BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

4-53 AND 6V-53 ENGINE

The blower drive gear is driven by the camshaft gear (4-53 engine) or the left-bank camshaft gear (6V-53 engine). The gear is keyed and pressed onto a shaft, which is supported in the blower drive support. This support, on a 4-53 engine, is attached to the rear end plate on the blower side of the engine (Fig. 1). On a 6V-53 engine, the blower drive support is mounted on the flywheel housing (Fig. 2).

Service the blower drive support on a 6V-53 engine as outlined in Section 2.7.1.1. The following procedures apply only to the 4-53 engine.

Remove and Install Blower Drive Shaft

1. Remove the air inlet housing from the blower (refer to Section 3.3).

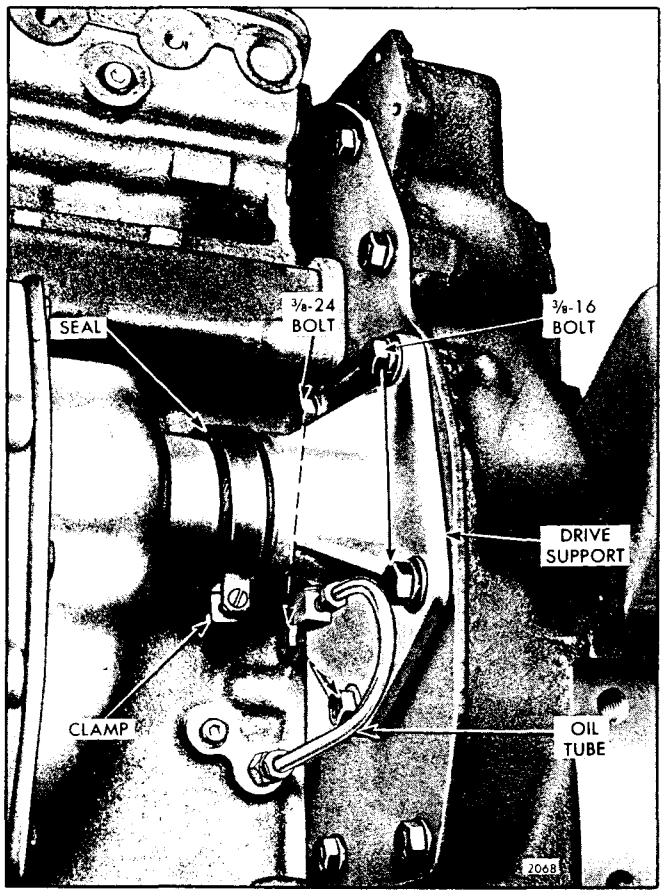


Fig. 1 - Blower Drive Support Mounting on 4-53 In-Line Engine

2. Refer to Fig. 1 and loosen the blower drive seal clamp.

3. Slide the clamp and seal off of the blower drive support.

4. Remove the four blower-to-block bolts. Then carefully lift the blower away from the blower drive support and the cylinder block so the serrations on the blower drive shaft are not damaged.

5. Withdraw the blower drive shaft from the blower drive support.

6. Install the shaft by reversing the removal procedures.

Remove Blower Drive Support Assembly

1. Remove the blower and the blower drive shaft as outlined above.

2. Disconnect the lubricating oil tube (Fig. 1) from the blower drive support.

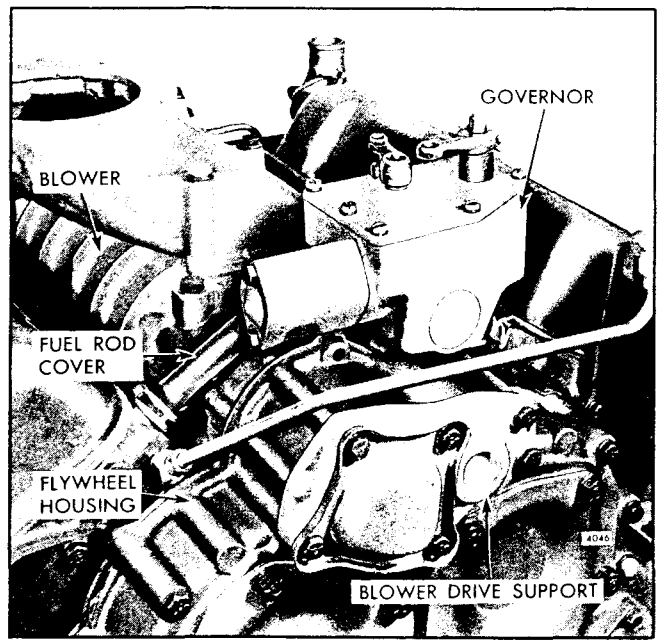


Fig. 2 - Blower Drive Support Mounting on 6V-53 Engine

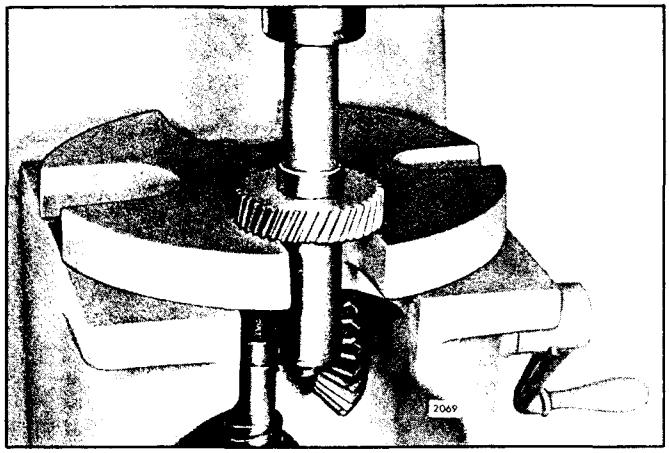


Fig. 3 - Pressing Blower Drive Gear From Shaft

3. Remove the blower drive support attaching bolts.

4. Tap the blower drive support to loosen it, then carefully withdraw the support from the rear end plate so the blower drive gear teeth will not be damaged.

Disassemble Blower Drive Support Assembly

1. Remove the snap ring and the thrust washer from the shaft.

2. If there are burrs on the edges of the snap ring groove, remove them with a stone. Then withdraw the gear and shaft from the support.

3. Support the blower drive gear in an arbor press (Fig. 3).

4. Place a short 1-1/8 " diameter brass rod on the end of the shaft and press the shaft out of the gear.

Inspection

Thoroughly clean the parts with fuel oil and dry them with compressed air.

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and the support should not be less than .0035 " (with new parts) or more than .007 " (with used parts).

Inspect the serrations on the blower drive shaft and, if worn so that excessive backlash is felt when the shaft is inserted into the blower drive gear shaft, install a new blower drive shaft.

Examine the blower drive support thrust washer for scoring and wear. Replace the thrust washer if necessary. The thickness of a new blower drive support thrust washer is .093 " to .103 ".

Inspect the gear teeth for evidence of scoring, pitting, burning and wear. If necessary, install a new gear.

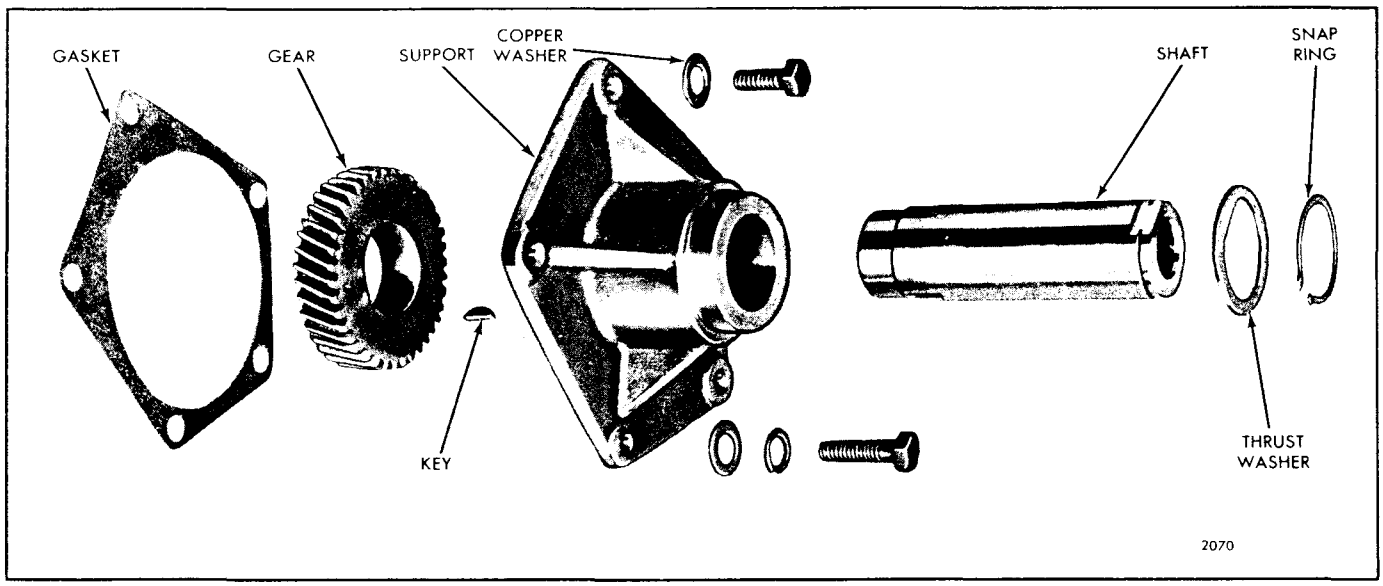


Fig. 4 - Blower Drive Gear and Support Assembly Details and Relative Location of Parts (In-Line Engine)

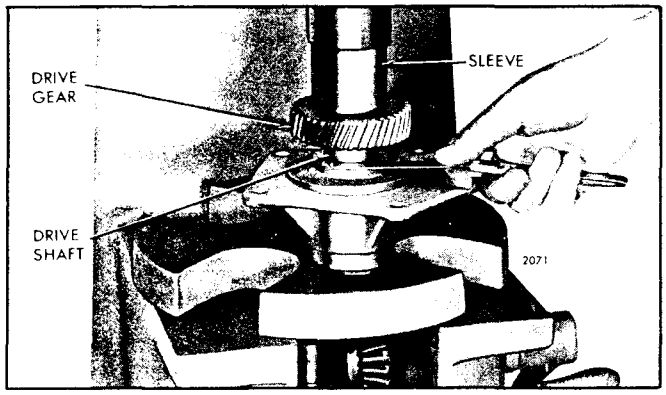


Fig. 5 - Pressing Blower Drive Gear On Shaft

Assemble Blower Drive Support Assembly

Refer to Fig. 4 for the relative position of the parts and assemble the blower drive support as follows:

1. Lubricate the blower drive gear shaft with clean engine oil and insert the shaft into the blower drive support.

2. Assemble the thrust washer and the snap ring on the shaft.

3. Install the key in the shaft, if it was removed.

4. Place the shaft and support in an arbor press.

5. Position the gear on the shaft so the keyway in the gear is in alignment with the key in the shaft. Then place a sleeve on the gear and press the gear on the shaft until the clearance between the gear and support is .004 " to .006 " (Fig. 5).

Install Blower Drive Support Assembly

1. Affix a new blower drive support gasket to the cylinder block rear end plate.

2. Install the blower drive support assembly by reversing the removal procedure.

3. Tighten the 3/8 "-24 support-to-end plate bolts (with copper washers) and the 3/8 "-16 support-to-flywheel housing bolts (with plain washers and lock washers) to 35 lb-ft torque.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

8V-53 ENGINE

The blower drive gear is driven by the right-bank camshaft gear. The drive gear is pressed onto a shaft which is supported in the blower drive support. The blower drive support assembly is attached to the blower rear end plate and the forward face of the cylinder block end plate.

The blower drive support bearing receives oil under pressure from the horizontal oil passage in the blower rear end plate which leads to the oil passage in the blower drive support.

Remove and Install Blower Drive Shaft

1. If an air compressor is attached to the rear right-hand face of the flywheel housing, disconnect and remove it from the flywheel housing.

2. Remove the five bolts and lock washers securing the blower drive hole cover to the flywheel housing. Remove the cover and gasket.

3. Remove the two bolts securing the blower drive shaft retainer to the blower drive coupling support, then remove the retainer.

4. Pull the blower drive shaft out of the blower drive hub and cam. If necessary, use a pair of small nose pliers.

5. Install the blower drive shaft by reversing the removal procedure.

Remove Blower Drive Support Assembly

1. Remove the blower, governor and drive support assembly from the engine as outlined under *Remove Blower* in Section 3.4.1.

2. Remove the six bolts, lock washers, plain washers and one socket head bolt securing the blower drive support to the blower rear end plate.

3. Tap each end of the blower drive support with a plastic hammer to loosen it from the gasket and dowel pins. Then remove the drive support assembly and gasket.

Disassemble Blower Drive Support

Refer to Figs. 6 and 7 and disassemble the blower drive support as follows:

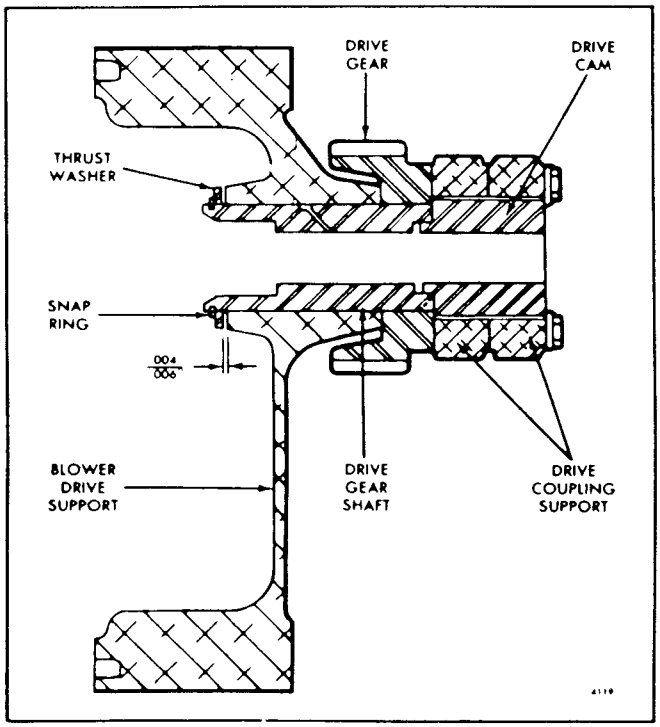


Fig. 6 - Blower Drive Support Assembly

1. Remove the thrust washer retaining snap ring from the blower drive gear shaft with a pair of snap ring pliers. Then remove the thrust washer from the shaft.

2. If there are any burrs on the edges of the snap ring groove, remove them with a fine stone. Then withdraw the drive gear and shaft from the support.

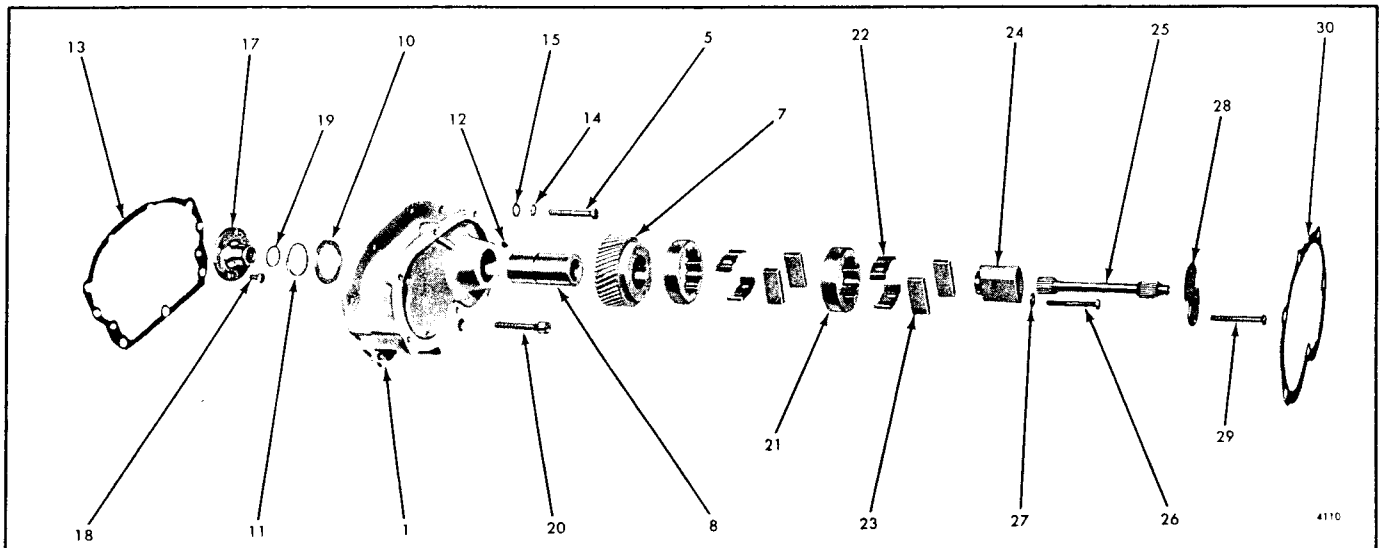
3. Support the blower drive gear and shaft, rear face of the gear up, on two wood blocks on the bed of an arbor press.

4. Place a short brass rod on the end of the shaft and press the drive gear shaft out of the gear. Catch the shaft by hand to prevent damage to the shaft.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air.

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and



1. Support--Blower Drive	12. Pipe Plug	19. Seal--Drive Hub Oil	26. Bolt--Drive Cam Retaining
5. Bolt--Drive Support	13. Gasket--Drive Support to Blower End Plate	20. Bolt--Drive Support to Blower	27. Plain Washer Retainer
7. Gear--Blower Drive	14. Lock Washer	21. Support--Blower Drive Spring	28. Retainer--Drive Shaft
8. Shaft--Drive Gear	15. Plain Washer	22. Seat--Drive Spring	29. Bolt--Drive Shaft
10. Washer--Thrust	17. Hub--Blower Drive	23. Spring--Blower Drive	30. Gasket--Drive Support to Cylinder Block End Plate
11. Snap Ring--Thrust Washer Retaining	18. Bolt--Drive Hub	24. Cam--Blower Drive	
		25. Shaft--Blower Drive	

Fig. 7 - Blower Drive Support Details and Relative Location of Parts (8V-53 Engine)

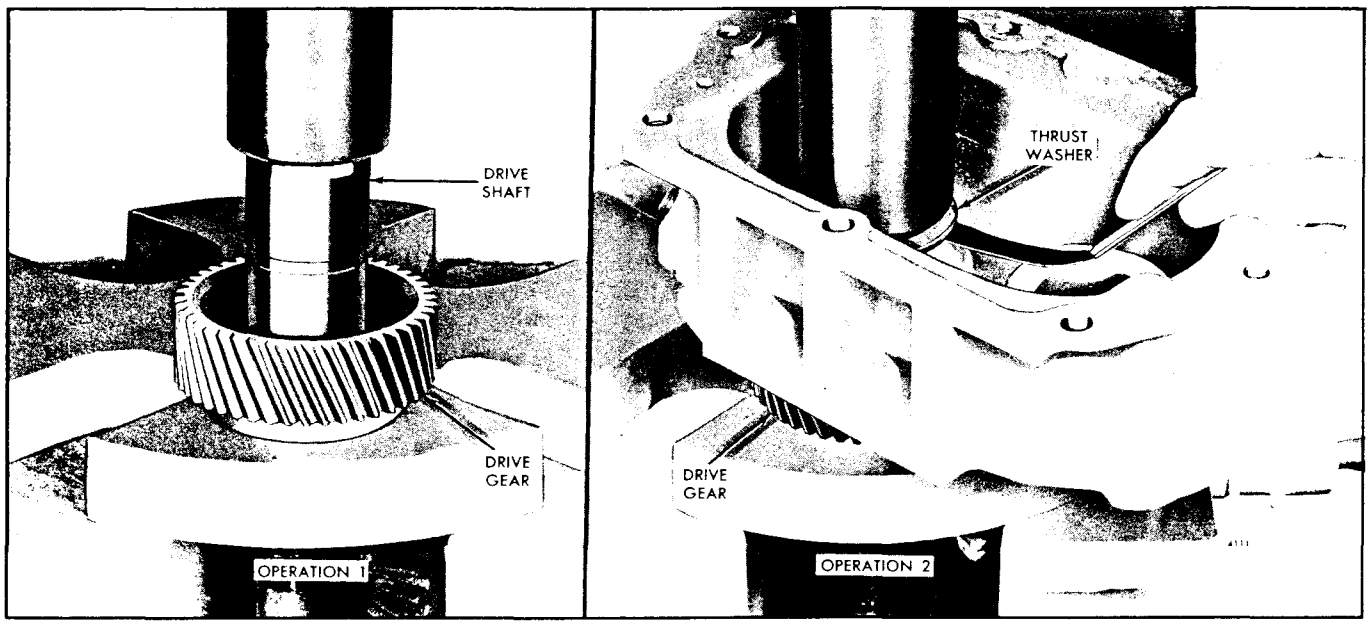


Fig. 8 - Installing Blower Drive Gear Shaft in Drive Gear

the support should not be less than .002 " (with new parts) or more than .007 " (with used parts).

Inspect the serrations on the blower drive shaft and, if worn so that excessive backlash is felt when the blower drive shaft is inserted into the blower drive cam and drive hub, install a new blower drive shaft.

Examine the blower drive support thrust washer for scoring and wear. Replace the thrust washer if necessary. The thickness of a new blower drive support thrust washer is .119 " to .121 ".

Inspect the gear teeth for evidence of scoring, pitting, burning and wear. If necessary, install a new gear.

Assemble Blower Drive Support Assembly

Refer to Figs. 6 and 7 for the relative position of the parts and assemble the blower drive support as follows:

1. Lubricate the drive gear end of the blower drive gear shaft with engine oil. Then start the shaft straight into the shaft bore in the drive gear from the recessed side.

2. Place the blower drive gear and shaft on the bed of an arbor press as shown in Fig. 8, Operation 1. Then press the shaft straight into the drive gear approximately one half inch.

3. Lubricate the blower drive gear shaft with engine oil. Then insert the shaft into the shaft bore in the support.

4. Place the thrust washer, oil groove side facing the support, on the blower drive gear shaft. Then install the snap ring in the groove in the shaft.

5. Support the blower drive gear, shaft and support on the bed of an arbor press as shown in Fig. 8, Operation 2. Then press the drive gear shaft into the drive gear until the clearance between the thrust washer and the support is .004 "-.006 " (Fig. 6).

Install Blower Drive Support Assembly

1. Affix a new blower drive support gasket to the forward face of the support.

2. Place the blower drive support assembly over the two dowel pins in the blower rear end plate and against the gasket.

3. Install the six bolts, lock washers, plain washers and one socket head bolt. Tighten the bolts to 20-24 lb-ft torque.

4. Install the blower, governor and drive support assembly on the engine as outlined under *Install Blower* in Section 3.4.1.

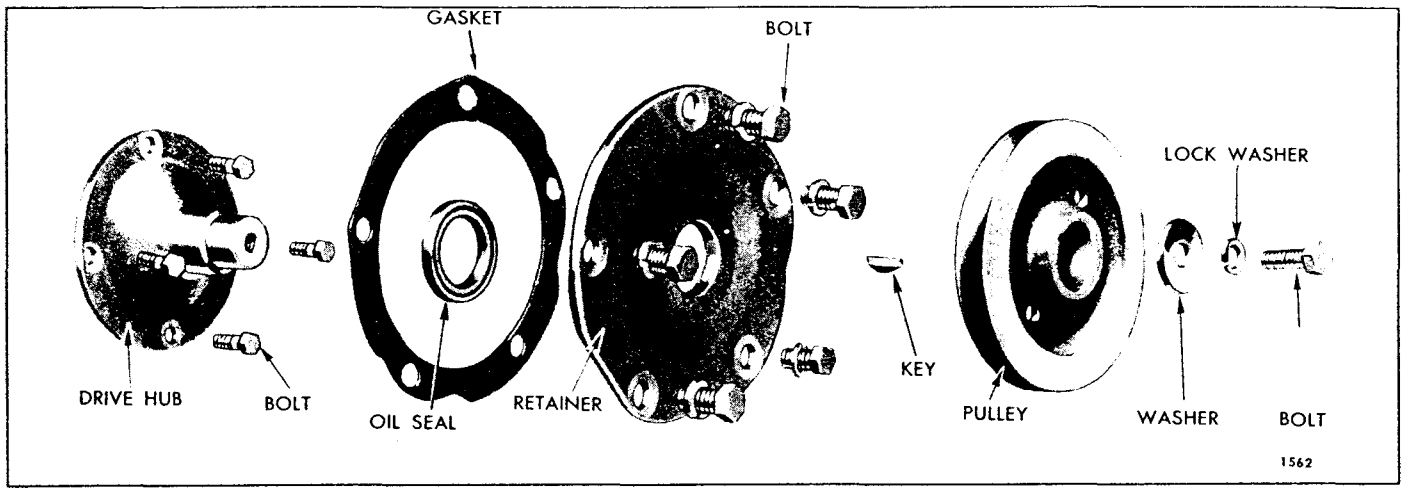


Fig. 4 – Components of Accessory Drive for Belt-Driven Accessory (Drive Hub Type)

2. Remove the five bolts and lock washers attaching the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing.

3. Remove the drive coupling.

4 Remove the drive hub from the accessory shaft, if necessary.

5. Place a clean, lintless cloth in the flywheel housing opening, underneath the accessory drive plate, to prevent bolts from accidentally falling into the gear train. Remove the lock wires, if used. Then remove the four bolts (and lock washers, if used) and remove the accessory, the drive plate and the spacer, if used.

Remove the drive assembly for a belt-driven type accessory as follows:

1. Remove any external piping or connections to the accessory.

2. Loosen the accessory and slide it toward the drive pulley. Then remove the drive belt and accessory.

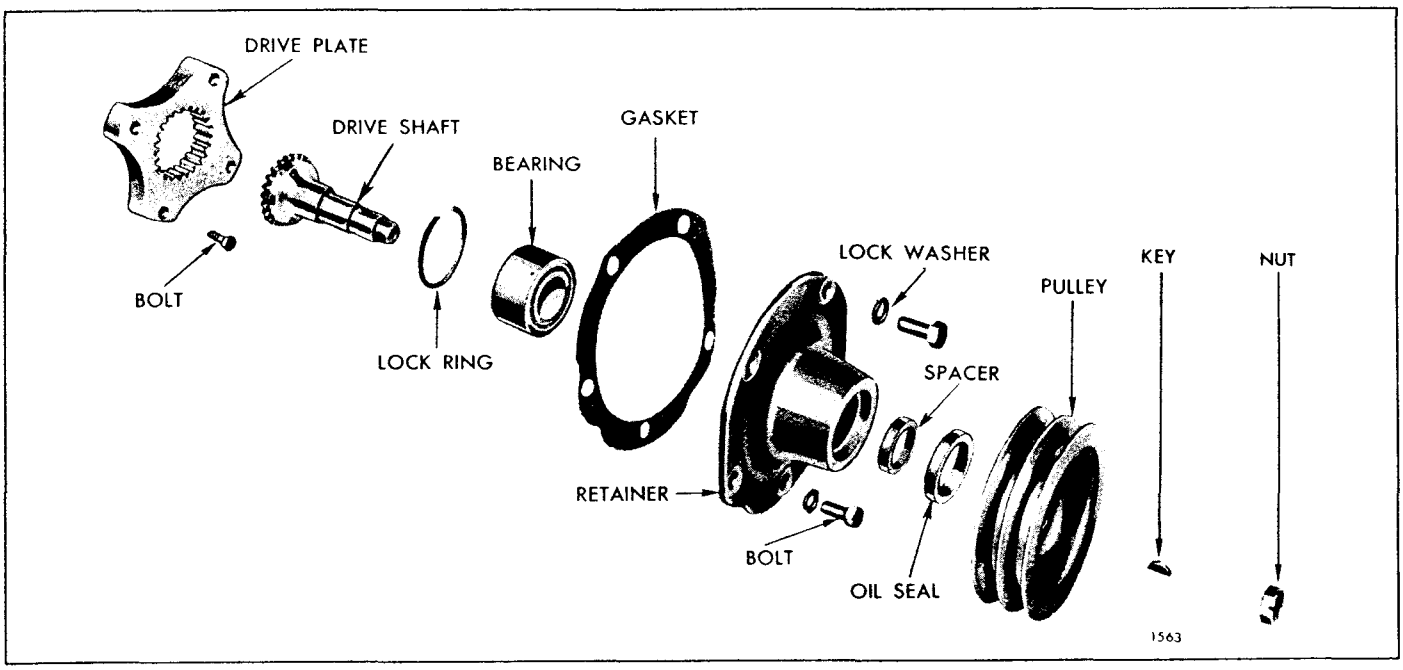


Fig. 5 – Components of Accessory Drive for Belt-Driven Accessory (Drive Plate Type)

ACCESSORY DRIVES

Accessory drives have been provided at the rear of the engines to accommodate both gear–driven and belt–driven accessories.

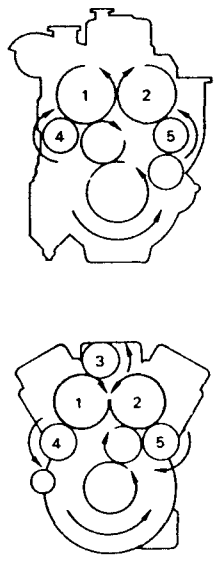
For the possible accessory drive locations and rotation of the drive at a particular position, refer to Fig. 1.

The drive for direct gear–driven accessories, such as air compressors or hydraulic pumps, consists of a drive hub, coupling and drive plate (Fig. 2) or a spacer, drive plate, drive coupling and hub (Fig. 3).

On certain 4–53 engines, the spacer has been eliminated and a drive coupling 1.940" long and a drive disc .560" wide is used.

The drive plate and spacer, when used, are bolted to the camshaft or balance shaft gear. The accessory is bolted to the flywheel housing and driven by a drive hub keyed to the accessory shaft and splined to the coupling which is splined to the drive plate attached to the camshaft or balance shaft gear. The current drive coupling, shown in Fig. 3, has 21 external teeth; the former coupling had 23 external teeth.

Belt–driven accessories, such as battery–charging generators or air compressors, are driven off the camshaft or balance shaft gears by a drive hub and pulley (Fig. 4), or a spacer, accessory drive plate, accessory drive shaft, accessory drive retainer assembly and pulley (Fig. 5).



