



**FAIRBANKS-MORSE  
MODEL 38D8 $\frac{1}{8}$   
OPPOSED PISTON  
LOCOMOTIVE  
ENGINES**

All specifications herein are subject to variations in design and construction, except such as would substantially affect installation or matters of performance otherwise expressly guaranteed.

Printed in U.S.A.

## *Foreword*

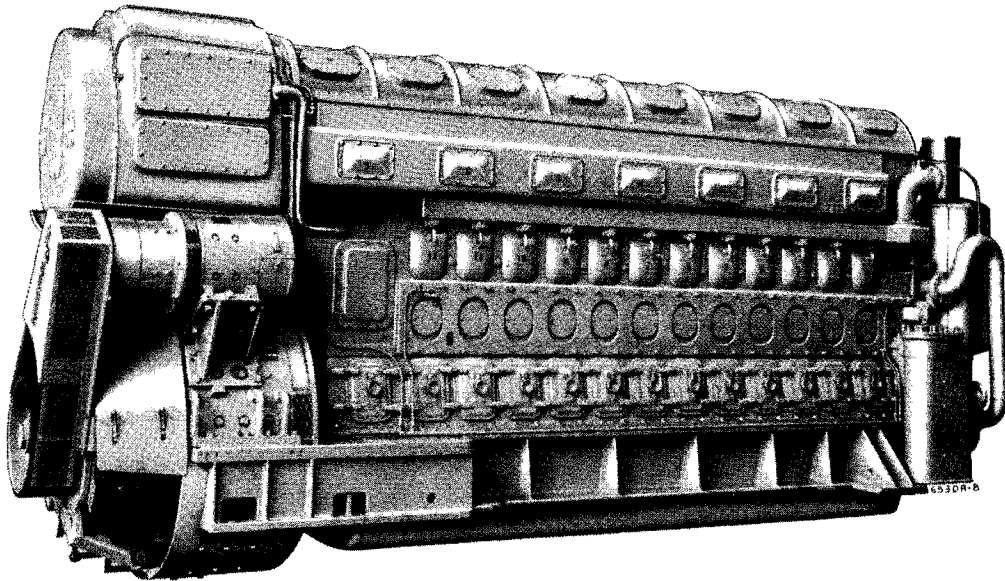
This handbook is published for the purpose of providing railroad Machinist's with readily accessible maintenance information applicable to the Model 38D8-1/8 Locomotive Engine.

This handbook is intended as a supplement to Maintenance Bulletin, Section 308 - Diesel Engine. The procedure as outlined in this book are those that are normally encountered in engine maintenance. Maintenance of some assemblies such as dampers and governors have not been included but are referenced to the particular chapter in Section 308.

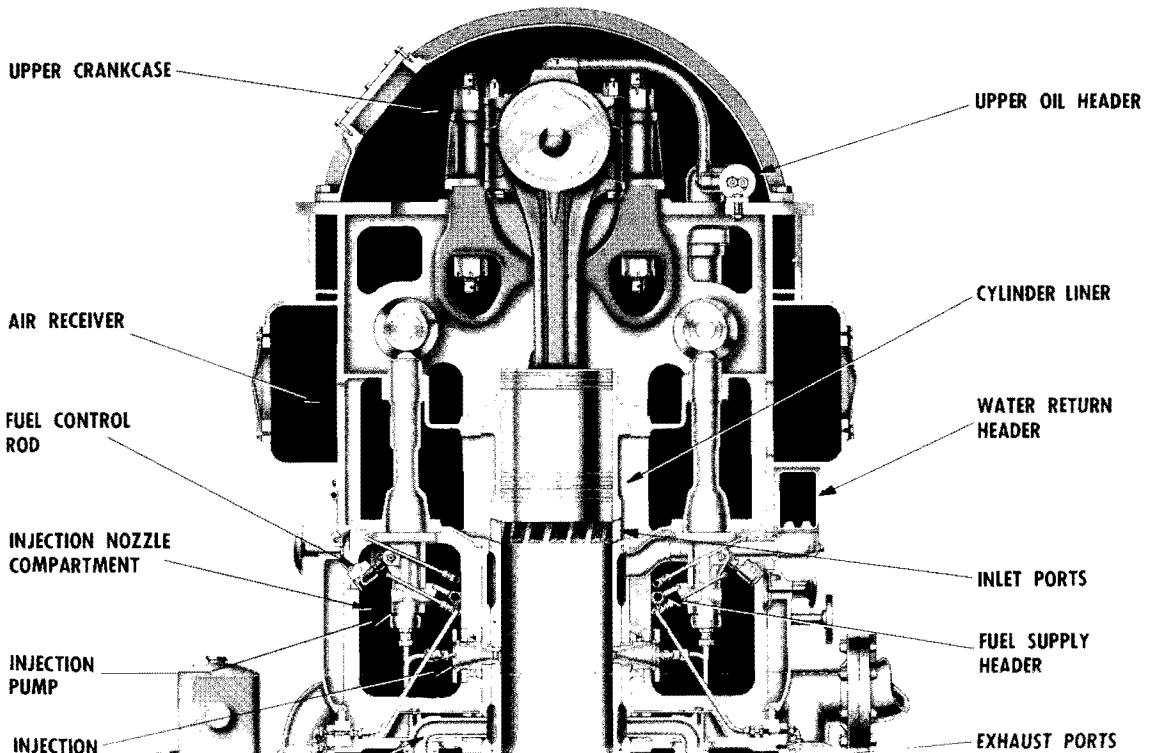
These instructions do not purport to provide for every possible contingency to be met in connection with the operation and maintenance of this equipment. Neither is the amount of material supplied by Fairbanks, Morse & Co. increased by anything shown in these instructions or associated drawings. Should 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., Railroad Division, Chicago, Ill.

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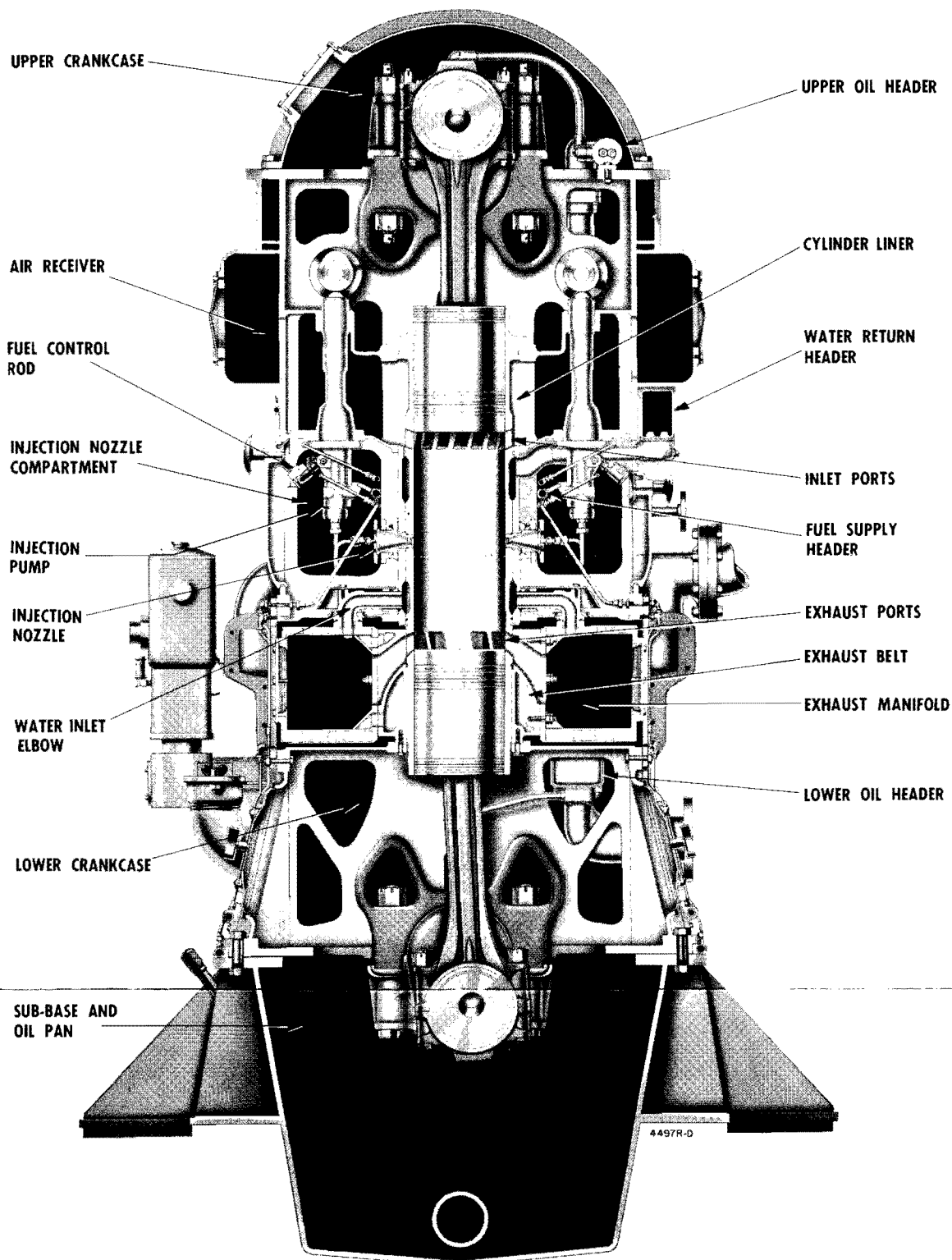
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Fairbanks-Morse 12 Cylinder Model 38D8-1/8 Diesel Engine  
Opposite Governor Side



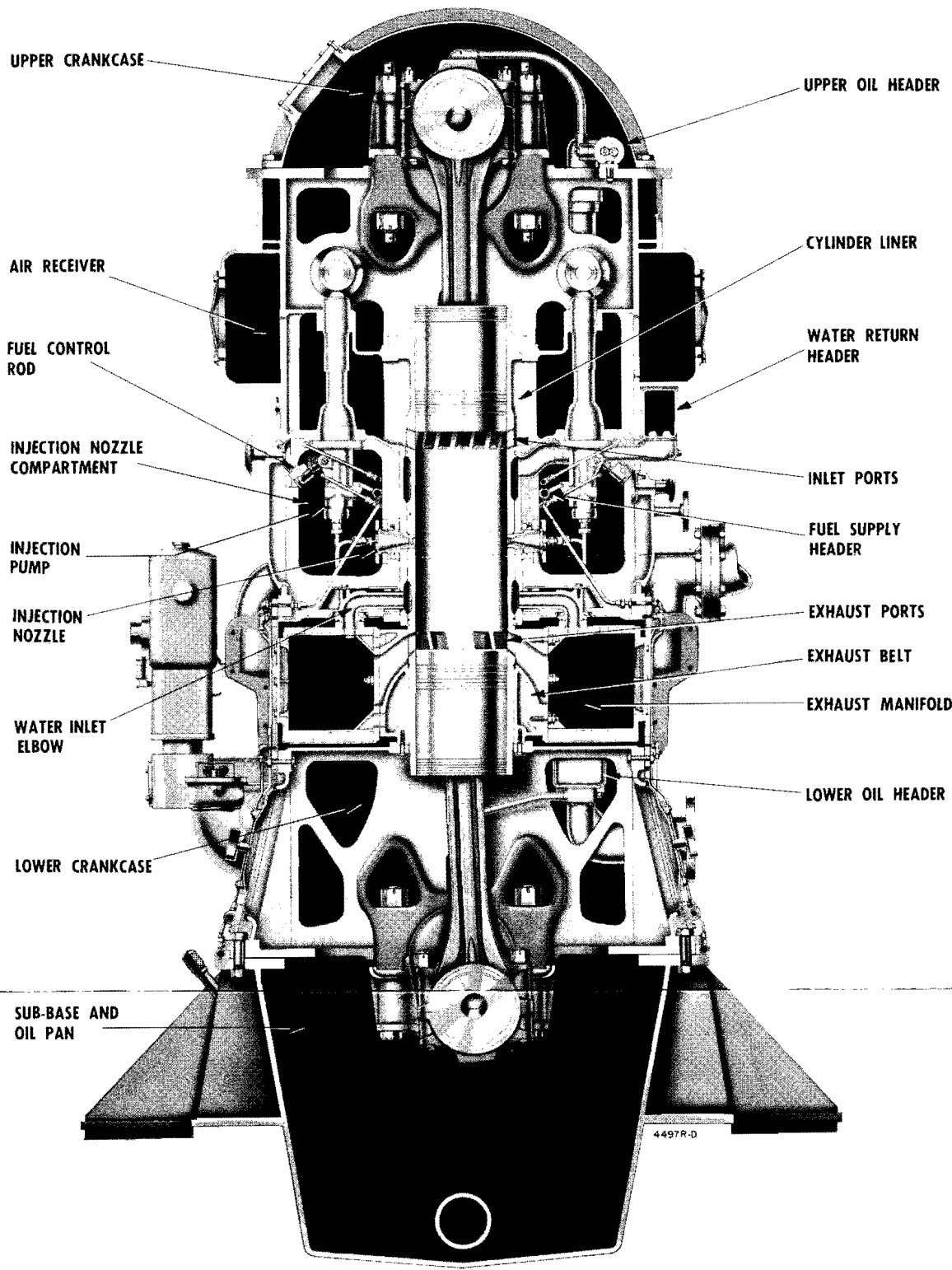
Fairbanks-Morse 12 Cylinder Model 38D8-1/8 Diesel Engine  
Opposite Governor Side



Transverse Section of Model 38D8-1/8 Diesel Engine



Fairbanks-Morse 12 Cylinder Model 38D8-1/8 Diesel Engine  
Opposite Governor Side



Transverse Section of Model 38D8-1/8 Diesel Engine

## 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 interconnected 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. 1 shows the lower crankshaft past outer dead center and the upper crankshaft on outer dead center. This difference in crankshaft setting is the "Lower Crank Lead."

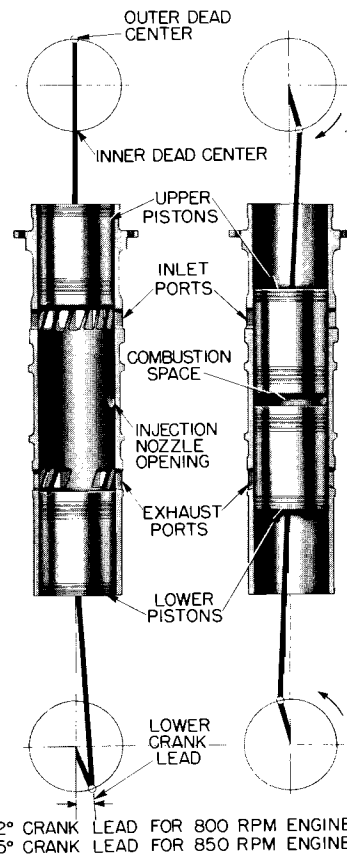
The combustion space is formed between recessed heads of the two pistons as the crankshafts approach inner dead center. When the upper crank is one-half the crank lead before inner dead center and the lower crank one-half the crank lead past inner dead center, the two pistons are the closest together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

### Cycle

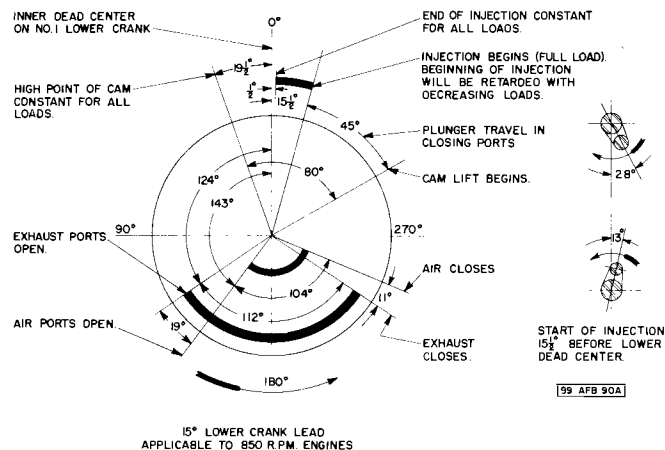
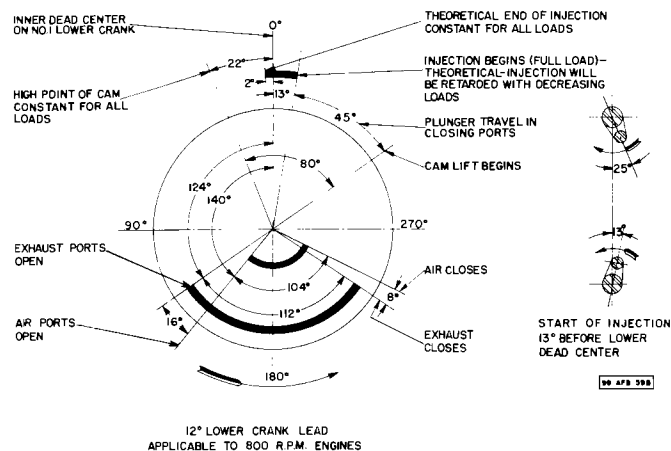
This engine operates on the "two-cycle" principle. Two strokes of each piston made by one complete revolution of the crankshafts are necessary to complete the cycle. Illus. 2 shows the action taking place in the cylinder with the engine operating at nominal rated load and full speed.

