

Group 6

This group covers injectors, tubing and connections which carry fuel to and from injectors.

Injectors

Injectors and Connections

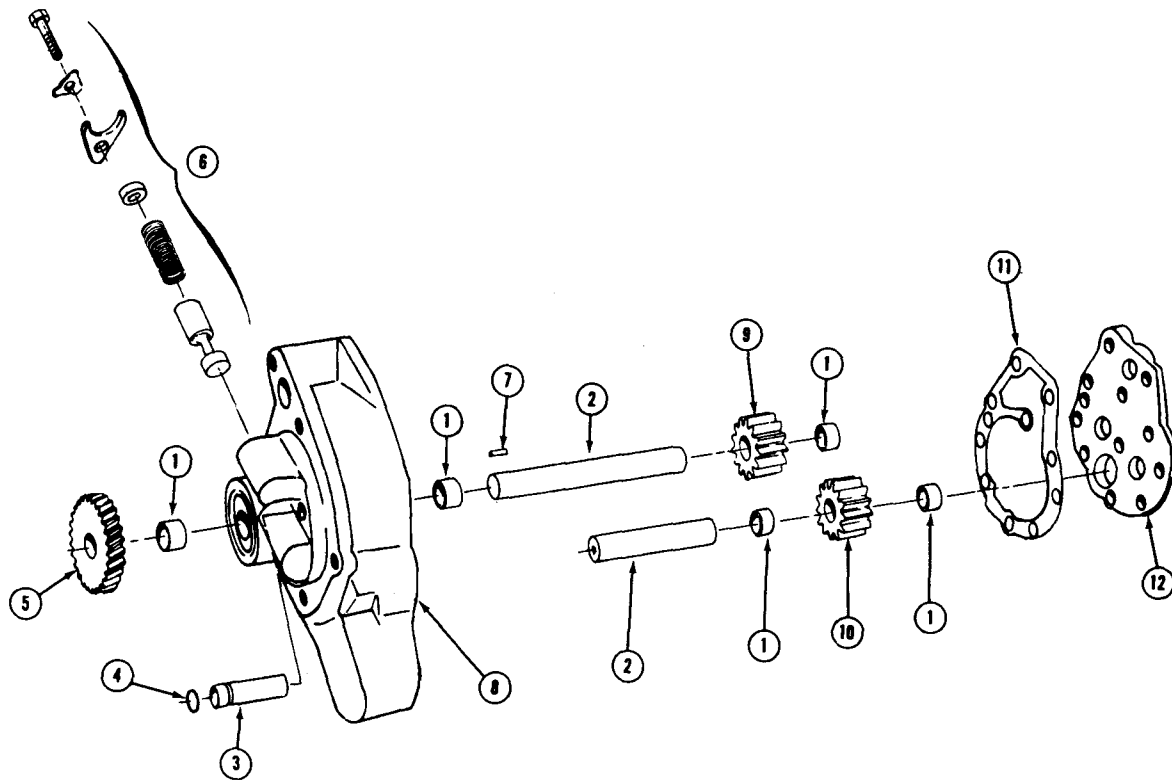
PT injectors and connections are described, with all repair and calibration information covered, in Bulletin No. 3379071 or reprints thereof.

Manuals on all Cummins products may be purchased through a Cummins Distributor.

Group 7

Lubricating system group consists of oil pan, liners, dipstick, filters, coolers, oil pumps and pressure regulators.

Lubricating System



- | | | |
|-------------|-----------------------|---------------|
| 1. Bushing | 5. Main Drive Gear | 9. Drive Gear |
| 2. Shaft | 6. Pressure Regulator | 10. Idler |
| 3. Tube | 7. Dowel | 11. Gasket |
| 4. "O" Ring | 8. Body | 12. Cover |

Fig. 7-0. Lubricating oil pump — exploded view

Service Tools (Or Equivalent) Required

Service Tool Number	Tool Name
ST-994	Bushing Mandrel
ST-1157	Spacer Mandrel
ST-1158	Bushing Mandrel

Desirable (Or Equivalent) Service Tools

ST-1134	Dowel Pin Extractor
ST-1160	Hose Assembly Tool Kit
ST-1218	Mandrel ("O" Ring)
ST-1223	Mandrel ("O" Ring)
3375082	Gear Puller
3375083	Gear Puller
3375253	Tube Bundle Tester

Lubricating Oil Pump

Lubricating oil pumps used on 855 C.I.D. Cummins Engines are disassembled, assembled and inspected in a like manner.

Care must be taken during disassembly to mark or identify parts, such as pressure regulator plunger, idler shaft, drive shaft, capscrews as to length, size, location, etc., as removed to aid in reassembly. Clean disassembled pump in an approved cleaning solvent as described in Engine Disassembly, Group O.

Note: On FFC engines, the oil pressure regulator in the lubricating oil pump has been replaced by a high pressure by-pass valve. Remove and install in same manner as oil pressure regulator. Check parts catalog for correct spring number.

Disassembly and Inspection

1. Remove pump cover or filter head from pump body. Tap lightly with a soft hammer to loosen from dowel.
2. Remove idler gear, press drive shaft through driven gear, remove shaft and gear or coupling (scavenger pump).

Note: Double lubricating oil pumps have a scavenger pump body that must be removed after drive shaft is pressed through driven gear. After removing scavenger body, repeat Step 2.

3. If piston cooling tube, on pumps so equipped, is mutilated, drive or press out from inside body.
4. Press idler shaft from body, if worn beyond worn replacement limits as listed in Table 7-1 (2).
5. Remove pressure regulator cap, spring and plunger; check plunger for freedom of movement in pump body.
6. Remove by-pass valve from filter mounting head, if so equipped; inspect disc, spring and seat for wear or distortion.
7. Remove damaged dowel pins with ST-1134 Dowel Puller.
8. If drive shaft is worn beyond worn replacement limits or gear is chipped or worn, press shaft from gear.
 - a. Inspect all gears for worn or broken teeth, all parts for pitting or cracks and body for distorted threads.
10. Check gasket mating surfaces for flatness, nicks or burrs. Replace all unserviceable parts.
11. Inspect bushings in body, cover and idler gear; if bushings are damaged or worn larger than worn replacement limits, replace as follows:
 - a. Remove bushings with ST-1158 Bushing Mandrel.
 - b. Press new bushings into gear, body or cover, as required, with ST-1158 Mandrel. Bushings must be flush to 0.020 inch [0.51 mm] below surface of gear, body or cover.
 - c. Bore new bushings to specifications as listed in Table 7-1 with appropriate boring machine.

Assembly

1. If removed, press large end of idler shaft in gear pocket side of pump body using deep end of ST-1157 Spacer Mandrel where applicable. If

mandrel is not used, press idler shaft in to protrude as listed in Table 7-1 (2).

2. Press driven gear onto drive shaft with shallow end of ST-1157 Mandrel. If mandrel is not used, press gear onto shaft so protrusion meets specifications. Table 7-1 (2).
3. Lubricate drive shaft, position drive shaft and gear into pump body. Support drive shaft on a suitable arbor press and press drive gear or coupling (scavenger pump) on drive shaft.

Note: Coupling protrusion or drive gear to body press fit clearance should meet specifications in Table 7-1 (2).

4. Lubricate idler shaft and place gear on shaft.

Note: On double lubricating oil pumps, install scavenger pump body, using new gasket, and press scavenger driven gear onto drive shaft, leave 0.002 to 0.004 inch [0.05 to 0.10 mm] clearance between gear surface and bottom of gear pocket. Repeat Step 4.

5. If removed, (piston cooled engine pumps), press new piston cooling oil tube into pump body with beveled edge up. Protrusion should be as listed in Table 7-1 (3).
6. Install new dowels in pump body, if removed.
7. Lubricate gears, bushing, shafts, etc., with clean lubricating oil.
8. Install by-pass spring, disc and seat or plate in filter mounting head, if so equipped.
9. Using new gasket, install cover or filter head to pump body; replace pipe plugs if removed.
10. Position spring in pressure regulator plunger open end. Install assembly in pump body, solid end of plunger down; secure with retainer assembly. Rotate drive-shaft, check end play. Ref. Table 7-1 (2).

Note: Double lubricating oil pumps with the letter "L" stamped following the part number have increased gear pocket depth to allow drive shaft end clearance to meet specifications. See Table 7-1 (2).

Lubricating Oil Coolers

Direct Mounted

Note: On FFC engines the pressure regulator valve is located in the front cooler support, controlling oil pressure before it passes through the filter element. Remove and install in same manner as in oil pump.

Disassembly

1. Remove cooler cover, "O" ring, brass retainer, being careful not to scratch or mar sealing surface on element.
2. Use mineral spirits or equivalent to clean out lubricating oil and contaminants trapped in housing by forcing cleaner through the oil ports.
3. To remove element from housing, insert two 7/32 inch [5.56 mm] rods 8 inches [203 mm] long into the outside row of tubes opposite each other, rods should not drag bottom of housing.
4. Place a bar on top of housing and bundle face between rods, and rotate element in housing to unseat lower "O" ring. Lift up gradually on rods to free "O" rings.

Inspection

1. To prevent hardening and drying of foreign substances, clean immediately, after removing end cover plates, with approved cleaning solvent that will not harm non-ferrous metal; blow through core with compressed air.
2. Inspect core for corrosion or cracks where tubes are welded to end plates. Inspect connections and liner for cracks or damage.
3. Inspect cooler assemblies for leakage between oil and water passages.
 - a. Clamp cooler assembly in 3375253 Fixture and assemble air connection.
 - b. Place unit in water tank and apply 1 to 4 psi [7 to 28 kPa] air pressure to water side. Inspect for air leaks, porosity in casing, etc.

- c. Apply line air pressure 35 to 40 psi [241 to 276 kPa] to oil side. Inspect for air leaks.

Repair

Repair damaged tubes by inserting a small O.D. tube inside damaged tube. Cut and flare ends then solder securely. Do not damage adjacent tubes with heat while soldering. If more than 5 percent of tubes are defective, discard cooler.

Caution: Engine lubricating oil cooler tube bundles must not be reused after an engine failure in which metal particles may have been circulated through the lubricating system. There is no practical method by which tube bundles may be cleaned economically by a distributor that will assure that all metal particles are removed. The metal particles may remain in lubricating oil cooler tube bundles and be circulated through the cleaned lubricating system which may cause subsequent engine damage.

Assembly

1. Lubricate rubber "O" ring and place in groove at bottom of housing. Make sure ring is not twisted and is free of cuts or nicks.
2. Push element (3, Fig. 7-1) into housing (1), aligning index marks (2) on housing and element.
3. Using proper "O" Ring Mandrel, install "O"

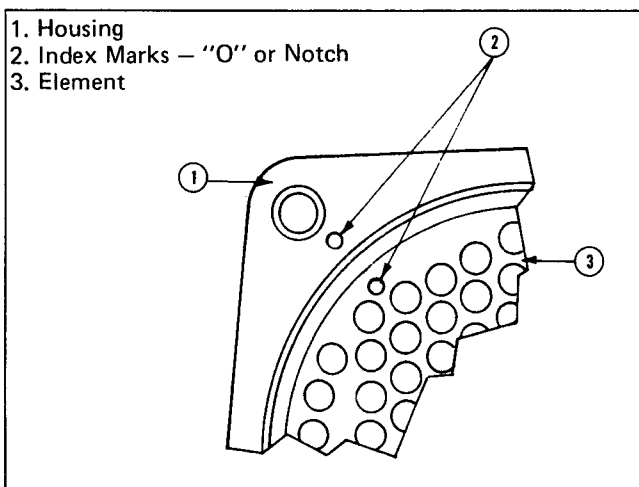


Fig. 7-1, (N10705). Aligning oil cooler index marks

ring around top of element. Place retainer ring over rubber "O" ring.