ACCESSORY DRIVE POSITION	DRIVE RATIO
INLINE ENGINE	
1	1:1
2	1:1
4 BLOWER GOV.	2.47:1
	1.98:1
5 BLOWER GOV.	2.47:1
	1.98:1
V-ENGINE	
1	1:1
2	1:1
3	*2.47:1
4	1.98:1
5	1.98:1
*2.20:1 ON 8V ENGINE	

L – 5325

Fig. 1 – Accessory Drive Locations

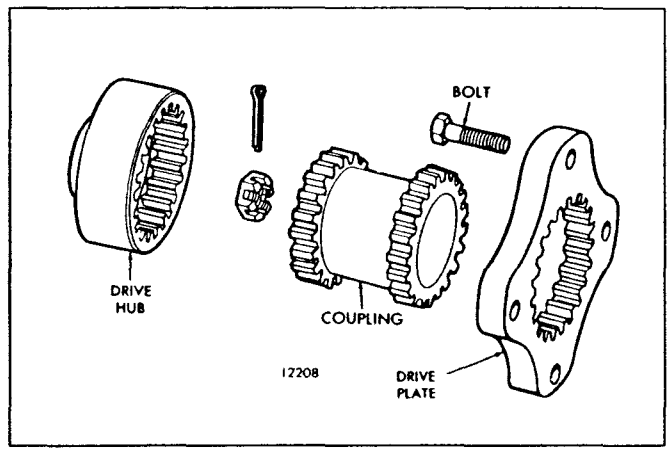


Fig. 2 – Air Compressor Drive

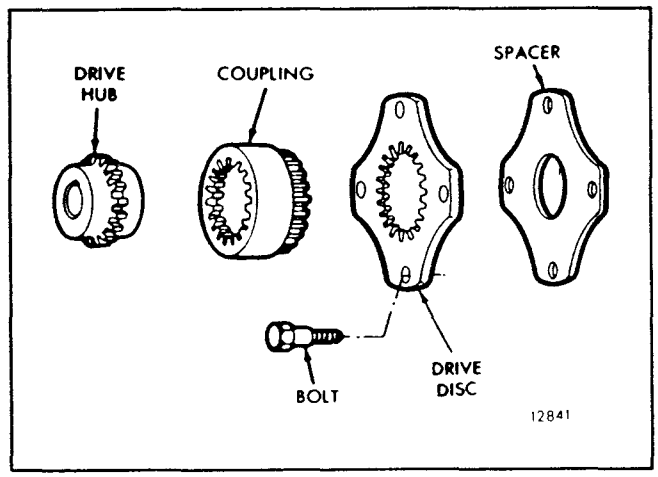


Fig. 3 – Hydraulic Pump Drive

In the first arrangement, illustrated in Fig. 4, the drive hub is bolted to the camshaft or balance shaft gear. The oil seal retainer is bolted to the flywheel housing and the pulley is keyed to the drive hub shaft which extends through the oil seal retainer.

In the second arrangement, shown in Fig. 5, the spacer and accessory drive plate are bolted to the camshaft or balance shaft gear. The accessory drive shaft is splined to the drive plate at one end and supported by a bearing in the accessory drive retainer at the other end. The accessory drive retainer, which also incorporates an oil seal, is bolted to the flywheel housing. The pulley is keyed to the drive shaft which extends through the drive retainer assembly.

Remove Accessory Drive

Remove the direct gear–driven type accessory drive as follows:

1. Remove any external piping or connections to the accessory.

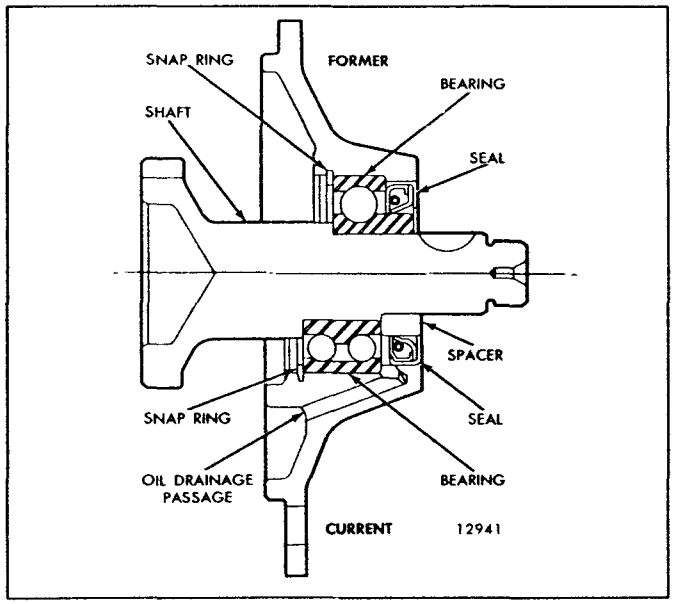


Fig. 6 – Former and Current Drive Plate Type Accessory Drive

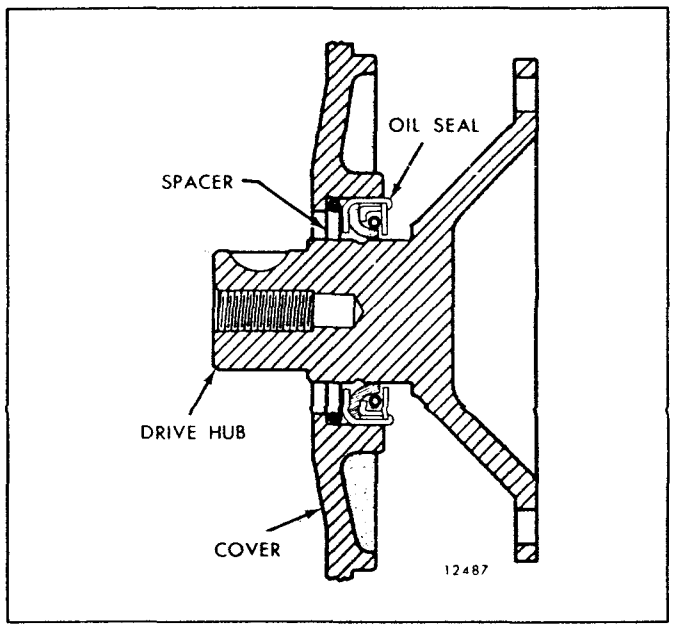


Fig. 7 – Location of Oil Seal Spacer

3. Remove the bolt and washer (Fig. 4), or nut (Fig. 5), retaining the pulley on the drive shaft.

4 Use a suitable gear puller to remove the pulley from the drive shaft. Remove the Woodruff key.

5. Remove the five bolts and lock washers which attach the drive retainer assembly to the flywheel housing. Remove the retainer assembly.

6. Remove the accessory drive shaft, drive plate and spacer (Fig. 5), or drive hub (Fig. 4), in a manner similar to that outlined in Step 5 under removal of the direct gear–driven type accessory drive.

7. Remove the snap ring and ball bearing from the accessory drive shaft retainer assembly shown in Fig. 5.

Inspection

Clean the accessory drive parts with clean fuel oil and dry them with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Examine the gear teeth of the drive shaft, drive coupling, drive hub or drive plate for wear. If worn excessively, replace them with new parts.

Inspect the ball bearing used to support the accessory drive shaft shown in Fig. 5. Wash the bearing in clean fuel oil and dry it with compressed air.

- **CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.**

Shielded bearings must not be washed; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Wipe the outside of the bearing clean, then hold the inner race and revolve the outer race slowly by hand. If the bearing is worn or does not roll freely, replace the bearing. Inspect the accessory drive hub, shown in Fig. 4, for grooving at the area of contact with the lip of the oil seal. If the hub is grooved to a point where the effectiveness of the oil seal is lost, a ring type oil seal spacer is available which serves to reposition the seal, thus providing a new sealing surface for the lip of the seal (Fig. 7).

Install Accessory Drive

1. Remove old gasket material from the flywheel housing. Use care so that no gasket material falls into the gear train compartment.

2. Insert a clean, lintless cloth in the flywheel housing opening to prevent bolts from accidentally falling in the gear train. Align the bolt holes in the accessory drive plate and spacer (if used), or the accessory drive hub, with the tapped holes in the camshaft or balance shaft gear. Then secure the plate and spacer, or drive hub, with four bolts (and lock washers or lock wire, if used). Remove the cloth from the flywheel housing opening.

3. If a gear–driven accessory is used as shown in Figs. 2 and 3, install the accessory drive coupling. When replacing the drive hub on the accessory shaft, drive

the hub squarely on the shaft (refer to Section 12.4). Then proceed as follows:

a. Place a new gasket on the flange and align the holes in the gasket with the bolt holes in the flange. Use a light coat of grease to retain the gasket in position.

b. Place the accessory in position against the flywheel housing, rotating it, if necessary, to align the teeth of the accessory hub with those in the drive coupling. Secure the accessory to the flywheel housing with five bolts and lock washers.

4. If the accessory drive shown in Figs. 5 or 6 is used, assemble as follows:

a. Install the accessory drive plate and spacer as outlined in Steps 1 and 2 above.

b. Place the drive shaft retainer on the bed of an arbor press, with the mounting flange side up. Press the double–row ball bearing straight in until the bearing contacts the shoulder in the bore of the retainer. Install the snap ring.

On former accessory drives (Fig. 6), install the bearing with the protruding face of the inner race towards the retainer.

c. Turn the retainer over and press the oil seal into the bore of the retainer with the lip of the seal toward the bearing.

d. Turn the retainer over again, bearing side up, and press the accessory drive shaft in the bearing until the shoulder on the shaft contacts the bearing.

e. Apply a light coat of grease to the mounting flange of the retainer and place a new gasket in position against the flange. Align the holes in the gasket with the bolt holes in the flange.

f. Place the retainer and drive shaft assembly against the flywheel housing, rotating the shaft slightly, if necessary, to permit the teeth of the drive shaft to mesh with the teeth in the drive plate. Secure the retainer assembly to the flywheel housing with five bolts and lock washers.

g. On current accessory drives, install the spacer over the shaft and against the bearing.

h. Install the Woodruff key in the drive shaft. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.

i. Thread the 3/4"–16 pulley retaining nut on the end of the drive shaft and tighten it to 120–140 lb–ft (163–190 N·m) torque.

j. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.

When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

5. Assemble the accessory drive shown in Fig. 4 as follows:

a. Press a new oil seal in the oil seal retainer, if the seal was removed.

b. Coat the mounting flange of the retainer lightly with grease and place a new gasket against the flange. Align the holes in the gasket with the bolt holes in the flange.

c. With the accessory drive hub in place (see Step 2 above), slip the retainer and oil seal assembly over the end of the shaft. Use care not to damage the oil seal. Secure the retainer to the flywheel housing with five bolts and lock washers.

d. Install the Woodruff key. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.

e. Install the washers and the pulley retaining bolt and draw the bolt up tight.

f. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.

When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

ENGINE FRONT COVER (Upper)

In-Line and 6V Engines

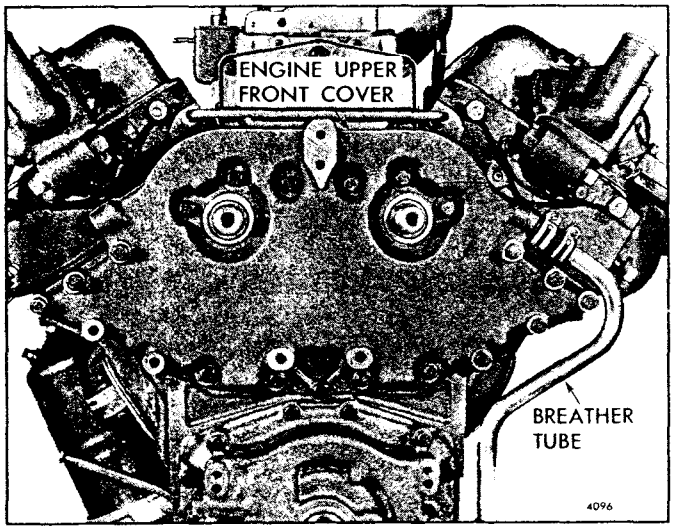


Fig. 1 – 6V Engine Upper Front Cover Mounting

The upper engine front cover is mounted against the cylinder block at the upper front end of the engine. On a 6V engine, the crankcase is ventilated through a breather tube connected to the cover (Fig. 1). The camshaft and balance shaft oil seals (In-line engine) or camshaft oil seals (6V engine) are pressed into the cover.

• To reduce operating noise levels, the upper front covers on 3, 4, and 6V-53 turbocharged industrial engines have been changed, effective with unit serial numbers 3D0197864, 4D0211728, and 6D0231643. On 3 and 4-53T units a new cast iron upper front cover with strategically placed cast-in ribs has replaced the former aluminum cover. On 6V-53T engines the current cast iron covers have been revised by the addition of cast-in ribs on their inside walls. The ribs make the covers less prone to vibration. Interchangeability is not affected, and only the new 3 and 4-53T cover and the revised 6V-53T cover will be available to service Series 53 turbocharged industrial engines.

Remove Cover

When necessary, the oil seals may be removed without removing the upper front cover. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars. Install the new seals with installer J 9790.

If necessary, remove the engine cover as follows:

1. Remove the various parts and subassemblies from the engine as outlined in their respective sections of this manual.
2. Remove the pulleys from the front end of the camshaft and balance shaft (In-line engine) or the camshafts (6V engine). Refer to Section 1.7.2.
3. Remove the upper front cover-to-cylinder block attaching bolts.
4. Tap the cover and dowel pin assembly away from the cylinder block.
5. Remove the Woodruff keys and oil seal spacers from the shafts.
6. Remove all traces of the old gasket material from the cylinder block and cover.

Inspection

Check the oil seals and the spacers for wear or damage. Replace them if necessary.

On a 6V engine, remove, clean and reinstall the wire mesh pad (element) in the upper front cover.

Remove Oil Seals

1. Support the inner face of the cover on wood blocks at least one inch thick to protect the dowel pins in the cover.
2. Drive the oil seals out of the cover.

Install Oil Seals

1. Support the inner face of the cover on wood blocks.
2. If the outside diameter of the oil seal is not pre-coated with sealant, coat the bore in the cover with non-hardening sealant.

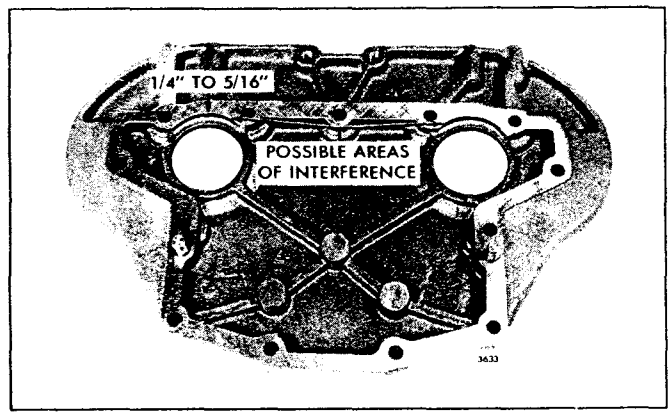


Fig. 2 – In-Line Engine Upper Front Cover

3. Position a new oil seal in the cover with the lip of the seal pointing toward the inner face of the cover. Keep the lip of the oil seal clean and free from scratches.
4. Press the seal into the cover with installer J 9790 until the seal is flush with the bottom of the counterbore.
5. Install the second oil seal in the same manner.
6. Remove excess sealant from the cover and the seals.

Install Cover

1. Affix a new gasket to the cover.
2. Install the cover on the engine and secure it with bolts and lock washers. Tighten the bolts to 35 lb–ft (47 N·m) torque.
3. Apply cup grease to the outside diameter of the oil seal spacers, then slide them on the shafts.

Current engines use an oil slinger between the oil seal spacer and the shoulder on the camshaft and between the spacer and the end bearing on the balance shaft (In–line engine). Addition of the oil slinger improves sealing by reducing the amount of oil in the area of the oil seals.

If oil slingers are installed on in–line engines built prior to serial numbers 2D–9278, 3D–573 and 4D–944, check the distance from the holes to the gasket flange (Fig. 2). If necessary, machine or grind the cover to provide sufficient clearance for the slingers.

4. Install a Woodruff key in each shaft.
5. Install the pulleys on the shafts.
6. Install and tighten the pulley retaining nuts to 300–325 lb–ft (407–441 N·m) torque.

SHOP NOTES - TROUBLESHOOTING - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

CHECKING BEARING CLEARANCES

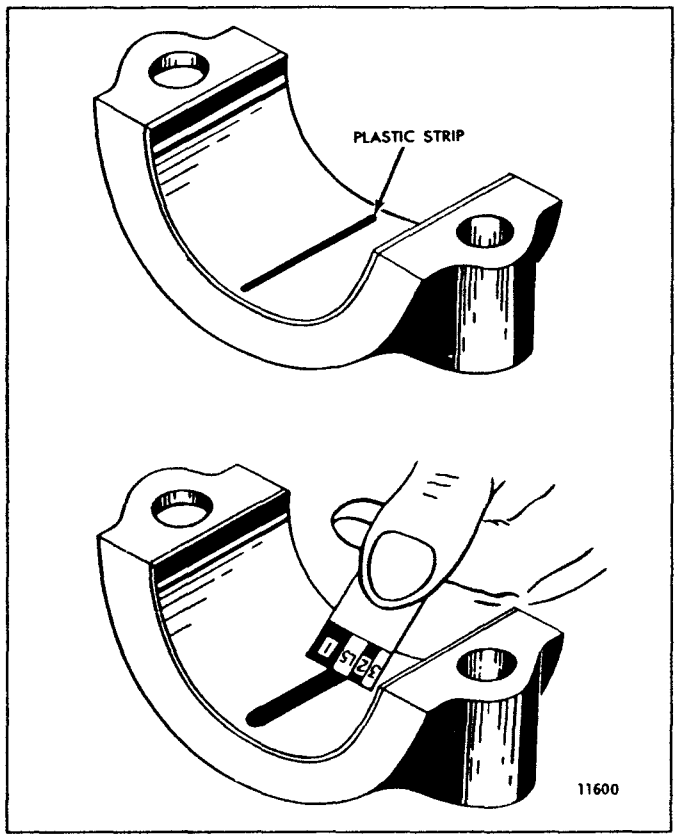


Fig. 1 - Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of .001" to .003", type PR-1 (red) has a range of .002" to .006" and type PB-1 (blue) has a range of .004" to .009".

The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and the crankshaft journal.

   When checking the main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading, due to the weight of the crankshaft and flywheel, can be eliminated by supporting the weight of the crankshaft with a jack under the counterweight adjoining the bearing being checked.

2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 1).

3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

4. Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.

5. Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope (Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

IN-FRAME OVERHAUL

Polyethylene plastic plugs (J 34697) help prevent solvent and debris from entering the crankcase while cleaning the airbox during in-frame overhaul or cylinder kit replacement.

CAMSHAFT CUP PLUG INSTALLATION

When an oil leak occurs at the drive plug area in the front end of the camshaft, install a cup plug in the end of the camshaft rather than removing and replacing the drive plug. It is not necessary to remove the camshaft from the engine when installing the cup plug.

Install the cup plug as follows:

1. Clean the hole in the front end of the camshaft and apply Permatex No. 1 sealant, or equivalent, to the outer diameter of the cup plug.
2. Install the plug to a depth of .180"–.210" with tool J 24094.

CYLINDER BLOCK LINE BORING

To line bore the main bearing bores, install the main bearing caps in the block and torque the bolts with their hardened washers to 120–130 lb–ft (163–177 N·m). The main bearing cap bolts are specially designed and must not be replaced by ordinary bolts. There should be a minimum of .0002" (In–line) or .0003" (V–engine) interference fit between the main bearing block saddle and the main bearing caps. If not, the cap must be replaced.

The tolerences shown below must be maintained during the reboring operation. If tolerances are not held, severe gear train damage may occur during engine operation.

1. All bores must be concentric within .001" TIR. If the bore cannot be held to .001" TIR, the block must be scrapped.
2. The surfaces from which all critical dimensions are measured for line boring are the dowel locating holes (.6245"–.6255" in diameter) at each end of the right pan rail, looking from the gear train end of the cylinder block. The crankshaft centerline is 4.239" to 4.241" in from the centerline of the dowel locating holes and 4.5985" to 4.6015" up from the pan rail surface.
3. Bore diameters for standard and oversized main bearing shells are shown in the following table:

Main Bearing	Main Bearing Bore Diameter
Standard (InLine 53)	3.251" - 3.252"
Standard (V-53)	3.751" - 3.752"
.010" Oversize (InLine 53)	3.261" - 3.262"
.010" Oversize (V-53)	3.761" - 3.762"
.020" Oversize (InLine 53)	3.271" - 3.272"
.020" Oversize (V-53)	3.771" - 3.772"

TABLE 1

4. The straightness of the finished bore must not vary more than .001" from end to end in the cylinder block.
5. After boring the block, stamp all main bearing caps to show they have been bored oversize and the amount (.010" or .020").

After installing oversize O.D. main bearing shells, always check bearing clearances before putting the engine back in service. Use the procedure found in this section.

• WELDING ENGINE CYLINDER HEADS

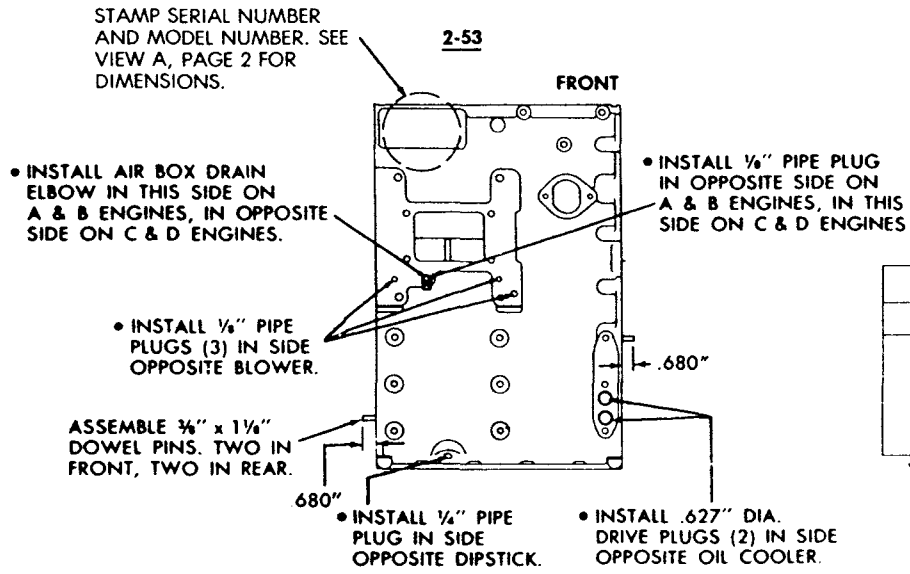
The welding of series 53 cylinder heads is not recommended. The welding of cylinder heads has been used as a salvage procedure for several years. As a salvage procedure, the resultant product has not been considered as good as a new casting.

REUSING CROSSHEAD PISTON ASSEMBLY COMPONENTS

Components of the piston assemblies can, in certain instances, be reused. Undamaged piston pins, crowns and bushings that meet dimensional limits for used parts can be reused if installed within the same piston assembly from which they were removed.

The crown, pin and bushing of a crosshead piston assembly should be considered as matched. If a crown is replaced, the piston pin and bushing must also be replaced. The reason for this is that the bushing takes the shape of the saddle area of the piston dome during engine operation. Installing a used bushing in a new crown can result in uneven piston pin loading and possible piston pin damage. If a bushing needs replacement, a new pin must also be used. Conversely, if a new pin is required, the bushing must also be replaced. Before reusing any crosshead piston assembly components, see wear limits in this Section.

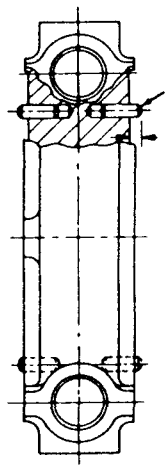
CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)



STANDARD PIPE PLUG TORQUE*		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

*CAUTION — Do Not Over Torque Teflon Wrapped Pipe Plugs.

CUTAWAY VIEW OF REAR MAIN BEARING CAP



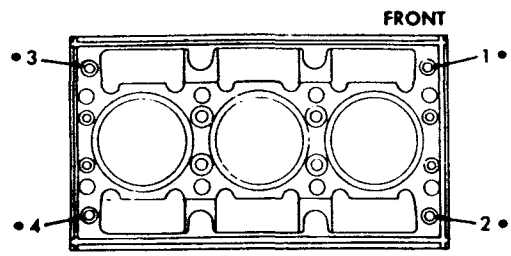
NOTES

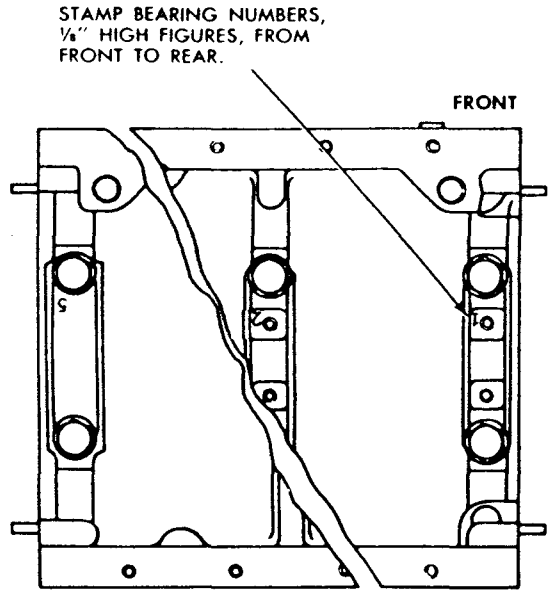
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

• **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**

• **TOP SURFACE PLUGGING INSTRUCTIONS 7/16" SPECIAL CUP PLUG**

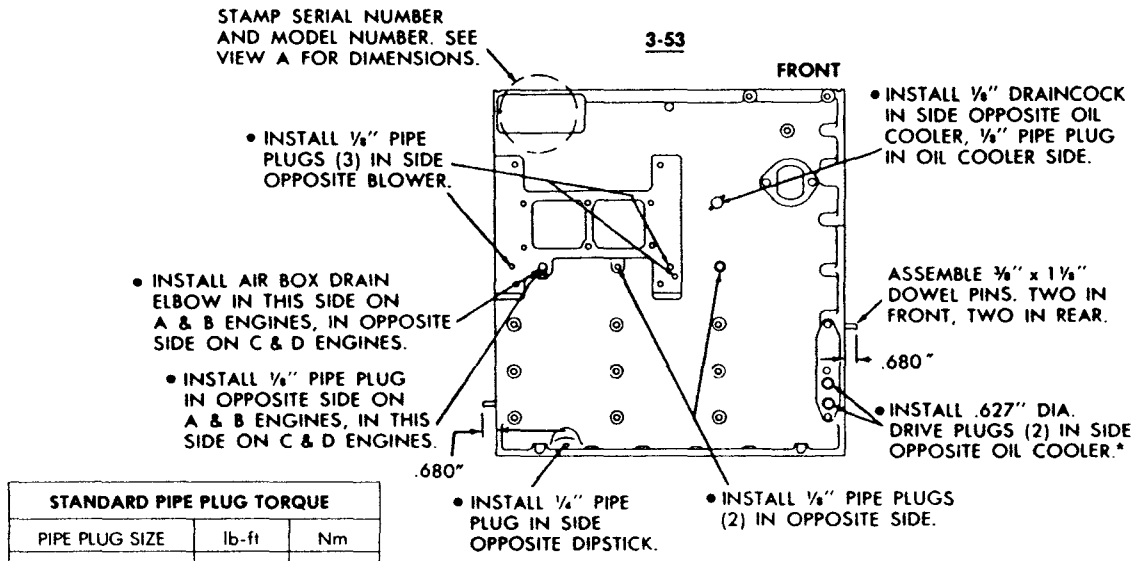
	HOLES PLUGGED			
2-53	1	2	3	4
RA,RD		X	X	X
RB,RC	X	X	X	
3-53, 4-53				
RA,LA,RD,LD		X		X
RB,LB,RC,LC	X		X	





REV. 9-77

CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)

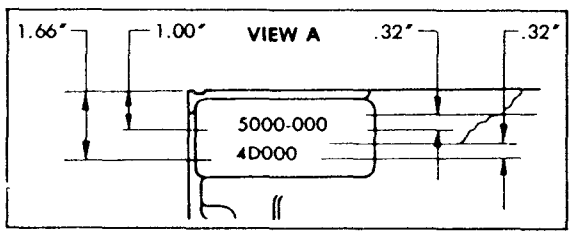


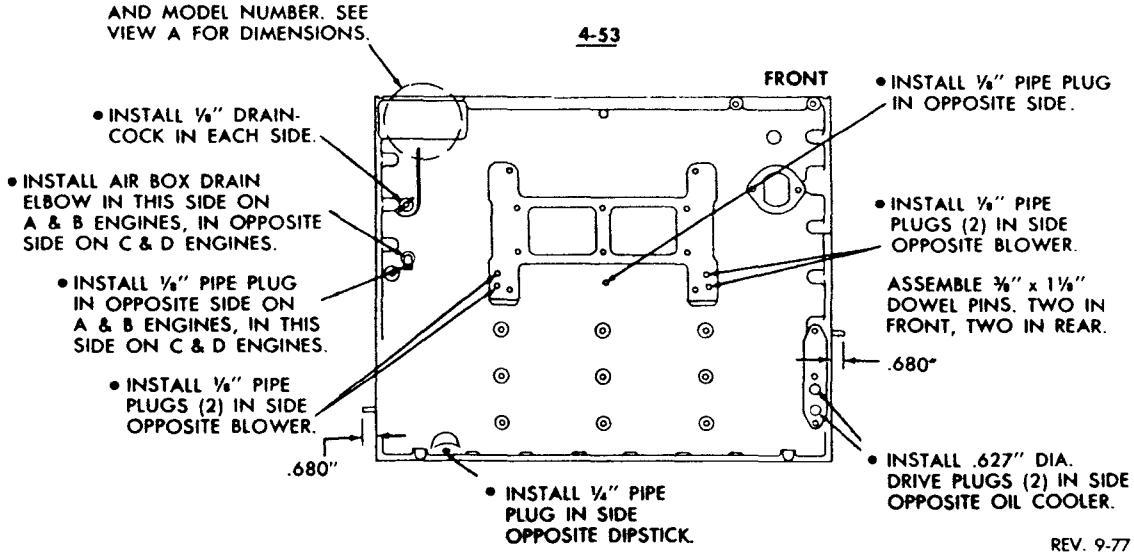
STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

- **APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.**

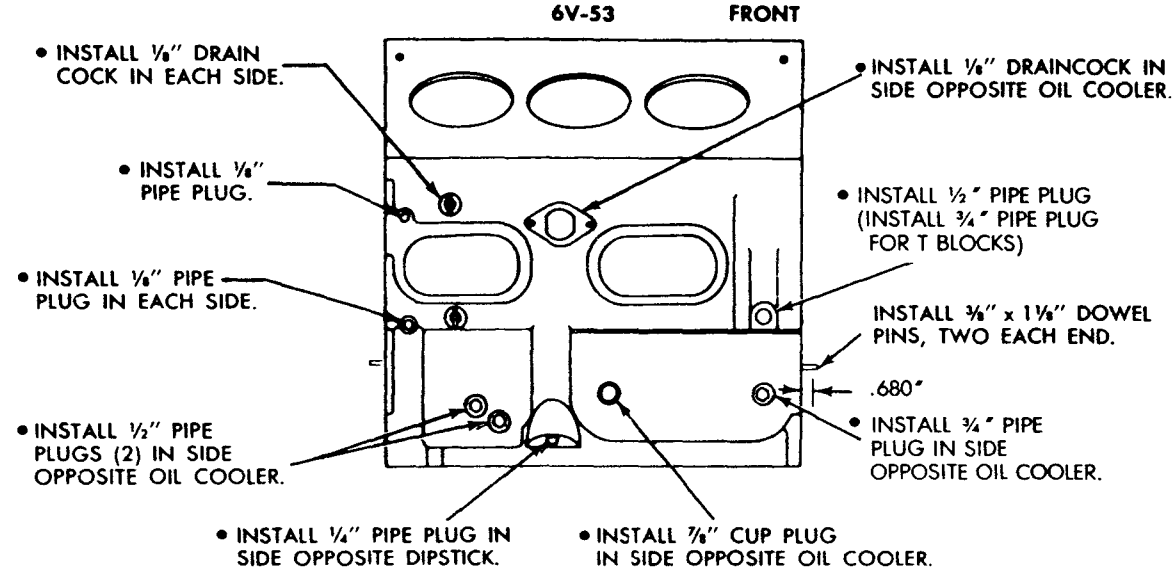




REV. 9-77

*Some Engine Require .751" Drive Plug at this Location.

CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)



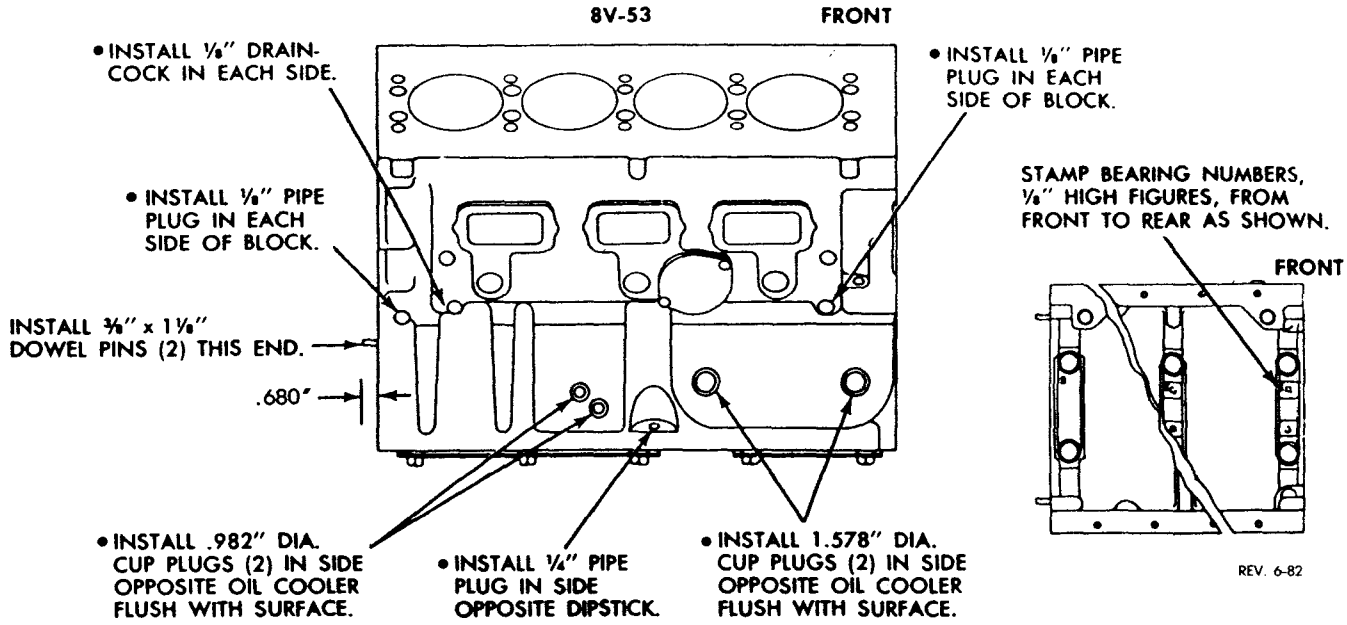
NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

• APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.

STANDARD PIPE PLUG TORQUE

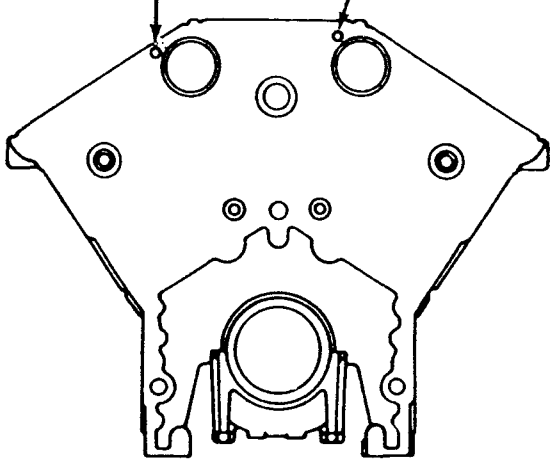
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50



CYLINDER BLOCK PLUGGING INSTRUCTIONS (6V AND 8V ENGINES)

INSTALL 5/16" x 5/16" DOWEL PIN AT EACH END. (COPPER-FLASHED FOR 8V-53, PLAIN FOR 6V-53) FLUSH TO .020" BELOW SURFACE.

• INSTALL 5/16" SPEC. CUP PLUG, FRONT AND REAR ON 8V-53, REAR ONLY ON 6V-53 FLUSH TO .030" BELOW SURFACE.



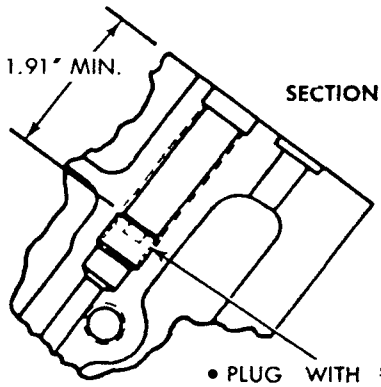
REAR

TOP SURFACE PLUGGING INSTRUCTIONS

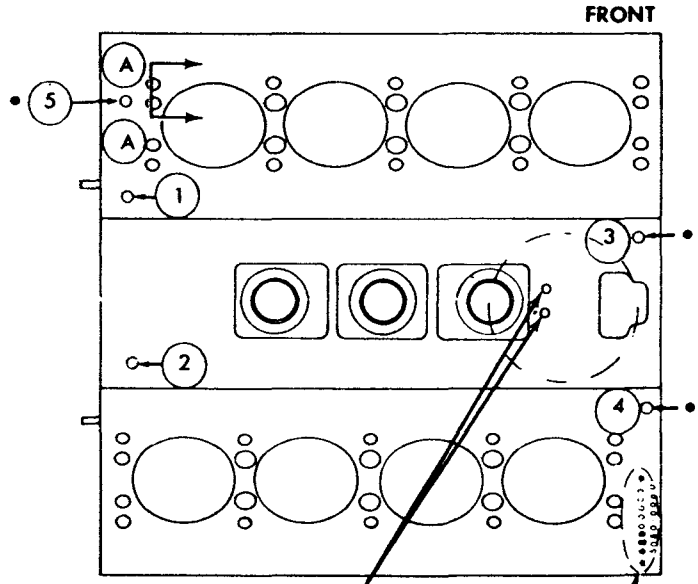
USE 5/16" COPPER FLASHED DOWEL PIN EXCEPT WHERE NOTED. INSTALL PINS FLUSH TO .020" BELOW SURFACE.

	HOLE NOS. 1	2	3	4	5
6V-53*	X	X		X	X
8V-53	X	X	X	X	

• *NO. 2 HOLE, PLUG WITH 5/16" PLAIN DOWEL PIN. NO. 5 HOLE, PLUG WITH 1/8" PIPE PLUG FLUSH TO .12" BELOW SURFACE.



• PLUG WITH 5/8" SOCKET CUP SET SCREW RIGHT AND LEFT BANK AT REAR 8V-53 ONLY

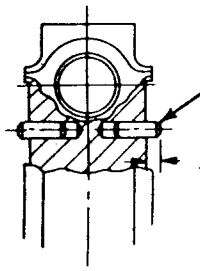


PLUG WITH .075" SPECIAL PLUG BLOCK 5149781 ONLY

NOTES

1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

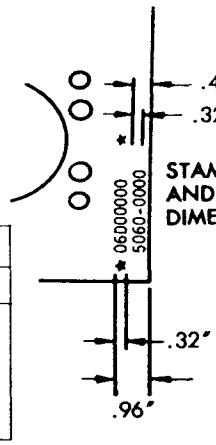
• APPLY LOCTITE J 26558-92 PIPE SEALER WITH TEFLON OR EQUIVALENT PRIOR TO INSTALLATION.



CUTAWAY SECTION OF REAR MAIN BEARING CAP

ASSEMBLE 3/16" x 1/2" DOWEL PINS IN REAR MAIN BEARING CAP. 4 PLACES

.117"
.107"

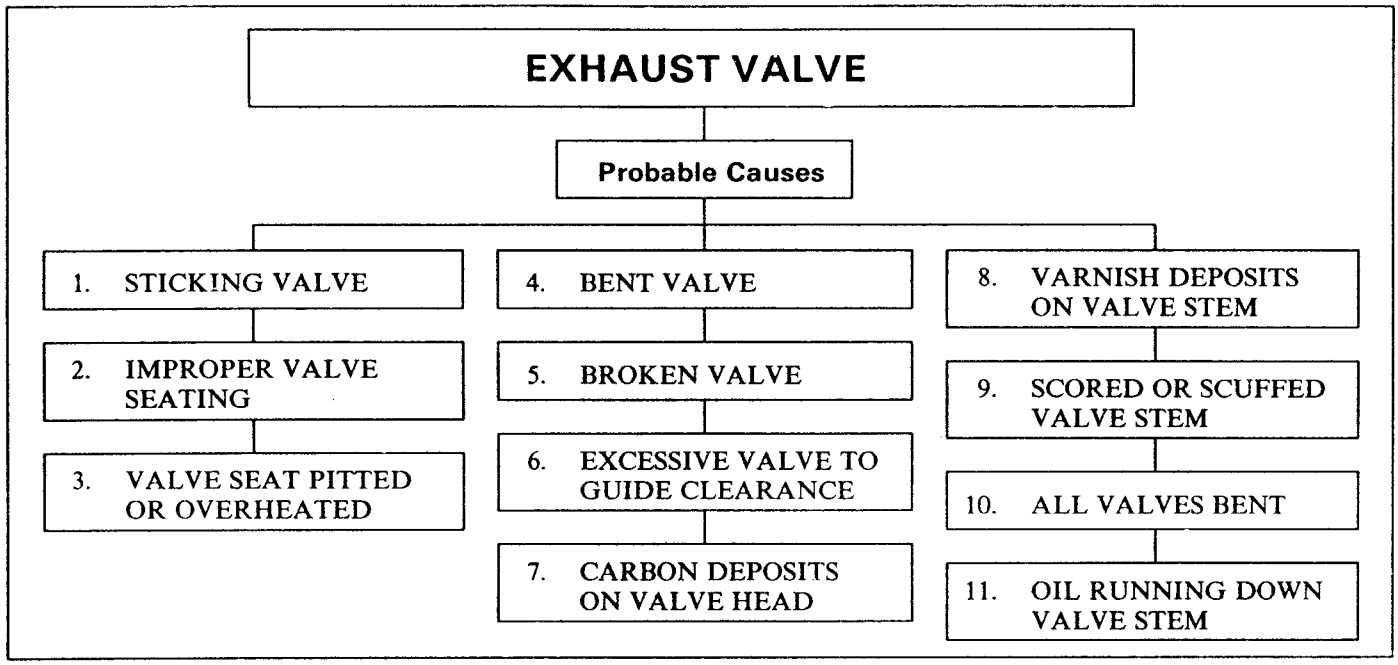


STAMP SERIAL NUMBER AND MODEL NUMBER TO DIMENSIONS SHOWN.

STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

REV. 6-82

TROUBLESHOOTING



SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (ethylene glycol) in the lubricating oil. Replace a bent guide. Clean–up and reface the valve. Replace the valve, if necessary.
2. Check for excessive valve–to–guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary.
3. Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder–face valve if operating conditions warrant.
4. Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge (four valve head) or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Replace damaged parts.
5. Check for excessive valve–to–guide clearance, defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder head and piston for damage. Replace damaged parts.
6. Replace a worn valve guide. Check and replace the valve, if necessary.
7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean–up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.
8. Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.
9. Check for a bent valve stem or guide, metal chips or dirt, or for lack of lubrication. Clean up the valve stem with crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap DOES NOT scrape the valve stem.
10. Check for a gear train failure or for improper gear train timing.
11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

SPECIFICATIONS

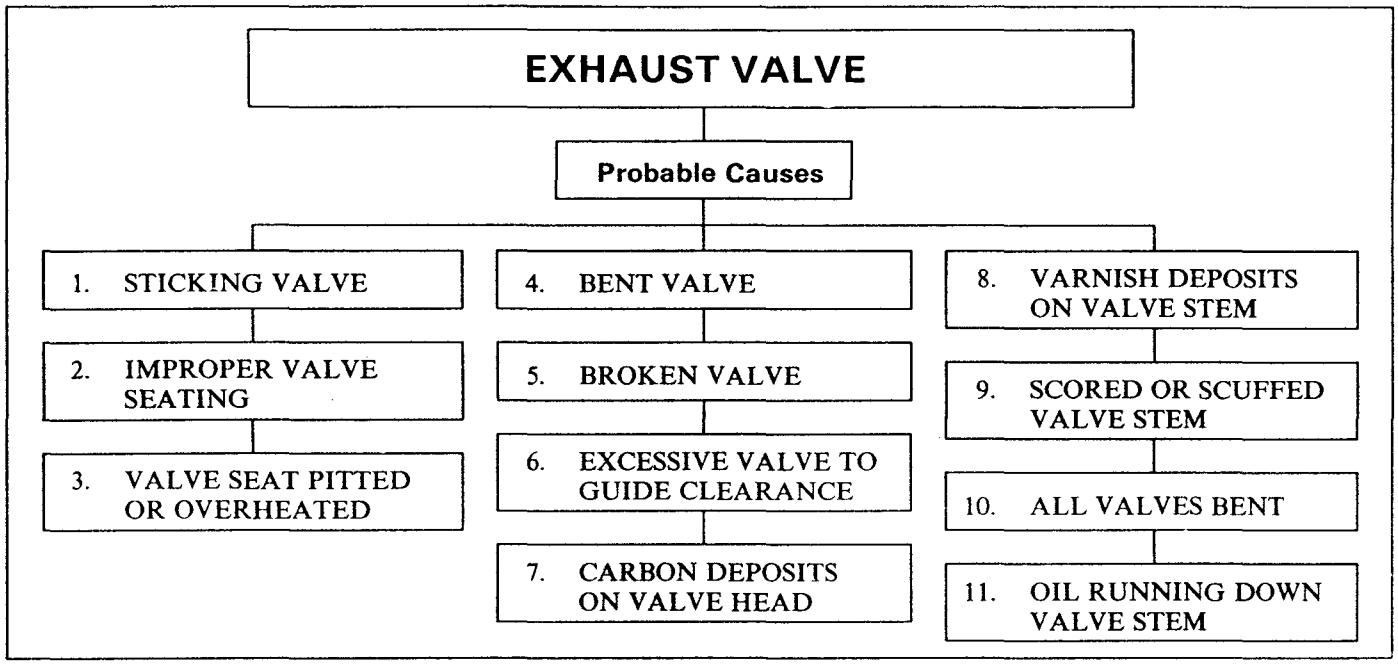
Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CYLINDER BLOCK			
Block bore:			
Diameter (top)	4.5195"	4.5215"	4.5235"
Diameter (center)	4.4865"	4.4880"	4.4900"
Diameter (bottom)	4.3565"	4.3575"	4.3595"
Out–of–round		.0015"	.0020"
Taper		.0015"	.0020"
Cylinder liner counterbore:			
Diameter	4.8200"	4.8350"	
Depth	.3000"	.3020"	
Main bearing bore:			
Inside diameter (vertical axis, In–line)	3.2510"	3.2520"	
Inside diameter (vertical axis, V–type)	3.7510"	3.7520"	
Cam and balance shaft bore (O.S. cam brg.):			
End (all engines)	2.3850"	2.3860"	
Intermediate (3–53, 4–53, 6V and 8V)	2.3750"	2.3760"	
Center (2–53)	2.3750"	2.3760"	
Center (3–53, 4–53, 6V and 8V)	2.3650"	2.3660"	
Top surface of block:			
Flatness—transverse (all)			.0030"
Flatness—longitudinal (2–53)			.0050"
Flatness—longitudinal (3–53 and 6V)			.0060"
Flatness—longitudinal (4–53 and 8V)			.0070"
Depth of counterbores (top surface):			
Cylinder head seal strip groove	.0970"	.1070"	
Water holes	.1090"	.1150"	
Water holes (at ends of 6V block)	.0920"	.0980"	
Oil holes	.0920"	.0980"	
CYLINDER LINER			
Outside diameter (upper seal ring surface)	4.4850"	4.4860"	
Outside diameter (lower seal ring surface)	4.3550"	4.3560"	
Inside diameter	3.8752"	3.8767"	
Out–of–round (inside diameter)		.0020"	.0030"
Taper (inside diameter)		.0010"	.0020"
Depth of flange BELOW block	.0465"	.0500"	.0500"
Variation in depth between adjacent liners		.0020"	.0020"

TROUBLESHOOTING



SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (ethylene glycol) in the lubricating oil. Replace a bent guide. Clean–up and reface the valve. Replace the valve, if necessary.
2. Check for excessive valve–to–guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary.
3. Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder–face valve if operating conditions warrant.
4. Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge (four valve head) or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Replace damaged parts.
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7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean–up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored.
8. Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.
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10. Check for a gear train failure or for improper gear train timing.
11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals.

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

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Diameter (top)	4.5195"	4.5215"	4.5235"
Diameter (center)	4.4865"	4.4880"	4.4900"
Diameter (bottom)	4.3565"	4.3575"	4.3595"
Out-of-round		.0015"	.0020"
Taper		.0015"	.0020"
Cylinder liner counterbore:			
Diameter	4.8200"	4.8350"	
Depth	.3000"	.3020"	
Main bearing bore:			
Inside diameter (vertical axis, In-line)	3.2510"	3.2520"	
Inside diameter (vertical axis, V-type)	3.7510"	3.7520"	
Cam and balance shaft bore (O.S. cam brg.):			
End (all engines)	2.3850"	2.3860"	
Intermediate (3-53, 4-53, 6V and 8V)	2.3750"	2.3760"	
Center (2-53)	2.3750"	2.3760"	
Center (3-53, 4-53, 6V and 8V)	2.3650"	2.3660"	
Top surface of block:			
Flatness—transverse (all)			.0030"
Flatness—longitudinal (2-53)			.0050"
Flatness—longitudinal (3-53 and 6V)			.0060"
Flatness—longitudinal (4-53 and 8V)			.0070"
Depth of counterbores (top surface):			
Cylinder head seal strip groove	.0970"	.1070"	
Water holes	.1090"	.1150"	
Water holes (at ends of 6V block)	.0920"	.0980"	
Oil holes	.0920"	.0980"	
CYLINDER LINER			
Outside diameter (upper seal ring surface)	4.4850"	4.4860"	
Outside diameter (lower seal ring surface)	4.3550"	4.3560"	
Inside diameter	3.8752"	3.8767"	
Out-of-round (inside diameter)		.0020"	.0030"
Taper (inside diameter)		.0010"	.0020"
Depth of flange BELOW block	.0465"	.0500"	.0500"
Variation in depth between adjacent liners		.0020"	.0020"

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
PISTONS and RINGS (TRUNK TYPE)			
Piston:			
Diameter (at skirt):			
Non–turbocharged engines	3.8699″	3.8721″	
Turbocharged engines	3.8679″	3.8701″	
Clearance—piston skirt–to–liner:			
Non–turbocharged engines	.0027″	.0068″	.0100″
Turbocharged engines	.0047″	.0088″	.0120″
Out–of–round or taper		.0005″	
Inside dia.—pin bushing	1.3775″	1.3780″	
Inside dia.—pin bushing (current turbo)	1.5025″	1.5030″	
Compression rings:			
Gap (chrome ring)	.0200″	.0460″	.0600″
Gap (cast iron ring)	.0200″	.0360″	.0600″
Clearance—ring–to–groove:			
Top (No. 1)	.0030″	.0060″	.0120″
No. 2	.0070″	.0100″	.0140″
No. 3 and 4	.0050″	.0080″	.0130″
No. 3 and 4 (21:1 ratio piston)	.0045″	.0070″	.0120″
Oil control rings:			
Gap	.0100″	.0250″	.0440″
Clearance—ring–to–groove	.0015″	.0055″	.0080″
PISTONS and RINGS (CROSSHEAD TYPE)			
Piston crown:			
Saddle–to–crown distance	2.8325″	2.8395″	
Diameter:			
Top	3.8486″	3.8516″	
Below both comp. rings	3.8636″	3.8666″	
Above/below seal ring groove	3.8666″	3.8676″	
Above/below bearing saddle	2.8350″	2.8380″	
Compression rings:			
Gap (top fire ring)	.0230″	.0380″	.0600″
Gap (No. 2 and 3)	.0200″	.0300″	.0600″
Clearance – ring–to–groove:			
Top fire ring	.0030″	.0066″	.0086″
No. 2 (rectangular sect.)	.0070″	.0100″	.0140″
No. 3 (rectangular sect.)	.0050″	.0080″	.0130″
Piston skirt:			
Diameter	3.8695″	3.8717″	
Clearance – skirt–to–liner	.0035″	.0072″	.0110″
Seal ring bore	.3700″	.3704″	.3706″
Piston pin bore	1.3775″	1.3785″	1.3790″
Oil control rings:			
Gap (two rings – lower groove)	.0100″	.0250″	.0440″
Gap (one ring – upper groove)	.0070″	.0170″	.0370″
Clearance (two rings – lower groove)	.0015″	.0055″	.0080″
Clearance (one ring – lower groove)	.0005″	.0040″	.0065″

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
PISTON PINS (TRUNK TYPE)			
Diameter (non–turbo and former turbo)	1.3746″	1.3750″	
Diameter (current turbo)	1.4996″	1.5000″	
Clearance—pin–to–piston bushing	.0025″	.0034″	.0100″
Clearance—pin–to–conn. rod bushing	.0010″	.0019″	.0100″
PISTON PINS (CROSS–HEAD TYPE)			
Length	3.2250″	3.2450″	
Diameter	1.3746″	1.3750″	1.3730″
Slipper bearing (bushing):			
Thickness*	.0870″	.0880″	.0860″
Clearance (bushing edge–groove in piston)	.0005″	.0105″	.0120″
CONNECTING ROD			
Length—center–to–center	8.7990″	8.8010″	
Inside diameter (upper bushing)	1.3760″	1.3765″	
Normal side clearance (In–line)	.0030″	.0120″	
Normal side clearance (V–type)	.0020″	.0160″	
CRANKSHAFT			
Journal diameter:			
Main bearing (In–line)	2.9990″	3.0000″	
• Main bearing (V–Type)	3.4985″	3.5002″	
Conn. rod bearing (In–line)	2.4990″	2.5000″	
• Conn. rod bearing (V–Type)	2.7485″	2.7502″	
Outboard bearing (8V–53)		2.8770″	2.8780″
Journal out–of–round		.00025″	.0030″
Journal taper		.0005″	.0030″
#Runout on journals—total indicator reading:			
2–53, 3–53 and 4–53 engine		.0020″	
#Runout at No. 2 and No. 4 journals (8V)		.0020″	
#Runout at No. 3 journal (8V)		.0040″	
#Runout on outboard journal (8V)		.0010″	
Thrust washer thickness	.1190″	.1220″	
End play (end thrust clearance)	.0040″	.0160″	.0180″

* Center land is .0002″ – .0008″ thinner than adjacent lands.

Runout tolerance given for guidance when regrinding crankshaft. Crankshaft for 2–53 supported on No. 1 and No. 3 journals; runout measured at No. 2 journal. Crankshaft for 3–53 supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 4–53 supported on No. 1 and No. 5 journals; runout measured at No. 2, 3 and 4 journals. Crankshaft for 6V supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 8V supported on No. 1 and No. 5 journals; runout measured at No. 2, 3, 4 and outboard journals.
When the runout on adjacent journals is in the opposite direction, the sum must not exceed .003″ total indicator reading. When in the same direction, the difference must not exceed .003″ total indicator reading. When high spots of runout on adjacent journals are at right angles to each other, the sum must not exceed .004″ total indicator reading, or .002″ on each journal.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CONNECTING ROD BEARING			
Inside diameter (vertical axis, In–line)	2.5015″	2.5035″	
Inside diameter (vertical axis, V–type)	2.7511″	2.7531″	
Bearing–to–journal clearance (In–line)	.0015″	.0045″	.0060″
Bearing–to–journal clearance (V–type)	.0011″	.0041″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1247″	.1252″	.1230″
MAIN BEARINGS			
Inside diameter (vertical axis, In–line)	3.0020″	3.0030″	
Inside diameter (vertical axis, V–type)	3.5030″	3.5040″	
Bearing–to–journal clearance	.0010″	.0040″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1240″	.1245″	.1230″
OUTBOARD BEARING			
Clearance—bearing–to–crankshaft (8V)	.0035″	.0071″	.0080″
CAMSHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Runout at center bearing (mounted end brg.)		.0020″	
Thrust washer thickness	.2080″	.2100″	
BALANCE SHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Thrust washer thickness	.2080″	.2100″	
CAMSHAFT and BALANCE SHAFT BEARINGS			
Inside diameter	2.1870″	2.1880″	
Clearance—bearing–to–shaft	.0035″	.0070″	.0080″
CAMSHAFT and BALANCE SHAFT GEARS			
Backlash	.0005″	.0050″	.0070″
IDLER GEAR (IN–LINE and 6V ENGINES)			
Backlash	.0005″	.0050″	.0070″
Bearing inside diameter	2.1860″	2.1870″	
Clearance—bearing–to–hub	.0025″	.0045″	.0070″
End play	.0060″	.0130″	.0170″
Hub outside diameter	2.1825″	2.1835″	
Thrust washer thickness	.1180″	.1200″	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CRANKSHAFT TIMING GEAR			
Backlash	.0005″	.0050″	.0070″
Inside diameter (97 tooth gear)	4.0580″	4.0590″	
Inside diameter (111 tooth gear)	4.0575″	4.0585″	
Outside diameter (crankshaft)	4.0600″	4.0610″	
BLOWER DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Thrust washer thickness (4–53 and 6V)	.0930″	.1030″	
Thrust washer thickness (8V)	.1190″	.1210″	
End play (blower drive gear shaft)	.0040″	.0120″	
GOVERNOR DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
FUEL PUMP DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Bearing (inside diameter)	1.1220″	1.1230″	
Clearance – Bearing–to–hub	.0020″	.0035″	
End play	.0050″	.0180″	.0220″
Hub (outside diameter)	1.1200″	1.1205″	
Thrust washer thickness	.1580″	.1600″	
CYLINDER HEAD			
Cam follower bore (current)	1.0626″	1.0636″	
Cam follower bore (former)	1.0620″	1.0630″	
Exhaust valve insert counterbore:			
Diameter (2–valve head)	1.4390″	1.4400″	
Diameter (4–valve head)	1.1590″	1.1600″	
EXHAUST VALVE SEAT INSERTS			
Outside diameter (2–valve)	1.4405″	1.4415″	
Outside diameter (4–valve)	1.1605″	1.1615″	
Seat width	.0468″	.0781″	.0781″
Valve seat runout		.0020″	.0020″
EXHAUST VALVES			
Stem diameter (2–valve)	.3100″	.3105″	
Stem diameter (current 4–valve)	.2480″	.2488″	
Stem diameter (former 4–valve)	.2475″	.2485″	
Valve head–to–cylinder head:			
2–valve head	.002″ protr.	.032″ recess.	.037″ recess.
Current 4–valve head	flush	.024″ recess.	.039″ recess.
Former 4–valve head	.006″ protr.	.018″ recess.	.033″ recess.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CONNECTING ROD BEARING			
Inside diameter (vertical axis, In–line)	2.5015″	2.5035″	
Inside diameter (vertical axis, V–type)	2.7511″	2.7531″	
Bearing–to–journal clearance (In–line)	.0015″	.0045″	.0060″
Bearing–to–journal clearance (V–type)	.0011″	.0041″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1247″	.1252″	.1230″
MAIN BEARINGS			
Inside diameter (vertical axis, In–line)	3.0020″	3.0030″	
Inside diameter (vertical axis, V–type)	3.5030″	3.5040″	
Bearing–to–journal clearance	.0010″	.0040″	.0060″
Bearing thickness 90° part line (In–line)	.1245″	.1250″	.1230″
Bearing thickness 90° part line (V–type)	.1240″	.1245″	.1230″
OUTBOARD BEARING			
Clearance—bearing–to–crankshaft (8V)	.0035″	.0071″	.0080″
CAMSHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Runout at center bearing (mounted end brg.)		.0020″	
Thrust washer thickness	.2080″	.2100″	
BALANCE SHAFT			
Diameter (at bearing journals)	2.1820″	2.1825″	
End thrust	.0030″	.0150″	.0190″
Thrust washer thickness	.2080″	.2100″	
CAMSHAFT and BALANCE SHAFT BEARINGS			
Inside diameter	2.1870″	2.1880″	
Clearance—bearing–to–shaft	.0035″	.0070″	.0080″
CAMSHAFT and BALANCE SHAFT GEARS			
Backlash	.0005″	.0050″	.0070″
IDLER GEAR (IN–LINE and 6V ENGINES)			
Backlash	.0005″	.0050″	.0070″
Bearing inside diameter	2.1860″	2.1870″	
Clearance—bearing–to–hub	.0025″	.0045″	.0070″
End play	.0060″	.0130″	.0170″
Hub outside diameter	2.1825″	2.1835″	
Thrust washer thickness	.1180″	.1200″	

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
CRANKSHAFT TIMING GEAR			
Backlash	.0005″	.0050″	.0070″
Inside diameter (97 tooth gear)	4.0580″	4.0590″	
Inside diameter (111 tooth gear)	4.0575″	4.0585″	
Outside diameter (crankshaft)	4.0600″	4.0610″	
BLOWER DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Thrust washer thickness (4–53 and 6V)	.0930″	.1030″	
Thrust washer thickness (8V)	.1190″	.1210″	
End play (blower drive gear shaft)	.0040″	.0120″	
GOVERNOR DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
FUEL PUMP DRIVE GEAR			
Backlash	.0030″	.0050″	.0070″
Bearing (inside diameter)	1.1220″	1.1230″	
Clearance – Bearing–to–hub	.0020″	.0035″	
End play	.0050″	.0180″	.0220″
Hub (outside diameter)	1.1200″	1.1205″	
Thrust washer thickness	.1580″	.1600″	
CYLINDER HEAD			
Cam follower bore (current)	1.0626″	1.0636″	
Cam follower bore (former)	1.0620″	1.0630″	
Exhaust valve insert counterbore:			
Diameter (2–valve head)	1.4390″	1.4400″	
Diameter (4–valve head)	1.1590″	1.1600″	
EXHAUST VALVE SEAT INSERTS			
Outside diameter (2–valve)	1.4405″	1.4415″	
Outside diameter (4–valve)	1.1605″	1.1615″	
Seat width	.0468″	.0781″	.0781″
Valve seat runout		.0020″	.0020″
EXHAUST VALVES			
Stem diameter (2–valve)	.3100″	.3105″	
Stem diameter (current 4–valve)	.2480″	.2488″	
Stem diameter (former 4–valve)	.2475″	.2485″	
Valve head–to–cylinder head:			
2–valve head	.002″ protr.	.032″ recess.	.037″ recess.
Current 4–valve head	flush	.024″ recess.	.039″ recess.
Former 4–valve head	.006″ protr.	.018″ recess.	.033″ recess.