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



Illus. 1. Operation in Single Cylinder  
(Rotation viewed from drive end)



Illus. 2. Sequence and Timing of Events  
(Rotation viewed from drive end)



nominal rated load starts 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 uncovers 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 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. 1, it will be noted 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.

#### ENGINE DATA

	6	6	6	8	8	8	10	12
Nominal Rated Load - BHP	1000	1200	1500	1600	2000	2400		
Model No.								
Type								
Cycle								
Bore and Stroke - Inches								
Rated rpm	800	850	850	850	850	850	850	850

38D8-1/8

Opposed Piston

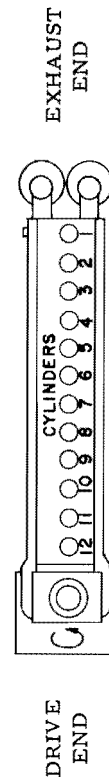
Two

8-1/8x10

#### ROTATION AND FIRING ORDER

The engines are left hand rotation. The lower crankshaft, when viewed from the drive end, rotates counterclockwise. Refer to Illus. 3.

The cylinders are arranged in sequence with No. 1 cylinder at the opposite drive end.



Illus. 3. Cylinder Arrangement and Engine Rotation

## Engine Data - (continued)

The firing order of the engines is as follows:

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

## WEAR LIMITS

Part	New Dimension	Condemnable Dimension
<b>CAMSHAFT</b>		
(Satco and Aluminum Bearings)		
Shell Inside Diameter . . . . .	2.499 to 2.5005	2.5025
Thrust Bearing End Clearance . . . . .	.006 to .015	.022
<b>CRANKSHAFT</b>		
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"	
<b>CONNECTING ROD</b>		
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
<b>MAIN BEARING</b>		
Shell Thickness (Satco) . . . . .	.747 to .748	.745
Shell Thickness (Aluminum) 90° from parting line	.747 to .748	.745
Thrust Bearing End Clearance (Satco) . . . . .	.008 to .012	.015
Thrust Bearing End Clearance (Aluminum) . . . . .	.012 to .017	.020
<b>CYLINDER LINER</b>		
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
<b>PISTON</b>		
Piston Diameter . . . . .		See Note
Piston Pin Diameter . . . . .	2.995 to 2.995	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: Pistons should be replaced when the tin plate on 25% of the thrust area below the compression rings has been worn off.

## WEAR LIMITS (continued)

Part	New Dimension	Condemnable Dimension
<b>PISTON RINGS</b>		
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
<b>TORSIONAL DAMPER</b>		
(Later 6 Cyl. Engines)		
Bushing Inside Diameter . . . . .	1.9625 to 1.9635	1.9725
Pin Diameter . . . . .	1.7475 to 1.7485	1.7455
(8 Cyl. Engines)		
Bushing Inside Diameter . . . . .	1.9625 to 1.9635	1.9725
3rd Order Pin Diameter . . . . .	1.1025 to 1.1035	1.1005
4th Order Pin Diameter . . . . .	1.4775 to 1.4785	1.4755
5th Order Pin Diameter . . . . .	1.6495 to 1.6505	1.6475
8th Order Pin Diameter . . . . .	1.8395 to 1.8405	1.8375
(10 Cyl. Engines)		
Bushing Inside Diameter . . . . .	1.9625 to 1.9635	1.9725
3rd Order Pin Diameter . . . . .	1.1025 to 1.1035	1.1005
4th Order Pin Diameter . . . . .	1.4775 to 1.4785	1.4755
6th Order Pin Diameter . . . . .	1.7475 to 1.7485	1.7455
7th Order Pin Diameter . . . . .	1.8055 to 1.8065	1.8035
10th Order Pin Diameter . . . . .	1.8865 to 1.8875	1.8845
(12 Cyl. Engines) Upper		
Bushing Inside Diameter . . . . .	1.9625 to 1.9635	1.9725
4th Order Pin Diameter . . . . .	1.4775 to 1.4785	1.4755
6th Order Pin Diameter . . . . .	1.7475 to 1.7485	1.7455
(12 Cyl. Engines) Lower		
Bushing Inside Diameter . . . . .	1.9625 to 1.9635	1.9725
3rd Order Pin Diameter . . . . .	1.1025 to 1.1035	1.1005
4th Order Pin Diameter . . . . .	1.4775 to 1.4785	1.4755
6th Order Pin Diameter . . . . .	1.7475 to 1.7485	1.7455
<b>GEARS</b>		
		<b>Backlash</b>
Blower Timing Gears . . . . .	.002 to .004	
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	

## 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 control 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 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:

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 Brg. 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	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 Cyl. Block Capscrews	70-90
Exhaust Manifold to Belt Nuts	60-75
Exhaust Deck to Belt Capscrews	70-80
Exhaust Manifold Cover Nuts	25-30
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 Cyl. Block	100-120
Lube Oil Header Capscrews	35-40
Lube Oil Oil Header Locknut	45-60
Main Bearing Bolt Nuts	700-1000

## TORQUE LIMITS (continued)

Name of Part	Torque Limit Ft. Lbs.
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 Adj. Flange Capscrews	35-40
Vertical Drive Coupling Bolt Nuts	140-160

## TIMING

### 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 control 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. 4 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.

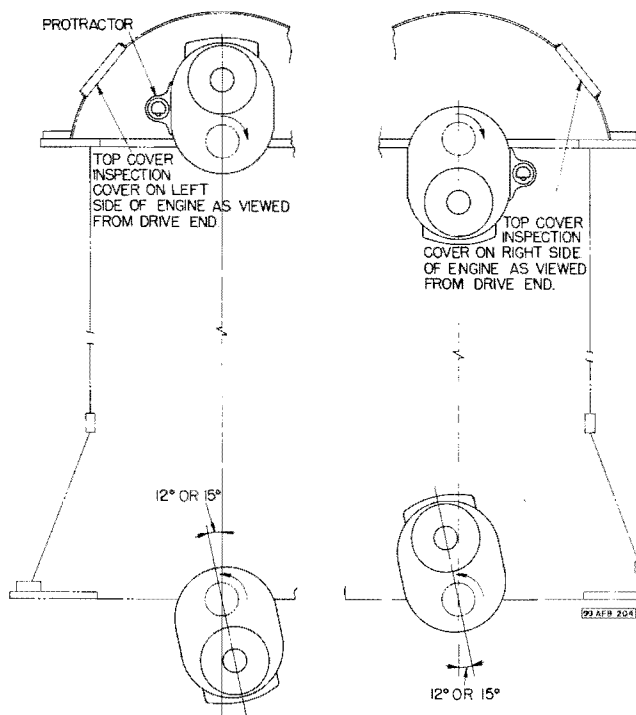
1. The lower crankshaft leads the upper by 12° or 15°. The crankshafts rotate in opposite directions.

2. Set protractor for  $90^{\circ}$  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.

4. Do not rotate engine. Check position 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.



Illus. 4. Crankshaft Lead Timing

6. Determine rotation of the crankshafts. Refer to Illus. 4.

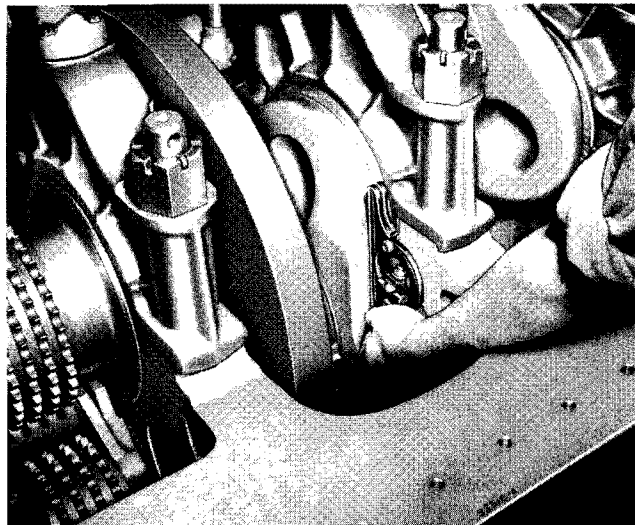
7. Compute the crank lead from the protractor readings. The computed value should be within  $\pm 1/2^{\circ}$  of the specified  $12^{\circ}$  or  $15^{\circ}$  crank lead.

8. Bar the engine one revolution and recheck crankshaft lead timing. If timing is not within the specified limit of  $12^{\circ}$  or  $15^{\circ}$ , the vertical drive coupling or quill shaft (6 cyl. engines) must be repositioned. Refer to Section 308, Chapter Fa or Fb.

#### B. Checking Timing with Top Cover Removed

1. Bar the engine until the No. 1 lower crankpin is  $12^{\circ}$  or  $15^{\circ}$  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, Illus. 5.



Illus. 5. Protractor in Position on Crankshaft

3. The machined surface, Illus. 5, 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 one revolution and recheck the crankshaft lead timing. If timing is not within the specified limit of  $12^{\circ}$  or  $15^{\circ} \pm 1/2^{\circ}$ , the vertical drive coupling or quill shaft (6 cyl. engines) must be repositioned. Refer to Sec. 308, 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.

### Injection Timing

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

Check the tension and condition of the timing chain. Refer to page 61. The proper relationship of the two camshafts 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 previous section for crank lead values. Install the plunger stroke gage on the No. 1 cylinder (opposite governor side) injection pump.

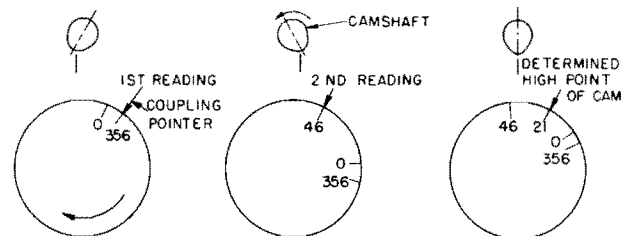
As a starting point, bar the engine until pointer is at  $15^{\circ}$  to  $20^{\circ}$  before I. D. C. ( $340^{\circ}$  to  $345^{\circ}$  coupling reading). In this position the plunger line should be above the line on the barrel. Continue to bar the engine in the direction of rotation until the hairline on the stroke gage plunger lines up with the hairline on the gage barrel. Record the

reading indicated by the coupling pointer.

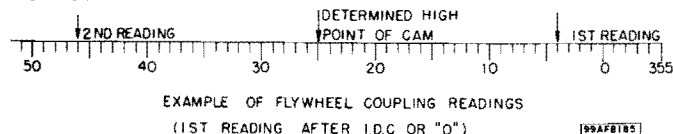
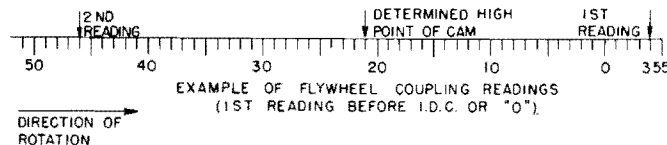
Continue to bar the engine in the direction of rotation until the plunger of the stroke gage moves down to the bottom of the stroke and returns to the position where the hairlines again line up. Record the flywheel coupling pointer reading.

The two flywheel coupling readings locate points on the camshaft lobe equal distance on either side of the high point of the cam, Illus. 6. It is necessary to find the center between these points with reference to inner dead center of the No. 1 lower piston or "O" on the flywheel coupling. The flywheel coupling markings are shown extended as a scale and are examples of typical coupling readings.

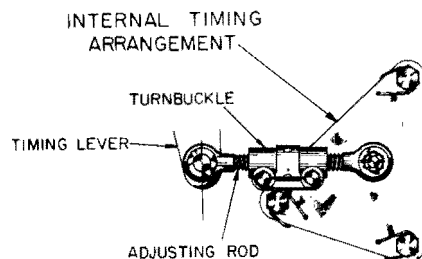
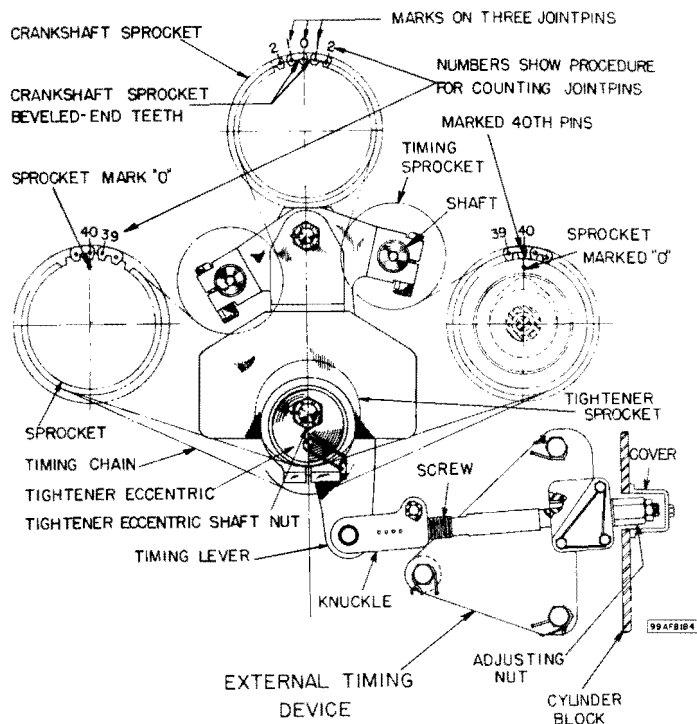
NOTE: The high point of cam should be  $22-1/2^{\circ} \pm 1/2^{\circ}$  after I. D. C. No. 1 lower piston for engines



FLYWHEEL COUPLING ROTATION AND MARKINGS  
VIEWED FROM ENGINE SIDE OF FLYWHEEL COUPLING.



Illus. 6. Graphic Timing Procedure



Illus. 7. Timing Lever

with  $12^{\circ}$  crank lead and  $19-1/2^{\circ} \pm 1/2^{\circ}$  for engines with  $15^{\circ}$  crank lead.

If the flywheel coupling reading denoting high point of cam as determined is not within the specified limit, the timing of the camshafts 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 retard the camshafts.

**NOTE:** Early timing requires the rotation of the camshafts opposite the direction of rotation. Late timing requires the rotation of the camshafts 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. 7.

**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 engine No. 967832 and thereafter, 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.

**Advance Timing (to make it earlier).** Rotate nut counterclockwise.

**Retard Timing (to make it later).** Rotate nut clockwise.



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 nuts and bar the engine. If the timing is late, rotate the crankshaft opposite the direction of rotation the required number of degrees.

### FUEL CONTROL ADJUSTMENTS

#### Offset Fuel Control Arm

(Applicable to engines previous to Engine No. 963984 with OFFSET fuel control arm, Illus. 8.)