4. Install pipe plugs (if removed), on coolers using 3/4 inch pipe plugs with raised bosses torque to 25 to 35 ft-lbs [34 to 47 N•m]. Torque others to values in Table 1-1, Cylinder Block Group.

Support, Pump Mounted or Auxiliary Oil Cooler

Disassembly

1. Remove cooler, cover, support and gaskets from cooler housing (2, Fig. 7-2) if not previously removed.
2. Remove retainer rings (4) from housing (2).
3. Remove exposed "O" ring (3) under retainer, being careful not to scratch or mar sealing surface on element.
4. Use mineral spirits or equivalent to clean out lubricating oil and contaminants trapped in housing by forcing cleaner through oil ports in reverse direction of normal flow.
5. To remove element (1) from housing (2):
 - a. Insert two long rods into outside row of tubes opposite each other.
 - b. Place a flat bar on top of housing and bundle face between rods, and rotate element in housing to unseal lower "O" ring.
 - c. Remove tube bundle from cooler housing. Two small threaded holes are provided in end of tube bundle; if necessary make a suitable puller utilizing the two threaded holes in end of tube bundle.
6. Discard "O" rings (3) and retainers (4).

Note: To prevent hardening and drying of foreign substances, clean core or cores as soon as possible after removal.

Cleaning (Oil Side)

1. Immerse core in approved cleaning solvent, let stand several minutes. Force cleaner around tubes until clean.

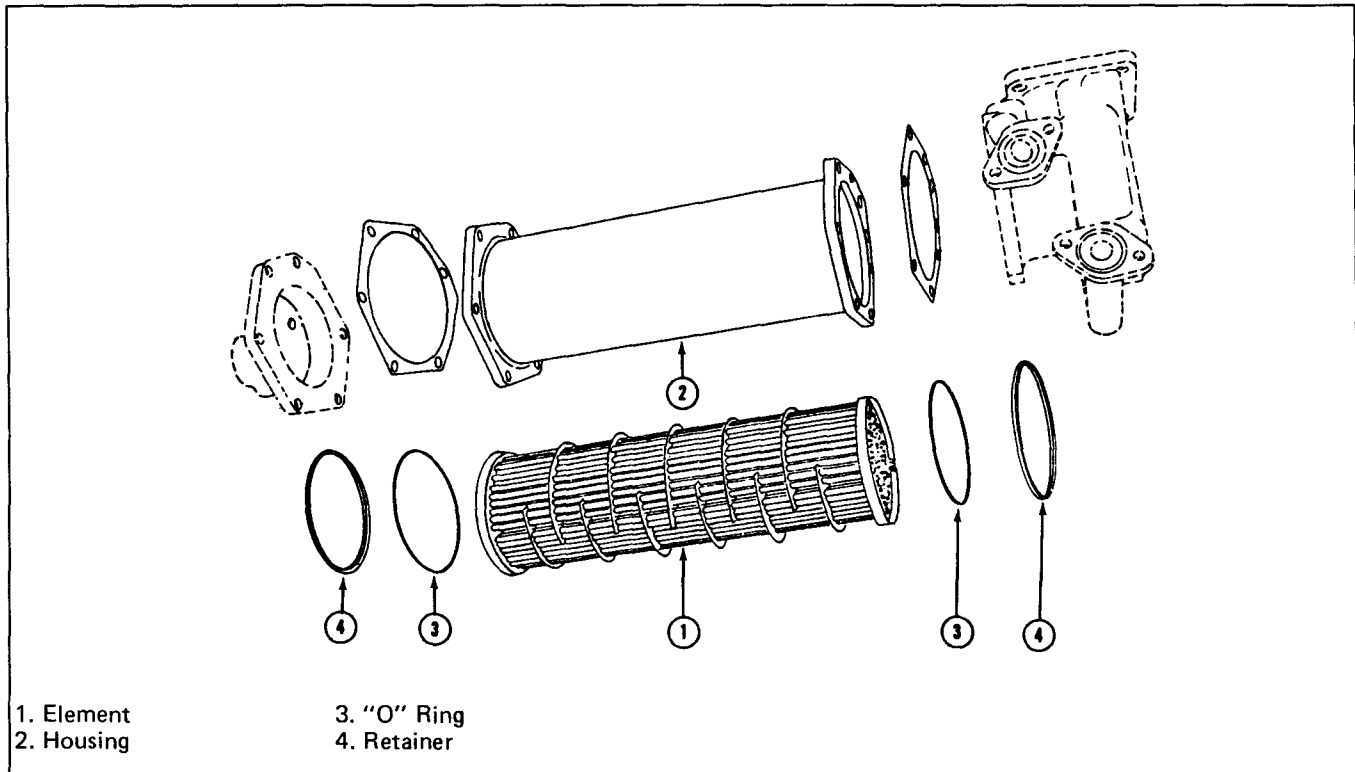


Fig. 7-2, (N10741). Lubricating oil cooler — exploded view

Warning: This operation should be done in open air or in a well ventilated room to avoid toxic effect of chemicals being used.

- If oil passages are badly clogged, circulate an oakite or alkaline solution through the tubes. After cleaning, flush thoroughly with hot water.

Cleaning (Water Side)

- Plug oil inlet and outlet.
- Immerse oil cooler in solution of one part muriatic acid and nine parts water after adding 1 lb. [0.45 kg] of oxalic acid and 0.010 gal. [40 ml] of pyridene to each 5 gal. [19 l] of acid.
- Remove core when foaming and bubbling stops. Immerse unit in a 5 percent solution of sodium carbonate. Remove when bubbling ceases and pressure flush with clean warm water.

Note: Flush inside of tubes with clean, light oil after both oil and water sides of cooler have been cleaned.

Inspection

- Seal both ends of tube bundle. Immerse tube bundle in water and apply approximately 40 psi [276 kPa] air pressure. If air bubbles are observed, mark bundle for repair or replacement.
- Inspect support for broken or cracked welds; repair or replace as necessary.

Repair (Header Leaks)

Header leaks may occur where tubes protrude through plate or where header is soldered into case. Repair damaged tubes by inserting a smaller outside diameter tube inside damaged tube. Cut and flare ends; then solder securely. Do not damage tubes or header material with heat while soldering. If more than 5 percent of tubes are defective, discard element.

Assembly

- Lubricate new rubber "O" ring (3, Fig. 7-2);

using appropriate mandrel, place in groove at bottom of housing (2). Make sure ring is fully seated, not twisted and is free of cuts or nicks.

2. Push element (1) carefully into housing, aligning index marks on housing and element.
3. Press second "O" ring around top of element with equal pressure around ring circumference.
4. Place retainer ring (4) over rubber "O" rings.
5. (Non FFC) Assemble new gaskets, cooler cover and support; secure snugly with capscrews and lockwashers. Tighten capscrews to 30 to 35 ft-lbs [41 to 47 N•m] torque. On FFC units, do not tighten housing to support capscrews. This allows proper positioning on engine.

Lubricating Oil Filters

Full-Flow Paper Element Filter

Disassembly

1. Remove filter case and element from filter head, remove seal ring and discard.
2. Lift element from case; inspect element pleats. If metal is found in elements, an inspection of connecting rod and main bearings should be made at once. Discard element.
3. The filter by-pass valve normally requires no servicing; however, check to make sure the valve works freely. The valve is spring loaded and opens on a pressure differential.

Inspection

1. Remove all pipe plugs and fittings from filter head. Remove filter by-pass valve retainer (1, Fig. 7-3) with a standard puller, relief valve (2) and spring (3) from filter head (1), if necessary after Step 3 above. Housing may remain in filter head. Clean housing and case in approved cleaning solvent and dry with compressed air.
2. Remove snap ring from capscrew securing support, seal washers and spring on capscrew in filter case. Slide bolt from case; remove and discard copper washer and seal.

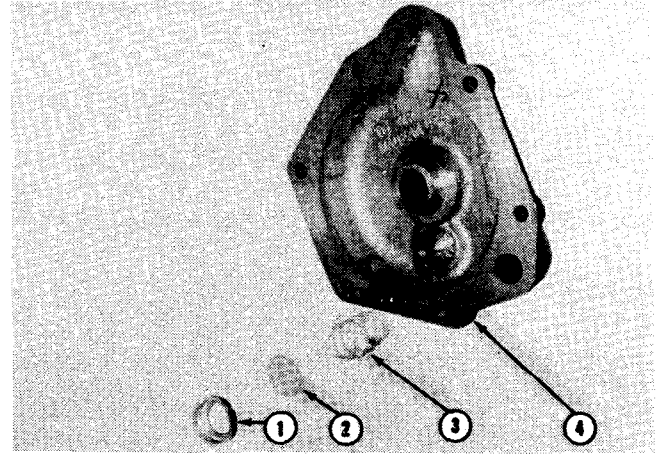


Fig. 7-3, (N10730). By-pass valve

3. Inspect all parts for wear or distortion; discard and replace all damaged parts.

Assembly

1. Position new copper washer on capscrew (if required).
2. Insert capscrew in filter case; slide seal spring, washer, seal and support over capscrew; secure in position with snap ring or circlip in case. Snap ring or circlip must be in proper position in groove in center bolt.
3. Coat all plugs and fittings with sealing tape or lead sealer; install in filter head.
4. If removed, insert filter by-pass valve spring (3, Fig. 7-3) (large end first) in filter head (4), position relief valve (2) in bore coated side out over spring (3) and secure with retainer (1), press retainer in bore flush with head.

Note: By-pass valve discs, hard composition type, have been replaced by steel disc valves (rubber coated one side) Part No. 200819. Hard composition discs removed, should be replaced with rubber coated steel discs.

5. Position new seal ring or gasket on filter head; slide new element with seals in place over capscrew and into filter case.
6. Position assembly to filter head and secure with capscrew; tighten to 25 to 35 ft-lbs [34 to 47 N•m].

By-Pass Filter

A by-pass filter is often used in conjunction with a full-flow filter; never use a by-pass filter instead of a full-flow filter.

Disassembly

1. Remove clamping ring capscrew and lift off cover.
2. Unscrew upper support element hold-down assembly and lift out hold-down assembly and element.
3. Clean housing and hold-down assembly in solvent.

Inspection

1. Inspect hold-down assembly spring/seal, drain plug, connections and filter cover "O" ring. Replace if damaged.
2. Clean orifice in tee-handle or orifice hole in standpipe; these are very important and control amount of flow through the by-pass filter.

Assembly

1. Install new element.
2. Replace upper support element hold-down assembly in filter and tighten down to stop.
3. Position "O" ring gasket on housing flange.
4. Install cover and clamping ring; tighten cap-screw until clamping lugs come together.

Hose Size

1. The supply and drain lines should be No. 6 (5/16 inch [7.9 mm] inside diameter) flexible hose up to 10 ft. [3 m] in length. For lines over 10 ft. [3 m], use No. 8 (13/32 inch [10.3 mm] inside diameter). All fittings in by-pass circuit should be no less than 1/4 inch [6.4 mm] pipe size.
2. The return line should discharge below oil level in the oil pan to prevent foaming.

3. Supply line should be connected to oil circuit between oil pump and full-flow filter.

Filter-Cooler Anti-Drain Back Valves

NT-280, NT-310, NTC-335 and NT-380 engine filter-cooler support is equipped with an anti-drain back valve to provide full lubricating oil pump prime at all times and prevent operating the engine without sufficient lubrication at start up. Valve should be checked for proper operation when cooler-filter is serviced.

The valve is located in the filter-cooler support housing, on the cooler housing side, and the lubricating oil goes through the valve before entering the cooler.

Disassembly and Inspection

1. Install filter-cooler housing in vise or press. Using screwdriver or small bar, remove spring seat (3, Fig. 7-4) from filter-cooler support housing.