ENGINE PARTS (Standard Size, New)	MINIMUM	MAXIMUM	WEAR LIMITS
VALVE GUIDES			
Distance below top of head (2–valve)	.0100″	.0400″	
Distance below top of head (4–valve)	.1500″	.1800″	
Diameter—inside (2–valve)	.3125″	.3135″	
Diameter—inside (4–valve)	.2505″	.2515″	
Clearance—valve–to–guide (2–valve)	.0020″	.0040″	.0060″
Clearance—valve–to–guide (current 4–valve)	.0017″	.0035″	.0050″
Clearance—valve–to–guide (former 4–valve)	.0020″	.0040″	.0050″
ROCKER ARMS and SHAFTS			
Diameter—rocker shaft	.8735″	.8740″	
Diameter—inside (rocker arm bushing)	.8750″	.8760″	
Diameter—inside (valve rocker arm bore)	.8753″	.8763″	
Clearance—shaft–to–injector rocker bushing	.0010″	.0025″	.0040″
Clearance—shaft–to–valve rocker bore	.0013″	.0028″	.0040″
CAM FOLLOWERS			
Diameter	1.0600″	1.0610″	
Clearance—follower–to–current head	.0016″	.0036″	.0060″
Clearance—follower–to–former head	.0010″	.0030″	.0060″
Rollers and pins:			
Clearance—pin–to–bushing	.0013″	.0021″	.010″ Horiz.
Side clearance—roller–to–follower	.0150″	.0230″	.0230″

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE (N·m)	NPTF SIZE THREAD	TORQUE (lb–ft)	TORQUE (N·m)
1/8	10–12	14–16	3/4	33–37	45–50
1/4	14–16	19–22	1	75–85	102–115
3/8	18–22	24–30	1–1/4	95–105	129–143
1/2	23–27	31–37	1–1/2	110–130	150–177

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb-ft)	(N·m)	THREAD SIZE	280M OR BETTER TORQUE (lb-ft)	(N·m)
1/4–20	5–7	7–9	1/4–20	7–9	10–12
1/4–28	6–8	8–11	1/4–28	8–10	11–14
5/16–18	10–13	14–18	5/16–18	13–17	18–23
5/16–24	11–14	15–19	5/16–24	15–19	20–26
3/8–16	23–26	31–35	3/8–16	30–35	41–47
3/8–24	26–29	35–40	3/8–24	35–39	47–53
7/16–14	35–38	47–51	7/16–14	46–50	62–68
7/16–20	43–46	58–62	7/16–20	57–61	77–83
1/2–13	53–56	72–76	1/2–13	71–75	96–102
1/2–20	62–70	84–95	1/2–20	83–93	113–126
9/16–12	68–75	92–102	9/16–12	90–100	122–136
9/16–18	80–88	109–119	9/16–18	107–117	146–159
5/8–11	103–110	140–149	5/8–11	137–147	186–200
5/8–18	126–134	171–181	5/8–18	168–178	228–242
3/4–10	180–188	244–254	3/4–10	240–250	325–339
3/4–16	218–225	295–305	3/4–16	290–300	393–407
7/8–9	308–315	417–427	7/8–9	410–420	556–569
7/8–14	356–364	483–494	7/8–14	475–485	644–657
1–8	435–443	590–600	1–8	580–590	786–800
1–14	514–521	697–705	1–14	685–695	928–942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	GM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

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BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD	(lb–ft)	(lb–in)	(N·m)
Cam follower guide bolts	1/4–20	12–15		16–20
Idler gear bearing retaining bolts (8V)	1/4–20	12–15		16–20
Injector control shaft bracket bolts	1/4–28	10–12		14–16
Governor to flywheel housing bolts	5/16–18	10–12		14–16
Idler gear hub and spacer bolts	5/16–18	19–23		26–31
Oil pan bolts	5/16–18	10–20		14–27
Connecting rod nuts (6V engine – former)	5/16–24	24–28		33–38
Air box cover bolts (6V – 1/4" thick clamp)	3/8–16	8–10		11–14
Air box cover bolts (except 1/4" clamp)	3/8–16	12–15		16–20
Flywheel housing bolts	3/8–16	25–30		34–41
Idler gear hub and spacer bolts	3/8–16	40–45		54–61
Injector clamp bolts	3/8–16	20–25		27–34
Valve rocker cover bolts (cast cover)	3/8–16	8–13		11–18
Connecting rod nuts	3/8–24	40–45		54–61
Flywheel housing bolts	3/8–24	25–30		34–41
Fuel connector (for flared end fuel pipe)	3/8–24	20–28		27–38
• Fuel connector (for O–ring sealed fuel pipe)	3/8–24	37		50
• Fuel pipe nuts (uncoated)	3/8–24		160	18.3
• Fuel pipe nuts (Endurion ®)	3/8–24		130	14.69
• Fuel pipe nuts (Jacobs brake)	3/8–24		120	13.6
• Fuel pipe nuts (Load limiting device)	3/8–24	–	160	18.3
C/S outboard main bearing support bolt (8V)	7/16–14	75–85		102–115
Rocker arm bracket bolts	7/16–14	50–55		68–75
*Flywheel bolts (Section 1.4)	1/2–20			
*Main bearing cap bolts	9/16–12	120–130		163–177
*Flywheel bolts (8V) (Section 1.4)	9/16–18			
*Cylinder head bolts	5/8–11	170–180		231–244
Flange mounted air compressor drive shaft nut	3/4–10	#		#
Accessory drive pulley retaining nut	3/4–16	120–140		163–190
Air compressor drive pulley nut	3/4–16	80–100		108–136
Crankshaft end bolt (In–line and 6V engines)	3/4–16	290–300		393–407
C/S end bolt pulley stamped "A"	1–14	200–220		271–298
Crankshaft end bolt (8V)	1–14	290–310		393–421
Crankshaft and balance shaft nut	1–1/8–18	300–325		407–441

* Lubricate at assembly with International Compound No. 2, or equivalent (refer to Parts Catalog or Microfiche, Section 12.8000A).

100 lb–ft (136 N·m) plus increase torque to line up cotter pin.

SERVICE TOOLS

TOOL NAME	TOOL NO.
CYLINDER BLOCK	
Bore gage	J 5347-B
Cylinder bore plug set	J 34697
Deck checker (measure crankshaft centerline-to-fire deck)	PT 5075-B
Dial bore gage master setting fixture	J 23059-01
Engine overhaul stand	J 29109
• Adaptor plate (In-line)	J 7622-01
• Adaptor plate (6V)	J 8683
• Adaptor plate (8V)	J 21966
• Adaptor plate (2, 3, 4-53, 6V-53, 8V-53))	J 33850
Pipe plug remover and installer (1/8' dia.)	J 34650
Sled gage	J 22273-01
• Loctite "chisel" gasket remover	PT 7275
CYLINDER HEAD	
• Cam follower service fixture adaptor	J 33421-22
• Load cell, cam follower roller fixture	J 33421-25
Cylinder head guide studs (set of 2)	J 9665
Cylinder head lifting	J 22062-01
Engine barring tool	J 22582
Injector body brush	J 8152
piston ring gap feeler gage set	J 3172
Push rod remover (set of 3)	J 3092-01
Socket	J 8932-01
Spring tester	J 22738-02
Valve guide cleaner (2-valve head)	J 5437
Valve guide cleaner (4-valve head)	J 7793
Valve guide installer (2-valve head)	J 7560
Valve guide installer (4-valve head)	J 24519
Valve guide oil seal installer (4-valve head)	J 29579
Valve guide remover (2-valve head)	J 6569
Valve guide remover (4-valve head)	J 7775
• Valve seat grinder, model V.I.P. (consists of dash (-) items)	J 7040-A
- Valve seat dial gage	J 8165-2
- Valve seat grinder	J 8165-1A
Valve seat grinder adaptor kit (2-valve head)	J 7924-02
Valve seat grinder adaptor kit (4-valve head)	J 7792-01
Valve seat insert installer (2-valve head)	J 6976
Valve seat insert installer (4-valve head)	J 7790
Valve seat insert remover	J 23479-15
Valve seat insert remover collet (2-valve head))	J 23479-7
Valve seat insert remover collet (4-valve head))	J 23479-8
Valve spring checking gage	J 25076-B
Valve spring compressor (2 or 4-valve head)	J 7455
CRANKSHAFT	
Front oil seal installer	J 22153
Front oil seal sleeve installer (In-line 6V)	J 22524
Pulley installer	J 7773

TOOL NAME	TOOL NO.
Pulley remover	J 5356
Rear oil seal expander (8V)	J 22425–A
Rear oil seal (O.S.) expander	J 21278–01
Rear Oil seal sleeve installer	J 21277
Handle	J 3154–1
Rear oil seal sleeve installer (8V)	J 4194–01
Timing gear installer	J 7557
Timing gear remover	J 4871
Micrometer ball attachment	J 4757
Oil seal expander	J 9769
Oil seal expander (In–line and 6V)	J 7454
Oil seal installer	J 9479
Oil seal installer	J 9727–A
Handle	J 3154–1
Oil seal installer	J 9783
Puller	J 24420–A
FLYWHEEL	
Flywheel lifting fixture	J 25026
Flywheel lifting tool	J 6361–01
Removing and replacer set	J 3154–04
Slide hammer puller set	J 5901–01
FLYWHEEL HOUSING	
Oil seal expander (8V)	J 22425–A
Oil seal expander (O.S. seal)	J 21278–01
Oil seal expander (Std. size seal)	J 9769
Dial indicator	J 8001–3
Post	J 9748
Sleeve	J 8001–2
Aligning studs (set of 2)	J 7540
Concentricity gage	J 9737–C
PISTON, CONNECTING ROD and CYLINDER LINER	
Bore gage	J 5347–B
Connecting rod bushing reamer set	J 7608–02
Connecting rod holding	J 7632
Cylinder hone set (2 1/2" to 5 3/4" range)	J 5902–01
Cylinder liner remover set	J 22490
Dial bore gage master setting fixture	J 23059–01
Hold down clamp	J 21793–B
Master ring – cylinder liner	J 8385–01
Micrometer ball attachment	J 4757
Piston and connecting rod bushing installer and remover	J 7587
Piston bushing reamer set	J 4970–02
Piston bushing reaming fixture	J 5273
Piston pin alignment tool (cross–head)	J 35619
• Piston pin bushing reamer set	J 3071–B
Piston pin retainer installer	J 23762–A
Piston pin retainer installer (cross–head)	J 35572
Piston pin retainer installer (turbo trunk)	J 24107–01

TOOL NAME	TOOL NO.
Piston pin retainer leak detector (plastic)	J 23987–01
• Piston pin retainer leak detector (all metal)	J 35134
Piston ring compressor	J 6883–01
Piston ring remover and installer	J 8128
Piston to liner feeler gage set	J 5438–01
Sled gage	J 22273–01
Spray nozzle remover	J 8995
Piston pin bushing reamer set	J 3071–B
CAMSHAFT	
Bar type puller	J 24420–A
Bearing remover/installer set	J 7593–03
Camshaft cup plug installer	J 24094
Camshaft oil seal installer	J 21899
Slide hammer	J 6471–02
Spring scale	J 8129
Upper front cover seal installer	J 9790

SECTION 2

FUEL SYSTEM AND GOVERNORS

CONTENTS

FUEL SYSTEM

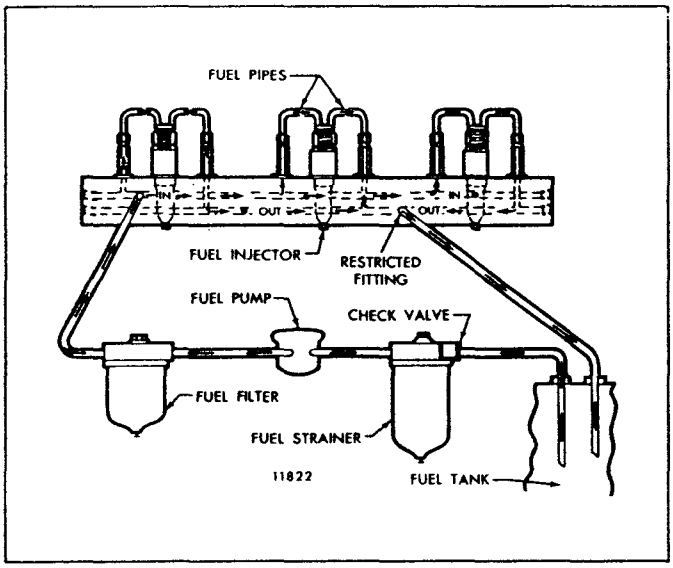


Fig. 1 – Typical Fuel System for In-Line Engines

The fuel system (Figs. 1 and 2) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each injector.

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines. Surplus fuel returns from the outlet side of the injectors to the fuel return manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain the fuel system pressure. On V-type engines, the restricted fitting is located at the rear of the left-bank cylinder head. Refer to Section 13.2 for the size fitting required.

A check valve may be installed in the supply line between the fuel tank and the fuel strainer to prevent fuel from draining back when the engine is shut down.

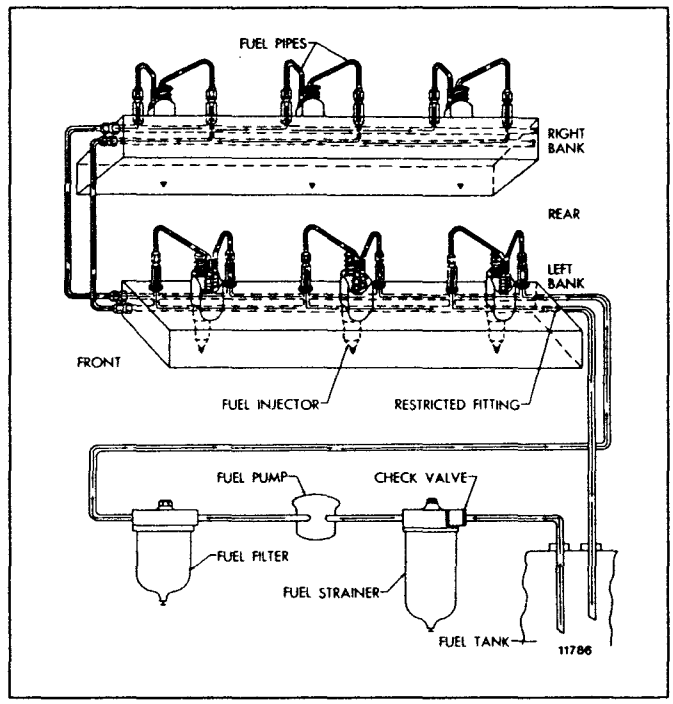


Fig. 2 – Fuel System for 6V-53 Engines

FUEL INJECTOR

MECHANICAL UNIT INJECTOR (MUI)

CROWN VALVE

The fuel injector (Fig. 1) is a lightweight compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple open type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

The fuel injector performs four functions (Times – Atomizes – Meters – Pressurizes):

1. Accurately times the moment of fuel injection.
2. Atomizes the fuel for vaporization and mixing with the air in the combustion chamber.
3. Meters and injects the correct amount of fuel required to maintain engine speed and to handle the load.
4. Creates the high pressure required for proper fuel injection.

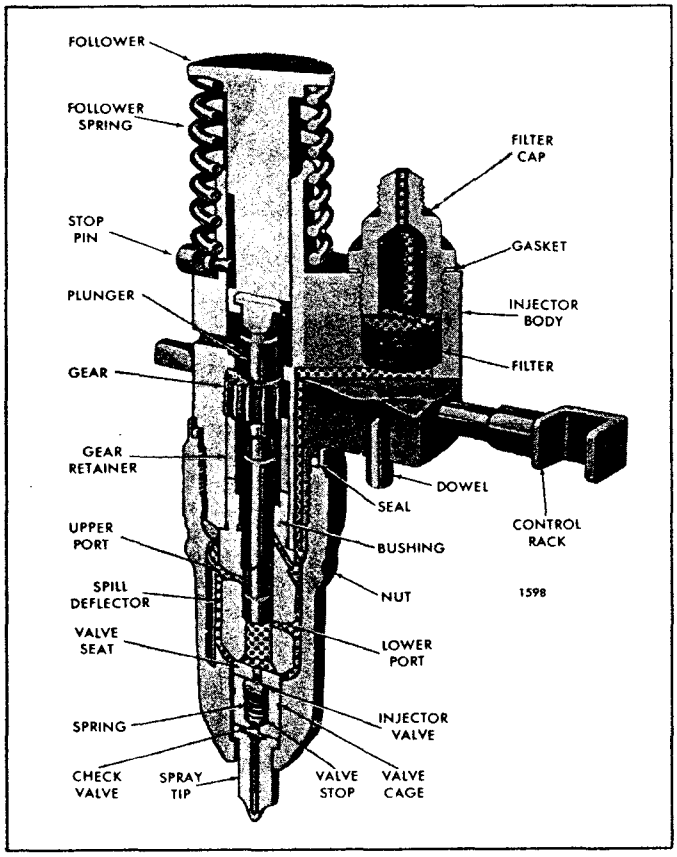


Fig. 1 – Fuel Injector Assembly

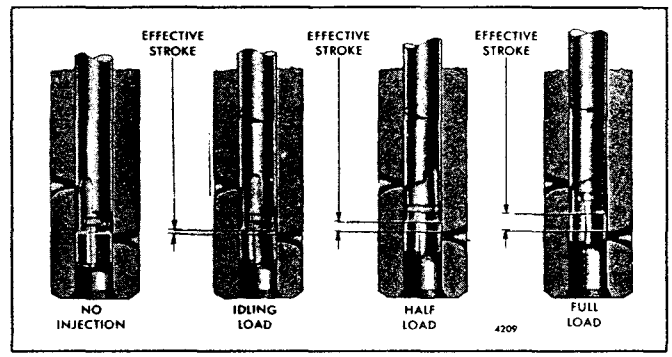


Fig. 2 – Fuel Metering from No Load to Full Load

Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately timed, metered and finely atomized fuel oil into the combustion chamber.

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. (Fig. 2) illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

(Fig. 3) illustrates the phases of injector operation by the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the effective stroke of the plunger and the flow rate of the spray tip.

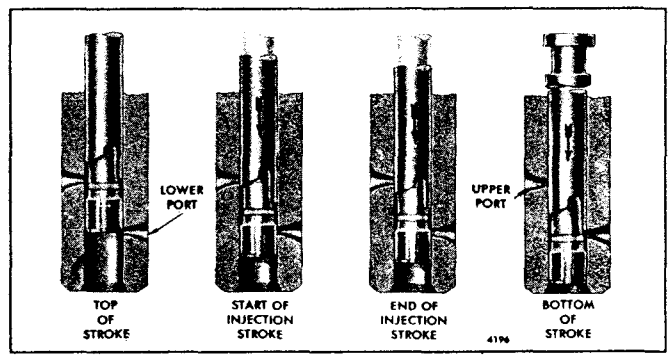


Fig. 3 – Phases of Injector Operation Through Vertical Travel of Plunger

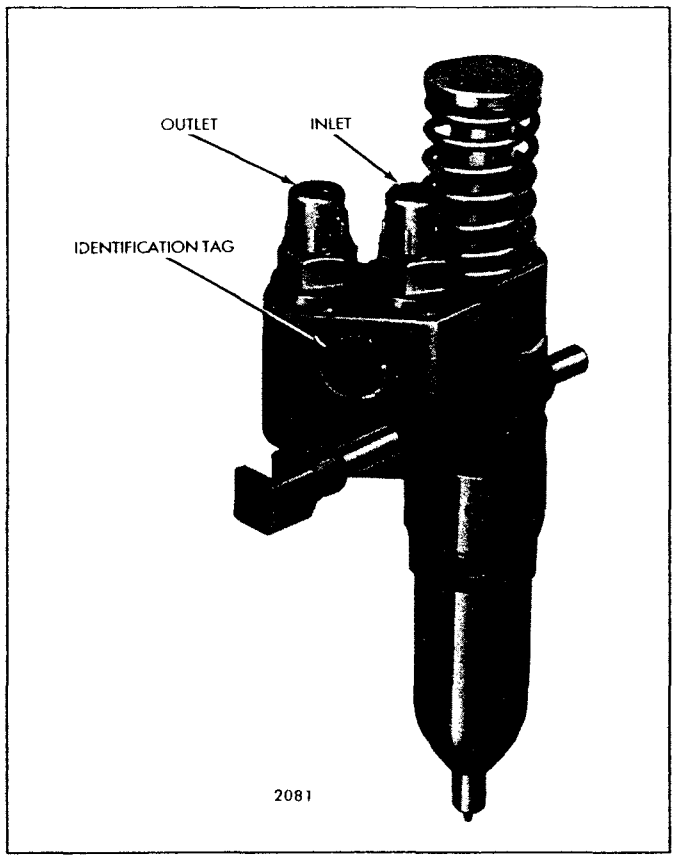


Fig. 4 – Injector Identification

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 4).

Each injector control rack (Fig. 1) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting or fine tuning of all of the injector racks.

The injectors used in engines with a four valve cylinder head require an offset injector body due to the restricted area around the exhaust valve mechanism. A narrower injector clamp is required with the offset injector body and may not be used with the standard injectors. Most offset body injectors, designated as the "S" type, incorporate a clamp seat which is machined lower on the injector body and requires the current narrower clamp (Fig. 5).

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

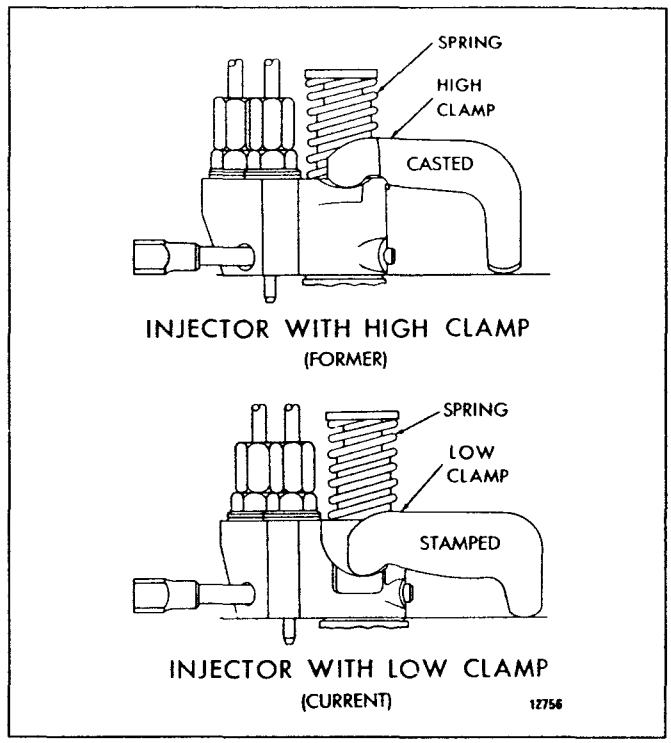


Fig. 5 – Comparison of High Clamp and Low Clamp Injectors

Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the rack (Fig. 1). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel–shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through the T–drilled passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

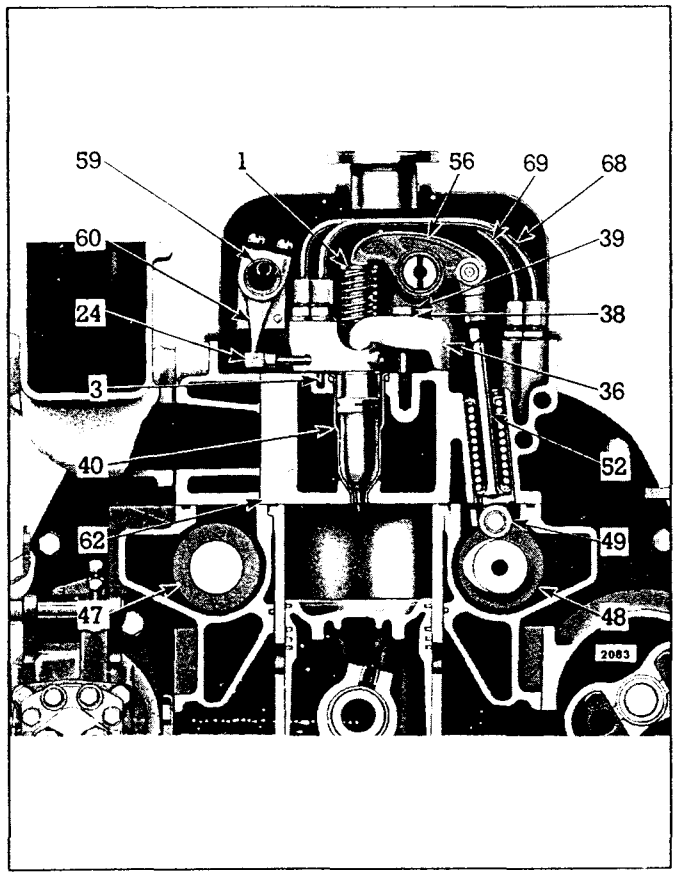


Fig. 6 – Fuel Injector Mounting

When sufficient pressure is built up, the injector valve is lifted off of its seat and the fuel is forced through small orifices in the spray tip and atomized into the combustion chamber until the lower port becomes uncovered.

A check valve, mounted in the spray tip, prevents air in the combustion chamber from entering the fuel injector through the spray holes.

At the end of the stroke the injector plunger is then returned to its *original* position by the injector follower spring. (Fig. 3) shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return stroke of the plunger, the bore of the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection cycle. At the same time, it increases or decreases the amount of fuel injected into the cylinder. (Fig. 2) shows the various plunger positions from no load to full load. With the control rack pulled out all the way (no injection), the upper port is not covered by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is covered shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this *no injection* position to *full injection* position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of atomized fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against the high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first–class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and *clean water–free fuel* are the keys to trouble–free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the door and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture–proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust–proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint–free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out

of the injector and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or other foreign material.

2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and overhaul of an injector.

3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:

   a. Time the injector.

   b. Position the injector control rack.

4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to Section 15.3).

5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

NOTICE: Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

- DDC recommends that flared end fuel pipes not be reused.

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

NOTICE: Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent damage and to prevent dirt from entering the injector. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or foreign material.

- DDC recommends that flared end fuel pipes not be reused.

3. Crank the engine to bring the upper ends of the push rods of the injector and valve rocker arms in line horizontally. If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation because the bolt could be loosened.