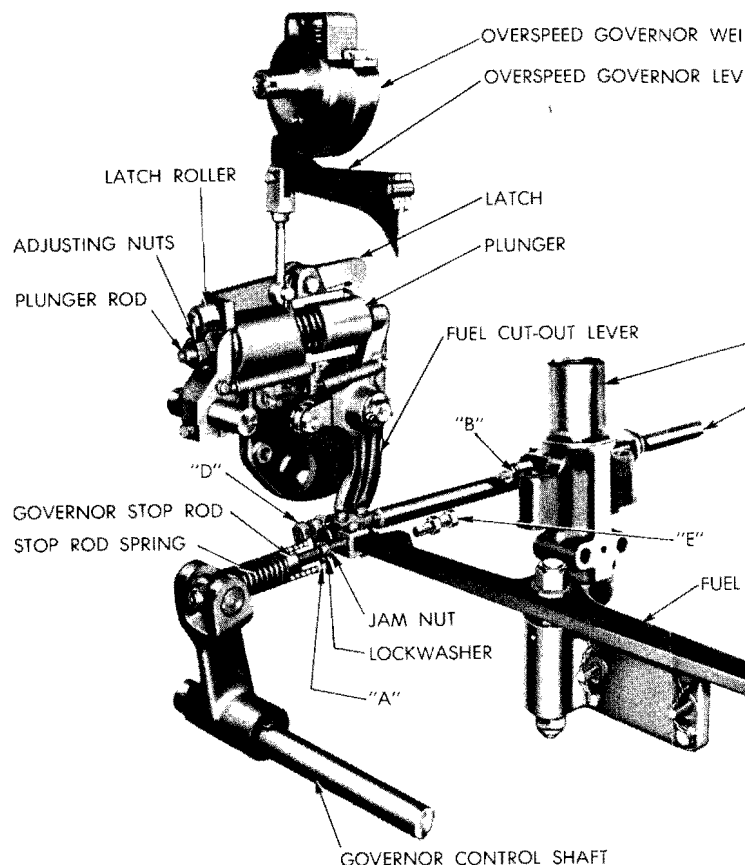
#### Injection Pump Overtravel Check

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. 9, 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 shims 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.



Illus. 8. Fuel Control Linkage Adjustments -  
(Refer to Illus. 10 for CENTER PI

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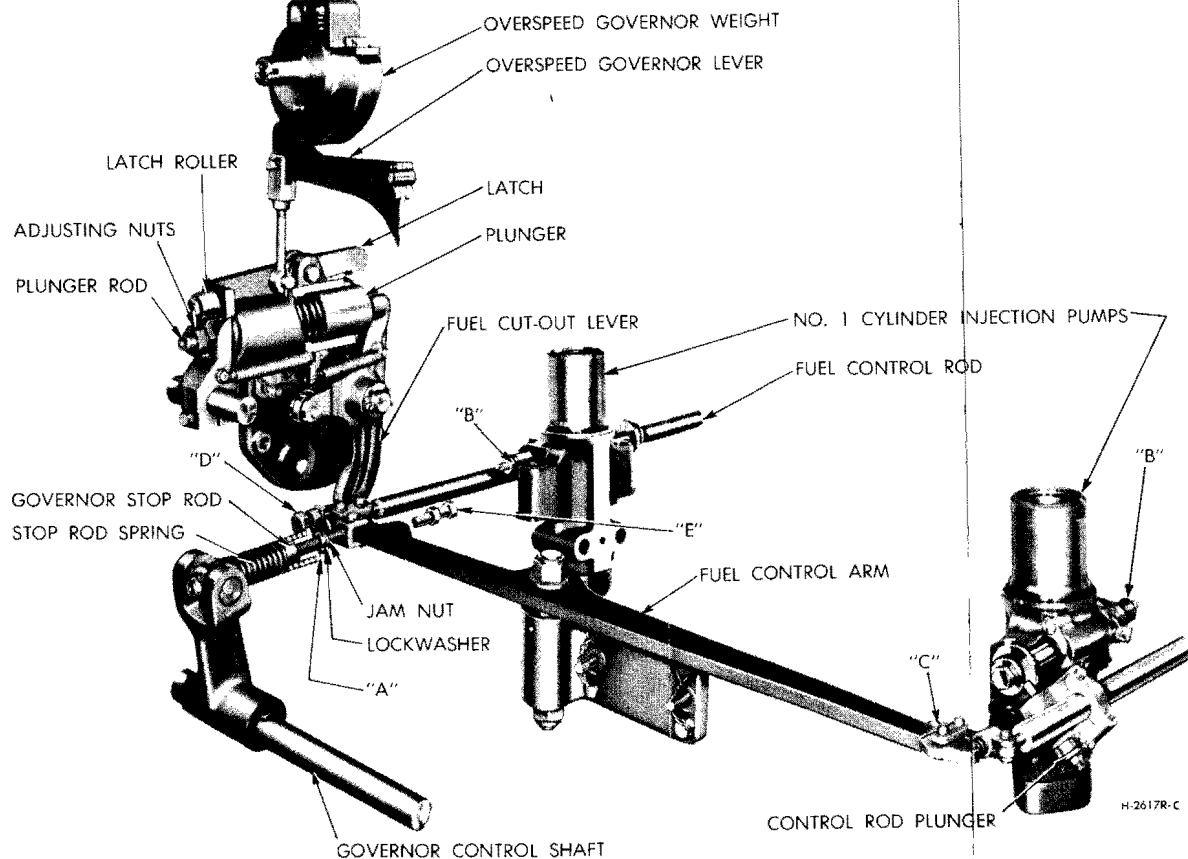
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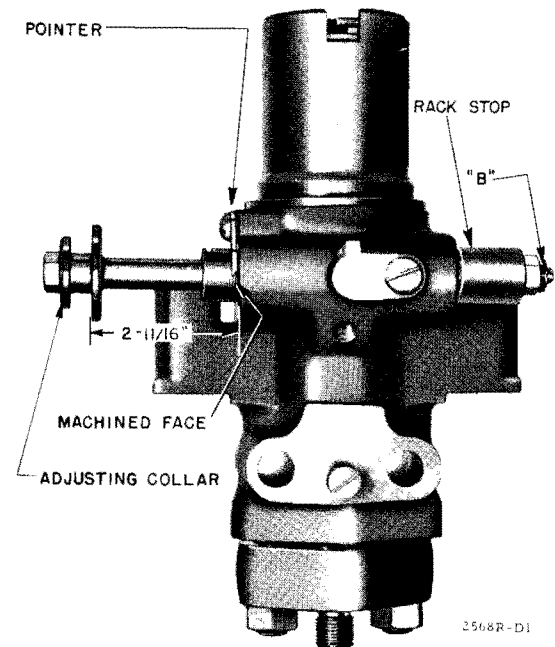
Illus. 8. Fuel Control Linkage Adjustments - OFFSET Fuel Control Arm Shown  
(Refer to Illus. 10 for CENTER PIVOT Fuel Control Arm)

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 until a  $\frac{3}{8}$ " 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. 8, is not limiting the rack travel to less than 17 total rack reading (all units other than 1000 and 1500 hp. Refer to Sec. 308, Chapter L, for complete settings).

Set the No. 1 injection pump on the opposite governor side of the engine so a  $2\text{-}11/16$ " measurement is obtained between the inner face of the control rack adjusting



Illus. 9. Fuel Injection Pump Adjustments

collar and the body of the pump adjacent to the pointer. This dimension is shown in Illus. 9. 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. 9.

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. 8 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. 8.

Adjust all the pumps to rack 8. Be sure the rack collar is not turned when the rack is adjusted. As each pump is set, jar the fuel control rod to eliminate any drag that can hinder the accuracy of the settings.

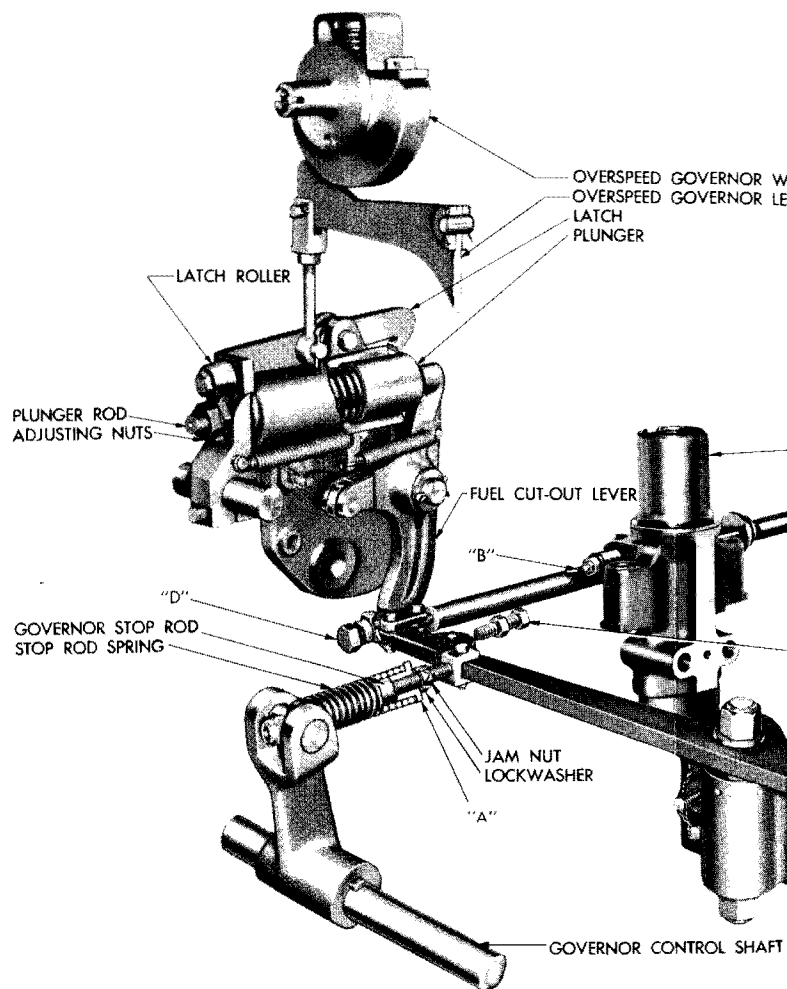
Reduce the rack position on the pumps by means of the power piston jack. As the No. 1 governor side pump reaches the zero position, the No. 1 opposite governor side pumps should be at approximately 3-1/4 rack.

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.

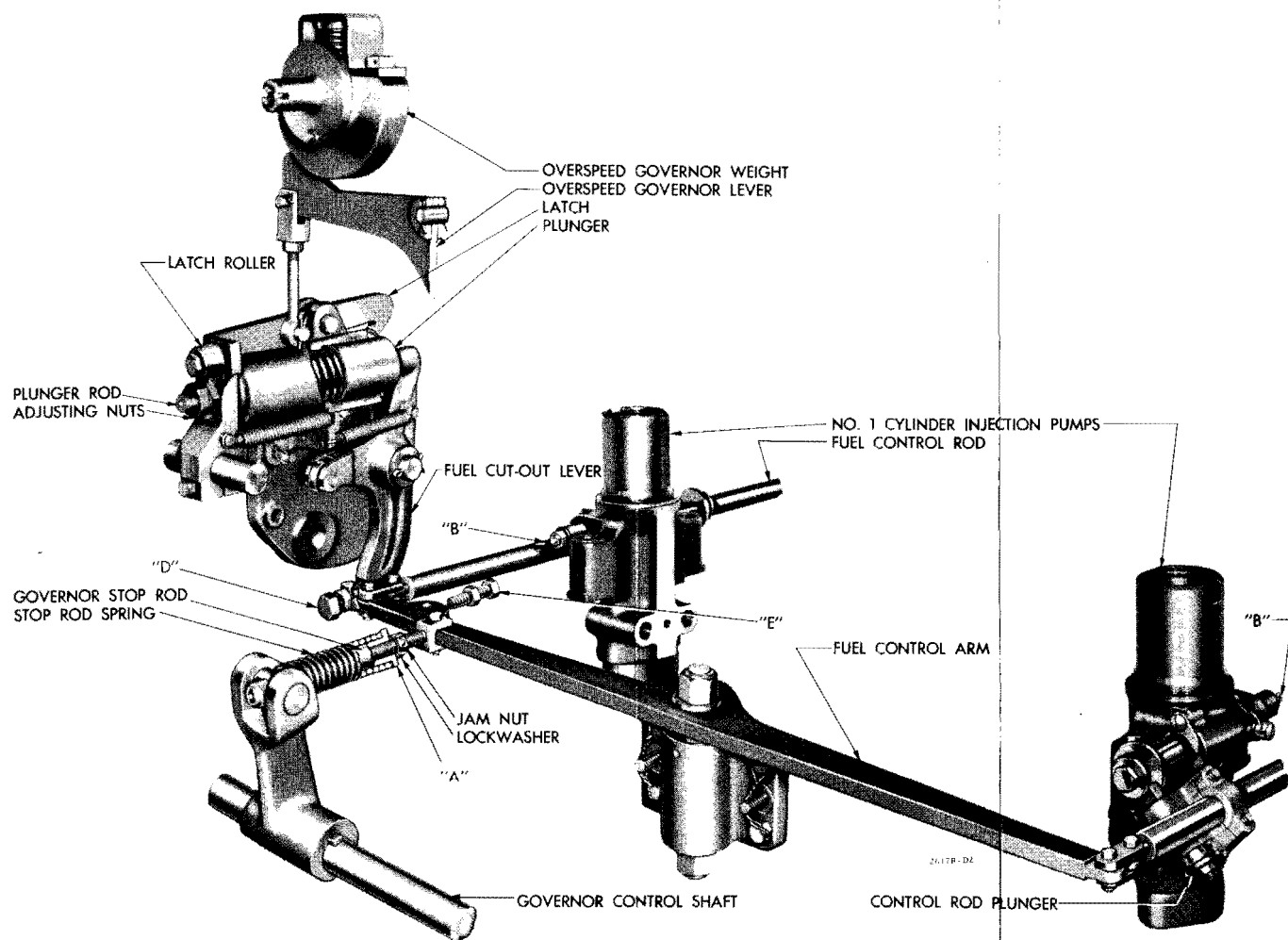
#### Injection Pump Overtravel Recheck

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. 8, to give 8-1/2 rack on



Illus. 10. Fuel Control Linkage  
(CENTER PIVOT Fuel Control)



Illus. 10. Fuel Control Linkage Adjustments  
(CENTER PIVOT Fuel Control Arm)

each side or a total of 17 rack (all units other than 1000 and 1500 hp). Refer to Sec. 308, 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 power piston gap and fuel rack setting.

## ENGINE ADJUSTMENT

### Center Pivot Fuel Control Arm

(Applicable to Engine No. 963984 and all thereafter with CENTER PIVOT fuel control arm, Illus. 10.)

### 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. 9, 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 gov-

ernor 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 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. 10, 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. 9. 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. 9.

Adjust all the pumps to rack 8. Be sure the rack collar is not turned when the rack is adjusted. As each pump is set, jar the fuel control rod to eliminate any drag that can hinder the accuracy of the settings.

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. 10, 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. 10, to give  $8-1/2$  rack on each side or a total of 17 rack (all units other than 1000 and 1500 hp). Refer to Sec. 308, 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 the full load governor piston gap and fuel rack settings.

## MAINTENANCE OF ASSEMBLIES

### CRANKPIN BEARINGS

#### Checking Bearing Shells

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

#### Removing Upper Bearing Shells

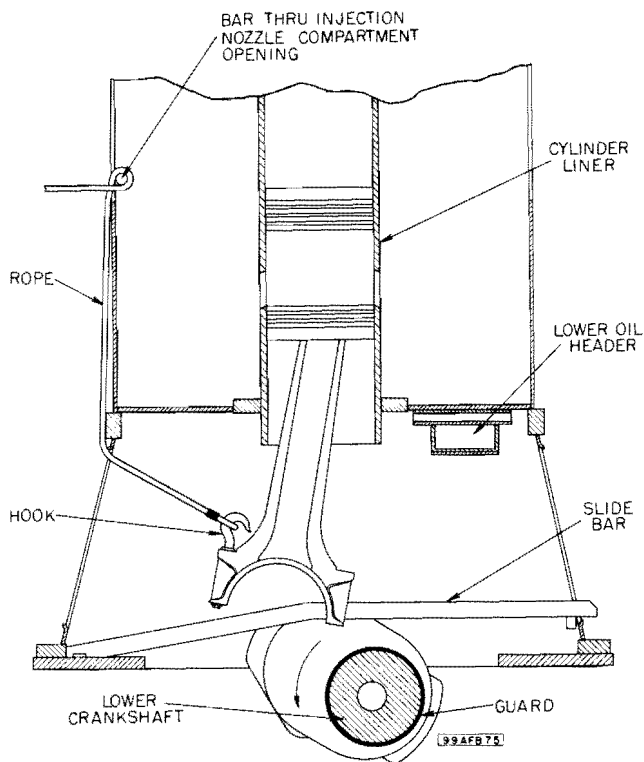
1. Loosen the exhaust end cover and remove the top cover.
2. Bar engine so crankpin to be removed is up.
3. Loosen and remove the bolts from one side of the cap.
4. Use a hook and rope fall to hold the connecting

rod while the other bolts are removed.