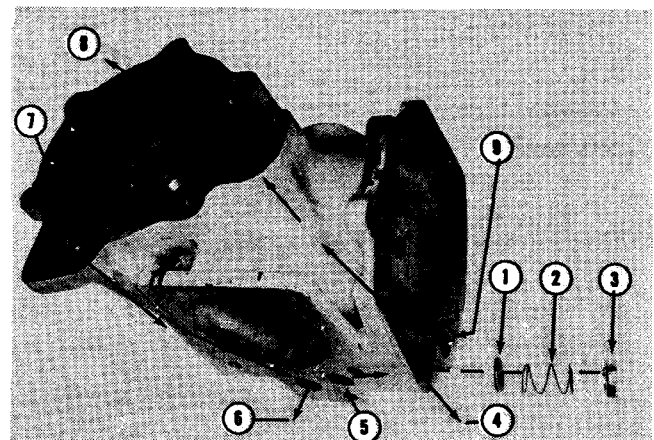


Fig. 7-4, (N10735). Anti-drain back valve and support assembly with flow diagram

2. Remove spring (2) and disc (1).
3. Inspect disc, spring and spring seat for wear or distortion. Discard all damaged parts.

Assembly

1. Install disc (1, Fig. 7-4) on seat in housing, coated surface toward seat.

2. Position spring (2) on metal surface of disc.
3. Press or drive spring seat (3) into housing, cupped portion of spring seat is installed away from spring, to a depth of 0.265 to 0.285 inch [6.75 to 7.25 mm].

Lubricating Oil Lines

Specifications

1. Hose used for lubricating oil or fuel should consist of a seamless synthetic rubber or Teflon inner tube reinforced with fabric braiding and wire braiding, and covered with a synthetic rubber-impregnated oil-resistant fabric braid or rubber coating.
2. Rubber-lined hose should be capable of handling fluids ranging in temperature from -40 to 300°F [-40 to 149°C] and be suitable for use with lubricating oil and/or fuel oil. Since engine lubricating oil temperature may exceed 250°F [121°C] at full load operation and high ambients, hose meeting SAE specifications 100 R 1 and 100 R 5 will not be adequate unless it is also capable of handling fluids within the temperature range as stated above.
3. Teflon-lined hose has a maximum temperature rating of 450°F [232°C] and corrosion resistant stainless steel wire braid over Teflon liner using permanent swaged type fittings.
4. Consideration should also be given to clamping of hose, that is, enough flexibility has to be provided to accommodate relative movement and at the same time clamps should be located as required to prevent chafing of the hose.
2. Hose should not be crushed while sawing (crushed hose will permit nipple to pick up hose inner tube and block passage).
3. Place socket in jaws of a vise. Check all fittings to make sure of fit on mating part.
4. Hold hose so it enters socket straight to prevent cocking of hose in socket. Fig. 7-5. Rotate hose counterclockwise while pushing it into socket.
5. Turn hose into socket until it bottoms; check to be sure it has bottomed and does not bell in from being pushed in too far.
6. Place socket and hose assembly in jaws of vise. (Clamp on the socket.) Apply lubrication on nipple (Fig. 7-6) and inside of hose for ease of assembly.
7. Hand assembly tools are available for assembling nipple assemblies into hose and socket assembly. ST-1160 Assembly Tool Kit, includes an assembly mandrel for each hose Size 4, 5, 6, 8, 10, 12 and 16. In an emergency a brass fitting can be tightened in the swivel nut enough to enable turning the flare seat (nipple) into the hose and socket. Fig. 7-7.
8. After assembly, always look carefully inside fittings and hose for possible hose damage. A cut in inside diameter of hose lining can plug hose bore when flow of fluid is sent through hose.

Assembly

Replace hose and worn or cracked connections with new parts. Average life of flexible oil hose is 100,000 to 200,000 miles [160,900 to 321,000 km] or 3200 to 6400 hours depending upon amount of bend and temperature to which hose is subjected. Table 7-3 and 7-4. For shops equipped to make up hose from bulk hose, follow steps below to ensure proper fitting installation.

1. Cut hose to required length using a hacksaw; cut should be square within 5 degrees.

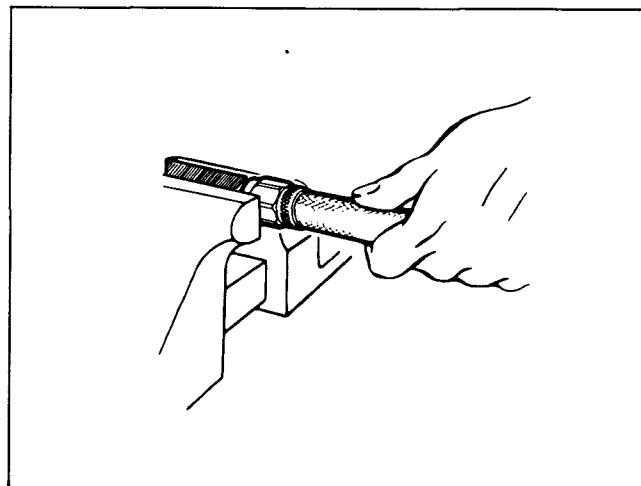


Fig. 7-5, (N10737). Installing hose into socket

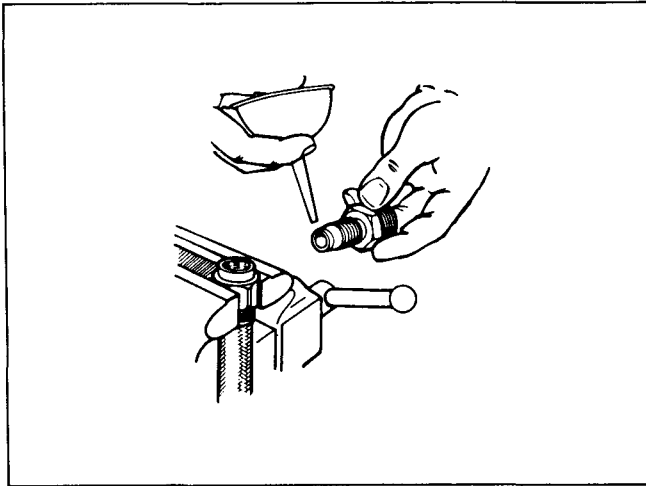


Fig. 7-6, (N10738). Lubricating nipple

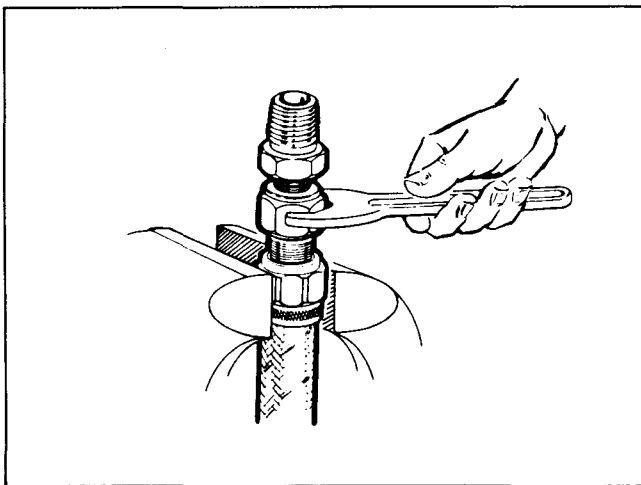


Fig. 7-7, (N10739). Assembling hose nipple and socket

Lubricating Oil Pan

The extreme angular operation at which a vehicle is to be operated must be known and a lubrication system provided that is suitable for the maximum angle of operation. Engines for automotive vehicles should be protected to at least 10 degrees vehicle angularity of operation and engines for construction equipment must be equipped with the necessary components to permit at least 30 degrees vehicle angularity of operation.

Inspection

1. Visually check oil pan for cracks or, if a leak is suspected, check using dye penetrant.

- a. Spray suspected area with dye penetrant. Allow penetrant to dry for fifteen minutes. Do not "force dry".
- b. Spray area with dye developer and check for crack indications.
2. Check thread inserts on aluminum oil parts. If damaged, replace. Check all threaded holes for damaged threads.

Repair

1. Repair damaged thread inserts.
 - a. Determine hole size; then use proper thread insert extraction tool to remove damaged Heli-Coils. Condition hole and insert new Heli-Coil. Refer to Cummins Service Tool Catalog for proper thread insert tool.
 - b. Use starting and finishing tap for Heli-Coil inserts for new or oversize holes in aluminum. When tapping aluminum, use fuel oil for lubricant to prevent tearing.
 - c. After inserting thread insert, bend starting end toward center then back toward side of hole to break off installation tip.
2. Repair small cracks in pan by welding. Do not weld finished surfaces.
3. Repair oil plug drain hole in aluminum oil pans when drain hole threads are damaged. Two oversize plugs are available to permit re-thread of oil pan drain holes at least twice.
 - a. Part No. 62117 Oil Pan Drain Plug; Size 1-1/4" x 12 thread.
 - 1) Enlarge damaged hole by drilling to 1-11/64 inch [29.77 mm].
 - 2) Tap hole with a 1-1/4"x 12 tap. When tapping aluminum, use fuel oil for lubricant to prevent tearing of metal.
 - 3) Install new drain plug with a new copper gasket. Tighten to 60 to 70 ft-lbs [81 to 95 N•m] torque.

b. Part No. 120349 Oil Pan Drain Plug; Size 2-3/8" x 12 thread.

1) Enlarge damaged hole by drilling 1-19/64 inch [32.94 mm] . Tap hole with a 1-3/8" x 12 tap.

2) Install new drain plug with a new copper gasket. Tighten to 60 to 70 ft-lbs [81 to 95 N• m] torque.

4. Install pipe plugs in oil pan securely. Do not overtighten.

Lubricating Oil Dipstick

The dipstick has been calibrated for a certain oil level when used with a specific oil gauge tube and with engine in a certain position. Too high an oil level will cause foaming, excessive oil temperature and power loss. Too low an oil level will result in oil pressure fluctuation and possible loss of oil pressure. In the event a dipstick should be lost or damaged a new dipstick is required.

Table 7-1: Lubricating Oil Pump Specifications – Inch [mm] (Reference Fig. 7-0)

Ref. No.	Measurement	Worn Limit	New Minimum	New Maximum
Single Lubricating Oil Pump				
1.	Bushings			
	Inside Diameter	0.6185 [15.710]	0.6165 [15.659]	0.6175 [15.684]
2.	Idler and Drive Shaft			
	Outside Diameter	0.6145 [15.608]	0.615 [15.62]	0.6155 [15.634]
	Drive Gear to Body			
	Clearance	0.012 [0.30]		
	Drive Shaft			
	End Play		0.002 [0.05]	0.005 [0.13]
	Idler Shaft			
	Shaft Protrusion		0.720 [18.29]	0.740 [18.80]
	Driven Gear/Drive Shaft			
	Shaft Protrusion		0.855 [21.72]	0.875 [22.22]
Single Double Capacity Lubricating Oil Pump				
1.	Bushings			
	Inside Diameter	0.879 [22.33]	0.8767 [22.268]	0.8777 [22.293]
2.	Idler and Drive Shaft			
	Outside Diameter	0.874 [22.17]	0.8745 [22.212]	0.875 [22.22]
	Drive Gear to Body			
	Clearance	0.012 [0.30]		
	Drive Shaft			
	End Play		0.002 [0.05]	0.008 [0.20]
	Idler Shaft			
	Shaft Protrusion			0.955 [24.26]
	Above Body to Cover Face			
	Driven Gear/Drive Shaft			
	Shaft Protrusion		1.035 [26.29]	1.055 [26.80]
3.	Piston Cooling Oil Tube			
	Protrusion Above Body		2.970 [75.44]	3.000 [76.20]
	Mounting Face			
Double Lubricating Oil Pump				
1.	Bushings			
	Inside Diameter	0.6185 [15.710]	0.6165 [15.659]	0.6175 [15.684]
2.	Idler and Drive Shaft			
	Outside Diameter	0.6145 [15.608]	0.615 [15.62]	0.6155 [15.634]

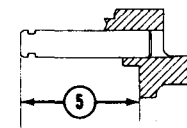
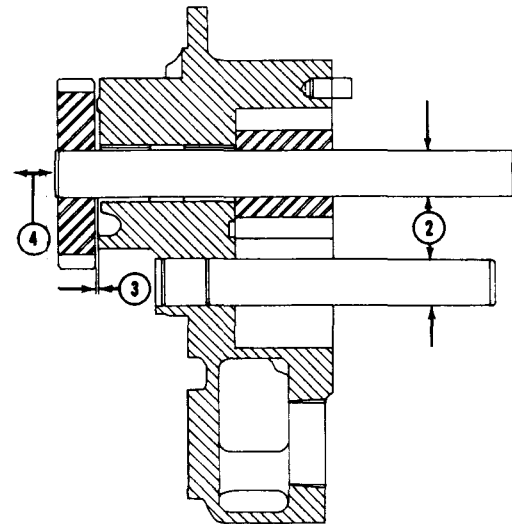
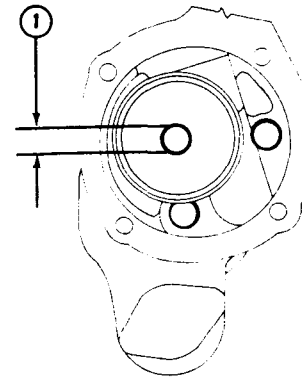


Table 7-1: Lubricating Oil Pump Specifications – Inch [mm] (Reference Fig. 7-0) (Cont'd.)