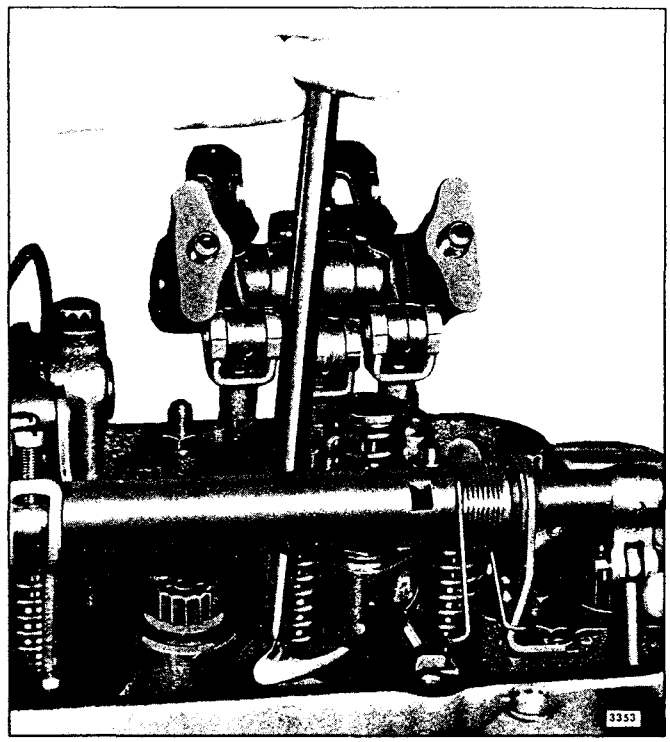


Fig. 7 – Removing Injector from Cylinder Head

CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

5. Remove the injector clamp bolt, special washer and clamp.

6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

7. Lift the injector from its seat in the cylinder head (Fig. 7).

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

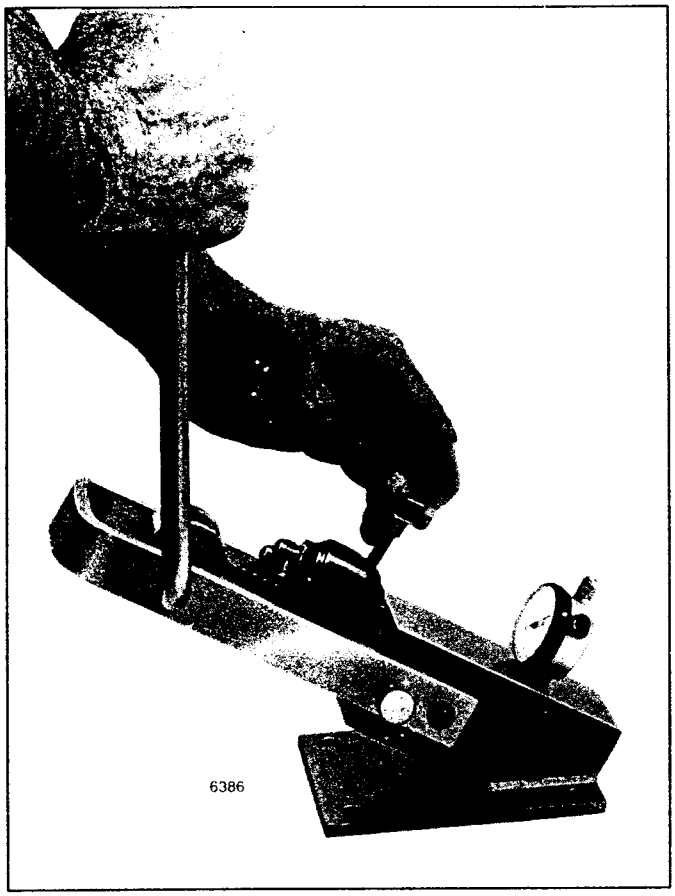


Fig. 8 – Checking Rack for Freeness in Tester J 29584

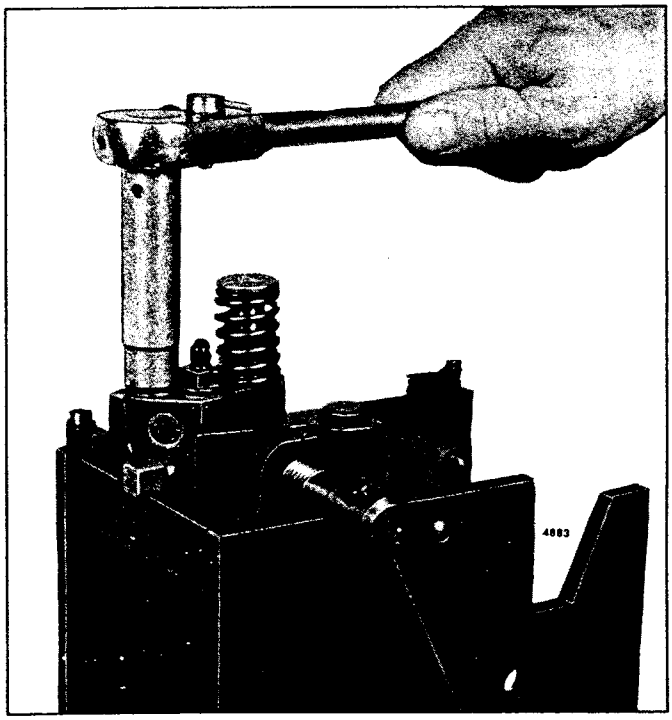


Fig. 9 – Removing Filter Cap

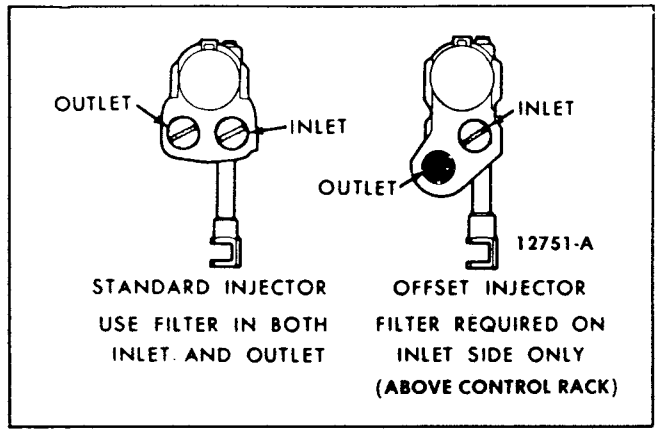


Fig. 10 – Location of Filter in Injector Body

Inspect and Test Prior to Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrostion.
   - Follower spring
   - Injector body
   - Body nut
   - Spray tip
   - Injector rack
   - Filter caps
2. Inspect the following parts for wear or abrasion deterioration.
   - Top of the follower
   - Follower spring
   - Injector body
   - Spray tip orifices
3. Check the rack for freeness and the plunger movement in Tester J 29584.

   With the injector control rack held in the *no-fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (Fig. 8). If the rack falls freely the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.

4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.

5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.

6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 9) and remove the filter caps, gaskets and filters.

   Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 10).

2. Compress the follower spring (Fig. 11). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to (Fig. 12) and remove the plunger follower, plunger and spring as an assembly.

4. Using socket J 4983–01, loosen the nut on the injector body (Fig. 13).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing.

   When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the tip down through the nut, using tool J 1291–02 (Fig. 14).

6. Refer to (Fig. 15) and remove the spill deflector. Then, lift the bushing straight out of the injector body.

7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

8. Withdraw the injector control rack from the injector body. Also, remove and discard the seal ring from the body.

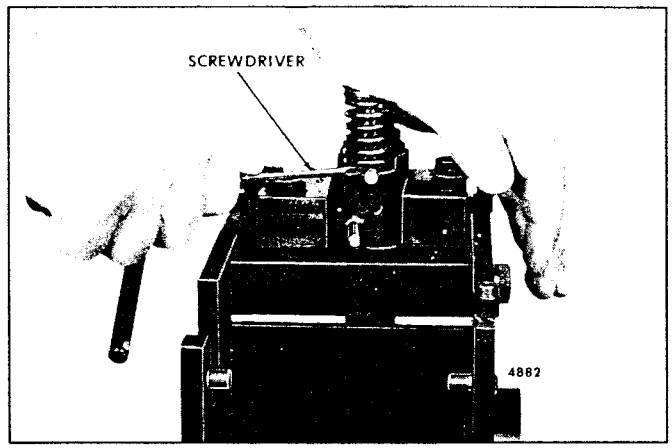


Fig. 11 – Removing Injector Follower Stop Pin

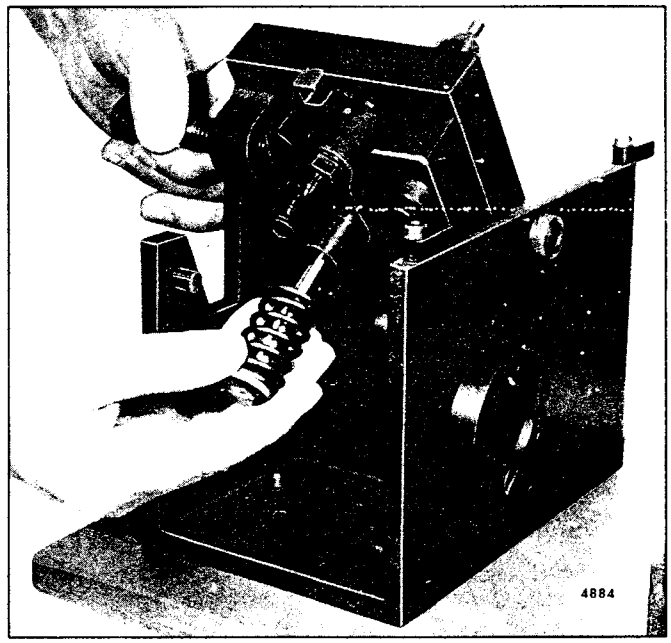


Fig. 12 – Removing or Installing Plunger Follower, Plunger and Spring

Clean Injector Parts

Since most injector problems are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with a suitable solvent and dry them with clean, filtered compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Use lint free towels to wipe off the parts. Clean out the passages, drilled holes and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation.

Clean the spray tip with Tool J 1243 (Fig. 16). Turn the reamer in a clockwise direction to remove the carbon deposits.

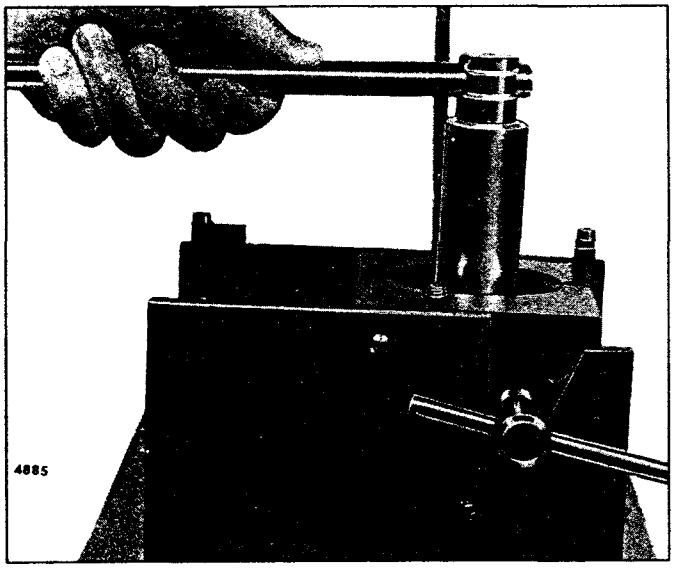


Fig. 13 – Removing Injector Nut Using Tool J 4983-01

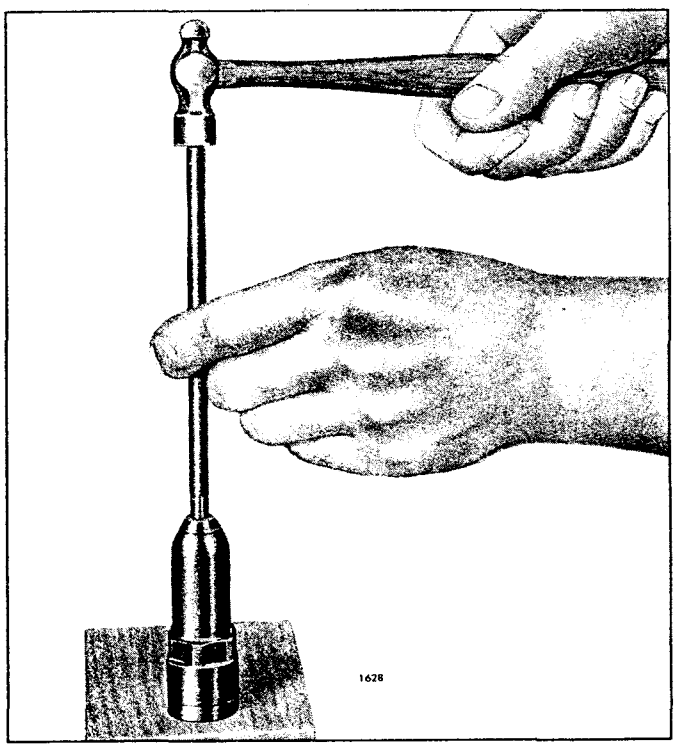


Fig. 14 – Removing Spray Tip from Injector Nut Using Tool J 1291-02

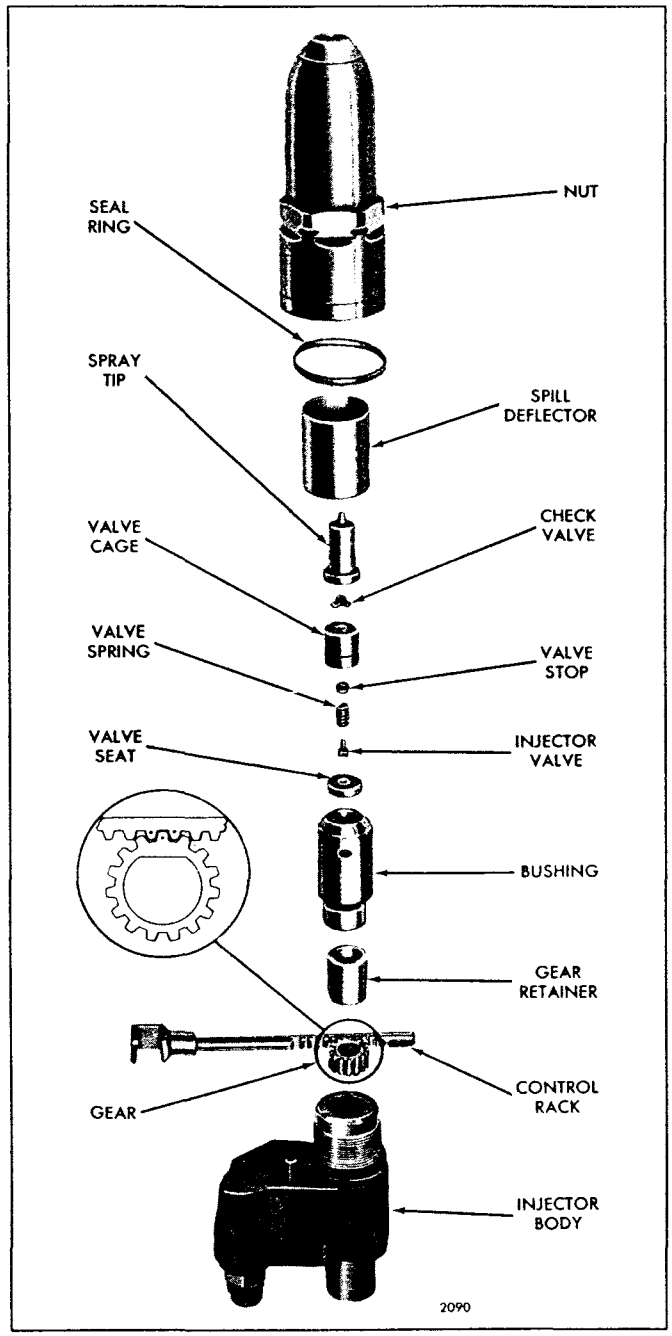


Fig. 15 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1, and the proper size spray tip cleaning wire. Use wire J 21459-01 to clean .005" diameter holes and wire J-21461-01 to clean .006" diameter holes (Fig. 17).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16" with stone J 8170. Allow the wire to extend 1/8" from tool J 4298-1. Ultra sonic cleaning is also an acceptable method.

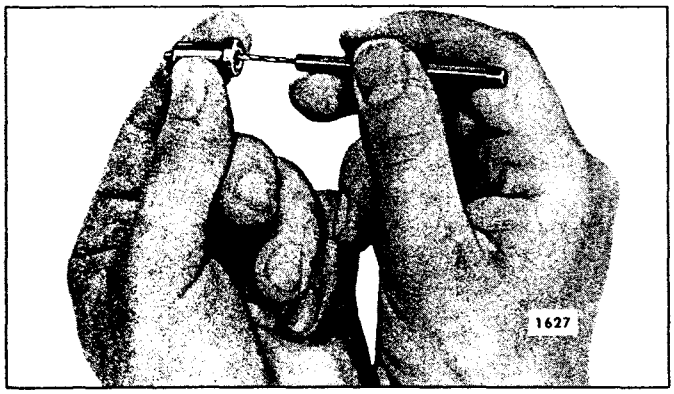


Fig. 16 – Cleaning Injector Spray Tip Using Tool J 1243

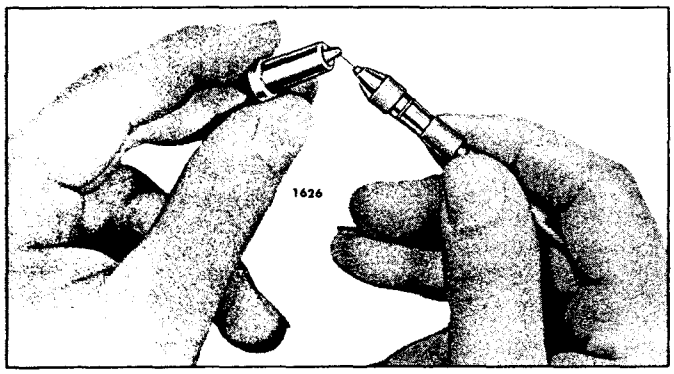


Fig. 17 – Cleaning Spray Tip Orifices Using Tool J 4298–1

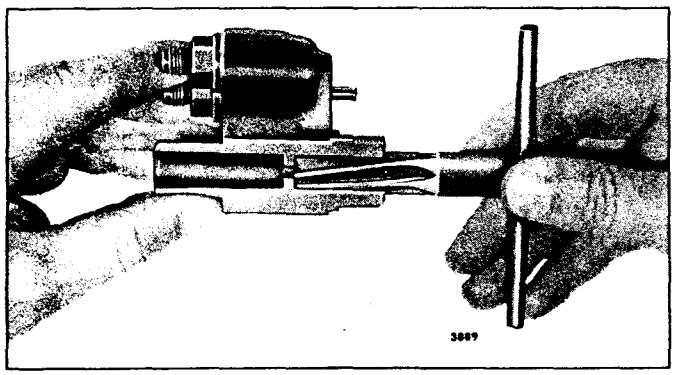


Fig. 18 – Cleaning Injector Body Ring with Tool J 21089

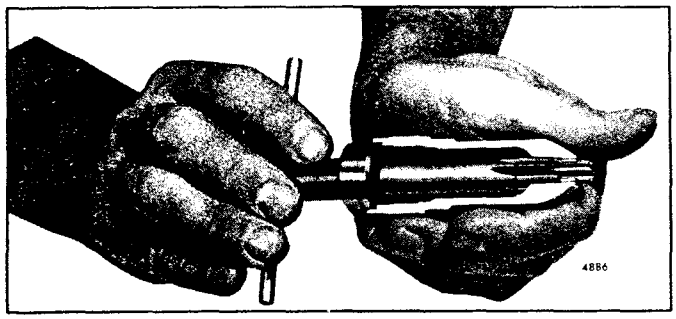


Fig. 19 – Cleaning Injector Nut Spray Tip Seat Using Tool J 4986–01

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTICE: Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kpa) air pressure.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully, insert reamer (J 21089) into the ring bore of the injector body (Fig. 18). Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then, wash the injector body in clean solvent and dry it with compressed air.

Carefully, insert reamer J 4986–01 in the injector nut (Fig. 19). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the seat for reamer contact over the entire surface. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the seat.

Wash the injector nut in clean solvent and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean solvent and dry them with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. *Keep the plunger and bushing together as they are mated parts.*

After washing, submerge the parts in a clean receptacle containing clean test oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts (Visual and Dimensional)

NOTICE: Injector components manufactured after January 1, 1988 may or may not be blued, at the discretion of the manufacturer. Bluing has no effect on a part's performance or service life.

1. Follower:

   Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002" (Fig. 20).

   Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002" wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

   Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

   Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

   Check the follower spring tension with spring Tester J 29196.

   The current injector follower spring (.142" diameter wire) has a free length of approximately 1.504" and should be replaced when a load of less than 70 lbs. will compress it to 1.028". The former spring wire was .120" diameter.

   It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (.142" diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

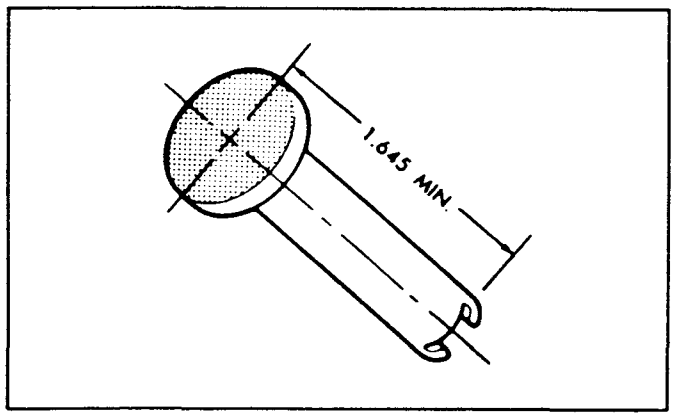


Fig. 20 – Injector Follower

3. Injector Body:

   Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces fordamage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Caps:

   Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack

   Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

   The notch in the clevis should be .3125" to .3145". A .250" inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer:

   Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

7 & 8 Plunger Bushing Assembly

Effective with injectors manufactured in October, 1985, the P & B (plunger and bushing) assemblies of all fuel injectors have a revised finish on the inside diameter of the bushing that provides greater resistance to scoring during injector operation.

Revised P & B assemblies are identified with a black locating pin at the top of the bushings. Injector assemblies containing revised P & B's are date stamped on the body with a "10–85" (for October, 1985) or later build date. Revised P & B assemblies are physically interchangeable with early P & B assemblies. However, because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.

NOTICE: Do not attempt to install the plunger of one P & B into the bushing of another P & B and vise-versa. Since the components of P & B assemblies are supplied as precision matched sets, any attempt to mix them can result in P & B seizure and serious injector damage.

Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring, the condition of the dowell pin and check for corrosion or varnish (Fig. 21).

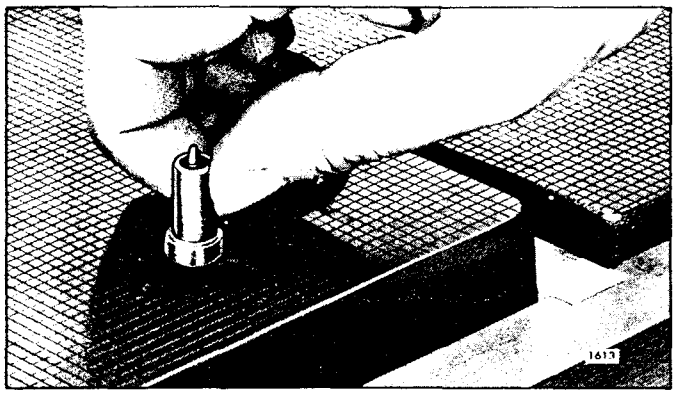


Fig. 25 – Lapping Spray Tip on Lapping Blocks J 22090

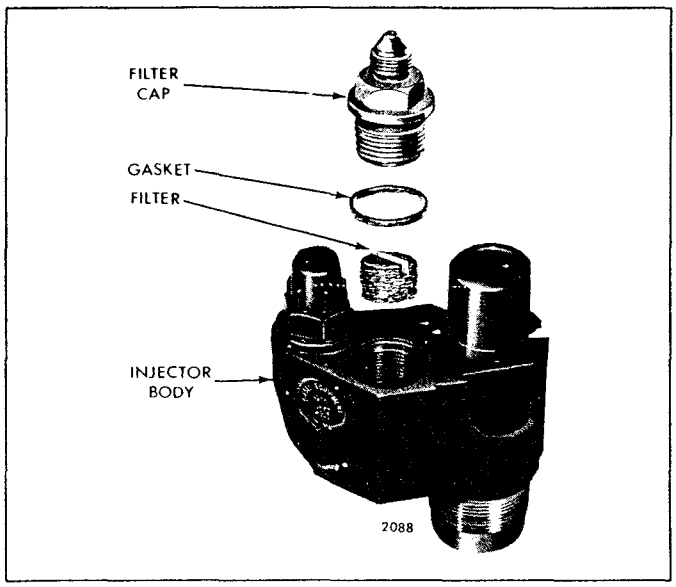


Fig. 26 – Details of Injector Filters and Caps and Their Relative Location

Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in (Fig. 24) as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.
2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.
3. Place the part to be lapped flat on the block (Fig. 25) and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.
4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*
5. When the part is flat, wash it in clean solvent and dry it with compressed air.
6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again, wash the part in cleaning solvent and dry it with compressed air.
7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives the "mirror" finish required for easy inspection.
8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Injector

1. Secure the body in vise J 22396–1.
- 2. Insert new filter(s) in the top of the body (Fig. 26). The current production service filter (stainless steel wire mesh pellet) is installed dimple end down, slotted end up. The former service filter (fiberglass–filled nylon cone) was installed with the pointed (cone) end up.

   Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 27).
- 3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps (Fig. 28). Using a 9/16" deep socket and a torque wrench tighten the filter caps as follows:

   Non–blued cap on non–blued body ..... 62 lb–ft (84 N·m) torque

   Blued cap on blued body ..... 70 lb–ft (95 N·m) torque

   Non–blued cap on blued body or blued cap on non–blued body ..... 62 lb–ft (84 N·m) torque
4. Install clean shipping caps to protect the sealing surfaces and to prevent dirt from entering the injector.
5. Lubricate thread protector J 29197 with injector test oil. Remove the injector from the vise and hold the injector body, bottom end up. Place the protector over the threads of the injector body.

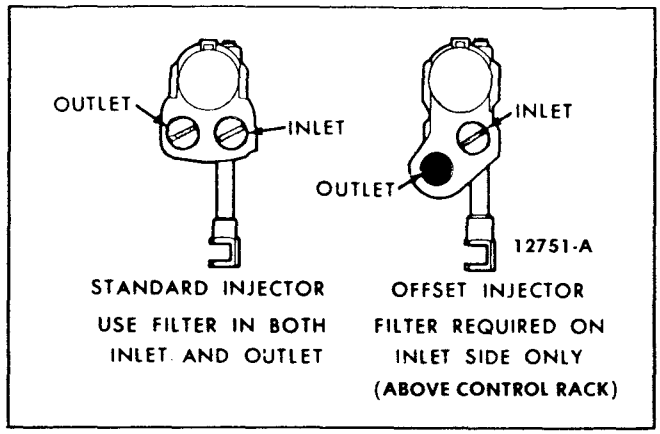


Fig. 27 – Location of Filter in Injector Body

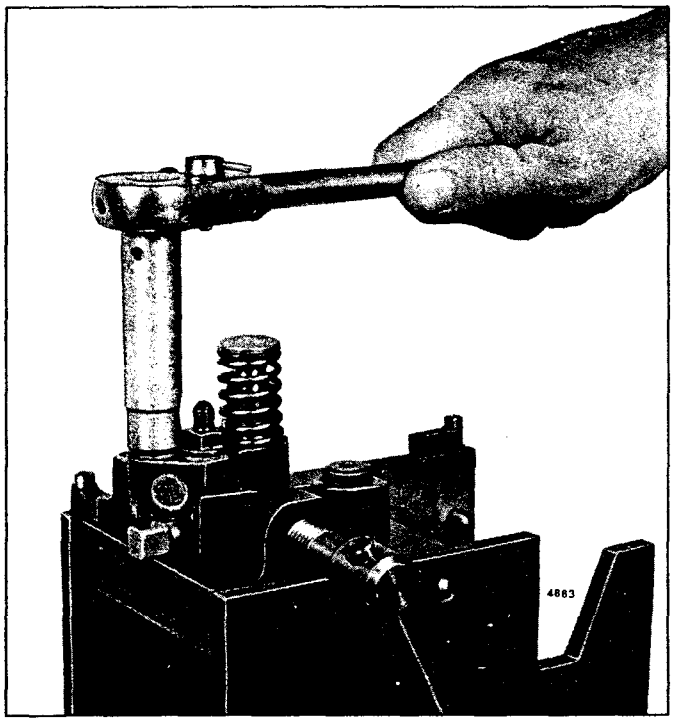


Fig. 28 – Installing Filter Cap

6. Lubricate the new seal ring and place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

- A new round (in cross-section) injector nut seal ring replaced the former diamond-shaped ring, effective with injectors manufactured approximately November 1, 1987. Only the round seal ring is serviced.

7. Remove the protector (J 29197).

8. Slide the control rack into the injector body.

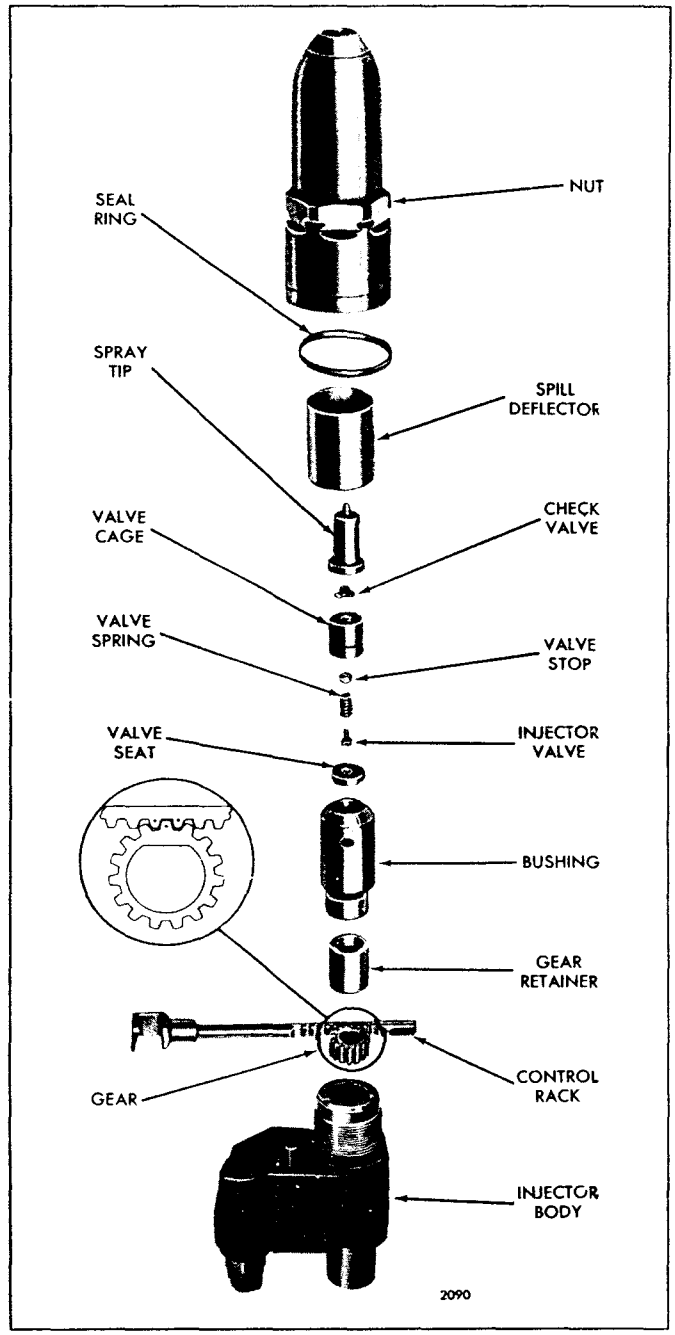


Fig. 29 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

9. Refer to (Fig. 29) and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

10. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 29).