5. If additional bearings are to be removed, lower the rod and piston so that the swing of the crankpin clears the connecting rod. Before lowering piston, remove injection nozzle and insert copper tube to keep piston from sticking in the combustion zone.

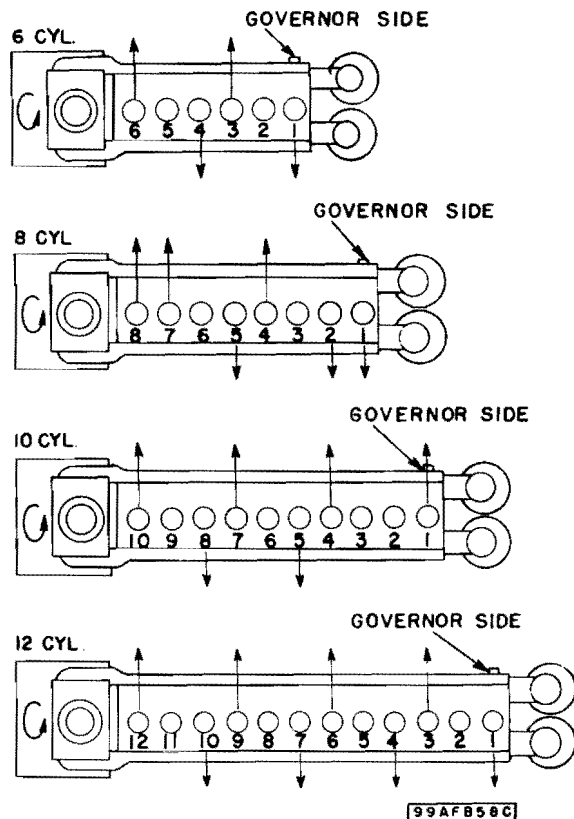
### Replacing Upper Bearing Shells

1. Install new shell in connecting rod.



Illus. 12. Removing Lower Piston

2. Apply "Oil Dag" to the crankpin journal.
3. Raise connecting rod to crankpin journal.
4. Stamp the new shells with similar marks and in the same location as the old shells.
5. Install bearing shell, connecting rod cap and bolts.



Illus. 13. Piston Removal Diagram



6. Tighten bolts to 175-200 ft. lbs. torque.

NOTE: When replacing bearing shells, it is imperative that complete sets of Satco or aluminum shells be installed. DO NOT MIX THE SHELLS ON THE SAME CRANKSHAFT.

#### Lower Bearing Shells

1. Remove crankcase covers and bar engine so crankpin is at inner dead center (up).
2. Support the cap and remove the bolts.
3. Install the winches and cables as shown in Illus. 11. Position the washers so the shell can be removed.
4. Tighten the winches to raise the connecting rod from the crankpin journal to allow the rod half of the shell to be removed.
5. Properly mark the new shells the same as the old shells.
6. Apply "Oil Dag" to the crankpin journal. Install the new bearing shell and lower the rod to the crankpin.
7. Replace the cap half bearing shell, cap and bolts. Tighten bolts to 175-200 ft. lbs. torque.

#### Inspection and Refinish Journals

The journals should be inspected and refinished if necessary after a bearing failure.  
Refer to the outline under "Main Bearings" page 46.

#### LOWER PISTON

##### Removing

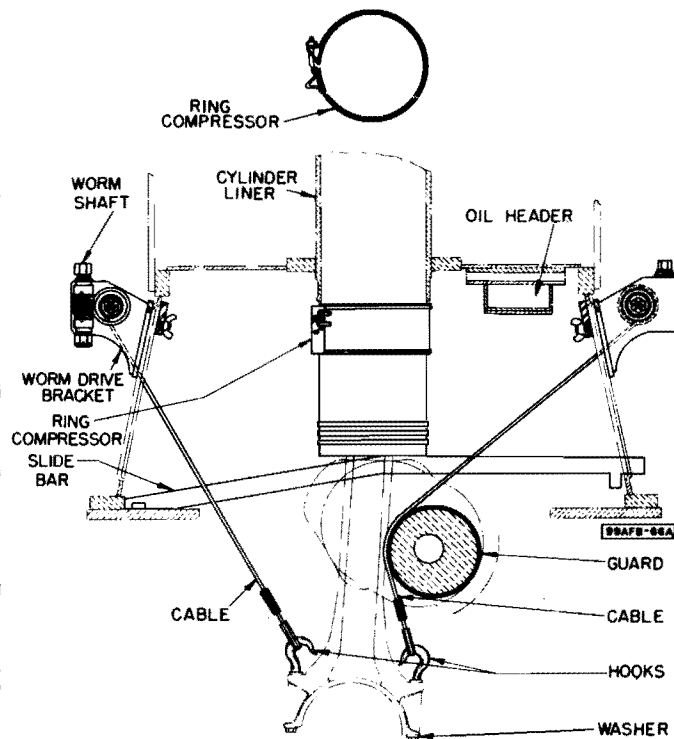
1. Remove nozzle holder assembly from cylinder to relieve vacuum.
2. Bar engine so crankpin is at inner dead center (up).
3. Remove bearing cap and shell and support with hook and rope as shown on Illus. 12. Support the piston on the side of the engine from which removal is made. Counterweighted crankshafts require the removal of cer-

tain pistons from only one side as indicated in Illus. 13.

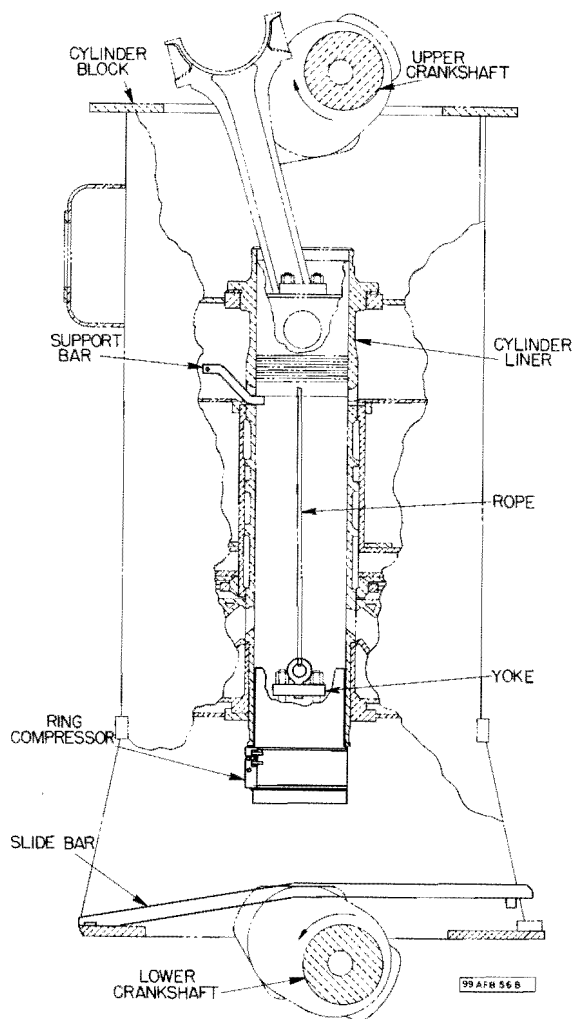
4. Install the slide bars as shown in Illus. 12 and bar engine so web of crankpin is flush with the slide bars.
5. Install the crankpin guard.
6. Slacken rope and lower piston onto the slide bars.
7. Move the piston to the opening. Pull the piston upward and swing out and down when the end of the rod clears the crankpin. Be careful not to damage the piston or rings.

##### Reinstalling

1. Install the slide bars.



Illus. 14. Lower Piston Inserting Tools



Illus. 15. Upper Piston Tools

2. Bar engine so web of crankpin is flush with the slide bars.

3. Place rod half of shell in place in rod. Install hooks and washers to hold in place.

4. Stagger piston ring gaps and apply lube oil to piston surface.

5. Apply piston ring compressor and crankpin guard.

6. Place piston and rod thru opening onto slide bars. Markings should be toward the exhaust end and governor side. Slide piston directly under the cylinder liner.

7. Fasten the winches to the cylinder block and connect the cables to the hooks as shown, Illus. 14.

8. Tighten the winches and pull the cables to raise the piston into the liner. Remove the ring compressor.

9. Remove the crankpin guard, clean the journal and apply "Oil Dag." Swing the connecting rod over the journal and lower into place.

10. Install bearing shell, cap and bolt. Note location of matchmarks.

11. Tighten nuts to 175-200 ft. lbs. torque.

## UPPER PISTON

### Removing

NOTE: The following steps are applicable for removal of individual pistons. If over one-half of the pistons are to be removed, remove the upper crankshaft and remove the piston from the top of the liner.

1. Loosen the exhaust end cover and remove the top cover.

2. Remove the lower connecting rod and piston as outlined under "Lower Piston."

3. Remove the nozzle holder assemblies from the cylinder liner adapter.

4. Remove one of the air receiver handhole covers.

5. Place a canvas thru the lower crankcase to keep dirt and carbon from dropping into the crankcase.

6. Reach in from the lower end of the liner and clean carbon from the combustion space.

7. Lubricate the liner.

8. With the upper crankpin at outer dead center (up), loosen the piston insert stud nuts. Remove three nuts.

9. Support the connecting rod and remove the cap.

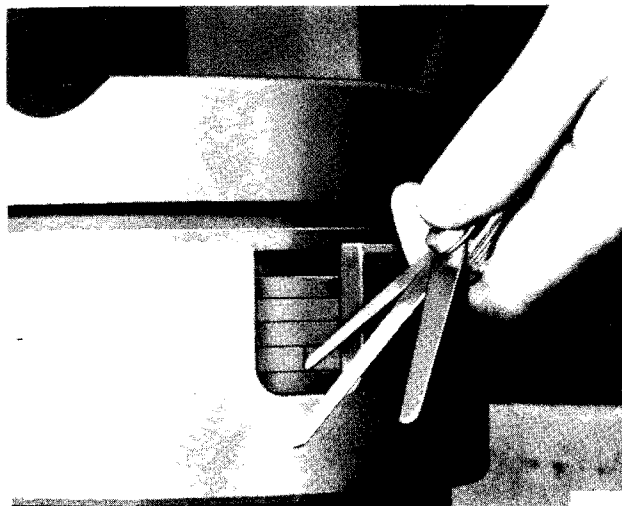
10. Insert the support bar, Illus. 15, thru the air receiver handhole opening.

11. Lower the assembly to the support bar and remove the insert stud nut.

12. Lift the connecting rod and insert from the piston. In removing some of the pistons and connecting rods, the crankshaft counterweights do not permit removal without barring the engine. Cautiously bar the engine and at the same time raise and remove the insert and rod assembly.

13. Place the lifting yoke on the insert studs. Tie a rope to the eyebolt.

14. Place the slide bars in the lower crankcase and bar engine so lower crankweb is horizontal. The upper piston is removed from the same side of the engine as



Illus. 16. Piston Ring End Clearance

the lower piston.

15. Remove the support bar and push the piston down thru the liner.

NOTE: 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.

### Replacing

1. With the piston compression ring gaps staggered, apply the ring compressor over the compression rings. Do not install the oil rings at this time.



Illus. 17. Piston Ring Side Clearance

2. Place piston on slide bars. Run rope thru liner and tie to eyebolt.

3. Place piston directly under liner and pull into liner until the support bar, Illus. 15, can be installed.

4. Raise the piston until oil ring grooves are exposed.

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

6. Install the ring compressor and push the piston into the liner. Remove the lifting yoke.

7. Install piston insert and connecting rod assembly into the piston.

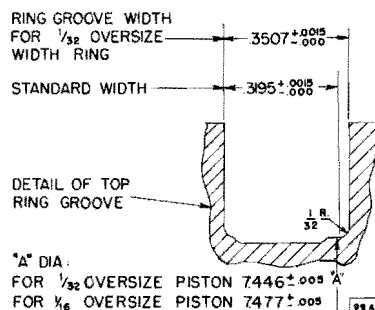
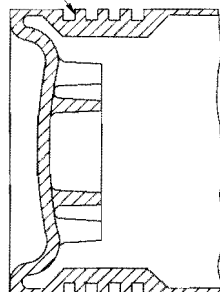
8. Tighten stud nuts to 45-50 ft.lbs. torque.

9. Replace bearing shells, connecting rod cap and bolts. Be sure parts are correctly located.

10. Tighten connecting rod bolt nuts to 175-200 ft.lbs. torque.

11. Be sure the support bar has been removed.

MACHINE THIS SIDE OF NO.1  
COMPRESSION RING GROOVE  
ONLY OF C-AF85AA3, AB3, AL  
AND AM PISTONS WIDTH  $\frac{1}{32}$   
LAND DIMENSION



Illus. 18. Piston Ring Groove Machining

12. Replace lower connecting rod and piston as outlined under "Lower Piston - Replacing."

### PISTON RINGS

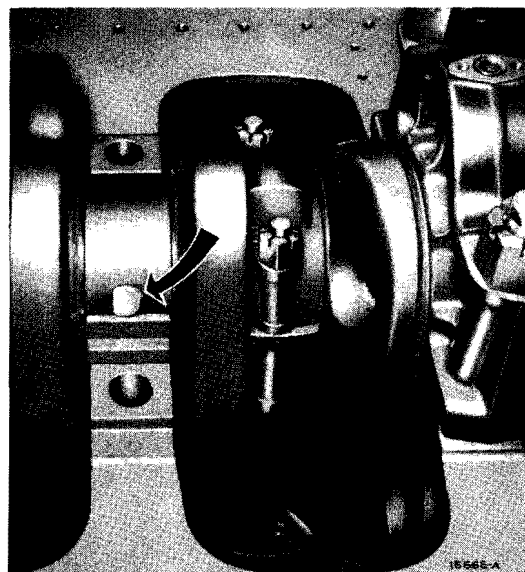
1. Install new piston rings if the cylinder liner or piston are replaced with a new liner or piston.

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

3. Check piston ring end clearance in ring gage or cylinder, Illus. 16. Refer to "Condemnable Dimensions" on page 8.

4. Check side clearance of ring in groove, Illus. 17. Refer to "Condemnable Dimensions" on page 8. Be sure ring groove is not tapered. Over-size width ring can be used in the top groove. Refer to Illus. 18 for machining dimensions.

5. When installing new compression rings, do not expand the rings excessively with the ring expander.



Illus. 19. Main Bearing Tool

6. Be careful not to distort or excessively expand the oil rings when installed.

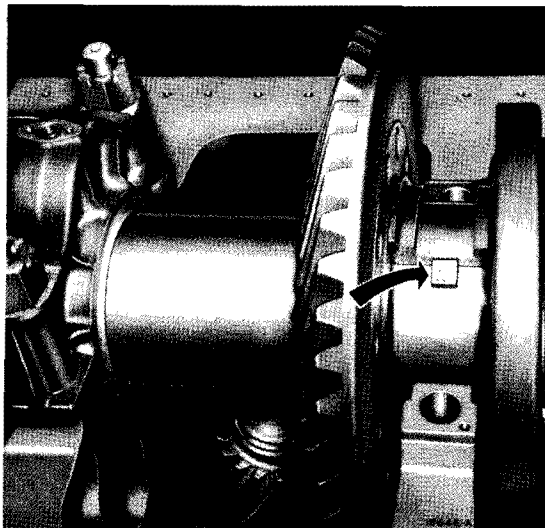
## MAIN AND THRUST BEARINGS

### Checking Bearing Shells

1. Feeler gage check will determine if bearing shell has failed.
2. Attempt to insert .002" feeler gage at the shell parting line or between the cap and back of the shell at the parting line.
3. If gage can be inserted, remove the bearing shell and recondition the journal. Refer to procedure page 46.
4. Check the cap to block fits. Refer to page 50.