Ref. No.	Measurement	Worn Limit	New Minimum	New Maximum
	Drive Gear to Body			
	Clearance	0.012		
	Suffix Letter L	[0.30]		
	Drive Shaft			
	End Play		0.004 [0.10]	0.007 [0.18]
	Idler Shaft			
	Shaft Protrusion Above Back Surface of Body		2.600 [66.04]	2.620 [66.55]
	Idler Shaft			
	Suffix Letter L		2.680 [68.07]	2.690 [68.33]
	Drive Gear/Drive Shaft			
	Shaft Protrusion		0.040 [1.02]	0.060 [1.52]
	Single Scavenger Pump			
1.	Bushings			
	Inside Diameter	0.6185 [15.710]	0.6165 [15.659]	0.6175 [15.684]
2.	Idler and Drive Shaft			
	Outside Diameter	0.6145 [15.608]	0.615 [15.62]	0.6155 [15.634]
	Idler Shaft			
	Protrusion	Flush with front surface of pump		
	Driven Gear/Drive Shaft			
	Protrusion		0.580 [14.73]	0.610 [15.49]
	Coupling Dowels			
	Protrusion Above Coupling Face		0.990 [25.15]	1.010 [25.65]
	Coupling/Drive Shaft			
	Shaft Protrusion		0.050 [1.27]	0.070 [1.78]
	Drive Shaft			
	End Play		0.004 [0.10]	0.010 [0.25]
	Double Scavenger Pump			
1.	Bushings			
	Inside Diameter	0.841 [21.36]	0.840 [21.34]	0.8405 [21.349]
2.	Idler and Drive Shaft			
	Outside Diameter	0.837 [21.26]	0.8375 [21.272]	0.838 [21.29]
	Idler Shaft			
	Protrusion	Flush with front surface of pump		
	Driven Gear/Drive Shaft			
	Protrusion		0.580 [14.73]	0.610 [15.49]

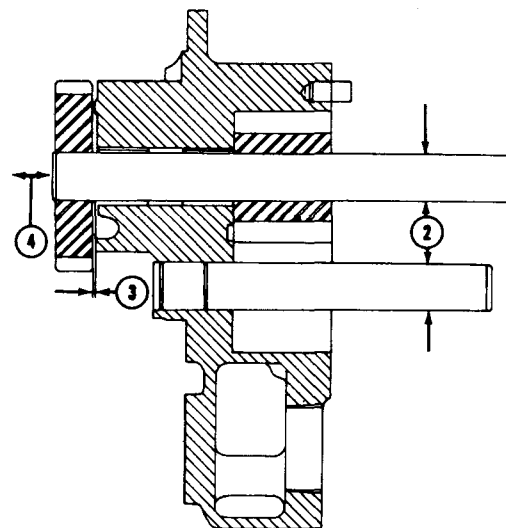
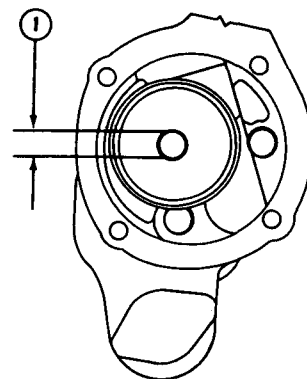


Table 7-1: Lubricating Oil Pump Specifications — Inch [mm] (Reference Fig. 7-0) (Cont'd.)

Ref. No.	Measurement	Worn Limit	New Minimum	New Maximum
Coupling Dowels				
	Protrusion Above Coupling Face		0.990 [25.15]	1.010 [25.65]
Coupling/Drive Shaft				
	Shaft Protrusion		0.050 [1.27]	0.070 [1.78]
Drive Shaft				
	End Play		0.004 [0.10]	0.010 [0.25]
FFC Filter/Cooler or Non-FFC Lubricating Oil Pump				
Pressure Regulator Spring				
	Free Length			3.410 [86.36]
	Load at 2.125 inch [53.98 mm]		45	50
	lb [N]		[200]	[222]
	Recommended Oil Pressure		50	70
	psi [kPa]		[345]	[483]
FFC Lubricating Oil Pump				
By-Pass Valve Spring				
	Free Length			2.500 [63.50]
	Load at 1.780 inch [45.21 mm]		79	91
	lb [N]		[351]	[405]
	Oil Pressure			130
	psi [kPa]			[896]

Table 7-2: Hose Size

Location	Minimum Hose Size
Turbocharger Oil Supply	No. 6
Full Flow Filter	No. 16
Turbocharger Oil Drain	No. 16
By-Pass Filter	See Page 7-7.

Table 7-3: Hose Bends — Inch [mm] (Rubber-Lined)

Hose Size	Inside Dia.	Outside Dia.	Minimum Bend Radius
4	3/16 [4.76]	31/64 [12.30]	2 [50.80]
5	1/4 [6.35]	35/64 [13.89]	2-1/4 [57.15]
6	5/16 [7.94]	39/64 [15.48]	2-3/4 [69.85]
8	13/32 [10.32]	47/64 [18.65]	4-5/8 [117.48]
10	1/2 [12.70]	53/64 [21.03]	5-1/2 [139.70]
12	5/8 [15.87]	61/64 [24.21]	6-1/2 [165.10]
16	7/8 [22.23]	1-13/64 [30.56]	7-3/8 [187.34]
20	1-1/8 [28.58]	1-31/64 [37.70]	9 [228.60]
24	1-3/8 [34.93]	1-23/32 [43.66]	11 [279.40]

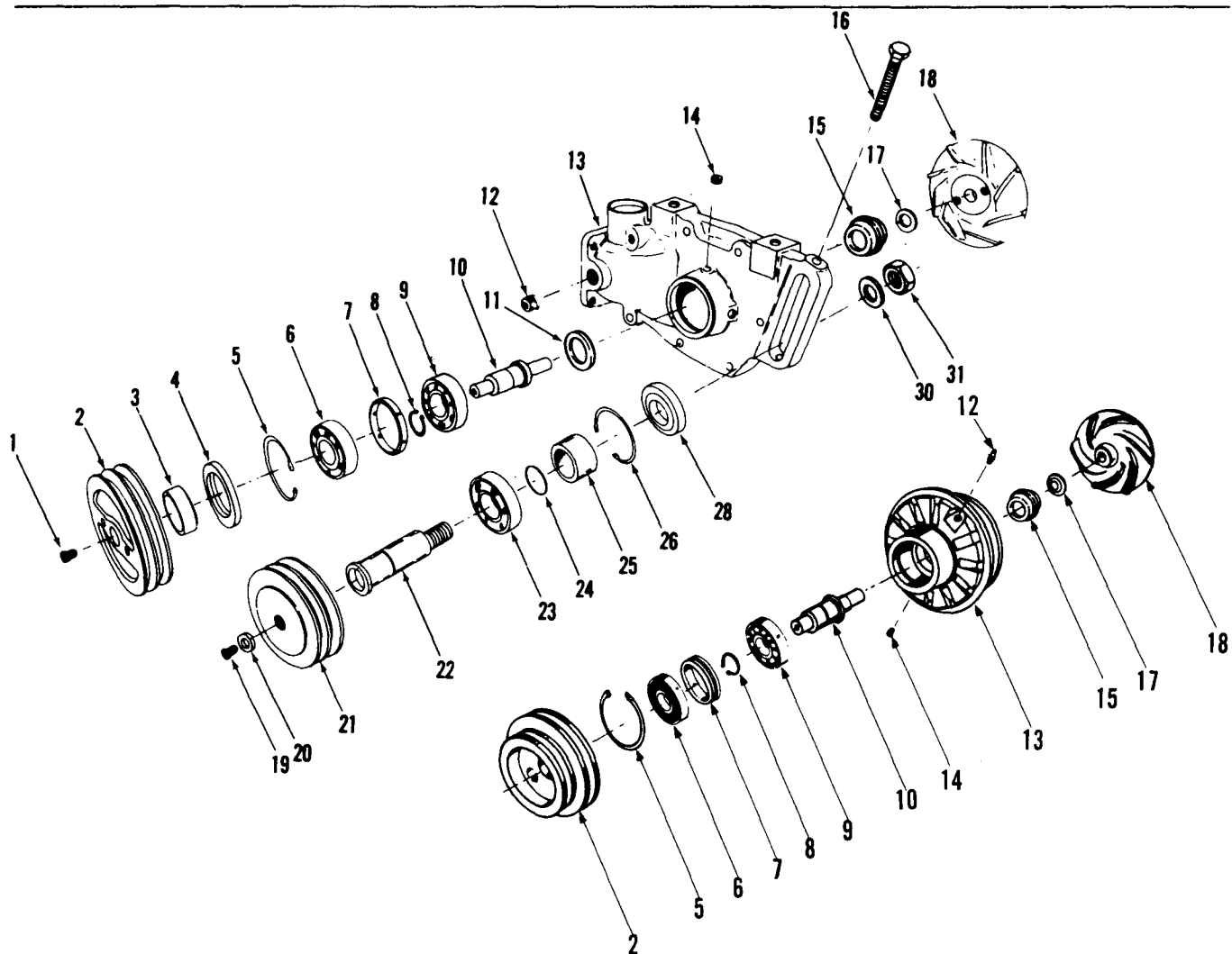
Table 7-4: Hose Bends — Inch [mm] (Teflon-Lined)

Hose Size	Inside Dia.	Outside Dia.	Minimum Bend Radius
6	5/16 [7.94]	39/64 [15.48]	4 [101.60]
16	7/8 [22.23]	1-13/64 [30.56]	7-3/8 [187.33]

Group 8

The cooling system consists of engine water pump, fan hub, thermostats, heat exchanger, sea or raw water pump and coolers.