11. Place the gear retainer on top of the gear.

12. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

13. Support the injector body, bottom end up, in injector vise J 22396–1.

14. Install the spill deflector over the barrel of the bushing.

15. Insert the valve stop, valve spring and injector valve into the valve cage.

16. Place the valve seat centrally on the top of the bushing.

17. Place the valve cage and related parts (injector valve down) on top of the valve seat.

18. Locate the check valve centrally on the cage and place the spray tip over the check valve and against the valve cage.

19. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 30). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

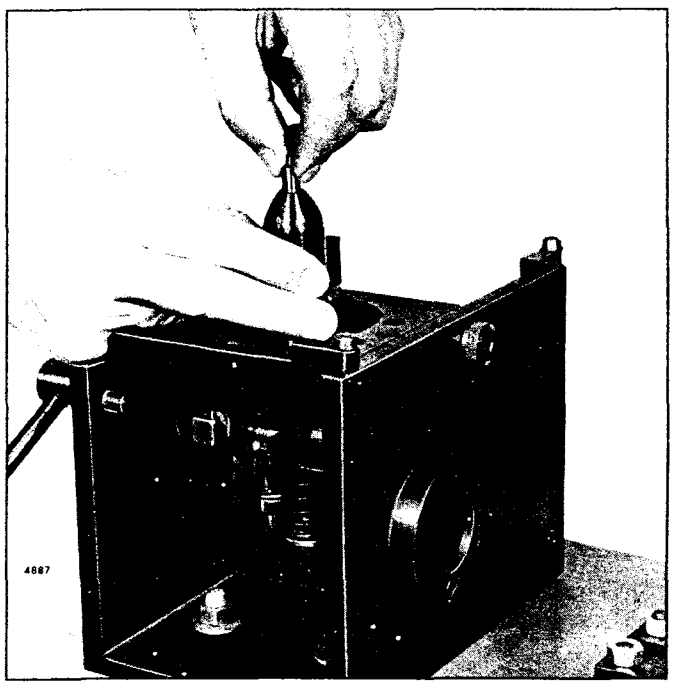


Fig. 30 – Tightening Injector Nut by Hand

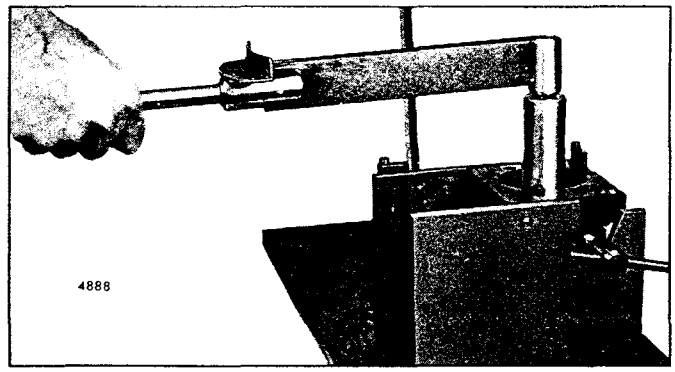


Fig. 31 – Tightening Injector Nut with Torque Wrench Using Tool J 4983-01

• 20. Use socket J 4983–01 and a torque wrench to tighten the injector nut as follows:

Non–blued nut on
non–blued body ..... 50 lb–ft (68 N·m) torque

Blued nut on
blued body ..... 80 lb–ft (108 N·m) torque

Non–blued nut on blued
body or blued nut on
non–blued body ..... 65 lb–ft (88 N·m) torque

21. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body–nut crevice.

NOTICE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

22. Turn the injector over and push the rack all the way in.

23. Place the follower spring on the injector body.

24. Refer to (Fig. 32) and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.

25. Refer to (Fig. 33) and slide the head of the plunger into the follower.

26. Align the slot in the follower with the stop pin hole in the injector body.

27. Align the flat side of the plunger with the flat in the gear.

28. Insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

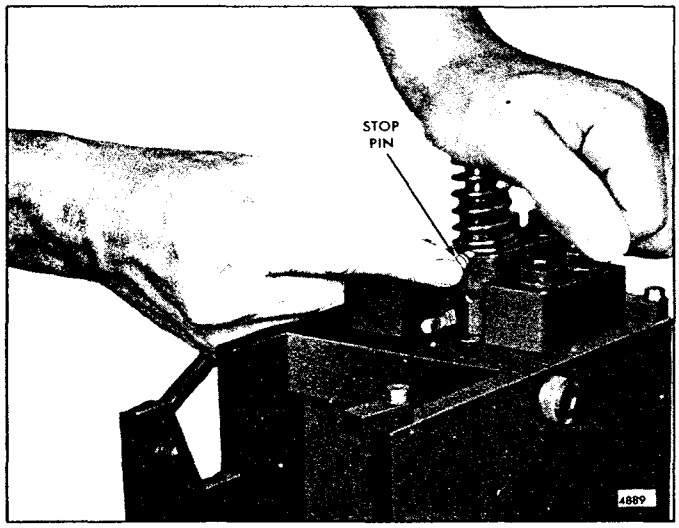


Fig. 32 – Installing Injector Follower Stop Pin

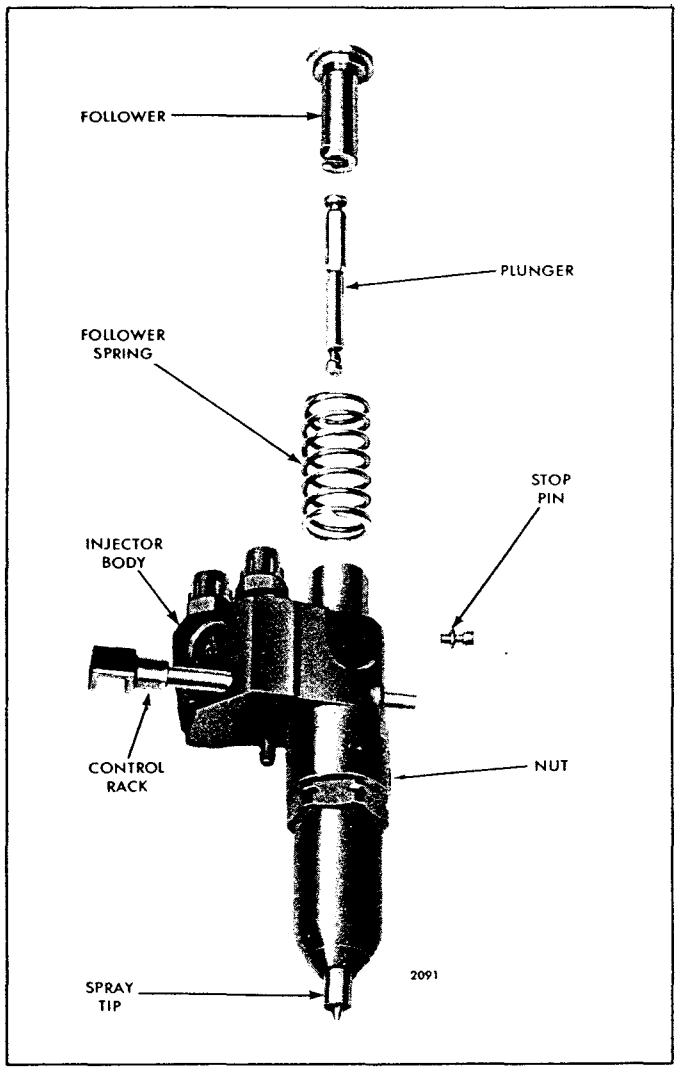


Fig. 33 – Injector Plunger, Follower and Relative Location of Parts

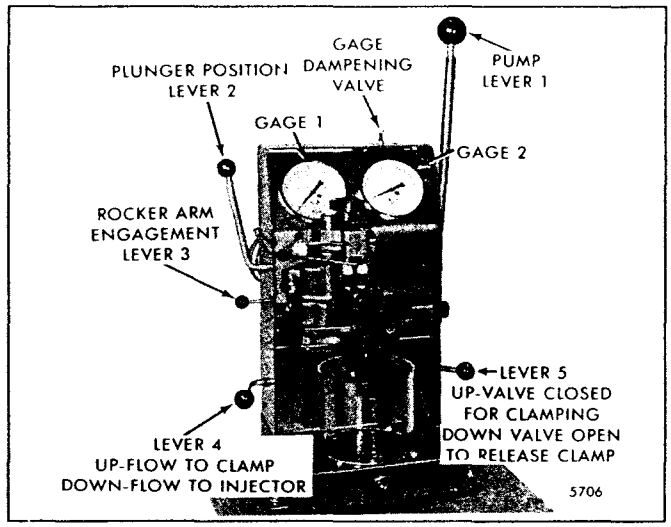


Fig. 34 – Injector in Position for Testing with Tester J 23010–A

Check Injector Output

Perform the injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

Check Atomization and Spray Pattern

This test determines spray pattern uniformity and atomization.

1. Clamp the injector properly and purge the air from the system (Fig. 34).
2. Move lever 4 down.
3. Position the injector rack in the *full–fuel* position.
4. Place pump lever 1 in the *vertical* position.
5. Move lever 3 to the *forward detent* position.
6. The injector follower should be depressed rapidly using pump lever 1 (at 40 to 80 strokes per minute) to simulate operation in the engine. Observe the spray pattern to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

Check Pressure Holding and Test for Leaks

This test determines if the body–to bushing mating surfaces in the injector are sealing properly and indicates proper plunger–to–bushing fit.

1. Clamp the injector properly in Tester J 23010–A and purge the air from the system (Fig. 34).
2. Close The Thru–Flow valve, but do not overtighten.
3. Move lever 2 to the rear, *horizontal* position.

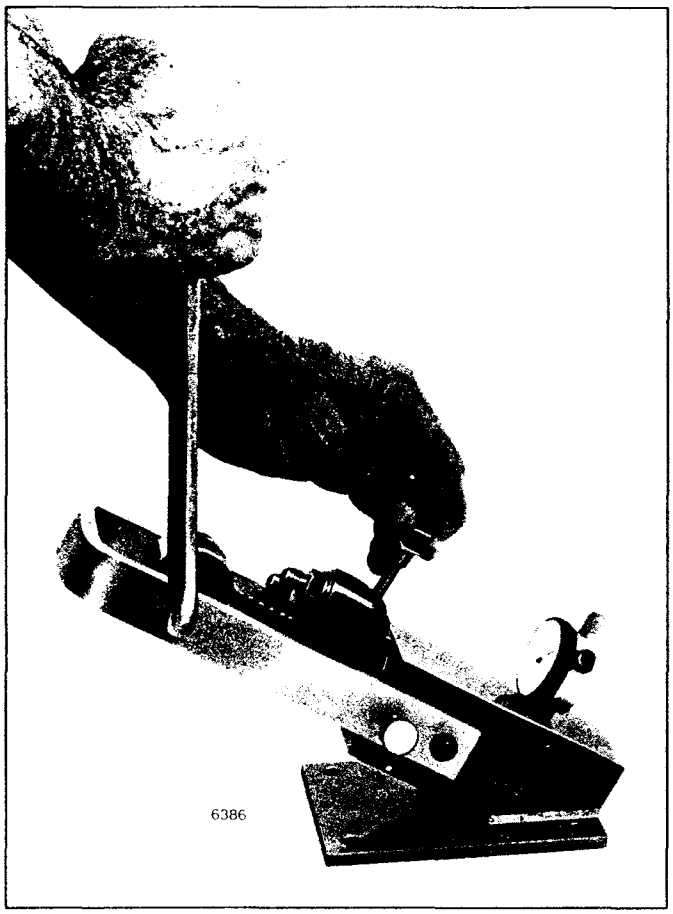


Fig. 35 – Checking Rack for Freeness in Tester J 29584

4. Operate pump lever 1 until gage 1 slowly reaches 100–200 psi (689–1378 kPa), check for injector nut seal ring leaks. Then, move lever 2 until the plunger closes both bushing parts. Operate pump lever 1 and increase the gage reading to 1500–2000 psi (10 335–13 780 kPa). Check for leaks at the filter cap gaskets and the body plugs. Allow the plunger to go back to the *normal* position. Operate pump lever 1 and bring the pressure up to 500 psi (3445 kPa). Note the time for the pressure to drop from 450 psi to 250 psi (3100 kPa to 1723 kPa). This should not occur in less than 7 seconds. This test determines if the body–to–bushing mating surfaces in the injector are sealing properly.

5. To unclamp the injector use the following procedure:

   a. Open the Thru–Flow valve to release the pressure in the system.

   b. Move lever 5 *down* to release the clamping pressure.

   c. Swing out the adaptor plate and remove the injector after the seals in the clamping head are free and clear of the injector filter caps.

   d. Carefully, return lever 5 to the *up (horizontal)* position.

Check Rack Freeness and Spray Tip Concentricity

Place the injector in Tester J 29584 (Fig. 35) and check rack freeness.

With the injector control rack held in the *no–fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel. If the rack falls freely the injector passes the test.

If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times, if necessary. Generally, this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts or to remove dirt.

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in Tester J 29584 (Fig. 35) and adjust the dial indicator to zero.

2. Rotate the injector 360° and note the total runout as indicated on the dial.

3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 55–65 lb–ft (75–88 N·m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Box and Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286–9 or a cylinderical wire brush (Section 2.1.4), to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrussion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)

*Not serviced. Available from Jacobs Manufacturing Company.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Insert the injector into the injector tube with the dowel in the injector body registering with the locating hole in the cylinder head.
2. Slide the rack control lever over so that it fully engages the injector rack clevis.
3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20–25 lb–ft (27–34 N·m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   NOTICE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0 – Specifications.

   NOTICE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridges are not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Refer to *Install Rocker Arm and Shaft* in Section 1.2.1 and note the position of the exhaust valve bridges before, during and after tightening the rocker shaft bolts.

- 5. Install fuel pipes:

   Remove the shipping caps. Align the fuel pipes and connect them to the injectors and the fuel connectors.

   NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

   NOTICE: Because of their low friction surface, Endurion® –coated nuts on fuel jumper lines must be tightened to 130 ***lb–in*** (14.69 N·m) torque, instead of the 160 ***lb–in*** (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

   Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

   NOTICE: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to Fuel Jumper Line Maintenance & Pressurize Fuel System – Check for Leaks in Section 2.0 – Shop Notes).

   An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover.

   A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil.

   Remove and replace the leaking fuel pipes and/or connectors. Use new gasket(s) and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

6. Perform a complete engine tune–up as outlined in Section 14. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control levers.

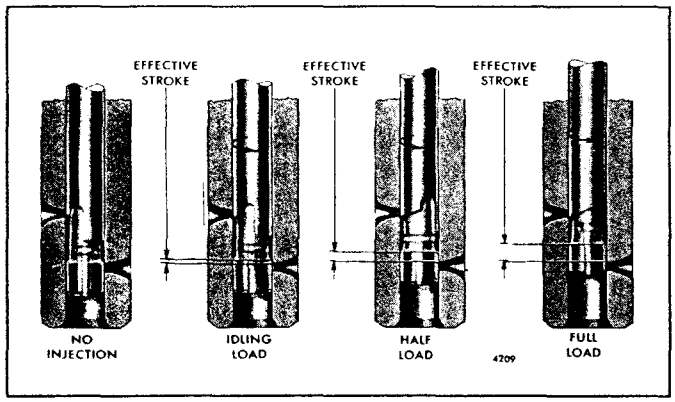


Fig. 3 – Fuel Metering from No Load to Full Load

Metering and timing during fuel injection is accomplished by an upper and lower helix machined in the lower end of the injector plunger. (Fig. 3) illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

(Fig. 4) illustrates the phases of injector operation by the vertical travel of the injector plunger.

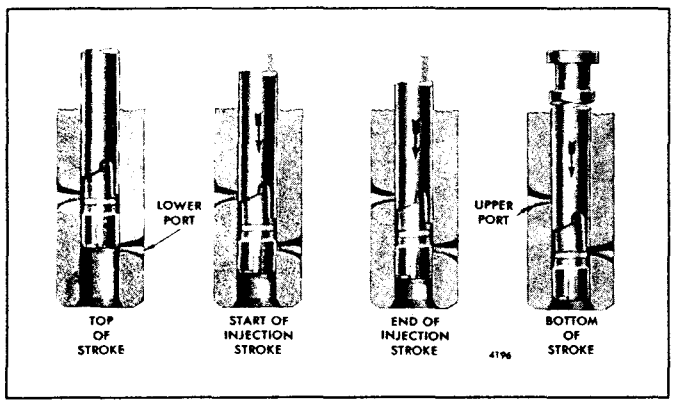


Fig. 4 – Phases of Injector Operation Through Vertical Travel of Plunger

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the effective stroke of the plunger and the flow rate of the spray tip.

Since the helix angle and the plunger design determines the operating characteristics of a particular injector, it is imperative that the specified injectors are used for each engine. If injectors of different types are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 1).

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting or fine tuning of all injector racks.

The fuel injector combines in a single unit all of the parts necessary to provide complete and independent fuel injection at each cylinder.

- New O–ring sealed fuel pipes are used on the mechanical unit injectors in marine engines, effective with units built approximately April, 1988. These fuel pipes feature a three–piece connector (collar, nut, o–ring seal) at both ends (Fig. 38). The primary sealing element is the replaceable fluoroelastomer (Viton) O–ring seal.

- To conform with this change, new connectors are installed in the cylinder head and new fuel injectors with redesigned filter caps are used. The connectors and caps have a 1/2" – 20 female thread to accept the 1/2"–20 male thread on the fuel pipe nuts.

- Flared tube design and O–ring design fuel pipes are not interchangeable on a part–for–part basis. The new pipes, connectors, and injector filter caps must be used together to insure interchangeability. The injector filter cap is not compatible with the former nylon cone fuel inlet filter. It must be used with the current stainless steel mesh pellet filter.

Operation

Fuel, under low pressure, enters the injector at the inlet side through a filter cap and filter positioned over the racks (Fig. 2). From the filter, the fuel passes through a drilled passage into the supply chamber, that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing. The plunger operates up and down in the bushing, and is supplied fuel through the two funnel–shaped ports in the bushing wall.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 5). In addition to the reciprocating motion, the plunger can be rotated around its axis by the gear which meshes with the control rack. To accomplish fuel metering, an upper helix and a lower helix are machined in the lower part of the plunger. The helix relationship to the ports changes with the rotation of the plunger.

As the plunger moves downward, under pressure of the injector rocker arm, some of the fuel under the plunger moves into the supply chamber through the lower port until the port is covered by the lower end of the plunger. The fuel below the plunger continues to move up through a central passage in the plunger into the fuel metering recess and into the supply chamber through the upper port until that port is covered by the upper helix of the plunger. With the upper and lower ports both covered, the remaining fuel trapped under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat check valve. The fuel in the check valve cage, spring cage, tip passages and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed–off of fuel leaking past the needle pilot in the tip assembly.

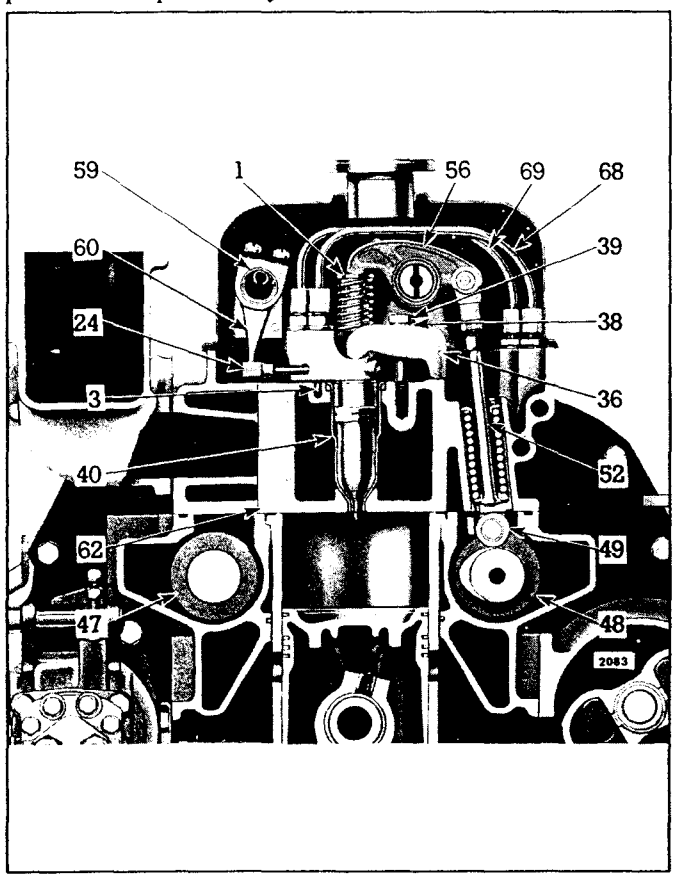


Fig. 5 – Fuel Injector Mounting

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its *original* position by the injector follower spring. (Fig. 4) shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. (Fig. 3) shows the various plunger positions from no load to full load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this *no injection* position to *full injection* position (full rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first–class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water–free fuel are the keys to trouble–free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well lighted room with a dust free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the

doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air.

Provide the injector repair room with a supply of filtered, moisture–proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rust–proof material and deep enough to permit all of the injector parts to be completely covered by the cleaning solvent, when submerged in wire baskets of 16 mesh wire screen. Use baskets which will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint–free paper tissue is a suitable material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors and prevent damage. Also, protect the fuel pipes and fuel connectors from damage and the entry of dirt or other foreign material.
2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and overhaul of an injector.
3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in Section 14:
   a. Time the injector.
   b. Position the injector control rack.
4. Whenever an engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to Section 15.3).
5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

   NOTICE: Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.
2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 5).

   NOTICE: Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also, protect the fuel pipes and fuel connectors from entry of dirt or foreign material.
3. Crank the engine to bring the upper ends of the push rods of the injector and valve rocker arms in line horizontally. If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left–hand direction of rotation because the bolt could be loosened.

   CAUTION: To reduce the risk of personal injury when barring over or "bumping" the starter, personnel should keep their hands and clothing away from the moving parts of the engine as there is a remote possibility the engine could start.
4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 6).
5. Remove the injector clamp bolt, special washer and clamp.
6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.

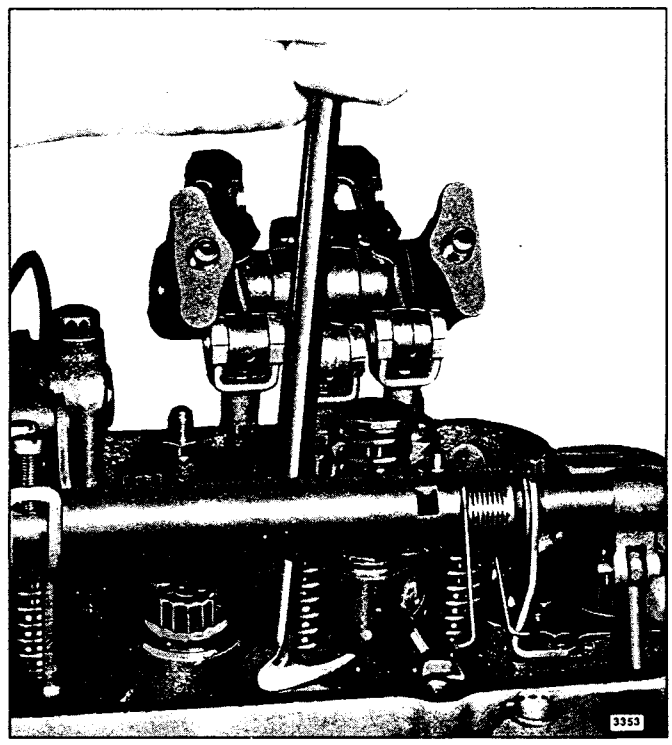


Fig. 6 – Removing Injector from Cylinder Head

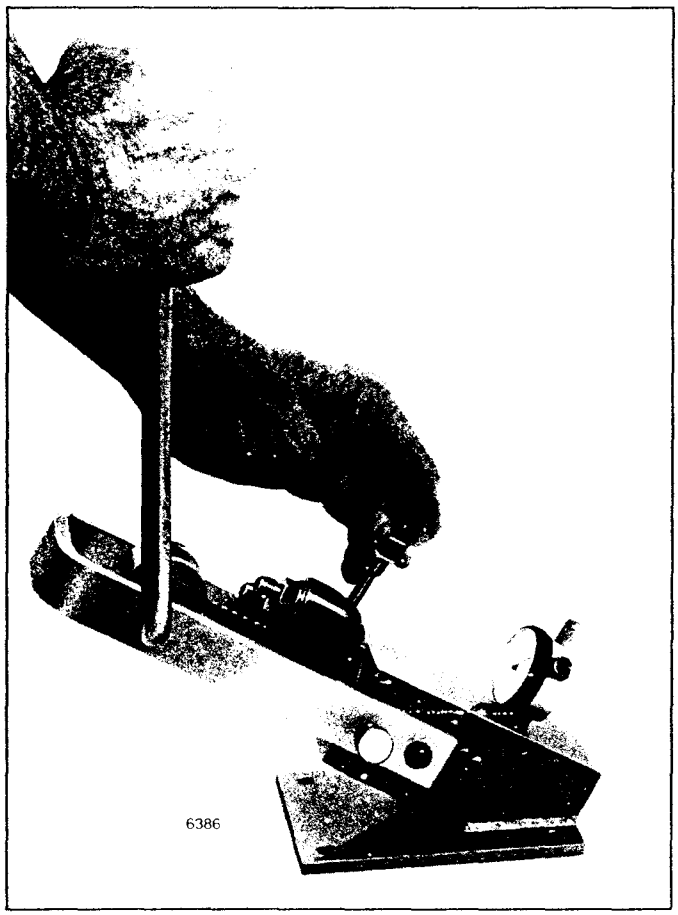


Fig. 7 – Checking Rack for Freeness in Tester J 29584

7. Lift the injector from its seat in the cylinder head (Fig. 6).
8. Cover the injector hole in the cylinder head to keep foreign material out.
9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Inspect and Test Prior to Reuse

This inspection and test process is necessary if the injector is being considered for reuse rather than complete overhaul. Submerge the injector in clean solvent to wash it. Blow dry with compressed air.

CAUTION: To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

1. Inspect the following injector parts for external wear, rust and corrosion.
   - Follower spring
   - Injector body
   - Body nut
   - Spray tip
   - Injector rack
   - Filter caps
2. Inspect the following parts for wear or abrasion deterioration.
   - Top of the follower
   - Follower spring
   - Injector body
   - Spray tip orifices
3. Check the rack for freeness and the plunger movement in Tester J 29584.

   With the injector control rack held in the *no-fuel* position, operate the handle to depress the follower to the bottom of its stroke. Then, very slowly release the pressure on the handle while moving the control rack up and down until the follower reaches the top of its travel (Fig. 7). If the rack falls freely, the injector passes the test. If the injector fails the rack freeness test, either the plunger is scored or there is a misalignment of the body, bushing or nut due to irregular or dirty parts.
4. Check the injector for leaks using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010–A as outlined in Section 2.0 – Shop Notes.
6. Perform injector fuel output test using Calibrator J 22410–A as outlined in Section 2.0 – Shop Notes.

   If the injector passes the above tests, it can be reused.

If the results of the above tests reveal marginal performance, removal of the plunger may assist with further diagnosis of internal injector problems. Plungers that reveal scratches, score marks, abnormal wear, helix chipping or other obvious damage would indicate that the injector should not be reused.

Disassemble Injector

1. Support the injector upright in injector holding fixture J 22396 (Fig. 8) and remove the filter caps, gaskets and filters.

   Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets. In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 9).
2. Compress the follower spring (Fig. 10). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.