### Removing Upper Bearing Shells

1. Loosen the exhaust end cover and remove the top



Illus. 20. Thrust Bearing Tool

cover.

2. Remove the lube oil supply tube to the bearing cap.
3. Remove the main bearing bolt nuts.
4. Pry off the bearing cap evenly from both sides.
5. Roll out the block shell half with the tool shown in Illus. 19.
6. Check the wear of the bearing shell by measuring the minimum thickness. Refer to page 7 for "Condemnable Dimensions."
7. Check the thrust bearing clearance. Force the crankshaft against the bearing in one direction. Check the clearance with feelers. Recheck in the opposite direction. Refer to page 6 for limits.
8. Roll out the thrust bearing block shell half with the square tool shown in Illus. 20.

### Removing Lower Bearing Shells

1. Remove the lower crankcase covers from both sides of the engine.
2. Remove the bolt nuts and pry off the bearing cap. Support the cap by inserting pins in the hole in the bolts.
3. Remove the cap half of the shell.
4. Roll out the block shell half with the button tool shown in Illus. 19. In most cases, the shell half can be pushed out by hand without the aid of the tool. If the shell is tight, roll out the shell with the button tool.
5. When removing bearing caps, leave the center and end caps in place until other caps have been replaced.
6. Check the wear of the bearing shell by measuring the minimum thickness. Refer to page 6, for "Condemnable Dimension."
7. Check the thrust bearing clearance. Force the crankshaft against the bearing in one direction. Check the clearance with feelers. Recheck in the opposite direction. Refer to page 6 for limits.
8. Roll out the thrust bearing block half with the square tool shown in Illus. 20.

### Replacing Bearing Shells

NOTE: Bearing shells should not be replaced after

6. Be careful not to distort or excessively expand the oil rings when installed.

## MAIN AND THRUST BEARINGS

### Checking Bearing Shells

1. Feeler gage check will determine if bearing shell has failed.

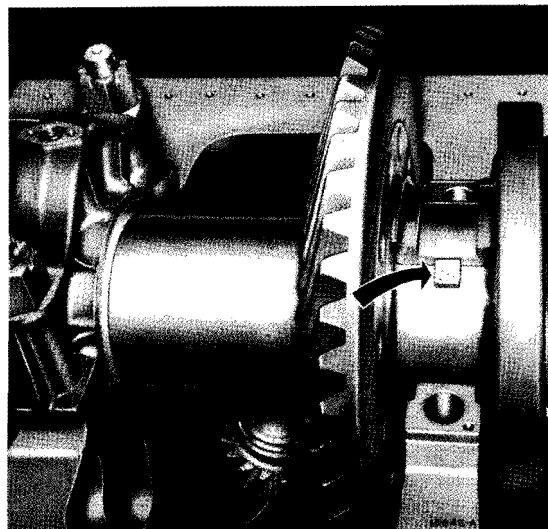
2. Attempt to insert .002" feeler gage at the shell parting line or between the cap and back of the shell at the parting line.

3. If gage can be inserted, remove the bearing shell and recondition the journal. Refer to procedure page 46.

4. Check the cap to block fits. Refer to page 50.

### Removing Upper Bearing Shells

1. Loosen the exhaust end cover and remove the top



Illus. 20. Thrust Bearing Tool

cover.

2. Remove the lube oil supply tube to the bearing cap.

3. Remove the main bearing bolt nuts.

4. Pry off the bearing cap evenly from both sides.

5. Roll out the block shell half with the tool shown in Illus. 19.

6. Check the wear of the bearing shell by measuring the minimum thickness. Refer to page 7 for "Condemnable Dimensions."

7. Check the thrust bearing clearance. Force the crankshaft against the bearing in one direction. Check the clearance with feelers. Recheck in the opposite direction. Refer to page 6 for limits.

8. Roll out the thrust bearing block shell half with the square tool shown in Illus. 20.

### Removing Lower Bearing Shells

1. Remove the lower crankcase covers from both sides of the engine.

2. Remove the bolt nuts and pry off the bearing cap. Support the cap by inserting pins in the hole in the bolts.

3. Remove the cap half of the shell.

4. Roll out the block shell half with the button tool shown in Illus. 19. In most cases, the shell half can be pushed out by hand without the aid of the tool. If the shell is tight, roll out the shell with the button tool.

5. When removing bearing caps, leave the center and end caps in place until other caps have been replaced.

6. Check the wear of the bearing shell by measuring the minimum thickness. Refer to page 6, for "Condemnable Dimension."

7. Check the thrust bearing clearance. Force the crankshaft against the bearing in one direction. Check the clearance with feelers. Recheck in the opposite direction. Refer to page 6 for limits.

8. Roll out the thrust bearing block half with the square tool shown in Illus. 20.

### Replacing Bearing Shells

NOTE: Bearing shells should not be replaced after

a bearing failure until after the journal has been re-finished if necessary and the cap fit checked.

### Main Bearings

1. Mark the new shells in the same manner and location as the old shell.
2. Apply "Oil Dag" to the journal surface.
3. Replace lower main bearing caps with the shell in place in the cap. Upper main bearing shells are replaced separately.
4. Roll the shell in place with the button tool.
5. Set the upper main bearing caps in place and tap with a soft hammer to seat. The lower main bearing caps are pulled in place by tightening the bolts evenly. Be sure dowels are properly located.
6. Tighten the bearing cap bolts to 700-1000 ft. lbs. or use the following procedure.
  - a. Assemble bearing hand tight with 8" light wrench.
  - b. Pull hand tight (one hand) with 20" wrench (200-250 ft. lbs.).
  - c. Turn nut an additional flat ( $60^{\circ}$ ).
  - d. Continue tightening (no more than an additional one-half flat to line up the cotter pin hole).

### Thrust Bearings

1. Mark the new shells in the same manner and location as the old shells.
2. Apply "Oil Dag" to the journal and thrust surfaces.
3. Replace lower thrust bearing shell in place in the cap. Upper shells are replaced separately.
4. Move the crankshaft in either direction until the block half of the thrust bearing shells slide into the fit in the cylinder block.
5. Roll the shell in place with the square tool.
6. Set the upper bearing cap in place and tap with a

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

7. Pull up bolts using a 20" wrench.
8. Loosen the bolts and retighten with the 8" wrench.
9. Force the crankshaft against narrow face and back against the thrust face.
10. Continue tightening the bolts.
  - a. Pull hand tight (one hand) with 20" wrench (200-250 ft. lbs.)
  - b. Turn nut an additional flat ( $60^{\circ}$ ).
  - c. 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.**

### Bearing Failure and Correction

After the feeler gage check of main and thrust bearings or the visual check of crankpin 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 through 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 ( $\text{NaOH}$ ) solution used in cleaning the failed crankshaft journal from entering the inter-connected 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 46.

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 50.

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 under "Main Bearings," page 42.

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

#### 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," page 46.

3. Inspect bearing cap for distortion. Use an outside micrometer. See "Bearing Cap Inspection and Repair," page 50.

4. Check block saddle for distortion, clean and correct as outlined under, "Thrust Bearing Block Saddle Repair," page 56.

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 under "Thrust Bearings," page 42.

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

#### Crankpin Bearing Journals

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 through 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 inter-connected oil tube and damaging the crank.

3. Clean and condition crankpin surface as outlined under "Conditioning of Crankshaft after an Aluminum Bearing Failure," page 46.

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 under "Crankpin Bearings," page 38.

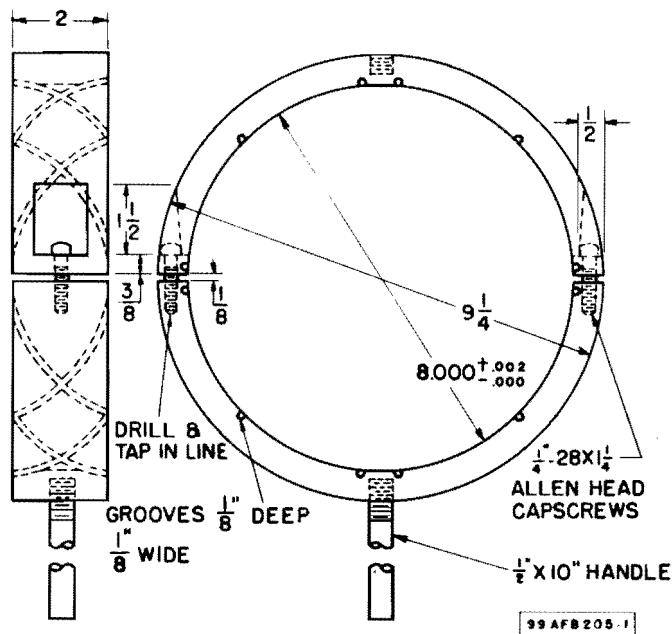
c. Bar the engine one complete turn prior to, and one-fourth turn during pre-lubrication.



## Conditioning Crankshaft after Aluminum Bearing Failure

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

1. Clean crankshaft journal or crankpin, 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.

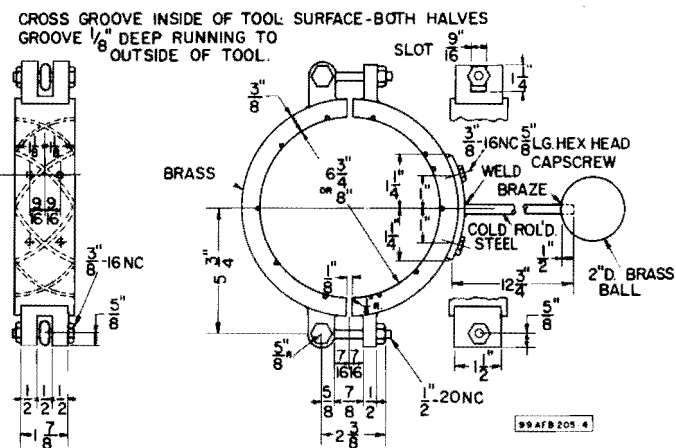


Illus. 21. Main Bearing Lapping Tool

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.

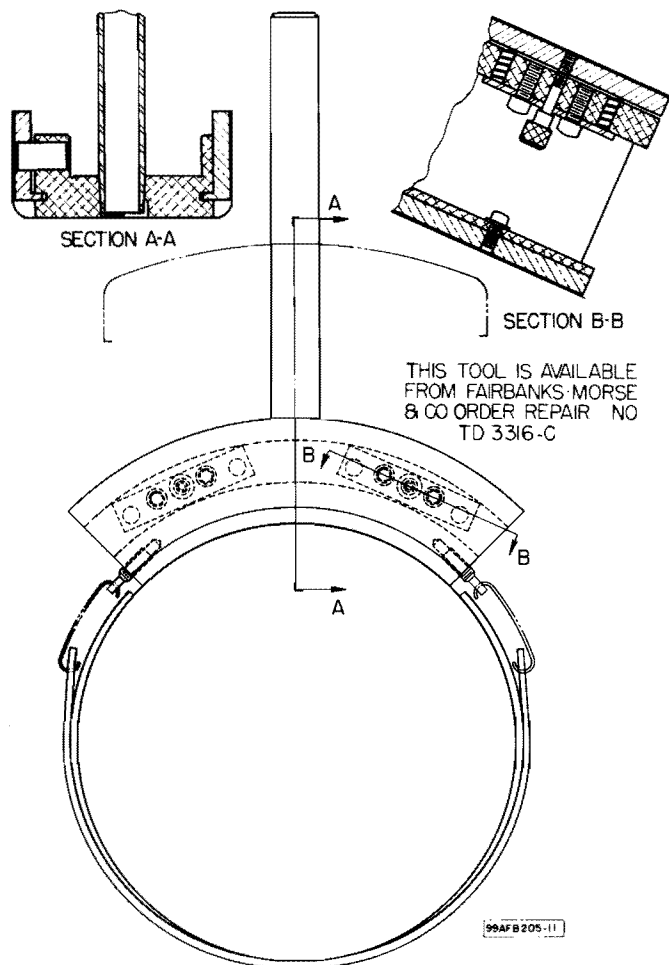
- a. Experimental tests were conducted with a solution of 10% NaOH by weight, however, this is not necessarily the strength that must be used.
- b. Precautions must be taken to prevent the solution of NaOH from contaminating the crank case while cleaning procedure is taking place.
- c. Personnel working with NaOH must wear rubber gloves because highly caustic solution is harmful to the skin.

4. With the proper lapping tool, Illus. 21 or 22, lap in the affected crankpin or main bearing journal. Illus. 21 is for lapping the main bearing journals



Illus. 22. Main and Crankpin Lapping Tools

with the crankshaft in place in the block. Illus. 22 is for lapping tools for the main journals and for the crankpins. The illustration shows two inside dimensions 8" and 6-3/4" for the main journals and crank-

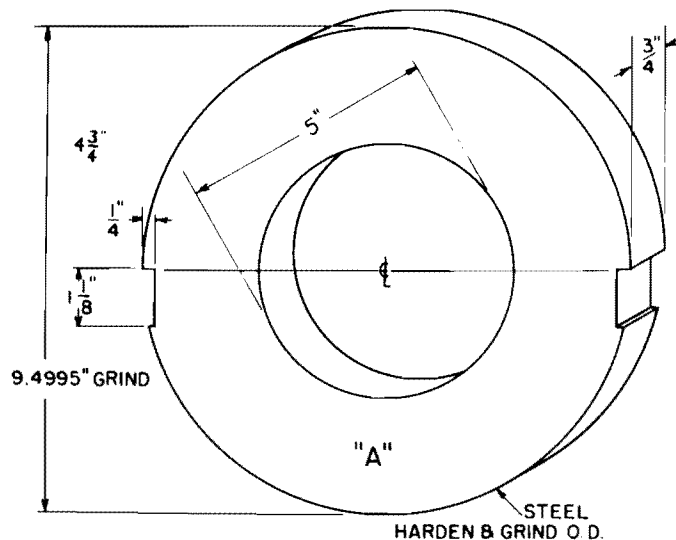


Illus. 23. Crank Thrust Face Lapping Tool

pins respectively. For lapping the thrust faces use tool shown in Illus. 23.

The lapping compound used is No. 111 Green Label Timesaver which is mixed to a consistency of a soft paste by adding No. 10 lube oil. This mixture should be used generously. The crank journals 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 or crankpin 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 surface lapped with lube oil is all that is necessary.

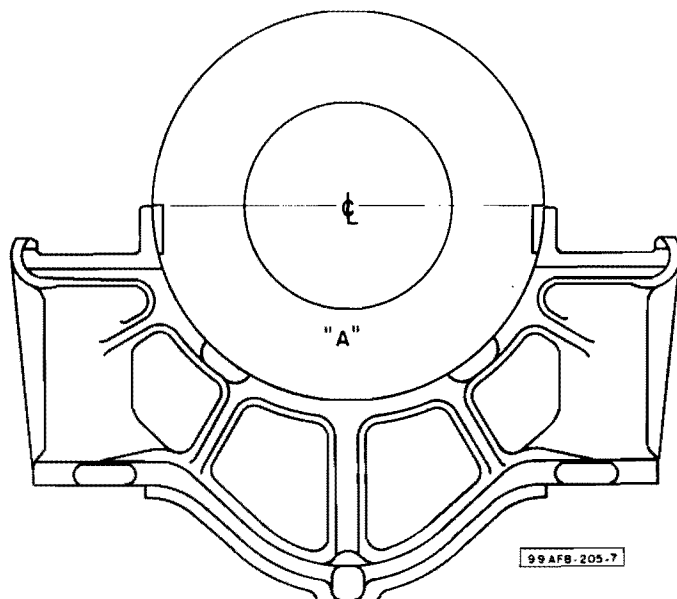


Illus. 24. Bearing Cap Checking Mandrel

6. After the crankshaft has been reconditioned, the bearing caps inspected and "conditioner" used on the journal, reapply the bearing as outlined on page 42 for main and thrust bearings and page 33 and 38 for crankpin bearings.