Cooling System



- | | | | | |
|-----------------|-----------------|------------------------|------------------|-----------------|
| 1. Pipe Plug | 7. Spacer | 13. Water Pump Housing | 19. Capscrew | 25. Spacer |
| 2. Pulley | 8. Snap Ring | 14. Pipe Plug | 20. Washer | 26. Snap Ring |
| 3. Wear Sleeve | 9. Ball Bearing | 15. Carbon Face Seal | 21. Idler Pulley | 27. Capscrew |
| 4. Grease Seal | 10. Shaft | 16. Adjusting Screw | 22. Idler Shaft | 28. Grease Seal |
| 5. Snap Ring | 11. Grease Seal | 17. Seat | 23. Ball Bearing | 29. Lockwasher |
| 6. Ball Bearing | 12. Pipe Plug | 18. Impeller | 24. "O" Ring | 30. Spacer |
| | | | | 31. Nut |

Fig. 8-1, (N10894). FFC and eccentric water pump — exploded view

Water Pump

Three basic water pumps are used on 855 C.I.D. engines. They are the eccentric or idler pulley belt adjustment pumps as shown in Fig. 8-1. NTA Series with idler belt adjustment as shown in Fig. 8-3. Remove idler pulley assembly before pump disassembly. Water pumps are to be lubricated with grease meeting specifications in Group 18 when reassembled.

Service Tools (Or Equivalent) Required

Service Tool Number	Tool Name
ST-657	Bearing Mandrel
ST-658	Bearing Mandrel
ST-709	Puller
ST-1114	Bearing Separator
ST-1159	Wear Sleeve Driver
ST-1161	Seal Mandrel
ST-1191	Seal Driver
3375110	Impeller Support Plate (Phenolic impellers only)
3375180	Oil Seal Pilot
3375257	Pulley/Impeller Puller
3375318	Bearing Mandrel
3375326	Bearing Separator
3375448	Seal and Seat Mandrel

Standard Tools

Snap Ring Pliers (Large and Small)
 Arbor Press
 Grease Gun
 Bearing Packer
 5/16-18, 3/8-16, 6/16-14 Taps
 Feeler Gauge Set
 0-1, 1-2, 2-3 Micrometers
 Telescoping Gauges

FFC and (Eccentric) Water Pump

Disassembly

1. Remove nut (31, Fig. 8-1) and adjusting screw (16) securing idler pulley assembly.

Note: On eccentric water pump with long nose, remove the huglock nut.

2. Using 3375257 Hydraulic Puller, remove pulley (2) and impeller (18) from shaft (10). Phenolic

impellers (FFC only), without pulley holes, remove large snap ring securing the bearing and shaft assembly and press impeller end of shaft through impeller. Eccentric water pumps having phenolic impellers, without puller holes, use 3375110 Support Plate between impeller and water pump housing; press shaft through impeller. Fig. 8-2.

3. Reverse jaws on ST-709 Puller and remove grease seal (4) from drive end of pump body (13). Discard seal.

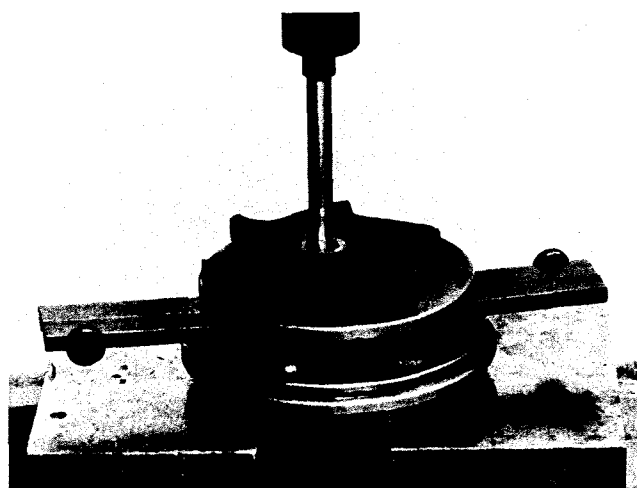


Fig. 8-2, (N10847). Pressing shaft through impeller

Note: If ST-709 Puller is not available, a pry bar with a rounded end may be used. Care must be taken not to damage seal bore surface.

4. Remove large snap ring (5) securing bearing and shaft assembly (6, 7, 8, 9, 10) in water pump body.
5. Supporting water pump body at pulley end, press bearing and shaft assembly from pump body by applying pressure to impeller end of shaft.
6. Remove cup seat (17), drive small grease seal (11) and carbon face seal (15) from body. Discard seat and seals.
7. Support outer bearing (6) and spacer (7) with ST-1114 Bearing Separator, press shaft from outer bearing and spacer. Fig. 8-3.

8. Remove snap ring (8) securing inner bearing (9) and press shaft from bearing, using ST-1114 Bearing Separator to support bearing.



Fig. 8-3, (N10848). Pressing shaft from bearing

Idler Pulley

Disassembly

1. Clamp the spacer (25) in a vise, using copper plates on the jaws, and tap shaft (22) through spacer with a plastic hammer.
2. Reverse jaws on ST-709 Puller and remove oil seal (28) from idler pulley (21); discard seal.

Note: If ST-709 Puller is not available, a pry bar with a rounded end may be used. Care must be taken not to damage seal bore surface.

3. Remove snap ring (26) retaining the bearing assembly.
4. Remove "O" ring (24) from groove in shaft and discard.
5. Remove the plug (19) from face of pulley. Support the pulley in a vise. Insert a flat-end punch through plug hole and tap bearing assembly from pulley. Fig. 8-4.
6. Using a suitable mandrel, press shaft from bearing.

Inspection

1. Inspect water pump and idler pulley bearings; rough or worn races indicate possible damage to shaft outside diameter and the pump housing bore. **Discard bearings.**
2. Visually inspect water pump impeller for cracks or erosion to the extent that it will retard coolant circulation.
3. Measure impeller bore and shaft diameter at impeller end. There should be a minimum of 0.001 inch [0.03 mm] press-fit between the shaft diameter and impeller bore. See Table 8-1.
4. Inspect shafts for straightness and galling on press-fit diameter surfaces.
5. Visually inspect pulley grooves for wear, chips or cracks.



Fig. 8-4, (N10881). Drive bearing assembly from pulley

Note: A new belt pushed down into the groove should protrude 1/16 to 1/8 inch [0.06 to 0.13 mm] above groove; belt should not bottom in groove.

6. Measure drive end and idler pulley bores. Measure drive end of shaft and idler shaft outside diameters. There must be a minimum of 0.001 inch [0.03 mm] press-fit between shaft diameters and pulley bores. See Table 8-1.
7. Inspect wear sleeve (3) on pulley (if used). If

grooves are visible, remove sleeve as follows:

- a. Grind a 15 degree angle on end of a 3/16 inch straight shaft round punch.
 - b. Secure pulley in vise. Do not tighten too tight, excessive pressure could crack pulley.
 - c. Using punch, drive sleeve from pulley hub by placing punch through puller holes in pulley; discard sleeve.
 - d. Press the new wear sleeve on until it is flush with the end of hub.
8. Inspect water pump housing for cracks, possible damage from bearing spinning and be sure "weep" hole is open. Measure housing bore (Fig. 8-5); if the bore is larger than maximum specifications replace housing. See Table 8-1.
 9. Clean all parts in an approved cleaning solvent and dry with moisture free compressed air. Replace all parts that do not meet inspection criteria.
2. Apply a thin coat of Loctite 601 to the bearing outer race. Press shaft and bearing assembly evenly into pulley (21) until bearing bottoms in the bore.
 3. Install snap ring (26) into groove in pulley, beveled side up.
 4. Install a clean grease fitting into hole in face of pulley. Pump in grease, meeting specifications, until grease appears through bearings. Remove grease fitting, install plug (19).
 5. Position new grease seal (28) in pulley bore with the lip side down. Using a suitable mandrel, press grease seal into the bore until it is flush with top of pulley.
 6. Apply a thin coat of lubricating oil to new "O" ring (24) and install it into groove on shaft.
 7. Place spacer (25) over shaft and slide over "O" ring until spacer bottoms on bearings. Fig. 8-6.

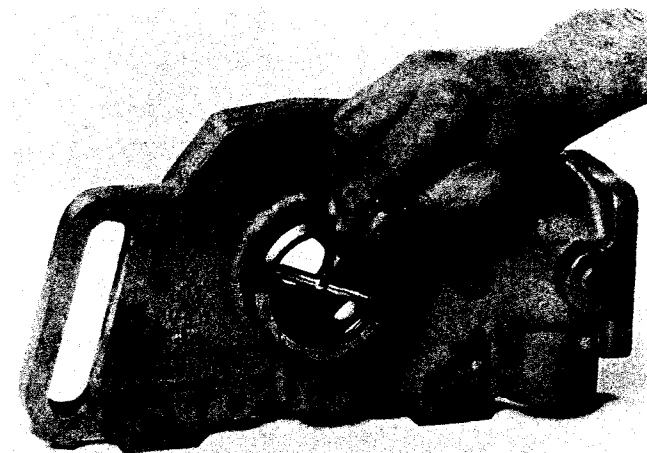


Fig. 8-5, (N10884). Measure housing bore

Idler Pulley

Assembly

1. Lubricate idler shaft (22) bearing surface with a thin coat of clean lubricating oil. Using ST-658 Mandrel to support the bearing inner race, press the shaft into the new bearing.



Fig. 8-6, (N10886). Install spacer

FFC and (Eccentric) Water Pump

Assembly

1. Position rear grease seal (11), FFC water pump only, on ST-1191 Seal Driver with seal lip toward driver. Support the impeller side of water pump housing (13) and press grease seal into water pump bore until it seats.

2. Lubricate shaft (10) bearing surface with a thin coat of clean lubricating oil. Using ST-658 Bearing Mandrel to support the inner bearing (9), press pulley-end of shaft through bearing until the shaft shoulder seats tight against bearing race.
3. Install the small snap ring (8) on shaft, securing bearing (9).
4. Support outer bearing (6) on ST-658 Bearing Mandrel. Position bearing spacer (7) on shaft and press shaft through the bearing until spacer seats firmly against bearings. Check to see that both bearings turn freely. Fig. 8-7.

Caution: Do not overload bearing inner race on contact with spacer; bearing failure may result.

Note: To assure the oil seal will not be damaged during assembly of FFC water pumps, install 3375180 Oil Seal Pilot to impeller end of shaft. Fig. 8-8.

5. Apply a thin coat of Loctite 601 to bearings outer race. Insert bearing and shaft assembly into water pump housing bore and press into housing until it seats using ST-658 Bearing Mandrel. Remove 3375180 Oil Seal Pilot.

Caution: Eccentric water pump housings should be supported at the seal surface of the impeller end. Do not support the housing on the thin section of the impeller cavity.

6. Install the large snap ring (5), with beveled side up, inside housing groove against bearing.
7. On FFC water pumps only, install a clean grease fitting and pump grease into cavity until it first appears at outer bearing (6). Cummins Engine Company, Inc. recommends the use of grease meeting specifications of MIL-G-3545 excluding those of sodium or soda soap thickeners. Contact lubricant supplier for grease meeting these specifications.

Caution: Do not overfill; overheating and bearing failure will result.

8. Using ST-1191 Seal Driver (FFC only), press front grease seal (4), with seal lip toward

bearing, into the water pump housing until it is flush with top edge of bore. Fig. 8-9.

9. Turn water pump housing over and support drive end of housing. Apply Loctite 3375066 to outside diameter of brass case on the seal (15). Fig. 8-10. Using 3375448 Mandrel, press carbon face seal into housing until seal bottoms out.

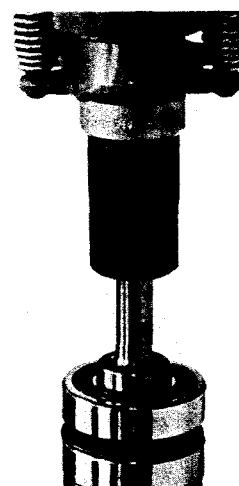


Fig. 8-7, (N10888). Press shaft into bearing

10. Using 3375448 Mandrel, press the new cup seat (17) into place on shaft. 3375448 Mandrel is designed to position the cup seat to an exact location against the carbon face seal.