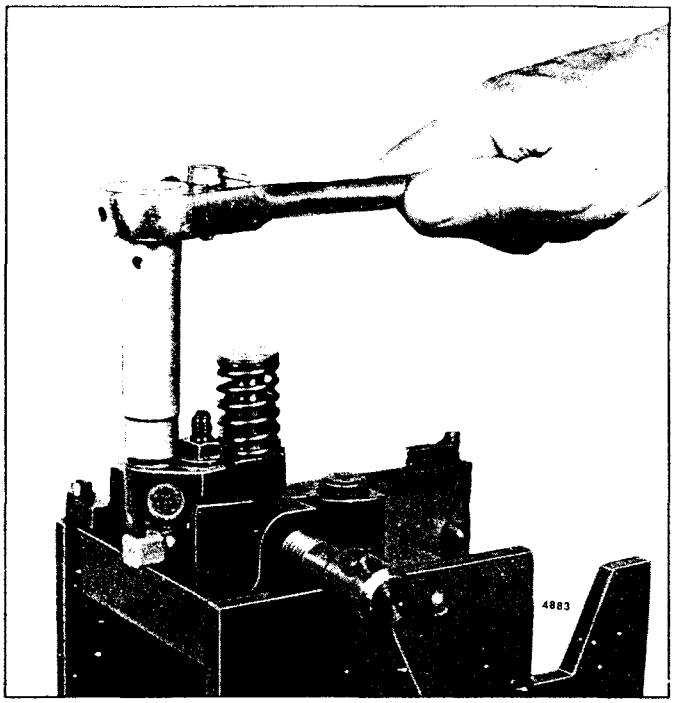


Fig. 8 – Removing Filter Cap

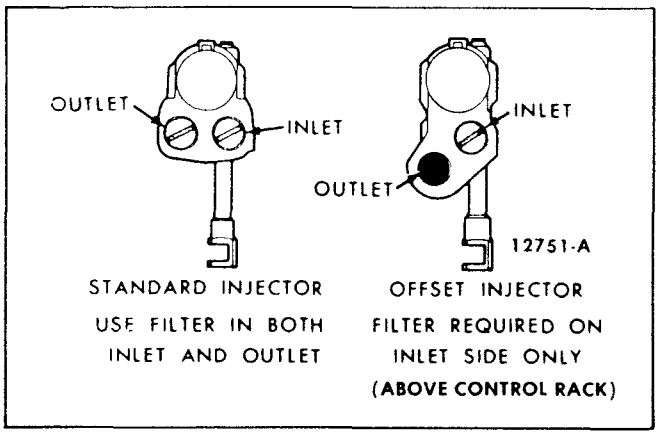


Fig. 9 – Location of Filter in Injector Body

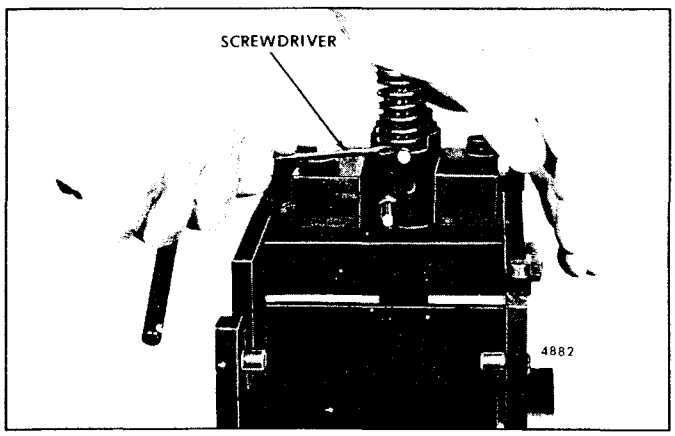


Fig. 10 – Removing Injector Follower Stop Pin

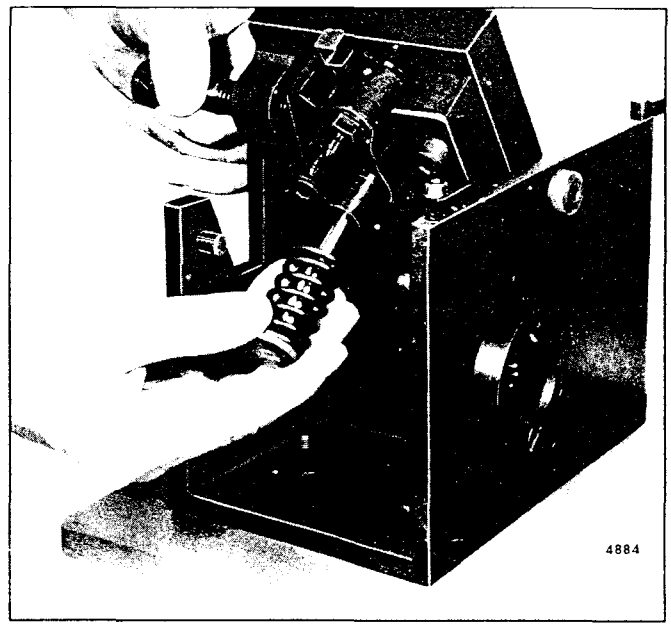


Fig. 11 – Removing or Installing Plunger Follower, Plunger and Spring

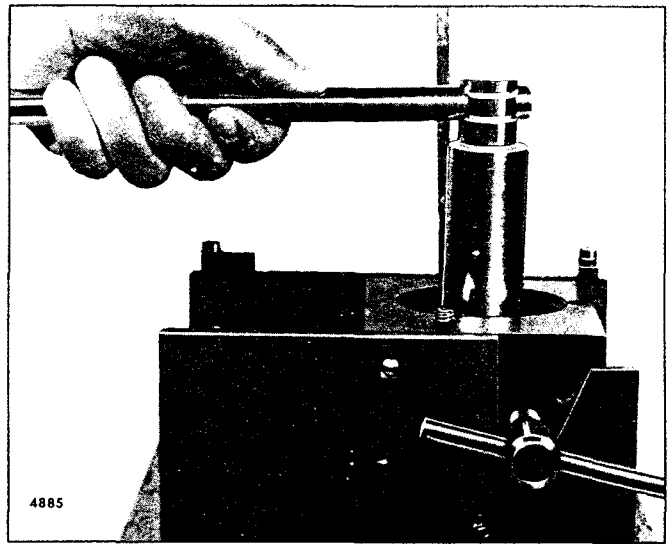


Fig. 12 – Removing Injector Nut Using Tool J 4983-01

3. Refer to (Fig. 11) and remove the plunger follower, plunger and spring as an assembly.

4. Using socket J 4983-01, loosen the nut on the injector body (Fig. 12).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip, spring cage, valve spring, spring seat, check valve cage and check valve.

   When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers. In this event, support the nut on a wood block and drive the

tip down through the nut, using tool J 1291–02 (Fig. 13).

6. Refer to (Fig. 14) and remove the spill deflector. Then, lift the bushing straight out of the injector body.

7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

8. Withdraw the injector control rack from the injector body. Also, remove the seal ring from the body.

Clean Injector Parts

Since most injector problems are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

Wash all of the parts with a suitable cleaning solvent and dry them with clean, filtered compressed air. Use lint free towels to wipe off the parts. Clean out the passages, drilled holes and slots in all of the injector parts.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

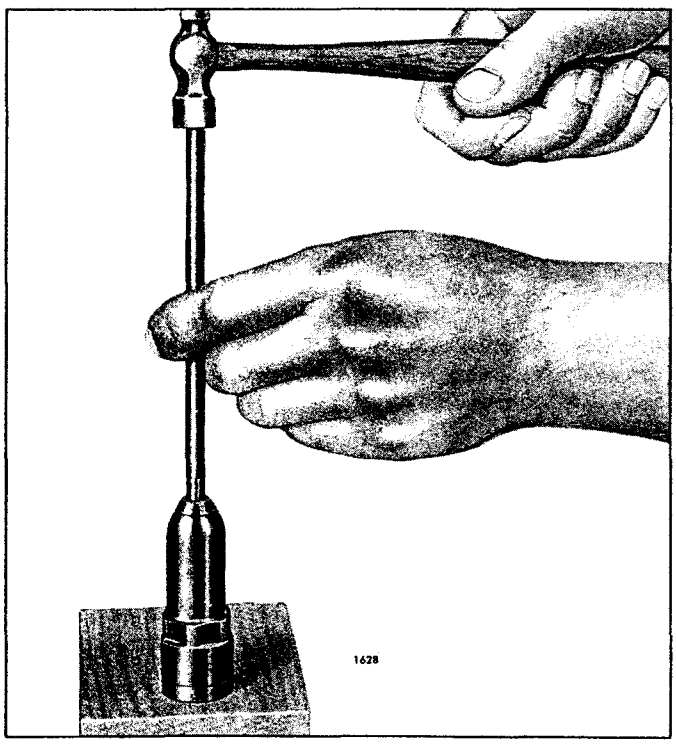


Fig. 13 – Removing Spray Tip from Injector Nut Using Tool J 1291–02

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately fifteen (15) minutes in a suitable solution prior to the external cleaning and buffing operation.

Clean the spray tip with tool J 24838 (Fig. 15).

NOTICE: Care must be exercised when inserting the carbon remover J 24838 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in solvent and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298–1 and the proper size spray tip cleaning wire. Use wire J 21460–01 to clean .0055" diameter holes and wire J 21461–01 to clean .006" diameter holes (Fig. 16).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16" with stone J 8170. Allow the wire to extend 1/8" from tool J 4298–1. Ultra sonic cleaning is also an acceptable method.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of the spray tip cleaner tool J 24838 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTICE: Do not buff the spray tip area excessively. *Do not use a steel wire buffing wheel or the spray tip holes may be distorted.*

When the body of the spray tip is clean, lightly buff the tip end in the same manner to clean the spray tip orifice area.

Wash the spray tip in clean solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Clean and brush all of the passages in the injector body, using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully, insert reamer J 21089 in the injector body (Fig. 17). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

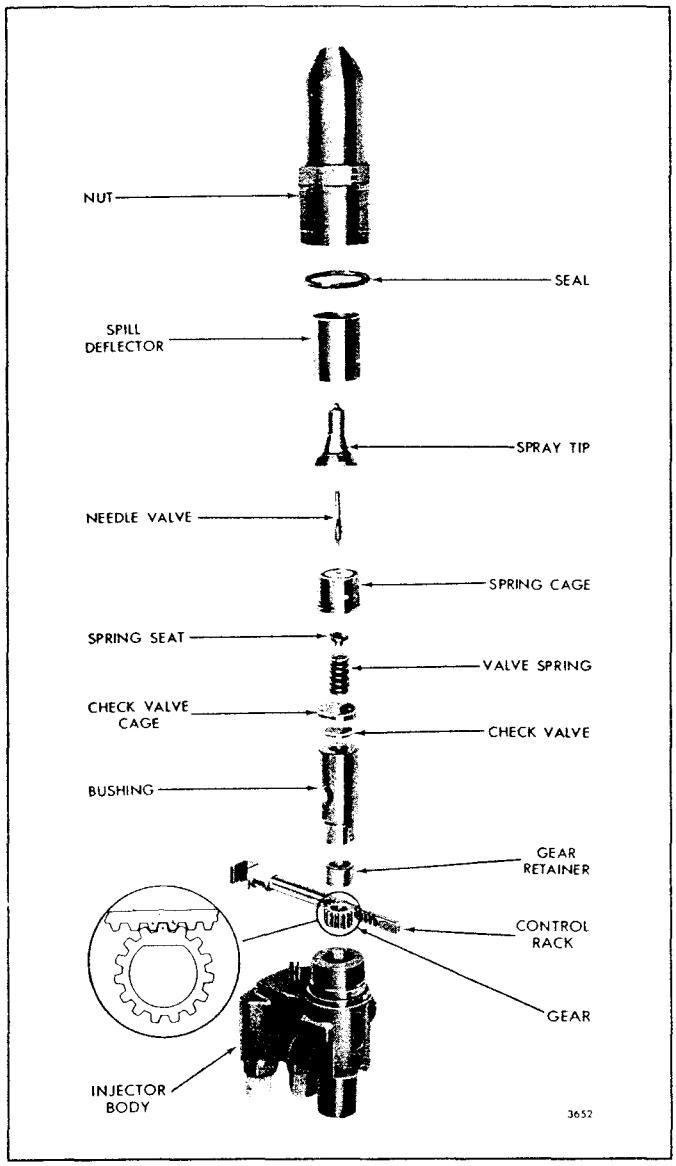


Fig. 14 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

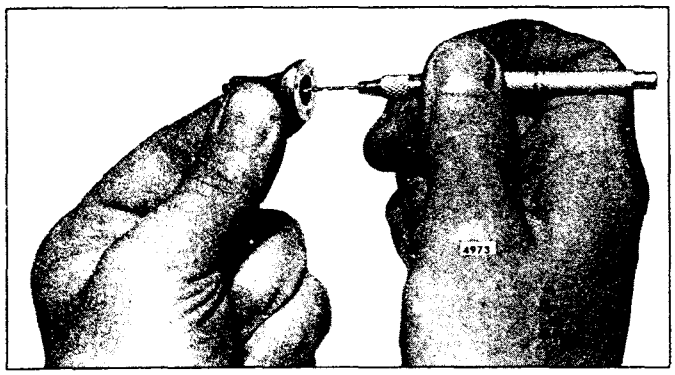


Fig. 15 – Cleaning Injector Spray Tip with Tool J 24838

Carefully, insert reamer (J 21089) into the ring bore of the injector body. Turn the reamer in a clockwise direction

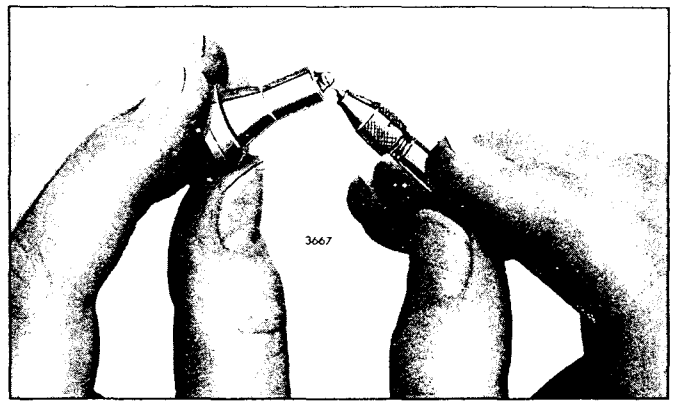


Fig. 16 – Cleaning Spray Tip Orifices with Tool J 4298–1

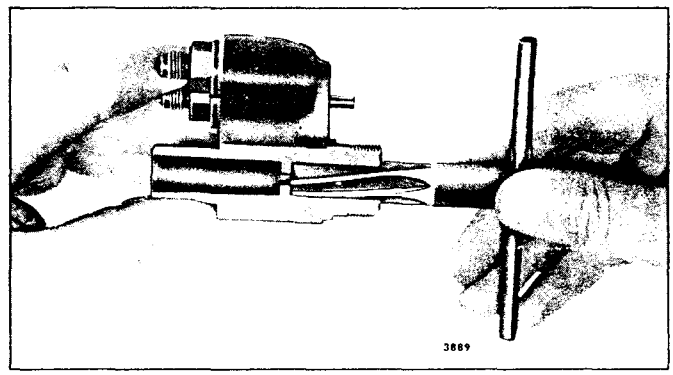


Fig. 17 – Cleaning Injector Body Ring with Tool J 21089

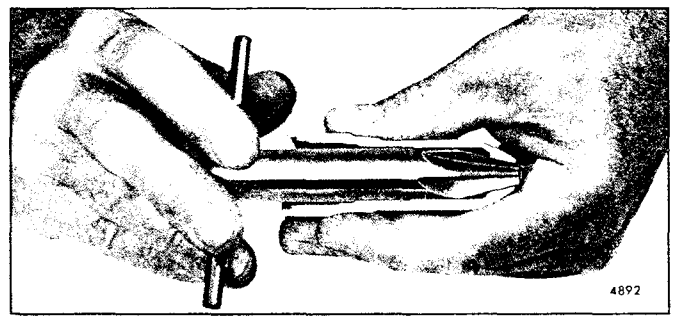


Fig. 18 – Cleaning Injector Nut Lower End with Tool J 9418–5

and remove any burrs inside the ring bore. Then, wash the injector body in clean solvent and dry it with compressed air.

- **NOTICE:** Do not damage the injector body ring during this operation. This spiral ring forms part of the injector body and is not serviced. If the ring is damaged, the injector body must be replaced.

Remove the carbon deposits from the lower end of the injector nut with reamer J 9418–5 (Fig. 18). Clean the tip seat with reamer J 9418–1. Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut.

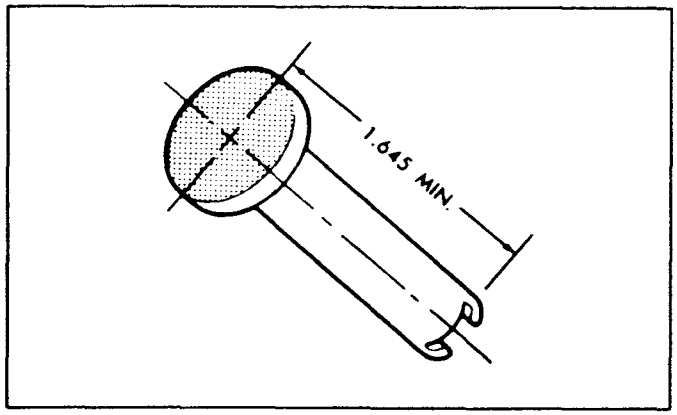


Fig. 19 – Injector Follower

Wash the injector nut in clean solvent and dry it with compressed air. Carbon deposits on the spray tip seating surfaces of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean solvent and dry them with compressed air. Be sure the high pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes, during engine operation, causing a serious oil dilution problem. *Keep the plunger/bushing together as they are matched parts.*

After washing, submerge the parts in a clean receptable containing clean test oil. *Keep the parts of each injector assembly together.*

Inspect Injector Parts (Visual and Dimensional)

1. Follower

   Measure between the top of the follower and the slot. This dimension must be 1.647 ± .002″ (Fig. 19).

   Check the stop pin groove in the side of the follower to be sure it is smooth and not damaged. The follower should not be reused if there is more than .002″ wear on the top or if there is any other visible damage or wear.

2. Follower Spring:

   Examine the outside diameter of the follower spring coils for wear caused by the rocker arms contacting the coils. If worn, do not reuse.

   Also, inspect for damage from rust pitting, nicks or notches in the coils, broken coils, broken coil ends and notches under the coil ends. If damaged, do not reuse.

   Check the follower spring tension with spring Tester J 29196.

   The current injector follower spring (.142″ diameter wire) has a free length of approximately 1.504″ and should be replaced when a load of less than 70 lbs. will compress it to 1.028″. The former spring wire was .120″ diameter.

   It is recommended that at the time of overhaul, all injectors in an engine be converted to incorporate the current spring (.142″ diameter wire). However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

3. Injector Body:

   Inspect the injector body threads, the bushing seating surface and the filter cap gasket sealing surfaces for damage. Then, inspect the rack hole, body seal ring sealing surface, clamp radius and dowel pin.

4. Filter Cap:

   Check the condition of the jumper line sealing surfaces on the filter caps, the copper gasket sealing surfaces, the threads and the fuel passage.

5. Control Rack

   Check the injector control rack for straightness, the teeth for wear and the width of the notch in the clevis. Also, check the rack for nicks, burrs, rust and hardness.

   The notch in the clevis should be .3125″ to .3145″. A .250″ inside diameter bushing may be used to check the rack for straightness. A slightly bent rack will not pass freely back and forth through the bore of the bushing.

6. Gear and Gear Retainer

   Inspect the gear and the gear retainer for nicks, burrs or rust and the gear teeth for wear.

- 7. & 8. Plunger and Bushing Assembly:
  - Effective with injectors manufactured in October, 1985, the P & B (plunger and bushing) assemblies of all fuel injectors have a revised finish on the inside diameter of the bushing that provides greater resistance to scoring during injector operation.
  - Revised P & B assemblies are identified with a black locating pin at the top of the bushings. Injector assemblies containing revised P & B's are date stamped on the body with a "10–85" (for October, 1985) or later build date. Revised P & B assemblies are physically interchangeable with early P & B assemblies. However, because of the increased resistance to scoring provided by the revised assemblies, DDC recommends using the revised assemblies when rebuilding fuel injectors.
  - **NOTICE:** Do not attempt to install the plunger of one P & B into the bushing of another P & B and vise–versa. Since the components of P & B assemblies are supplied as precision matched sets, any attempt to mix them can result in P & B seizure and serious injector damage.

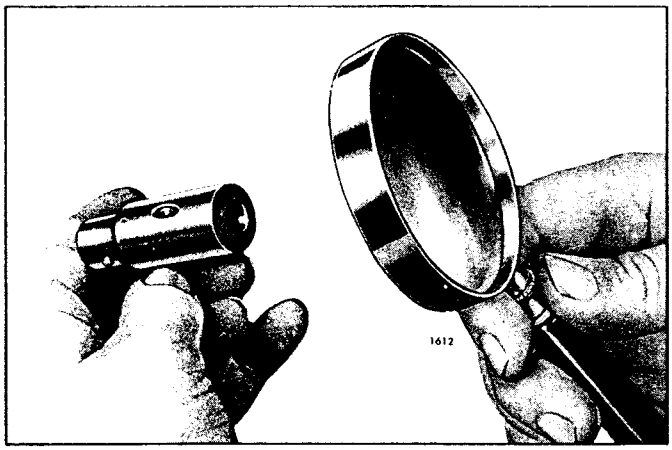


Fig. 20 – Examining Sealing Surface with a Magnifying Glass

7. Bushing:

   Check the bushing lapped sealing surface for scratches, the bushing internal diameter for scoring, the condition of the dowell pin and check for corrosion or varnish (Fig. 20).

8. Plunger:

   Check the plunger for corrosion or varnish, scoring, scratching or wear and chips along the edge of the helix (Fig. 21).

9. Check Valve:

   Inspect the check valve for cracks and scratches on the lapped surfaces or for corrosion and varnish.

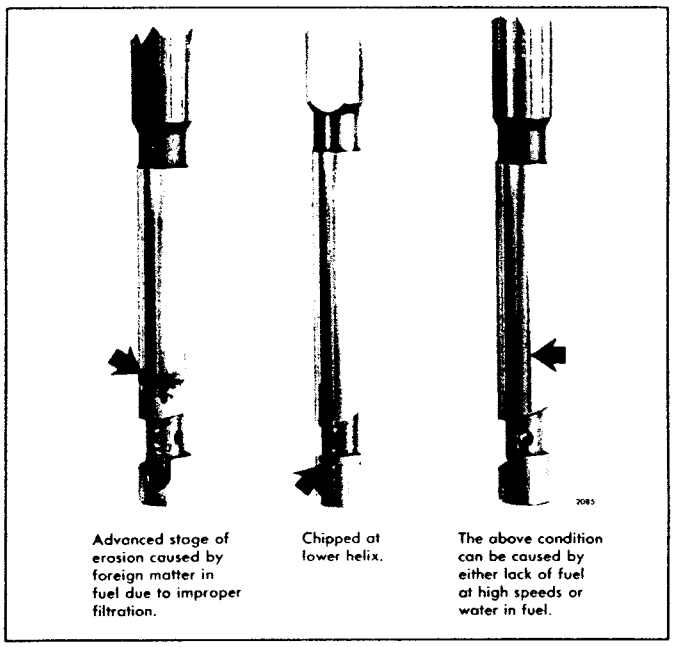


Fig. 21 – Unusable Injector Plungers

10. Check Valve Cage:

    Inspect the check valve cage for cracks and scratches on the lapped surfaces or for corrosion, varnish and wear.

11. Valve Spring:

    Check the injector valve spring for wear on the coil ends, broken coil ends and notches under the coil ends. Then, check for corrosion, nicks and cavitation erosion on the inside at approximately 1-1/2 coils from the end.

- **NOTICE:** A high V.O.P. (valve opening pressure) valve spring and seat are being used in certain high output engine injectors. The high V.O.P. spring is made of a thicker diameter wire than the standard valve spring and has a smaller inside diameter (.174" I.D. vs .184" I.D.). A no. 15 (.180") drill may be used to distinguish the two springs. The drill will fit into the standard spring, but not into the high V.O.P. spring. The high V.O.P. spring seat can be distinguished from the standard spring seat by its smaller diameter post and the groove on the end of this post. To ensure proper operation, the high V.O.P. spring and seat must be used together. *Do not mix injectors containing standard springs and seats with injectors having high V.O.P. springs and seats in the same engine.*

12. Spring Seat:

    Check the surfaces for wear.

13. Spring Cage:

    Inspect for cracks, corrosion or varnish and scratches on the lapped sealing surfaces. Also, inspect the spring seat surface and the needle valve seating surface for wear.

14. Spray Tip:

    Check for cracks, enlarged spray holes, corrosion on the outside diameter taper and oxide scale on the spray hole end. Then, check the nut–to–tip sealing surface and the lapped sealing surface for scratches. Do not reuse if there is scale, cracks or enlarged spray holes.

15. Needle Valve:

    Check the spray tip needle valve for erosion at the seat shoulder, scratches and overheating (discolored).

16. Nut:

    Check the nut for damaged threads, the condition of the seal ring seating area, the condition of spray tip seating area and the spray tip hole for being corroded irregularly.

17. Spill Deflector:

    Inspect both ends of the spill deflector for sharp edges or burrs.

18. Part Thickness:

Check the minimum thickness of the parts (see Table 1).

Part Name	Minimum Thickness
Spray Tip (shoulder)	.199"
Check Valve Cage	.163"—.165"
Check Valve	.022"
Valve Spring Cage	.602"

TABLE 1 – MINIMUM THICKNESS (Used Parts)

19. Needle Valve Lift:

Measure the needle valve lift, using tool J 9462–02 (Fig. 22) as follows:

a. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

b. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

c. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be .008" to .018". If it exceeds .018", the tip assembly must be replaced. If it is less than .008", inspect for foreign material between the needle valve and the tip seat.

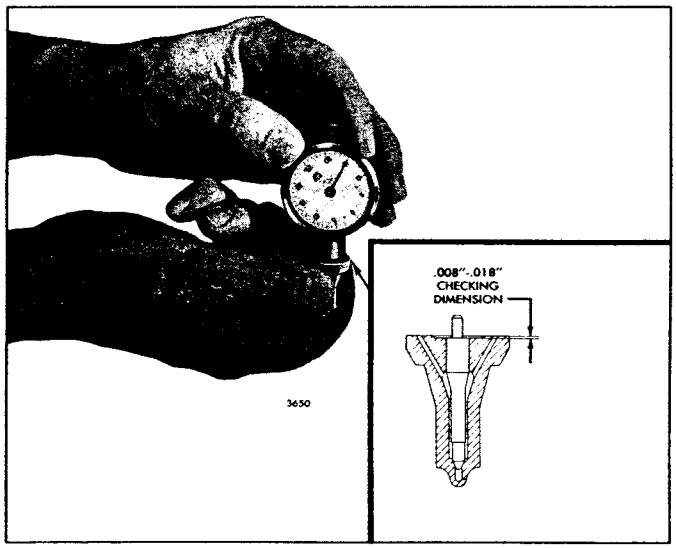


Fig. 22 – Checking Needle Valve Lift with Tool J 9462–02

d. If the needle valve lift is within limits, install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly should be replaced.

20. Classify Spray Tip:

Match the plunger/bushing assembly with the proper spray tip using Flow Gage J 25600–A (see Section 2.0).

Recondition Injector

If any of the injector parts listed below cannot be reconditioned satisfactorily, use new parts. Al parts must be cleaned to be free of rust, varnish and carbon before reuse.

1. Follower:
   - Resurface or replace if worn beyond dimensional limits.
2. Follower Spring:
   - Reuse unless damaged, worn or won't meet test specifications.
3. Body:
   - Lap bushing seat.
   - Reblue.
   - Repair damaged threads.
   - Replace body if the clamp radius is badly worn or if the threads are less than 90% good.
4. Filter Caps:
   - Recondition tapered seat.
   - Clean and deburr hole.
   - Reblue.
   - Replace if the threads or sealing surfaces are damaged.
5. Control Rack:
   - Deburr teeth – check for straightness.
   - Replace if the teeth show significant wear.
6. Gear and Gear Retainer:
   - Deburr.
   - Replace if cracked or significantly worn.
7. Bushing:
   - Replace if scored, cracked or if residue cannot be removed.
   - Lap the check valve seat (sealing) surface.
8. Plunger:
   - Clean – remove varnish.
   - Replace if scored, chipped or scratched.
9. Check Valve:
   - Lap both flat (sealing) surfaces.
   - Replace if scratched, cracked or badly worn.

10. Check Valve Cage:
    - Lap both flat sealing surfaces.
    - Replace if cracked or too thin (see Table 1).
11. Valve Spring:
    - Replace. Do not reuse unless there is absolutely no wear or damage.
12. Spring Seat:
    - Replace if there is a hole worn in the rounded end where the needle quill touches.
13. Spring Cage:
    - Lap both flat (sealing) surfaces.
    - Replace if cracked or too thin (see Table 1) or if the needle has worn a pocket around the small hole.
14. Spray Tip:
    - Regrind seat.
    - Lap flat sealing surface.
    - Regrind the needle conicol seat.
    - Replace if beyond flow limits i.e., eroded spray holes.
15. Nut:
    - Remove carbon from the seat and tapered I.D.
    - Reblue.
    - Replace if the threads are damaged more than 10% or if the small I.D. is badly eroded.
16. Spill Deflector:
    - Remove burrs.
    - Reuse if the ends are smooth and even and the deflector is not cracked.

Normally, new parts do not require lapping prior to use. Wash the service parts in clean solvent to remove the solitified preservative. However, if new parts become nicked or burred during handling, then lapping will be necessary to provide adequate sealing between the flat parts.

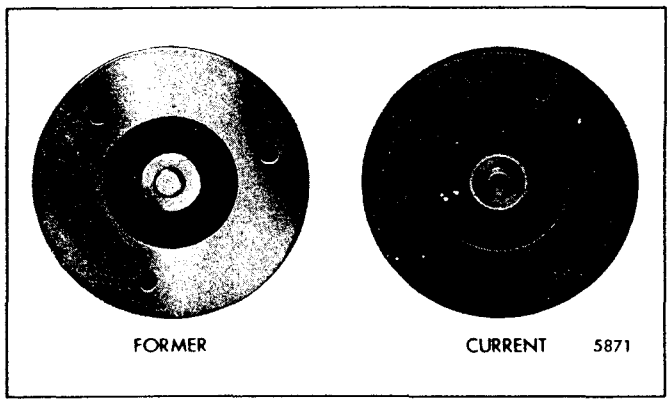


Fig. 23 – Spray Tip Sealing Surface Identification

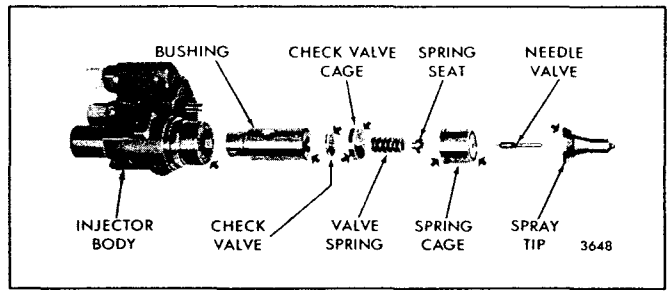


Fig. 24 – Sealing Surfaces which May Require Lapping

The sealing surface of current spray tips is precision lapped by a new process which leaves the surface with a dull satin–like finish; the lapped surface on former spray tips was bright and shiny (Fig. 23). DDC does not recommended lapping the surface of a *new* current spray tip.