#### Main Bearing Cap Inspection and Repair

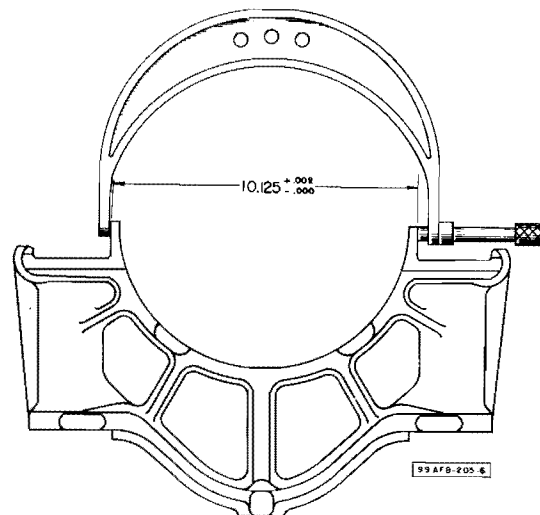
1. Remove bearing cap dowels.
2. Using mandrel, Illus. 24, check bearing cap for distortion.
  - a. Set mandrel in cap so that side "A," Illus. 25, is centered in the cap proper.
  - b. Check for distortion with feeler gage. This check is to determine if the bearing cap proper has distorted in any way. In placing the mandrel



Illus. 25. Checking Cap with 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. 25 and no clearance is found between mandrel and the cap, the cap bore is not distorted.



Illus. 26. Checking Cap Ear Dimension

3. Check dimension across the outside of the ears as shown in Illus. 26.

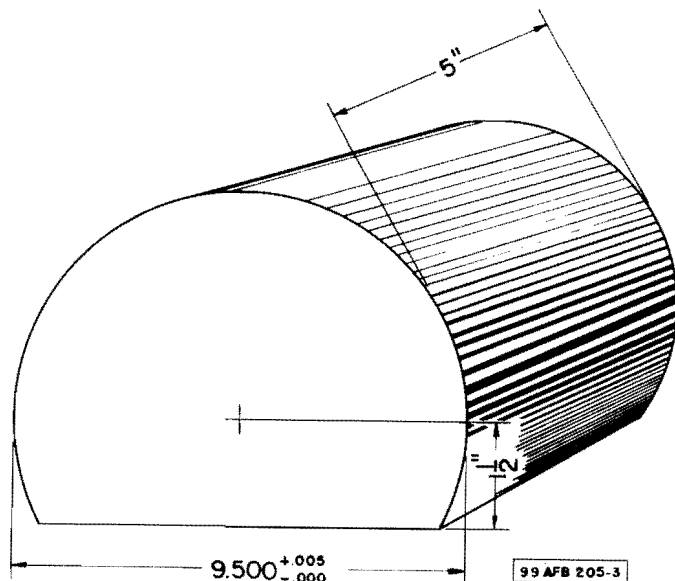
a. If the ears show close-in only, the necessary repair will be to the ears only. Caution: Be sure that all inspections on the cap are made before repair of cap is attempted. A correction of the cap proper will very possibly correct the ear pull-in also. Before the ears are corrected, the cap proper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

b. For correction of distorted cap see following outline.

#### Repair of Distorted Bearing Cap

##### 1. Material Required

a. Press mandrel - See Illus. 27.



Illus. 27. Press Mandrel

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

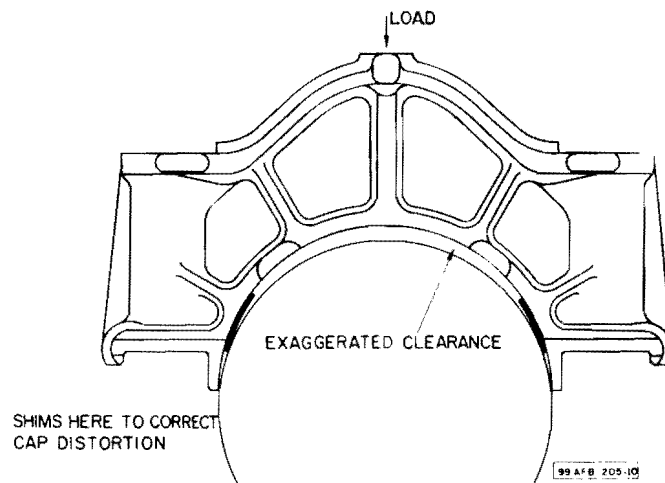
c. Hydraulic press - (15 to 20 ton capacity)

2. With bearing cap to shell dowel removed from the capsaddle, set cap over press mandrel as shown in Illus. 28. Level cap on mandrel using a liquid level set on machined surface.

3. Apply pressure as shown on Illus. 28, (approximately 15 tons, not over 20 tons).

4. Remove cap from press mandrel and check with checking mandrel, Illus. 25. If further correction is needed place .003" shims between cap and press mandrel as shown in Illus. 28 and apply pressure as in 3 above.

5. Continue checking and adding shims in sequence to their thickness until cap proper is correct to check-

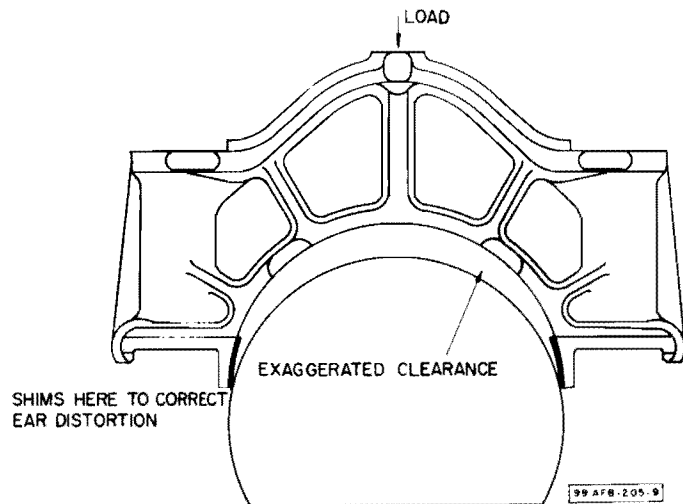


Illus. 28. Cap Positioned on Press Mandrel

ing 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. 26, place .003" shims between the cap ears and the press mandrel as shown in Illus. 29. 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 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



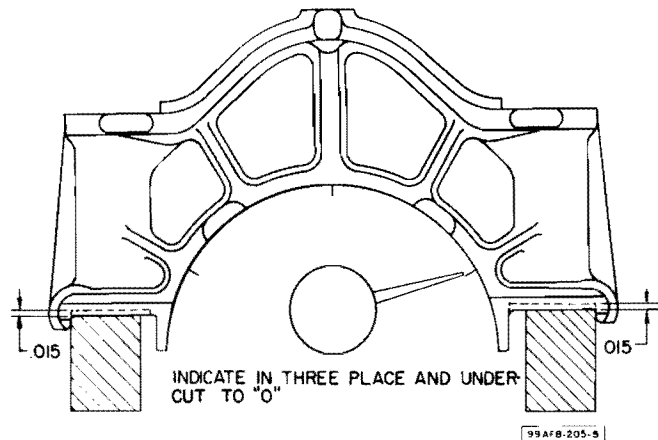
Illus. 29. Correcting Cap Ear Deflection

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 but 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. 30. 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 not lost.

b. Remove from the engine an adjacent cap to the one being machined. This cap must pass the mandrel check, Illus. 25. 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.



Illus. 30. Bearing Cap Machining

c. Set pattern cap up on parallels on the machine to be used in re boring damaged cap so that a common parallel set up can be used for positioning the cap to be re bored. Indicate the pattern cap to zero bore contour in relation to swing of indicator on tool stock. See Illus. 31.

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

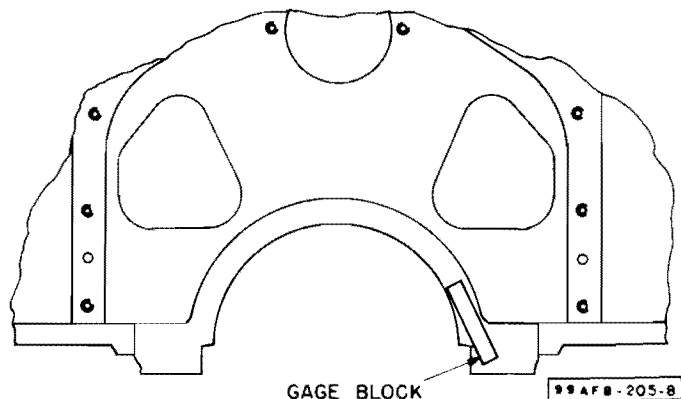
e. Burr cap and replace dowel. Check cap with mandrel.

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.

#### Thrust Bearing Block Saddle Repair

The block saddle must be checked for distortion as



Illus. 31. Thrust Bearing Block Saddle

as well as the bearing cap after an aluminum thrust bearing failure. Refer to outline "Repair of Distorted Bearing Caps," page 52. 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. 31.

2. This surface can be checked by using surface blue and a surface block, as shown in Illus. 31. The area affected or swellout 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.

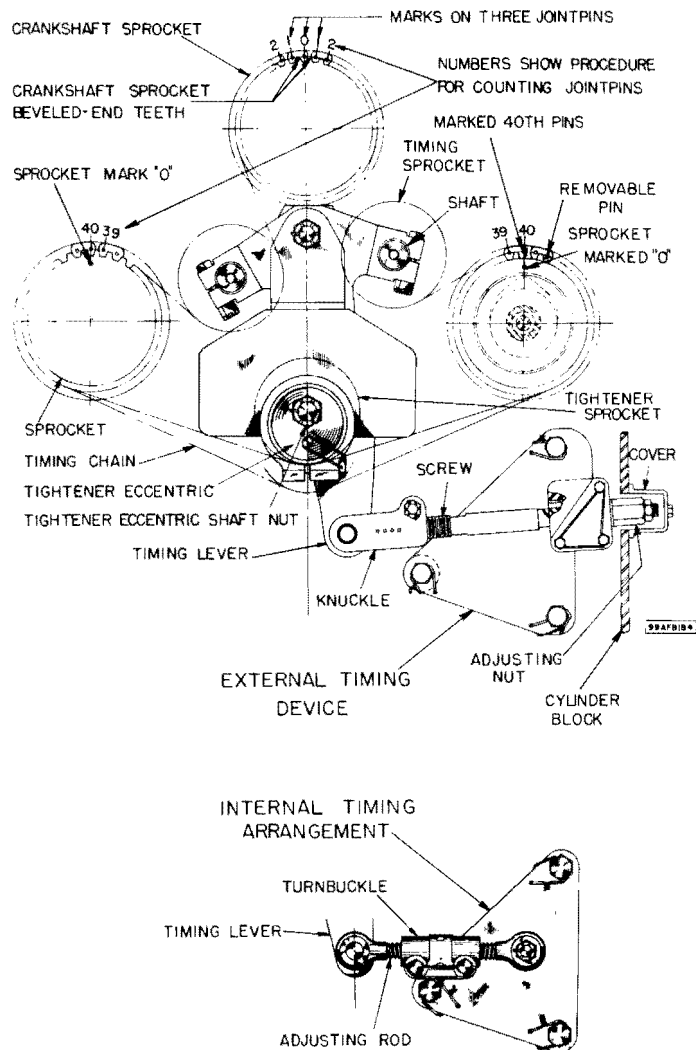
Correction can be made by removing the over dimension of stock from area shown in above check by using a pencil grinder and checking intermittantly with the surface block to be sure the correction is being made properly. Be sure grinding chips do not get into the engine. When the surface block shows 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 & Co.

#### TIMING CHAIN AND CAMSHAFT

##### Disconnecting and Removing Chain

1. Remove the exhaust end cover.
2. Loosen the clamp screw on the tightener sprocket bracket, Illus. 32.



Illus. 32. Timing Chain Installation

3. Place a bar between the dowel and tightener eccentric shaft nut and bar until the tightener sprocket moves to release tension of the timing chain.
4. Remove the joint pin to disconnect the chain.

**NOTE:** 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 cap-screw 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 Chain

1. The three punch or grinder marked pins on the timing chain must be centered at outer dead center over the two beveled teeth on the crankshaft sprocket. The middle marked pin will be between the two beveled teeth.
2. Starting with the middle pin as "O" count 40 pins in each direction. The marked 40th pin must be aligned with the "O" marks on the camshaft sprockets. Turn the camshafts if necessary to align the marking.
3. Replace the joint pin.
4. Place a bar between the dowel and tightener eccentric shaft nut and bar to tighten the chain.
5. 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.
6. Recheck injection timing if the chain has been tightened or a new chain applied.

**NOTE:** On engines with an endless chain, place the chain on the sprockets with the marks coinciding as under step 1 and 2 above. Replace the timing sprocket shaft. Tighten the chain as under steps 4 and 5.

Refer to Section 308, Chapter H for complete outline on servicing the camshaft and bearings.

## UPPER CRANKSHAFT

### Removing

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

**CAUTION: NEVER REMOVE OR REPLACE AN UPPER CRANKSHAFT WITH THE BLOCK HALF OF THE THRUST BEARING SHELL IN PLACE.**

1. Remove the exhaust end cover and top cover.
2. Remove cotter pins and loosen all main and connecting rod bolts.
3. Remove the thrust bearing cap and roll out the block shell half.
4. Remove the injection nozzles and insert copper tube in one hole.
5. Remove the connecting rod bearing caps and lower the pistons.
6. Remove the main bearing caps.
7. Loosen and remove or disconnect the timing chain. Refer to "Timing Chain" procedures.
8. Bar the engine carefully so that the No. 1 crankpin is at outer dead center (up) position.
9. Secure a rope sling to the No. 1 crankpin and around the crankshaft beyond the vertical drive gear. (12 cyl. crankshafts must be lifted at the ends and at the middle.)
10. Slowly lift the crankshaft from the engine. Remove bearing shells which may have adhered to the crankshaft.
11. Clean all parts and wipe dry with lint free cloth.
12. Keep the engine and parts free of dirt while work is performed.

### Installing

1. Install the block half of the main bearing shells. Be sure marking is toward exhaust end and on the governor side of the engine. **DO NOT INSTALL THE BLOCK HALF OF THE THRUST BEARING SHELL.**

2. Apply "Oil Dag" to the bearing shells.
3. Use a protractor to position the lower crankshaft. Set  $9^{\circ}$  after outer dead center for  $15^{\circ}$  crank lead or  $6^{\circ}$  after outer dead center for  $12^{\circ}$  crank lead.
4. 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.
5. Check the crankshaft lead timing as outlined on page 13.
6. Apply "Oil Dag" to the bearing journals.
7. Install the upper main bearing shells and caps and tighten as outlined, page 44.
8. Install the connecting rod bearing shells and caps and tighten bolts to 175-200 ft. lbs. torque.
9. Shift the crankshaft endwise to start the block half of the thrust bearing shell. Roll the shell in place with the button tool.
10. Install the timing chain as outlined on page 59.
11. If a new crankshaft or vertical drive gears are installed, check the gear backlash. Refer to Chapter Fa or Fb, Section 308.
12. Complete the engine assembly.

## CYLINDER LINER

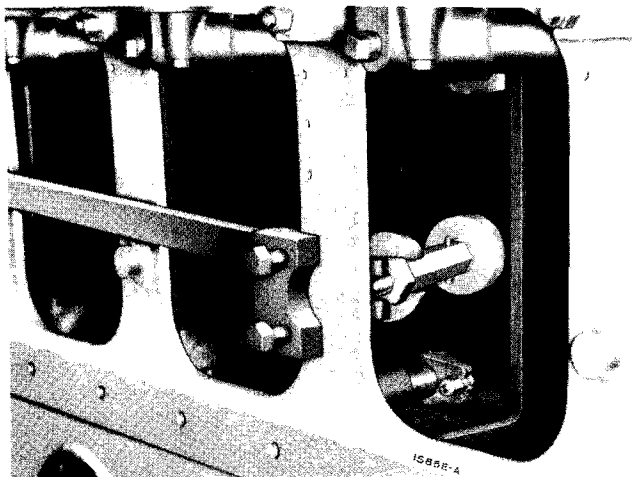
### Removal

1. Remove the engine top cover. The upper crankshaft and upper and lower connecting rods and pistons as outlined on page 60, 29 and 32.