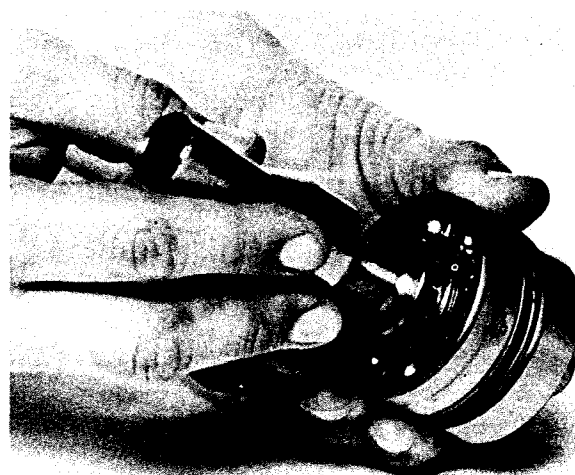


Fig. 8-8, (N10889). Install 3375180 Pilot

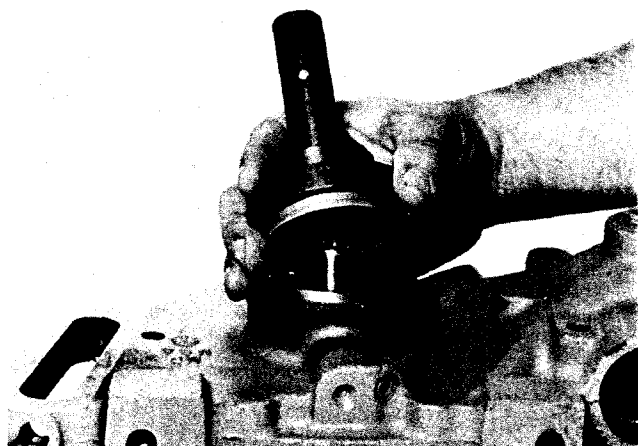


Fig. 8-9, (N10890). Press seal into housing

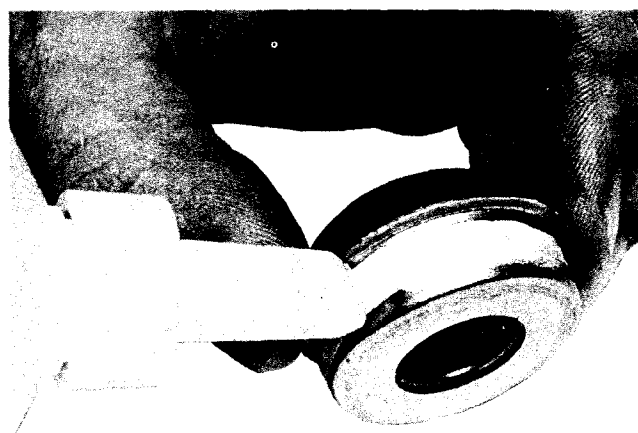


Fig. 8-10, (N10853). Apply pipe sealant to seal

11. For FFC water pumps, install impeller and pulley in the following manner:

- a. Remove grease fitting and install pipe plug in its place. Install all other pipe plugs in water pump housing.
- b. Apply a thin coat of Loctite 601 in pulley bore and place the pulley face down on press. Center pump assembly shaft into pulley bore and press shaft into pulley until end of shaft is flush with pulley face.
- c. Apply a thin coat of Loctite 601 in impeller bore and support drive end of shaft; press impeller (18) on shaft maintaining 0.020 to 0.040 inch [0.51 to 1.02 mm] clearance

between impeller vanes and housings. Fig. 8-11.

Note: When "phenolic" water pump impeller is used, press impeller on shaft maintaining 0.030 to 0.050 inch [0.76 to 1.27 mm] clearance between impeller vanes and housing.

12. Position idler assembly to water pump housing. Secure with flatwasher and nut (30, 31) finger tight.

13. For eccentric type water pumps, install impeller and pulley using the instructions below:

- a. Apply a thin coat of Loctite 601 to inside diameter of impeller (13). Support water pump on pulley end of shaft and press impeller on shaft, maintaining 0.020 to 0.040 inch [0.51 to 1.02 mm] clearance between impeller vanes and water pump housing. Fig. 8-11.

Note: When "phenolic" water pump impeller is used, press impeller on shaft, maintaining 0.030 to 0.050 inch [0.76 to 1.27 mm] clearance between impeller vanes and water pump housing.

- b. Install clean grease fitting (10) and pump in grease until it appears in opposite fitting hole. Cummins Engine Company, Inc. recommends use of grease meeting the specifications of MIL-G-3545, excluding those of sodium or soda soap thickeners. Contact lubricant supplier for grease meeting these specifications.

Caution: Do not overfill; overheating and bearing failure will result if filled over 2/3 full.

- c. Install clean relief fitting (8).
- d. Support water pump assembly on impeller end of shaft – not on impeller – and press pulley (1) on shaft until pulley hub is tight against the outer bearing (3) inner race. Fig. 8-12.
- e. On long shaft, fan-mounted water pumps, install huglock nut and washer. Tighten huglock nut 90 to 100 ft-lbs [122 to 136 N•m] torque.

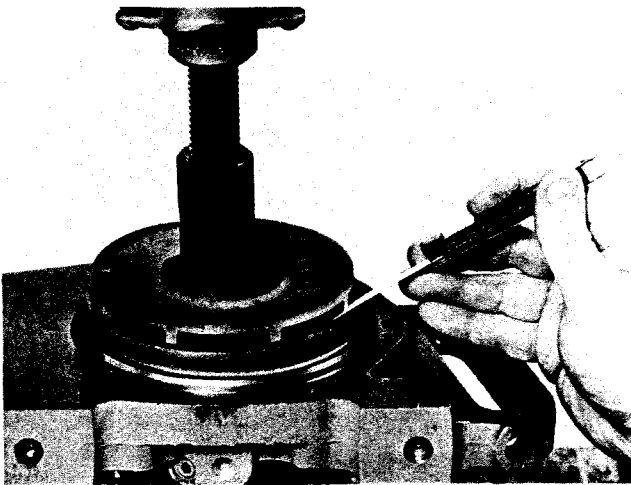


Fig. 8-11, (N10892). Checking impeller clearance

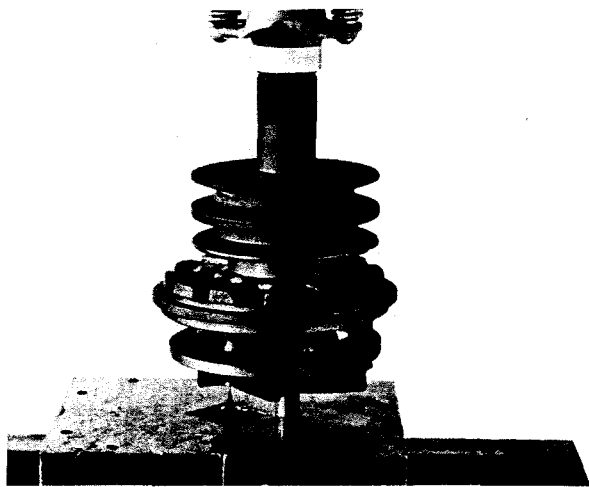


Fig. 8-12, (N10856). Pressing pulley in place

(NTA) Water Pump and Idler Assembly

Disassembly

1. Remove capscrews and lockwashers securing inlet housing (24, Fig. 8-13) to water pump housing (8). Remove inlet housing and discard "O" ring (10).
2. Using 3375257 Puller, remove pulley (1) from shaft (6). Loosen capscrews and remove idler pulley assembly from housing.
3. Reverse jaws on ST-709 Puller and remove grease seal (3) from water pump housing. Discard seal.

Note: If ST-709 Puller is not available, a pry bar with a rounded end may be used. Care must be taken not to damage seal bore surface. Fig. 8-14.

4. Remove large snap ring (4), securing large bearing (5) in water pump housing.
5. Remove impeller (11) from shaft (6) with 3375257 Puller.
6. Support water pump housing (8) at drive end; press shaft and bearing assembly (5, 6, 7) from housing by applying pressure to impeller end of shaft.
7. Remove cup seat (12), drive carbon face seal (13) and small oil seal (14) from housing and discard.
8. Using 3375326 Bearing Separator, supporting large bearing, press shaft through bearing (5). Fig. 8-15.
9. Supporting small bearing (7) with 3375326 Bearing Separator, press shaft (6) through bearing.

Idler Pulley Disassembly

1. Remove large pipe plug (17) from idler pulley (19).
2. Remove small snap ring (18) from shaft (23).
3. Using 3375326 Bearing Separator to support idler pulley (19), press shaft and bracket assembly (20) from pulley. Fig. 8-16.
4. Remove oil seal (22) and snap ring (2). Using a flat end punch through the pipe plug hole in face of pulley, drive bearing out of pulley.

Inspection

1. Inspect water pump and idler pulley bearings; rough or worn races indicate possible damage to shaft outside diameter and the pump housing bore. **Discard bearings.**
2. Inspect water pump impeller for cracks or erosion to the extent that it will retard coolant circulation.

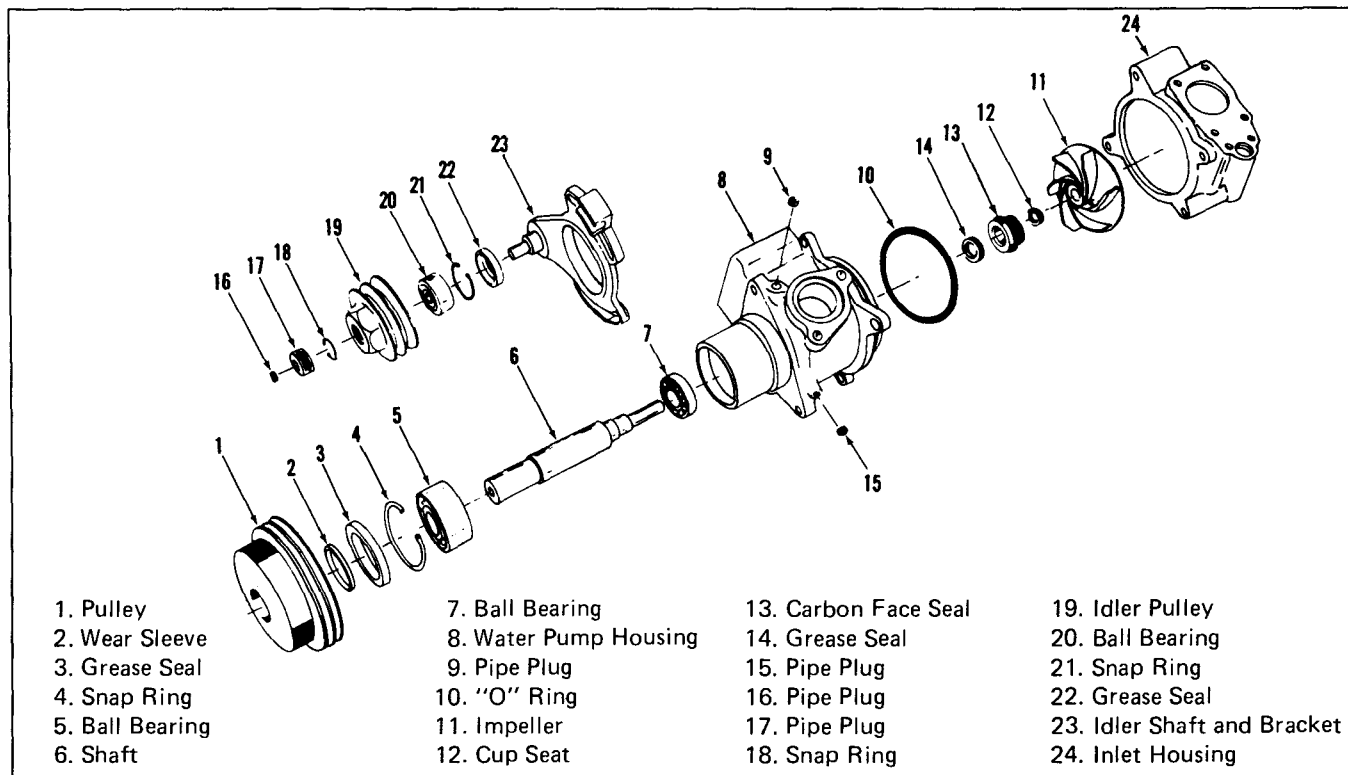


Fig. 8-13, (N10857). (NTA) Water pump — exploded view

3. Measure impeller bore and shaft diameter at impeller end. There should be a minimum of 0.001 inch [0.03 mm] press-fit between the shaft diameter and impeller bore. See Table 8-2.
4. Inspect shafts for straightness and galling on press-fit diameter surfaces.
5. Inspect pulley grooves for wear; chips or cracks.