Lapping Injector Parts

If necessary, lap the sealing surfaces indicated in (Fig. 24) as follows:

1. Clean the lapping blocks (J 22090) with compressed air. Do not use a cloth or any other material for this purpose.

   CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

2. Spread a good quality 600 grit dry lapping powder on one of the lapping blocks.

3. Place the part to be lapped flat on the block (Fig. 25) and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. *Do not lap excessively.*

5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

   CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

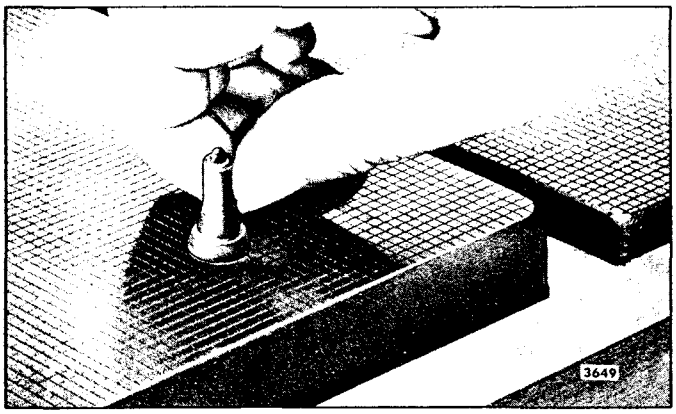


Fig. 25 – Lapping Spray Tip on Lapping Blocks J 22090

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. *Do not lap excessively.* Again wash the part in cleaning solvent and dry it with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the "mirror" finish required for perfect sealing.

8. Wash all of the lapped parts in clean solvent and dry them with compressed air.

CAUTION:To prevent possible personal injury, wear adequate eye protection and do not exceed 40 psi (276 kPa) air pressure.

Assemble Injector

1. Secure the body in vise J 22396–1.

• 2. Insert new filter(s) in the top of the body (Fig. 26). The current production service filter (stainless steel wire mesh pellet) is installed dimple end down, slotted end up. The former service filter (fiberglass–filled nylon cone) was installed with the pointed (cone) end up.

Insert a new filter in the inlet side (located over the injector rack) in an offset injector. No filter is required at the outlet side (Fig. 27).

• 3. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten injector filter caps with a 9/16" deep socket as follows:

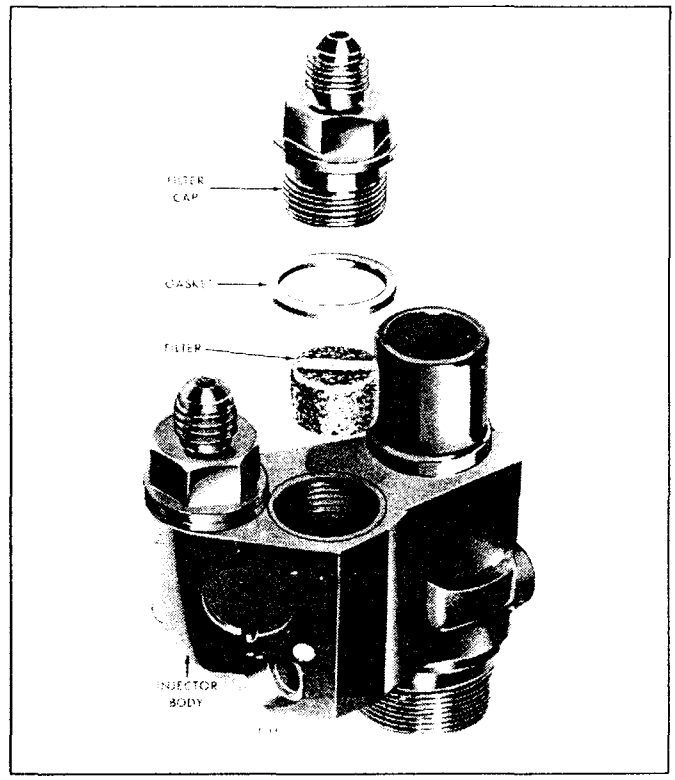


Fig. 26 – Details of Injector Filters and Caps and Their Relative Location

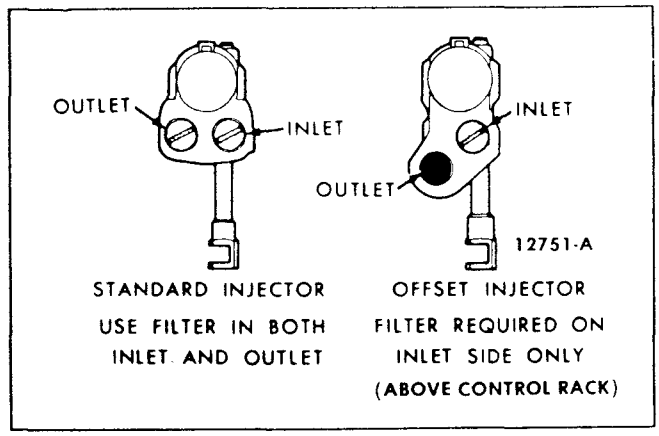


Fig. 27 – Location of Filter in Injector Body

Non–blued cap on non–blued body ..... 62 lb–ft (84 N·m) torque

Blued cap on blued body ..... 70 lb–ft (95 N·m) torque

Non–blued cap on blued body or blued cap on non–blued body ..... 62 lb–ft (84 N·m) torque

Cap for O–Ring sealed fuel pipe ..... 70 lb–ft (95 N·m) torque

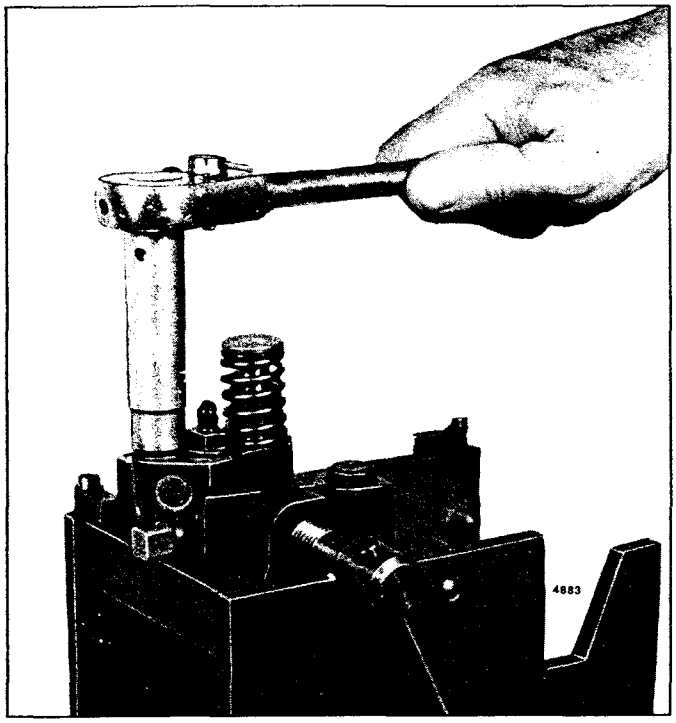


Fig. 28 – Installing Filter Cap

4. Install clean shipping caps to protect the sealing surfaces and to prevent dirt from entering the injector.

5. Lubricate the injector nut seal ring installer J 29197 with injector test oil. Remove the injector from the vise and hold the injector body, bottom end up. Place the installer over the threads of the injector body.

6. Lubricate the new seal ring and place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

   • A new round (in cross-section) injector nut seal ring replaced the former diamond-shaped ring, effective with injectors manufactured approximately November 1, 1987. Only the round seal ring is serviced.

7. Remove the protector (J 29197).

8. Slide the control rack into the injector body.

9. Refer to (Fig. 29) and note the marked teeth on the control rack and gear. Then, look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

10. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 29).

11. Place the gear retainer on top of the gear.

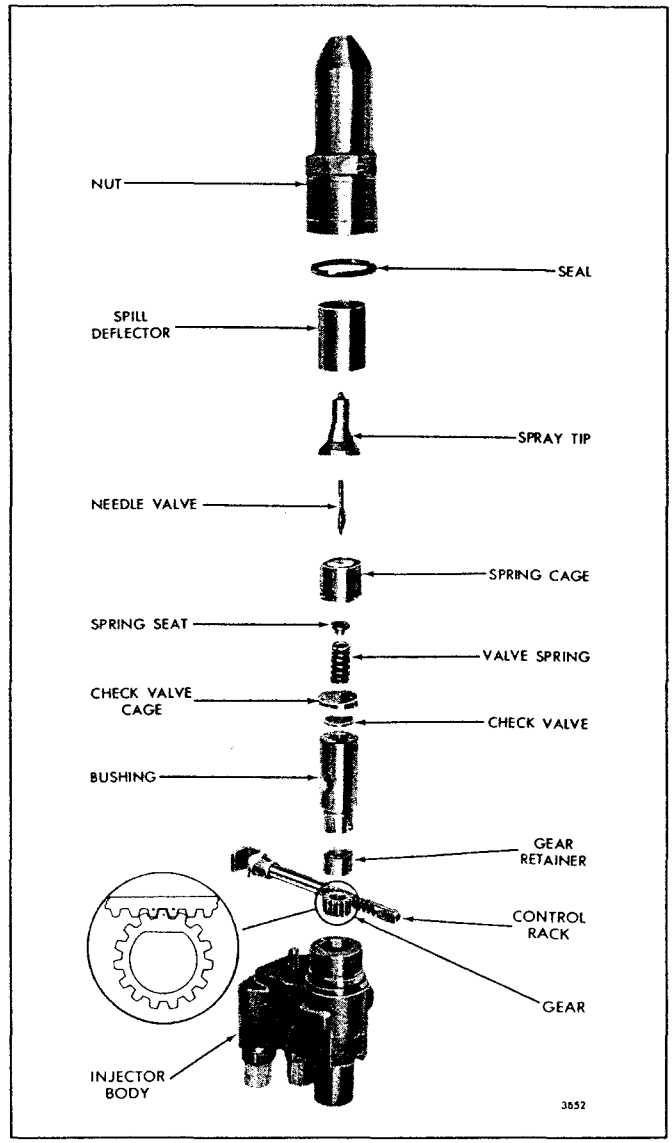


Fig. 29 – Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

12. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

13. Support the injector body, bottom end up, in injector vise J 22396–1.

14. Install the spill deflector over the barrel of the bushing.

15. Perform the spray tip test, as outlined in Section 2.0 using injector tip Tester J 22640–A before proceeding with the injector assembly.

16. Place the check valve (without the .010" hole) centrally on the top of the bushing. Then, place the check valve cage over the check valve and against the bushing. The check valve cage must not rest on the check valve.

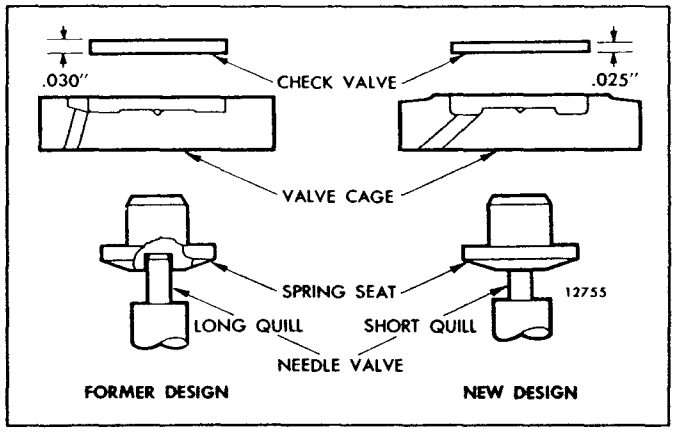


Fig. 30 – Comparison of Former and New Design Injector Parts

The former and new check valve and check valve cage are not separately interchangeable in a former injector (Fig. 30).

17. Insert the spring seat in the valve spring, then insert the assembly into the cage, spring seat first.

18. Place the spring cage, spring seat and valve spring assembly (valve spring down) on top of the check valve cage.

    Do not use new design needle valve spray tip with former design spring seat (Fig. 30).

19. Put the needle, tapered end down, into the spray tip (Fig. 31). Then, place the spray tip assembly on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

20. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 32). Tighten the nut as tight as possible by hand. At this point there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

• 21. Use socket J 4983–01 and a torque wrench to tighten the injector nut as follows:

    Non–blued nut on
    non–blued body ..... 50 lb–ft (68 N·m) torque

    Blued nut on
    blued body ..... 80 lb–ft (108 N·m) torque

    Non–blued nut on blued
    body or blued nut on
    non–blued body ..... 65 lb–ft (88 N·m) torque

22. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut and a new seal which may allow assembly on the body without extruding the seal and forcing it out of the body–nut crevice.

    NOTICE: Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

23. Turn the injector over and push the rack all the way in.

24. Place the follower spring on the injector body.

25. Refer to (Fig. 34) and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin.

26. Refer to (Fig. 35) and slide the head of the plunger into the follower.

27. Align the slot in the follower with the stop pin hole in the injector body.

28. Align the flat side of the plunger with the flat in the gear.

29. Insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

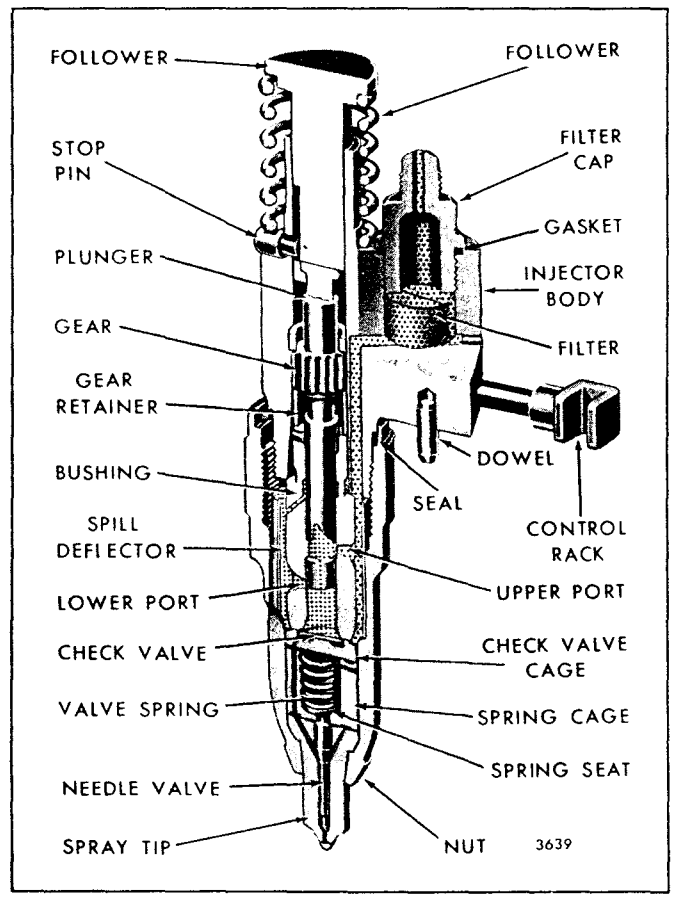


Fig. 31 – Cutaway View of Fuel Injector

2. Rotate the injector 360° and note the total runout as indicated on the dial.

3. If the total runout exceeds .008", remove the injector from the gage. Loosen the injector nut, center the spray tip and tighten the nut to 75–85 lb–ft (102–115 N·m) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Box and Store Injector

If the reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. *Do not use fuel oil.* Install shipping caps on both filter caps immediately after filling. Store the injector in an *upright* position to prevent test oil leakage.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286–9 or a cylindrical wire brush, Section 2.1.4, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper tip protrusion is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to (Fig. 5) and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.

2. Slide the injector rack control lever over so that it registers with the injector rack.

3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20–25 lb–ft (27–34 N·m) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

   NOTICE: Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in Section 2.0 – Specifications.

   NOTICE: On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Refer to *Install Rocker Arm and Shaft* in Section 1.2.1 and note the position of the exhaust valve bridge before, during and after tightening the rocker shaft bolts.

5. Install fuel pipes:

- *A. Flared end fuel pipes.* Remove the injector shipping caps. Align the fuel pipes and connect them to the injectors and the fuel connectors.

  NOTICE: DDC recommends that the original fuel pipes not be reused. New flared end fuel pipes should be installed. When installing flared end fuel pipes, use fuel pipe nut wrench J 8932–01 and "clicker" type torque wrench J 24405 (calibrated in inch–pounds) to apply proper torque and avoid damaging the fuel pipes. Refer to the chart for torque specifications. Fuel leakage from damaged or improperly installed fuel pipes can cause lube oil dilution, which may result in serious engine damage.

Fuel Pipe Usage	Torque
Endurion®–coated	130 lb–in. (14.69 N·m)
Uncoated	160 lb–in. (18.3 N·m)
Jacobs Brakes*	120 lb–in. (13.6 N·m)
Load limiting devices	160 lb–in. (18.3 N·m)

*Not serviced. Available from Jacobs Manufacturing Company.

NOTICE: Because of their low friction surface, Endurion® –coated nuts on fuel jumper lines must be tightened to 130 ***lb–in*** (14.69 N·m) torque, instead of the 160 lb–in (18.3 N·m) required with uncoated nuts. To avoid possible confusion when tightening jumper line nuts, do not mix lines with uncoated and Endurion® –coated nuts on the same cylinder head.

Jacobs brake jumper lines and jumper lines used with load–limiting devices do not have coated nuts. Tighten these to the values shown on the Chart.

NOTICE: Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to Fuel Jumper Line Maintenance & Pressurize Fuel System – Check for Leaks in Section 2.0 – Shop Notes).

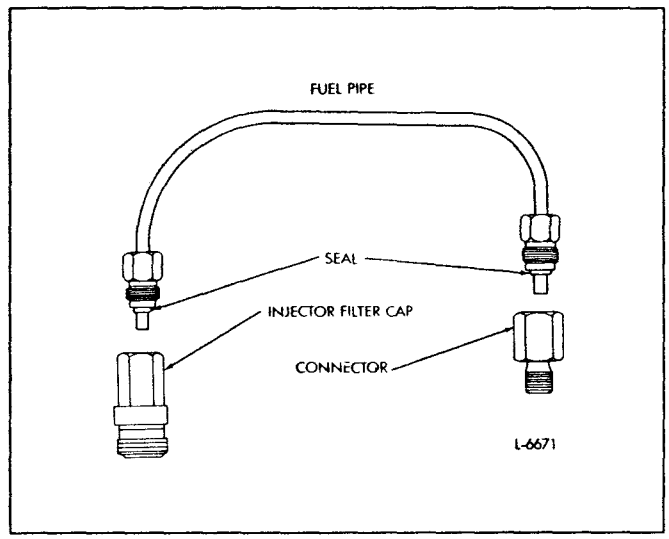
An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Use a new gasket and reinstall the rocker cover. Then, drain the lubricating oil and change the oil filter elements. Refer to Section 13.3 (Lubrication Specifications) and refill the crankcase to the proper level with the recommended grade of oil.

- *B. O–ring sealed fuel pipes.* Inspect fuel pipes and connectors (Fig. 38) carefully. Fuel pipes may be reused if they are not twisted, bent, distorted or otherwise damaged. O–ring design fuel pipes are not interchangeable with flared tube design fuel pipes on a part–for–part basis. O–ring design fuel pipe connectors and injector filter caps have a 1/2" – 20 female thread to accept the 1/2" – 20 male thread on the fuel pipe nuts. These parts *must* be used together to insure interchangeability.

NOTICE: To avoid fuel leakage, always use new O–ring seals when replacing the fuel pipes on an engine. Do not reuse seals.

Remove the injector shipping caps. Align the fuel pipes and connect them to the injector filter caps and the cylinder head connectors. Using "clicker" type torque wrench J 24405 (calibrated in inch–pounds), tighten the O–ring sealed fuel pipe nuts to 143 ***lb–in*** (16.16 N·m) torque.

6. Perform a complete engine tune–up as outlined in Section 14. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.



● Fig. – 38 O–Ring Sealed Fuel Pipes, Connectors, Injector Filter Caps

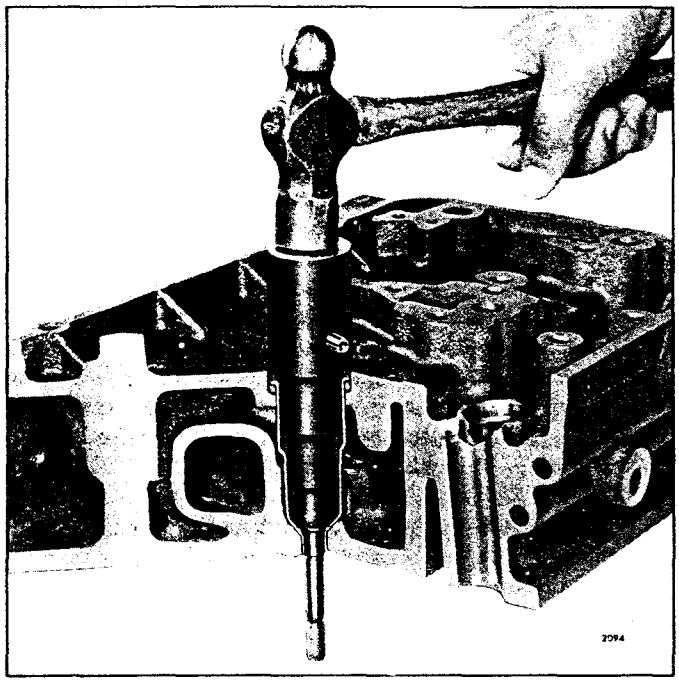


Fig. 2 – Installing Injector Tube Using Tools J 5286–4A and J 5286–5

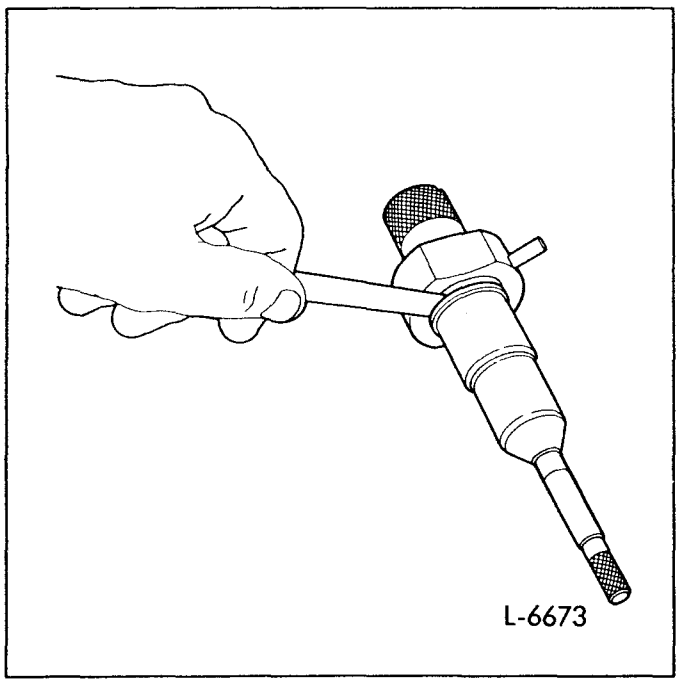


Fig. 3 – Measuring Clearance Between Installation Tool and Top of Hole Tube Flange

• 2. Place the installer J 5286–4C in the injector tube. Then, insert the pilot J 5286–5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2). For proper installation of any injector hole tube, the tool must contact the tube at the bottom before it touches the flange at the top. The clearance at the top, between the flange and the tool, should be .001" to .010" (Fig. 3).

3. Slip the injector tube into the injector bore and drive it in place (Fig. 2). Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

• During installation the tube will stretch slightly before the tool contacts the flange, thus allowing the tool to properly install the tube. If there is no clearance at the flange, the tube will buckle slightly during installation until the tool contacts the tube at the lower end. The buckling causes compressive stress which will result in tube cracking during engine operation and subsequent engine damage.

It is permissable for the tube flange at the O–ring seal end to protrude up to .120" above the cylinder head casting without sealing being affected. Sealing is accomplished by compressing the O–ring seal between the head counterbore and the outside diameter of the injector tube. The tube flange is merely used to retain the seal ring in the head counterbore.

4. With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

a. Turn the cylinder head bottom side up, remove the pilot J 5286–5 and thread the upsetting die J 5286–6 into the tapped end of the installer J 5286–4C (Fig. 4).

b. Then, using a socket and torque wrench, apply approximately 30 lb–ft (41 N·m) torque on the upsetting die.

c. Remove the installing tools and ream the injector tube as outlined below.

Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations:

First, *hand reamed,* as shown in Fig. 5, to receive the injector body nut and spray tip.

Second, *spot–faced* to remove excess stock at the lower end of the injector tube.

Third, *hand reamed,* as shown in Fig. 6, to provide a good seating surface for the bevel or the lower end of the injector nut.

• The new tube takes less time to install than the former tube because the large I.D. (inside diameter) of the new tube does not require reaming. Reaming is only necessary at the small I.D. and the injector nut seat. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

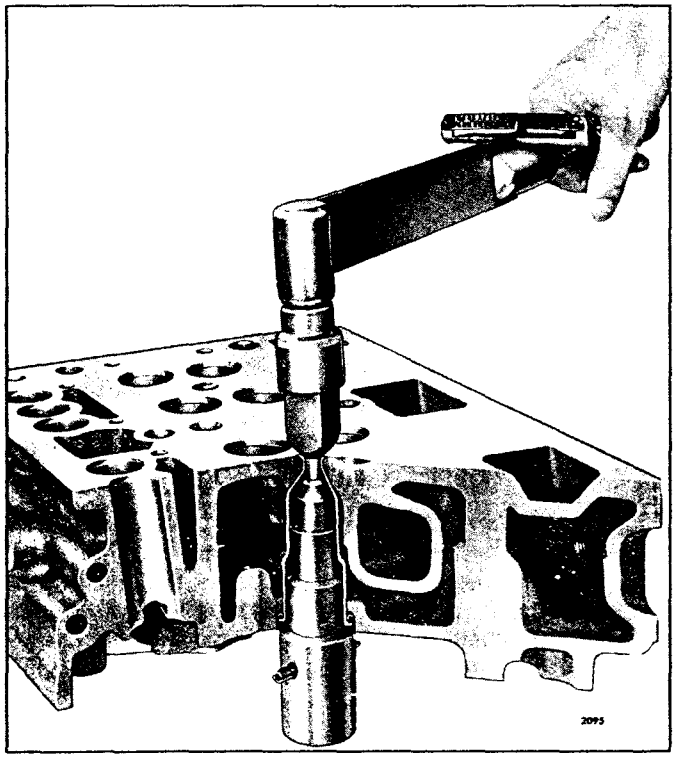


Fig. 4 – Upsetting Injector Tube Using Tools J 5286–4A and J 5286–6

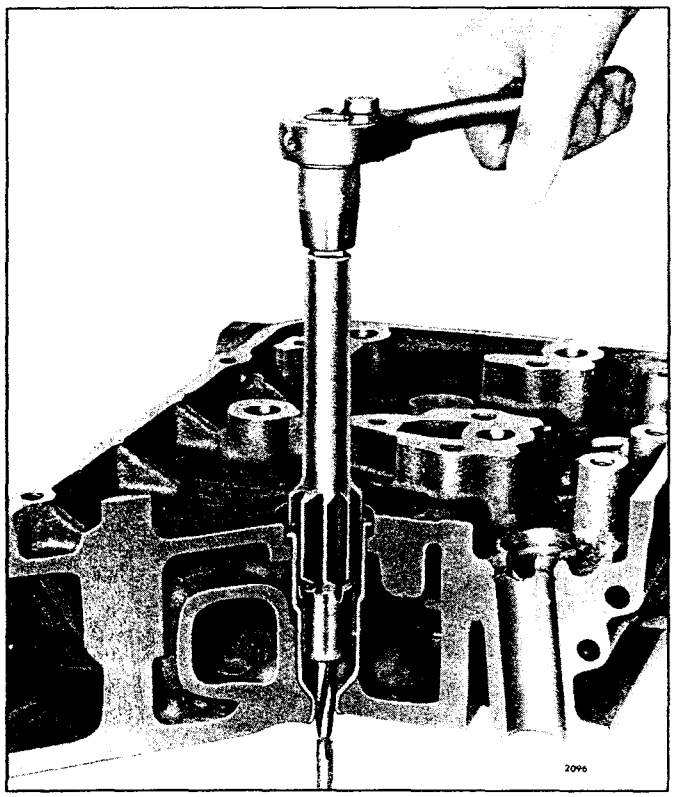


Fig. 5 – Reaming Injector Tube for Injector Body Nut and Spray Tip Using Tool J 22525–1

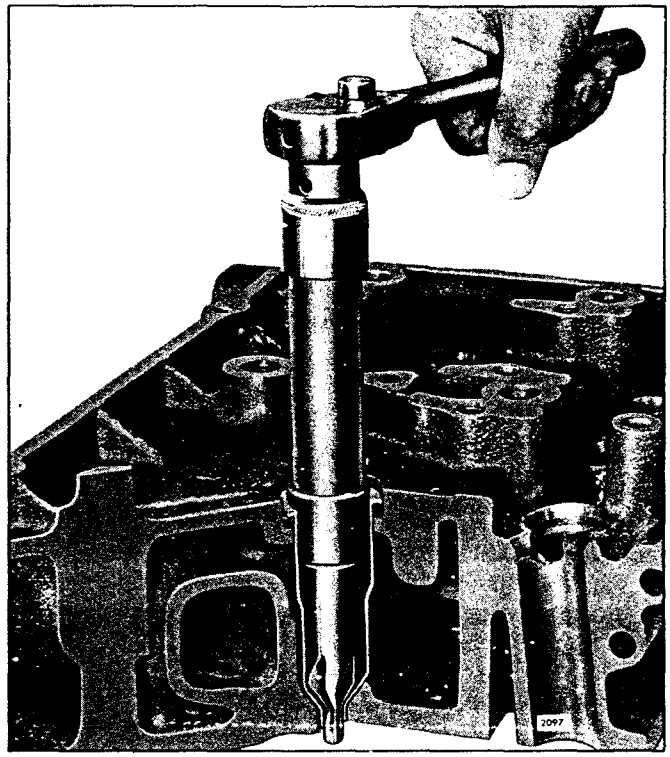


Fig. 6 – Reaming Injector Tube for Injector Nut Using Tool J 5286–9

NOTICE: The reamer should be turned in a *clockwise direction* only, both when inserting and when withdrawing the reamer, because movement in the opposite direction will dull the cutting edges of the flutes.

1. Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:

   a. Place a few drops of light cutting oil on the reamer flutes, then carefully position the reamer J 22525–1 in the injector tube.

   b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 5). Clean out all of the chips.

2. Remove excess stock:

   a. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286–8 into the small hole of the injector tube.

   b. Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to .005″ below the finished surface of the cylinder head.