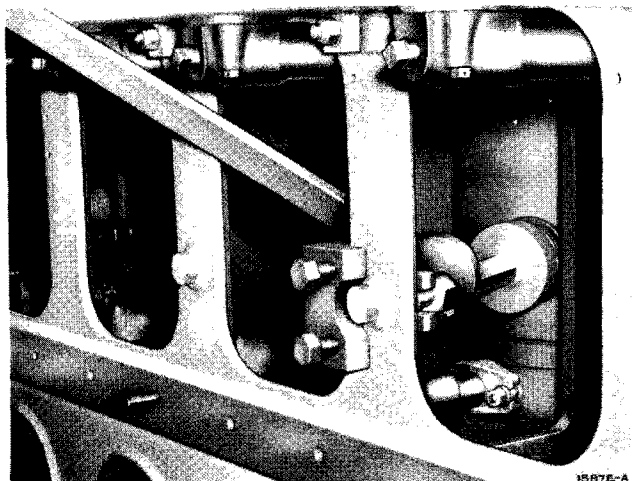
**NOTE:** It is advisable to water test the engine before removing the cylinder liners. The water test may disclose other parts which should be replaced.

2. Drain the jacket water cooling system.
3. Remove the injection nozzles from the adapters.
4. Remove the adapter collars from the adapters.





Illus. 33. Adapter Gland Nut Tool



Illus. 34. Adapter Tool

Remove the gland nuts with the tool, Illus. 33.

5. Remove the adapter with the tool, Illus. 34.

6. Remove the stud nuts securing the water outlet pipe.

7. Remove the cover over the water inlet elbow and remove the stud nuts and inlet elbows.

8. Remove the studs from the cylinder liner.

9. Remove the nuts holding the liner to the upper cylinder block deck.

10. Place a canvas or pan across the lower crankcase to prevent dirt dropping into the lube oil.

11. Install two 5/8-11 N.C. jackscrews into the liner lug and jack the liner free. Remove the jackscrews and install eyebolts for lifting the liner.

**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.**

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

#### Cleaning

1. Clean the liner, air and exhaust ports, the combustion zone and water jacket space thoroughly.

2. Clean the block fits on the liners and block.

3. Water test liner. Install adapters to close adapter holes. Close off one inlet hole and connect pressure line to other. Block off outlet and provide a petcock to bleed off air. Open pressure line, bleed off air and check for leaks with 50 psi pressure on line. If no leaks are noted, increase to 100 psi and check for leaks.

## Installation

1. Check all liner and block fits for burrs.
2. Install new seal rings over the liner.
3. Support liner and have ready to install.
4. Apply a seal ring in the upper groove and leave the other free over the air ports.
5. Apply surgical green soap to the upper seal ring and to the groove in the jacket.
6. Insert the liner into the cylinder block with the water outlet opening at the opposite governor side. Lower the liner so the groove in the jacket is below the upper deck of the cylinder block.
7. Reach in thru the air receivers and roll the ring into the groove in the jacket.
8. Lower the liner into place and tighten the liner to block stud nuts. The liner must not bind in the block fits. Refer to page 12 for torque limits.
9. Check the liner for out-of-roundness using a bore gage one inch down from the top of the liner and at the liner to block fits.

If the liner is over .003" out-of-round, one inch down from the top at assembly, check for burrs or chips on the block and liner pads. Also check for burrs on the block to liner fits. When the liner remains out-of-round after checking for burrs, etc., a .003 shim may be used under the liner pads for the following conditions.

a. The out-of-roundness is general on the engine and not on an individual cylinder.

b. The liner is elongated along the centerline of the engine. In shimming out-of-round liners, meeting conditions a and b above, use the following procedure.

- 1) Jack the liner up slightly.
- 2) Cut shims from .003" stock 3/16" wide and slightly longer than the holddown pads and cut to follow the liner contour.
- 3) Insert a single .003" shim next to the liner under each of the pads. A .003 shim will correct .005" out-of-roundness. Never use more than a single shim.
- 4) Pull liner down and tighten stud nuts.
- 5) Recheck liner dimension.

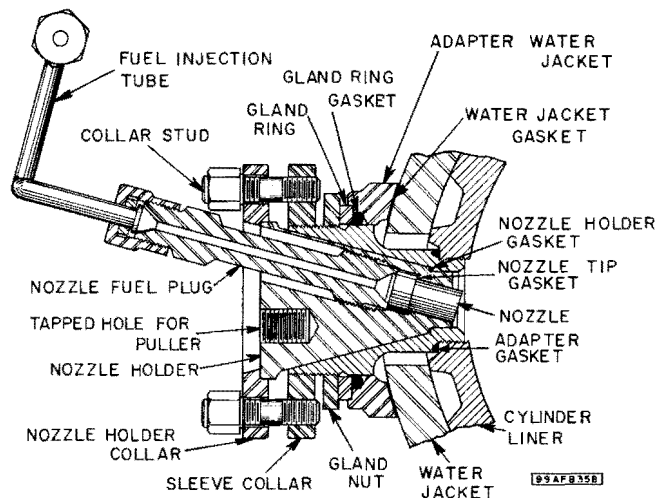
10. Replace the cylinder liner studs at the water inlet and outlet holes. Replace the outlet pipe and using new seal rings, replace the inlet fittings.

11. Replace the injection nozzle adapters, Illus. 35, as follows:

Lubricate the adapter threads with a small amount of graphite. Apply a light coating of grease (graphite grease preferred) to the adapter seat and install a new copper gasket with the beveled side mating 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. 34, screw the adapters securely into their proper locations in the liner.

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 "O" seal ring.

Screw the gland nuts on the adapters in place as far as possible by hand being careful that the water jackets are properly seated against the cylinder liner and



Illus. 35. Cylinder Liner Adapter

the gaskets are in place. With the gland nut inserting tool, Illus. 33, screw the gland nuts tightly in place until the rubber is slightly compressed; excessive tightening should be avoided. Retighten the glandnut after the water jacket gasket has positioned itself (approx. 15 min. after the first tightening).

Screw the adapter collars in place on the injection nozzle adapters.

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

12. Replace the injection nozzles. Refer to page 78 and 79.

13. Replace the pistons and connecting rods. Refer to page 31 and 35.

14. Replace the upper crankshaft. Refer to page 61.

15. Refill the cooling system and add water treatment.

## VERTICAL DRIVE

### Inspection

1. Check crankshaft timing as outlined on page 13 to determine if vertical drive coupling as used on other than 6 cylinder engines has slipped.

2. Inspect coupling springs (other than 6 cyl. engines).

### Servicing

Refer to Section 308, Chapters Fa or Fb for maintenance and backlash check procedures.

## TORSIONAL DAMPERS

Torsional dampers are mounted on the crankshafts at the exhaust end of the engine.

The 6, 8, and 10 cyl. engines have a damper on the

lower crankshaft. The 12 cyl. engines have a damper on the upper and lower crankshaft.

Refer to Sec. 308, Chapter E, for complete damper servicing procedures.

## SCAVENGE AIR BLOWER

### Inspection

1. Remove blower inspection covers and check condition of impellers. Oily impellers may indicate leakage of the oil retainer rings. Check internal tappet drain lines (when used) and crankcase oil separator before determining the oil retainer rings are the cause of the oil leakage.

2. Check impeller clearance. Refer to Sec. 308, Chapter K, for procedure and Chapter B for limits.

### Blower Removal

1. Remove the air filter and cover blower inlet.
2. Attach blower to suitable hoist.
3. Disconnect the drippan and remove the drip pan.
4. Remove the air receiver ducts (when used), crankcase oil separator tube, and oil lines.
5. Remove the dowels locating the blower.
6. Remove the top cover to blower capscrews and stud nuts holding the blower to the cylinder block.
7. Move the blower endwise to clear the drive gear.

Refer to Sec. 308, Chapter K, for complete servicing procedure of the blower and blower drive.

### Replacing the Blower

1. Use new .010" thick blower to block gasket. Do not use a thicker gasket.
2. Move blower endwise to engine meshing the drive pinion to the drive gear.
3. Install the blower to block stud nuts. Leave the studs loose.
4. Shift the blower and replace the dowels. Tighten

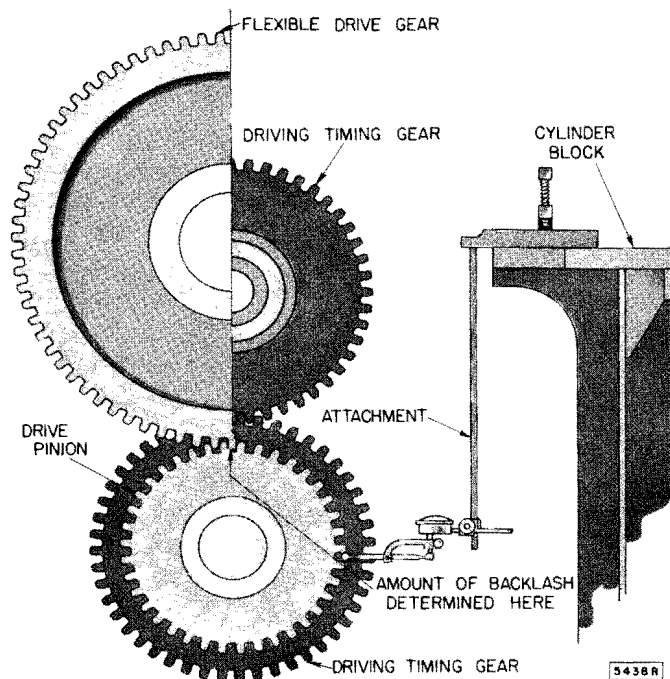
a few of the stud nuts.

5. Check the blower drive gear backlash as follows:

To properly check the backlash, the top cover must be removed.

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

Clamp a surface gage block with an indicator attachment to the top flange of one side of the cylinder



Illus. 36. Blower Drive Gear and Pinion Backlash Check

block, Illus. 36. Set the indicator attachment so that the ball point is in contact with a tooth of the blower drive pinion, 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.)

Move the driven timing gear until the teeth of the drive pinion contact the drive gear teeth.

Move 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.

When installing a new blower onto the cylinder block, always center the blower on the end of the block and make the backlash check as outlined previously.

The blower should be centered on the end of the cylinder block and a straightedge used to check the surfaces to which the air receiver ducts, when used, are to be attached. The overall width of these surfaces is more across at the cylinder block than across at the blower. This difference should be divided equally so that the ducts when used, will fit squarely. Raise or lower to meet requirements and locate with oversize dowels.

Use a level transversely across the top face of the cylinder block and the top face of the blower and line up the two horizontal surfaces so that they are parallel.

## INJECTION PUMPS

### Removal

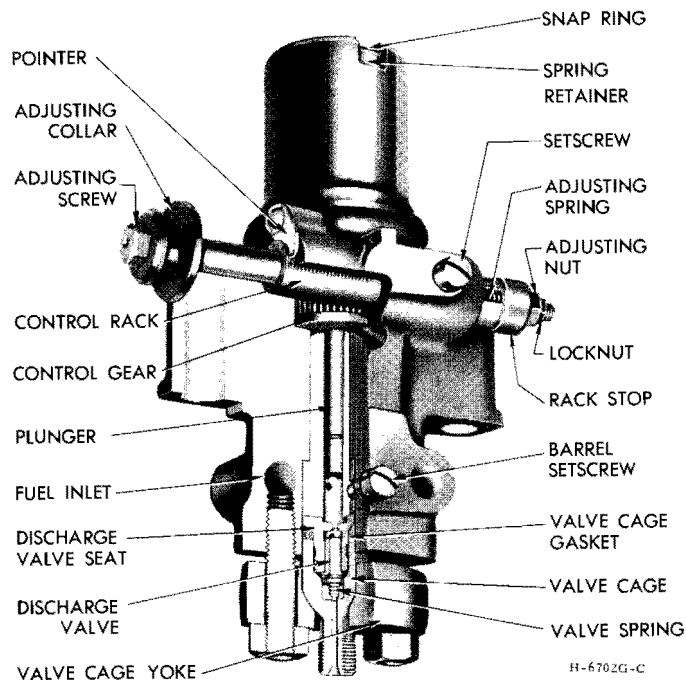
1. Disconnect the inlet and outlet fitting and disengage the control rod plunger.
2. Rotate the engine so tappet roller is on low cam to relieve the spring pressure.
3. Remove the nuts holding the pump to the tappet housing.

4. Remove the pump from the studs. Be careful not to loose the pump body shims.

#### Replacing

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

2. Replace the shims that were taken from the injection pump body and assemble the pump to the tappet



Illus. 37. Injection Pump

housing. Tighten the nuts evenly to 110-120 ft. lbs.

3. Check the pump vertical position with the plunger stroke gage.

4. Remove the injection tube, pump discharge valve cage yoke, cage, valve and spring. Leave the valve seat and the cage gasket in place, Illus. 37.

5. Insert the plunger 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.**

6. 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  $\pm .005$ ".

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 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 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.

7. Attach the fuel header to the back of the pump with the two capscrews. Tighten to 80-90 ft. lbs. torque. Be sure the gasket between the pump and the header is properly in place.

8. 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.

## TAPPET ASSEMBLY

### Removal

1. Remove the injection pump as outlined above.  
2. Bar the engine so that the cam for the tappet being removed is at low cam.

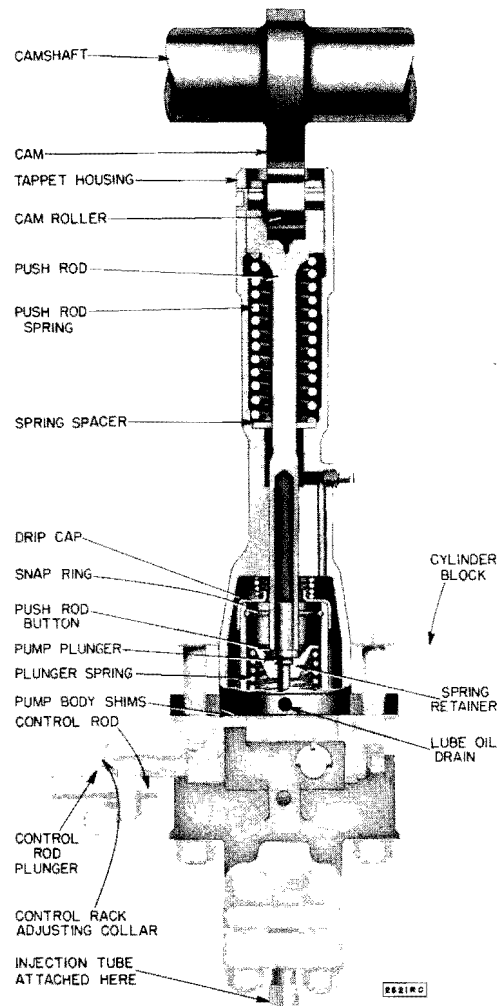
3. Disconnect the lubricating oil drain tube from the tappet housing and remove the drain tube connector by reaching thru the air receiver inspection openings (Internal drain type).

4. Remove one of the bolt nuts holding the tappet to the block. Loosen the other nut slowly which will remove the remaining spring tension in the tappet. Be sure the spring tension is entirely removed before removing the nut.

5. 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.

6. The roller assembly, push rod, spring and spacer are then removed as an assembly out of the tappet housing, Illus. 38.

7. Disassemble and wash parts in suitable commercial solvent, and dry. Inspect spring for cracks and roller and bushing for wear. Use new parts if necessary.

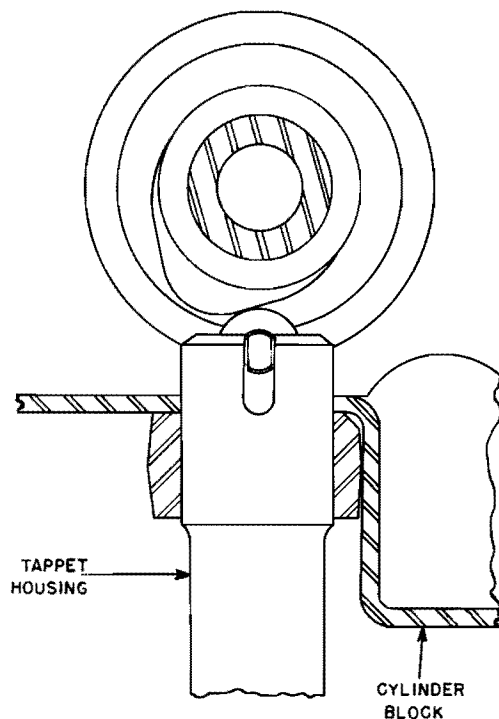


Illus. 38. Tappet Assembly  
Internal Drain Type

## Replacing

1. 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.

