Pin OD	1.911	
Pin OD	2.410	
Weight (4.875 OD)		2.511
Weight (5.000 OD)		2.011
Weight (5.625 OD)		2.761
Weight (7.125 OD)		2.511
Spider Bushing Bore - 2 Holes		2.760
Spider Bushing Bore - 4 Holes		3.260
Spider Bushing Bore - 2 Holes		3.510
(12 Cyl. Engines) Upper		
Bushing 2.996 OD (ID		2.386
Bushing 2.996 OD (OD	2.9935	
Pin OD	1.842	
Pin OD	2.133	
Weight (5.750 OD) ID		2.386
Weight (6.188 OD) ID		2.386
Spider Bushing Bore - 8 Holes		3.010
(12 Cyl. Engines) Lower		
Bushing 3.246 OD (ID		2.511
Bushing 3.246 OD (OD	3.2435	
Bushing 3.496 OD (ID		2.761
Bushing 3.496 OD (OD	3.4935	
Pin OD	1.801	
Pin OD	1.911	
Pin OD	2.255	
Weight (5.625 OD) ID		2.761
Weight (4.875 OD) ID		2.511
Weight (6.625 OD) ID		2.511
Spider Bushing Bore - 6 Holes		3.260
Spider Bushing Bore - 2 Holes		3.510