6. Measure drive and idler pulley bores. Measure drive end of water pump shaft and idler shaft outside diameters. There must be a minimum of 0.001 inch [0.03 mm] press-fit between shaft diameters and pulley bores. See Table 8-2.

Note: A new belt pushed down into the groove should protrude 1/16 to 1/8 inch [0.06 to 0.13

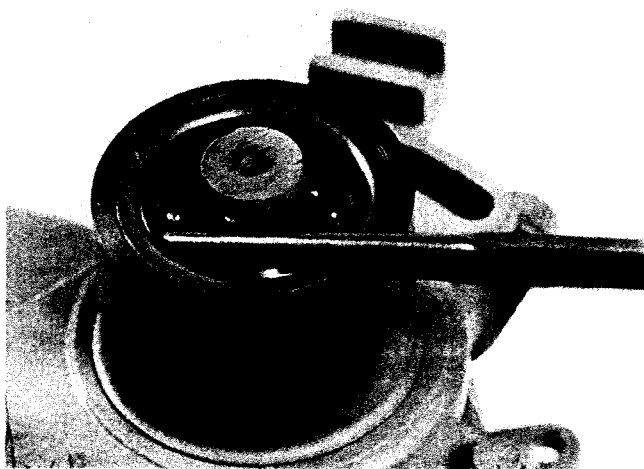


Fig. 8-14, (N10859). Pry seal out of housing

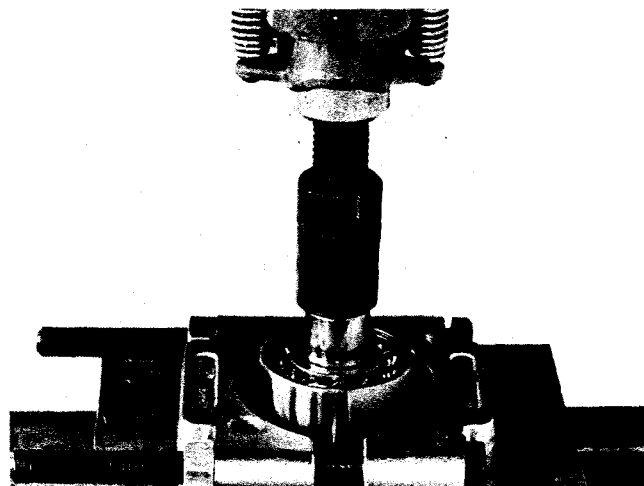


Fig. 8-15, (N10861). Pressing shaft from bearing

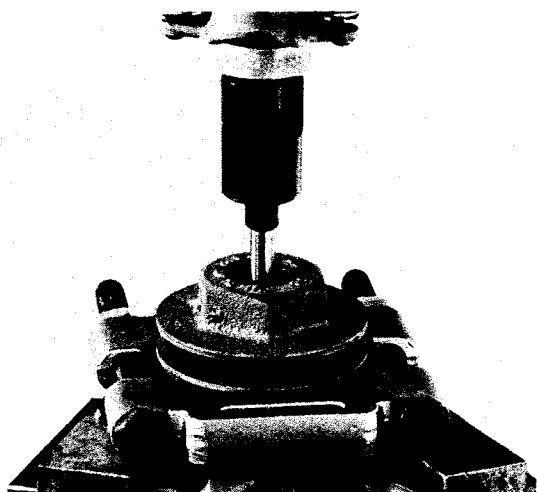


Fig. 8-16, (N10862). Press idler shaft assembly from pulley

mm] above groove; belt should not bottom in groove.

8. Use ST-1159 Wear Sleeve Drive to install new wear sleeve.
7. Inspect wear sleeve; if worn or damaged cut a groove part way through using a special "angled" chisel. Using a small punch through a puller hole, drive sleeve off. Fig. 8-17.
9. Inspect water pump housing for cracks, possible damage from bearing spinning and be sure "weep" hole is open. Remove grease fittings. Measure housing bore; if the bore is larger than maximum specifications replace housing. See Table 8-1.
10. Inspect by-pass valve, retainer disc and spring for wear and mutilation.
11. Clean all parts in an approved cleaning solvent and dry with moisture free compressed air. Replace all parts that do not meet inspection criteria.

Idler Pulley and Bracket

Assembly

1. Pack bearings with grease meeting specifications.
2. Press bearing (20, Fig. 8-13) into pulley (19) using ST-657 Bearing Mandrel.

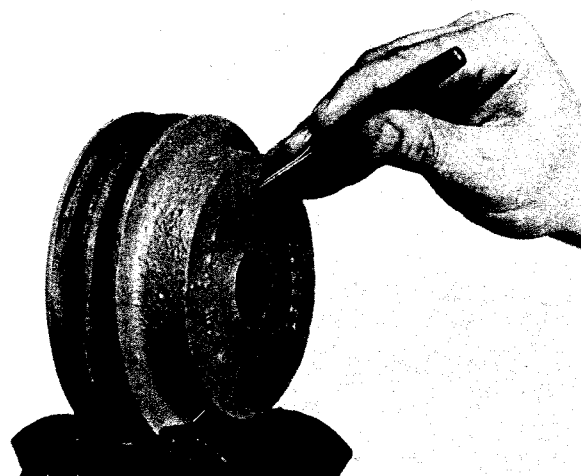


Fig. 8-17, (N10865). Drive wear sleeve from pulley

3. Install snap ring (21), flat side to bearing. Using ST-1159 Seal Driver install new seal (22) flush with pulley. Fig. 8-18.
4. Press pulley and bearing assembly onto shaft (23) and install small snap ring (18).
5. Before installing pipe plug (17) into pulley, hand pack cavity 1/2 to 2/3 full with grease meeting specifications. Install pipe plug.

(NTA) Water Pump

Assembly

1. Lubricate shaft bearing surface with thin coat of clean lubricating oil. Using ST-658 Bearing



Fig. 8-18, (N10867). Seal flush with pulley bore

Mandrel to support the small inner bearing (7), press impeller end of shaft through bearing until the shaft shoulder seats tight against bearing race.

2. Using 3375318 Bearing Mandrel to support the large outer bearing (5), press pulley end of shaft through bearing until bearing seats on shoulder.
3. Use ST-1154 Seal Mandrel, press small seal (14) into water pump housing (8), until seal is flush to 0.015 inch [0.38 mm] below shoulder of bore.
4. Apply a thin coat of Loctite 601 to bearing (2) outer race. Fig. 8-19. Insert shaft and bearing assembly (5, 6, 7) into water pump housing and, with 3375318 Bearing Mandrel, press assembly into housing until it seats. Secure with large snap ring (4).



Fig. 8-19, (N10870). Apply Loctite to bearings

5. Install clean grease fitting and pump in grease until grease becomes visible in opposite pipe plug hole. Cummins Engine Company, Inc. recommends the use of grease meeting specifications of MIL-G-3545 excluding those of sodium or soda soap thickeners. Contact lubricant supplier for grease meeting these specifications.
6. Support housing at impeller end; press large grease seal (3), seal face toward driver, into water pump housing with ST-1161 Seal Driver.
7. Position idler pulley bracket assembly on pump

assembly and secure with capscrews and lockwashers.

8. Support assembly on impeller end of shaft, press drive pulley (1) onto shaft until it bottoms on the bearing inner race.
9. Turn water pump inlet housing over and support drive end of housing. Apply Loctite 3376066 to outside diameter of brass case on the seal (13). Fig. 8-10. Using 3375448 Mandrel, press carbon face seal into housing until seal bottoms out. Fig. 8-20.
10. Using 3375448 Mandrel, press the new cup seat (12) into place over shaft. 3375448 Mandrel is designed to position the cup seat to an exact location against the carbon face seal.
11. Supporting drive end of shaft (6), press impeller (1) on shaft maintaining 0.020 to 0.040 inch [0.51 to 1.02 mm] clearance between impeller vanes and housing.

Note: When "phenolic" water pump impeller is used, press impeller on shaft, maintaining 0.030 to 0.050 inch [0.76 to 1.27 mm] clearance between impeller vanes and water pump body.

12. Lubricate new "O" ring (10) with clean lubricating oil and position it in groove of water pump housing (8). Insert water pump housing into water inlet housing (24), being careful not to damage "O" ring while aligning capscrew holes. Secure with capscrews and lockwashers.



Fig. 8-20, (N10873). Pressing carbon face seal in housing

Fan Inspection

Check fan blades for bends, dents or cracks. If fan does not meet inspection criteria; replace at once.

Warning: Do not attempt any repairs on fans.

Cleaning

Clean thoroughly with a steam jet and blow dry with compressed air.

Fan Hub — Less Bearing Spacer

Disassembly

1. Remove pipe plugs, pilot (3, Fig. 8-21), gasket (4), cotter pin (5), fan pulley slotted nut (6) and clamp washer (7) from fan hub shaft (12).
2. Support hub (9) on arbor press with small end of shaft up. Press shaft from hub.
3. Press bearings (8) and (1) and oil seal (13) from shaft.

Inspection

1. Inspect bearings and fan pulley shaft bearing surfaces, replace if rough or worn. Press-fit between mating parts must be a minimum of 0.000 to 0.001 inch [0.00 to 0.03 mm].
2. Inspect fan hub and pilot for cracks.
3. Inspect pulley grooves for wear, chips or cracks.

Note: A new belt pushed down into the groove should protrude 1/16 to 1/8 inch [0.06 to 0.13 mm] above groove; belt should not bottom in groove.

4. Clean all parts in an approved cleaning solvent and dry with moisture free compressed air. Replace all parts that do not meet inspection criteria.

Assembly

Note: Bearings installed in fan hubs that DO NOT use lip type grease seal must be packed with grease at time of installation.

1. Press (do not drive) outer race of bearing (8) into fan hub housing (9) with cupped area up, race must seat against shoulders provided in housing.
2. Press inner race and rollers of rear bearing (11) or ball bearing onto fan hub shaft (12) against shaft shoulder, press ball bearing and shaft into housing.
3. Install inner race and rollers of outer bearing on shaft; install washer (7) and nut (6) to shaft.
4. Slowly rotate hub and tighten nut (6) until a small amount of "drag" is felt.

Caution: Hub must be rotated while nut is being tightened. Failure to rotate hub will result in excessive end play.