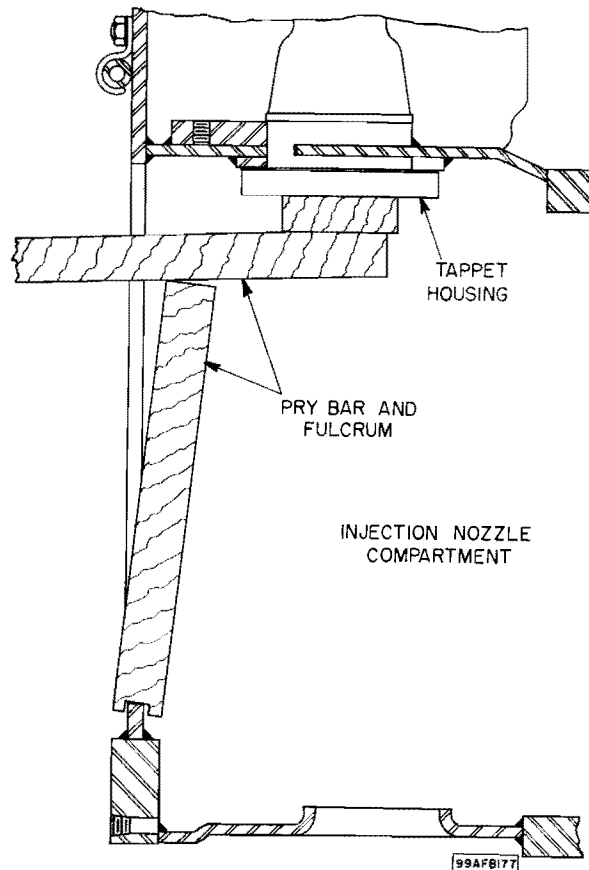
2. Insert the assembly, roller end up, thru the hole in the block. The camshaft should be positioned so that the cam is near but not completely to high cam as shown, Illus. 39.



Illus. 39. Positioning Camshaft

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 connections.

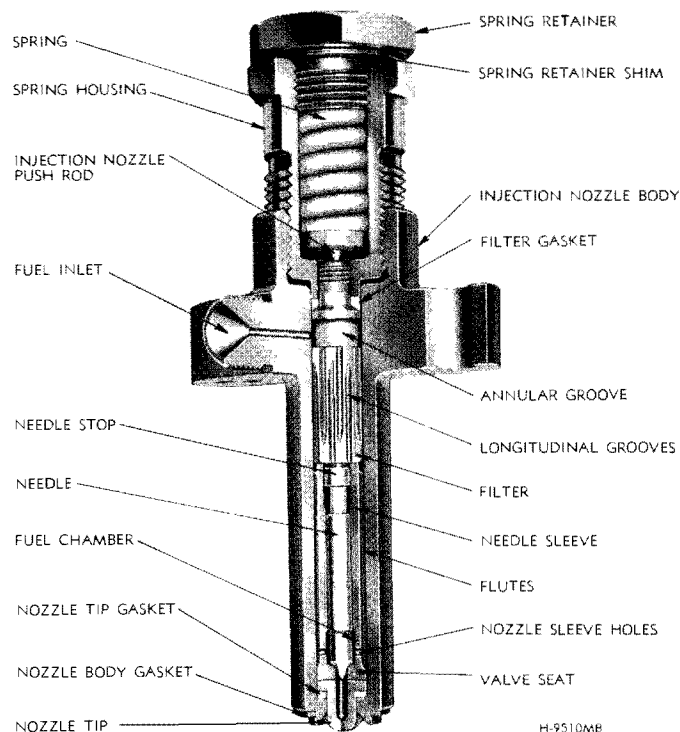
3. Raise the tappet assembly up so that the nuts can be started. Use a pry lever to complete the lift of the tappet assembly into place in the cylinder block. Be



Illus. 40. Installing Tappet Assembly

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. 40.

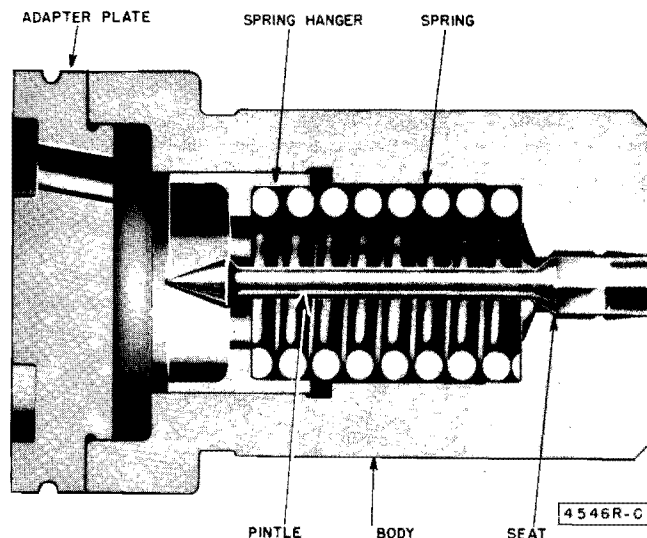


Illus. 41. Injection Nozzle - F.M. & Co.

4. 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.

5. 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. Tighten the nuts to 110-120 ft. lbs. torque.



Illus. 41. Injection Nozzle - Pintle Type



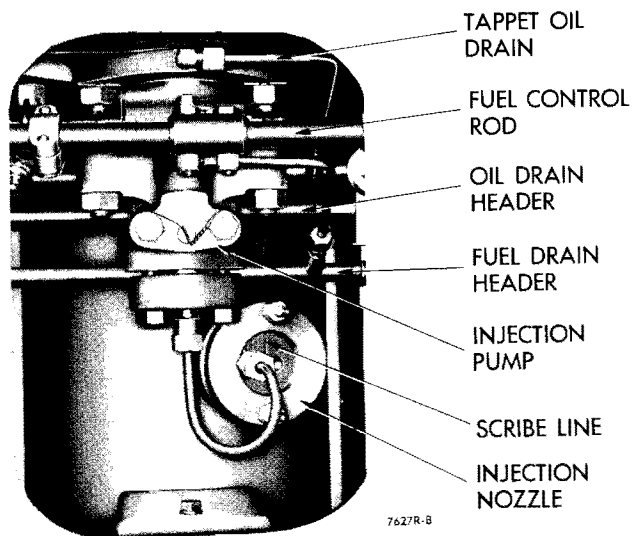
## INJECTION NOZZLE (F.M. & Co. Nozzle)

### Removal

1. Disconnect the injection tube, Illus. 41.
2. Remove the collar stud nuts.
3. Remove the nozzle from the adapter. Slight prying may be necessary to remove the nozzle.
4. Refer to Sec. 308, Chapter L, for complete testing and servicing procedures.

### Replacing

1. Use new body gasket.
2. Push nozzle into adapter. Flat must be horizontal and fuel inlet down.
3. Tighten collar stud nuts evenly to 35-40 ft. lbs. torque.
4. Install the fuel connections.



Illus. 43. Injection Nozzle Compartment - Pintle Type

## INJECTION NOZZLE (Pintle Type)

### Removal

1. Clean fuel connections before removing.
2. Remove the collar stud nuts, Illus. 42.
3. Remove nozzle holder and fuel plug using the puller tool.
4. Be careful not to damage the nozzle.
5. Refer to Sec. 308, Chapter L, for complete instructions for testing and repair of the nozzle.

### Replacing

1. Install collar over the fuel plug before installing the nozzle holder.
2. Fit the collar on the studs as the holder is inserted into the adapter.
3. Position the nozzle holder so the nozzle will spray to the right of the cylinder as viewed facing the engine.
4. The scribe line must be in a vertical position, Illus. 43.
5. Tighten the nozzle fuel plug to 40 ft. lbs. torque and collar stud nuts to 35-40 ft. lbs. torque. Hold the nozzle fuel plug with a wrench when tightening the fuel connection.

## WATER PUMP

### Removal

1. Remove piping connections at the pump.
2. Remove the pump from the mounting plate.
3. Refer to Sec. 308, Chapter Q, for procedure for replacing the shaft seal and servicing the pump.

### Replacing

1. Install pump to mounting plate.
2. Check backlash of drive gear. Refer to page 9 for limits.
3. Reconnect piping.

## LUBE OIL PUMP

### Removal

1. Disconnect piping.
2. Remove pump from mounting plate.
3. Refer to Sec. 308, Chapter P, for complete servicing outline for the various pumps.

### Replacing

1. Replace the pump on the mounting plate dowels.
2. Check alignment and free movement of drive before tightening nuts to 60-80 ft. lbs. torque.
3. Reconnect piping.

## FLEXIBLE PUMP DRIVE

Refer to Sec. 308, Chapter N, for servicing of the flexible pump drive.

## GOVERNORS

Refer to Sec. 308, Chapter Ma, Mb, Mc, or Md for outline on installation and adjustment of the governor.

## EXHAUST MANIFOLDS

### Installing

When installing the exhaust manifold and elbow or silencer, always use new gaskets on cleaned surfaces. Make the exhaust belt gaskets and select for uniform thickness.

1. 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.
2. 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.

3. Install the capscrews and tighten to pull the outlet flange to the cylinder block. Do not tighten securely.

4. Install the exhaust belt stud nuts on the No. 1 cylinder. Alternately tighten the capscrews and stud nuts to 80 to 100 ft. lbs. torque.

5. Replace and tighten the exhaust belt stud nuts on the remaining cylinders in order, starting at No. 2 cylinder.

6. 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.

7. Replace remaining parts.

8. Make a hydrostatic test 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 recon-

9. Refill the jacket water cooling system.

Refer to Maintenance Bulletin Sec. 206B for inspection and retightening program for an overhauled unit.

Refer to Section 308, Chapter S, for servicing outline on the exhaust belts.

## PREVENTIVE MAINTENANCE AND/OR TROUBLE SHOOTING

Lube Oil Strainer (Hoffman with Air Maze disc type elements)

All the lube oil supplied the engine passes thru the strainer mounted on the opposite governor side. It is imperative that the following procedure for cleaning the strainer be strictly adhered to, to prevent damage to the bearing shells.

1. Remove the strainer cover.
2. Remove the large nuts holding the elements in place.

3. Remove the elements. Plug the opening of the elements with clean tapered machined wooden plugs.

4. Handle the elements carefully. A long can enclosing the element is preferred when handling the elements.

5. Inspect the element for ruptured discs. If discs are found damaged, set the element in upright position with nut end up. Remove the nut and remove the discs as a unit down to the damaged disc. Remove the damaged disc and replace with new disc. Carefully replace remaining discs in order that dirt does not enter the discs. Reapply the nut.

6. Lay the element on a flat surface. Do not rest the elements on the edge of a tank. Be careful not to rupture the mesh.

7. Leave the plugs in place and submerge the element in an approved solvent. Clean the element with a soft narrow paint brush.

8. Blow the element dry with air. Replace the protecting jacket.

9. Drain the strainer housing and thoroughly clean of all sediment. Clean the inside of the cover.

10. Replace the elements in the housing. Screw the nuts tight. Tap the nuts lightly with a block of wood until the lock fits in place. Fill the housing with lube oil.

11. Wipe the inside of cover clean and apply. Be careful not to allow dirt, chips, etc. to enter the housing before the cover is applied as this dirt will go into the engine system when the engine is started.

#### Firing Pressure Test to Determine Cracked Pistons

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 injection system.

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 control 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 loud hissing noise.

8. The procedure is repeated for the other cylinders, checking each in turn.

#### Water Test

Proper procedure of water testing is most important as a preventive measure to eliminate water leaks after maintenance to the water system.

Water test instructions include the following points of inspection as well as specific procedures of application and repairs:

1. Blank off the engine system from the rest of the cooling system.
2. Apply proper water pressure - 50 psi in locomotive, 100 psi at engine overhaul out of locomotive. Be sure that air is bled from the system at the highest point possible (water header outlet).
3. Use water which is not warmer than room temperature.
4. Make a complete inspection of all points of possible water leaks. This, of course, involves the removal of the inspection covers on the air receiver, exhaust manifold and the lower crankcase.
5. Allow the pressure to stand on the engine system at least 15 minutes.

Points of Inspection	Inspection Location
Water jacket gaskets	In fuel pump compartment
Exhaust manifold to cylinder liner jumper line	In fuel pump compartment
Exhaust manifold to exhaust belt gasket	Through manifold inspection cover and between manifold and block
Adapter gaskets (copper)	Through injection nozzle openings viewing across to opposite wall of liner Through exhaust ports at the bottom of the liner
Liner jacket	At the air and exhaust ports

The external portion of the cooling system should be checked very closely for leaks with the engine running or a water test applied not to exceed 20 psi.

The proper procedure in the application of the exhaust manifold, water jacket adapter gaskets, and the

copper nozzle adapter gaskets would aid in giving longer trouble-free operation of the locomotives. An engine that loses its cooling water and becomes over-heated has without a doubt caused serious damage to all gaskets in its cooling system.

#### Air Receiver Cleaning

It has been found that monthly cleaning (wiping) of the air receiver will definitely reduce port carboning to a minimum. Air port carboning in most cases will be eliminated entirely and exhaust port carboning greatly reduced.

An engine with critical port carbon troubles can usually be cleared up by cleaning the air receiver thoroughly at regular monthly intervals. Once the air receiver is completely cleaned, wiping at monthly intervals will be sufficient.

It is very good practice to maintain this program on new engines or after the engine has been cleaned at an overhaul.

The practice of air receiver wiping for control of carbon conditions will aid in the reduction of cylinder and ring wear and increase the overall engine performance.

#### Lube Oil Pressure

The following is a list of thoughts regarding the engine lube oil system:

1. Adequate lube oil filtration and proper pressure and temperature control are essential for maximum bearing, piston ring, and cylinder liner life as well as proper piston cooling.

2. Realize that an internal oil leaking problem must be corrected in order to prevent heavy bearing wear, piston failures, etc.

3. Be sure that the strainers and the strainer housings are kept clean. The failure to clean the Hoffman strainer housing has been the direct cause in many cases of repeated lube oil failures. Lack of strainer maintenance has also been the direct cause of piston failures.

4. Cooler cleaning is very important. Be sure the cleaning is done properly. A dirty cooler restricts the oil flow to the engine increasing the pump discharge pressure so that the relief valve opens, by-passing oil to the subbase.

5. Do not assume that it is natural for engine oil pressure to be low due to engine age. Low oil pressure may possibly be the result of age but other causes such as internal leaks, worn bearings, dirty strainer, etc. are the usual causes of low oil pressure. Investigate and correct the contributing cause for low oil pressure.

6. Acknowledge the low oil pressure shut-down switch operation. Very seldom has it been found that faulty switch operation has been the cause of a shutdown. Serious engine failures will result from the failure to acknowledge "low oil pressure." The resetting of the shutdown point of a switch to a lower value, the increasing of the idle speed of an engine to keep the engine from shutting down because of low lube oil pressure will only bring disastrous results.

7. Examine the failed parts to determine the cause of failure. Where an oil condition is the cause, the correction can prevent repeated failures. A study of operational and work reports will also assist in this diagnosis.

8. Be sure the filter has been filled with lube oil after the elements have been changed out. Filling the filter before replacing the cover will prevent the lube system from not picking up the prime when the engine is started.

#### Pre-lubrication Before Starting

The engine should be pre-lubricated before starting under the following conditions.

- a. Locomotive placed in service.
- b. After replacement of main or crankpin bearings.
- c. Upper crankshaft has been installed.
- d. Engine has been out of service and extend time.
- e. After an oil change when system was drained.

To pre-lubricate the engine, connect a portable pump to the engine system. Remove the lower crankcase covers and top cover inspection covers to determine that oil has reached the main bearings and upper pistons.