5. Loosen nut (6) approximately one-half castellation if cotter pin (5) is used. If locknut is used, loosen nut approximately 30 degrees.
6. Support fan hub assembly in a press. Apply sufficient force to nut end of shaft to force cone against nut which will give bearing clearance. The force required to move inner core against nut should never exceed that required to press cone on shaft.
7. Check fan hub end clearance; it must be 0.003 to 0.016 inch [0.08 to 0.40 mm]. Hub must rotate freely. Loosen or tighten nut if required and repeat Steps 4, 5 and 6. Bend cotter pin to lock nut in place.
8. Apply 0.2 to 0.3 oz. [5.7 to 8.5 g] of grease (approximately 2 teaspoonfuls) to the rear bearing before installing grease seal. Press new oil seal (13) into fan hub housing with "lip" side down (facing bearing). See Group 18 for type grease.
9. Apply 0.2 to 0.3 oz. [5.7 to 8.5 g] of grease to outer (front) bearing and assemble gasket and fan pilot.
10. Install fan bracket washers (1) and locknut.
11. Fill fan hub grease cavity approximately 60 to 70 percent of capacity with grease. If fan hub spacers are used which increase the grease

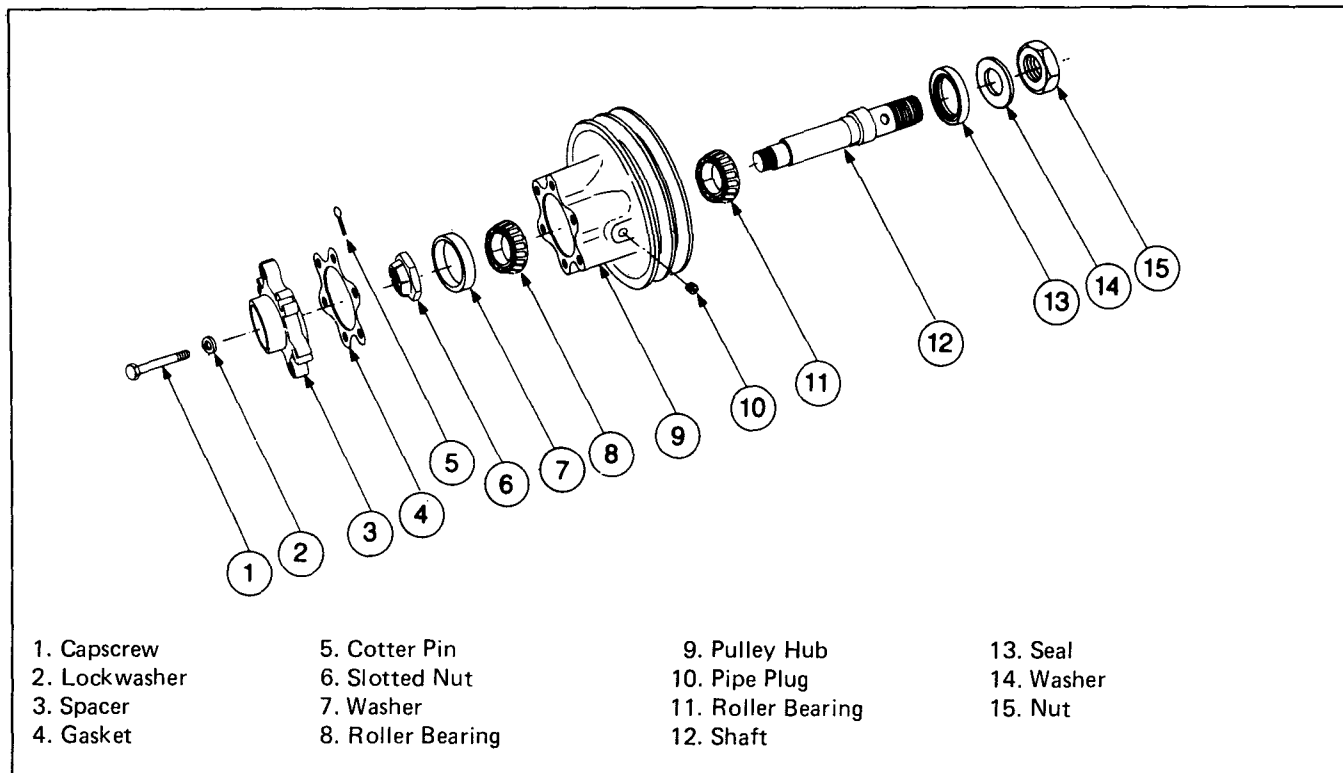


Fig. 8-21, (N10895). Fan hub assembly — exploded view

cavity, this area must be filled with grease also.

12. After lubrication, remove grease fittings and install pipe plugs. Tighten to 5 to 7 ft-lbs [7 to 9 N•m] torque.

Tapered Roller Bearing Type With Bearing Spacer

Disassembly

1. Remove pipe plugs (6, Fig. 8-22).
2. Remove spacer (12), "O" ring retainer (10), locknut (9) and washer (if used).
3. Remove pulley (5) from shaft, remove front bearing (3) and spacer (7) from pulley.
4. Remove seal (2) and rear bearing (3), discard seal.

Inspection

1. Inspect bearings, races, and fan hub shaft for roughness, pitting and wear.

2. If shaft is damaged in seal mating area it can be cleaned up by using 240 grit or finer emery paper.

3. Bearing races (4) may be removed with a flat punch by striking, from the back side, alternately from side to side until the race drops out.

4. If bearing races are removed, inspect snap rings (8). Do not remove snap rings unless damaged.

5. Inspect parts for chips, cracks, wear or distorted threads.

6. Clean all parts in an approved cleaning solvent and dry with moisture free compressed air. Replace all parts that do not meet inspection criteria.

Assembly

1. If removed, install new snap ring (8) in grooves inside bore.
2. Press in bearing races (4), beveled side out, until

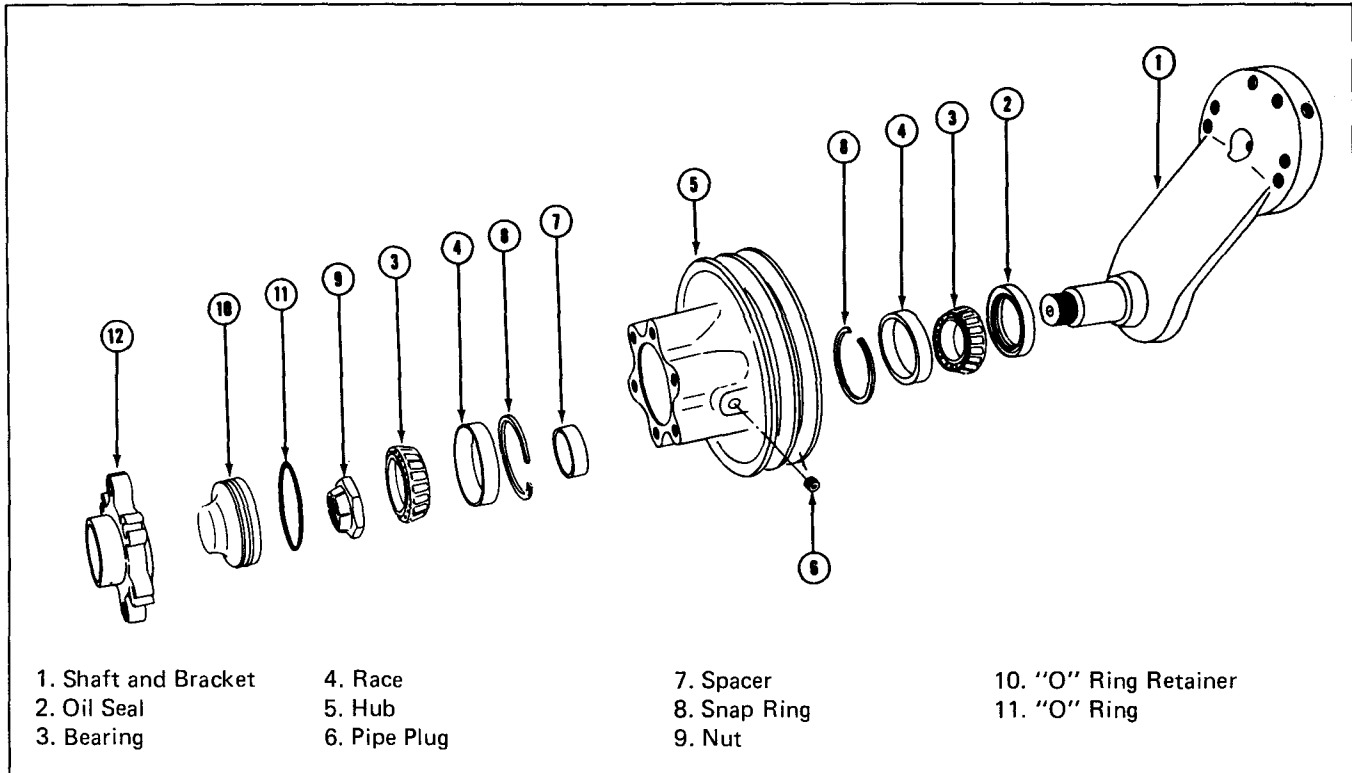


Fig. 8-22, (N10839). Fan hub assembly with tapered roller bearing and spacer

paces "bottom" against snap rings.

3. Position rear bearing (3) in race (4) and press seal (2) into pulley bore until flush. (Lip of seal toward bearing.)
4. Pack bearings with grease meeting specifications.

Caution: Do not mix grease and lubricating oil or damage to bearing may result.

5. Coat lip of seal (2) with lubricating oil, slide shaft (1) through seal and bearing. Do not damage seal.
6. Place bearing spacer (7) over shaft and install front bearing (3).
7. Install washer (if used) and locknut (9). Tighten nut to 150 ft-lbs [203 N•m] torque.
8. Rotate fan hub and check end clearance. Fan hub must rotate freely, end clearance must be 0.003 to 0.016 inch [0.08 to 0.40 mm].

9. Place lubricated "O" ring (11) on retainer (10) and press or drive into pulley bore.

10. Install fan spacer (12) with cupped side next to retainer.

11. Fill fan hub cavity approximately 60 to 70 percent of capacity with grease. Cummins Engine Company, Inc. recommends the use of grease meeting specifications of MIL-G-3545 excluding those of sodium or soda soap thickeners. Contact lubricant supplier for grease meeting these specifications.

Caution: Do not over fill; overheating and bearing failure will result.

12. Install pipe plugs, tighten to 5 to 7 ft-lbs [7 to 9 N•m] torque.

Thermostat and Housing

Thermostats are not subject to repair, but should be checked to make sure they are opening and closing at the proper temperatures. Most thermo-

stats are now of the ventless by-pass design for use with shutterless cooling system as shown in Fig. 8-23.

Engines should never be operated without thermostats which aid in the proper control of combustion chamber temperatures under all operating conditions.

Disassembly

1. Remove water outlet connection (1, Fig. 8-24) and thermostat housing (5).
2. Remove gasket (3), thermostat (4) and seal (6).

Inspection and Testing

1. Check connections and housings for deterioration, cracks and leaks.
2. Check thermostat operation.
 - a. Immerse thermostat and thermometer in a container of water as shown in Fig. 8-25.

b. Heat water to rated opening temperature (stamped on body) $+2$ to -3°F [$+1$ to -2°C] and note cracked open seat position (0.005 inch [0.13 mm]) after allowing time to stabilize (3 minutes).

c. Heat water to 20°F [11°C] above rating and

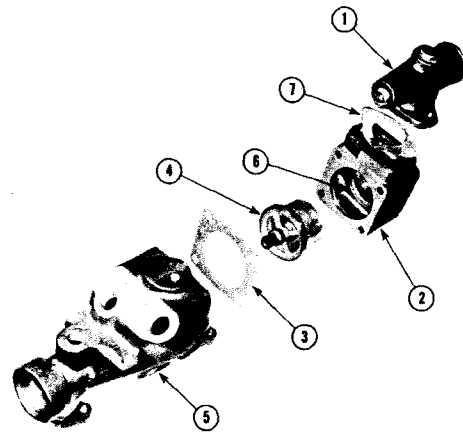


Fig. 8-24, (N10814). Thermostat housing and seal

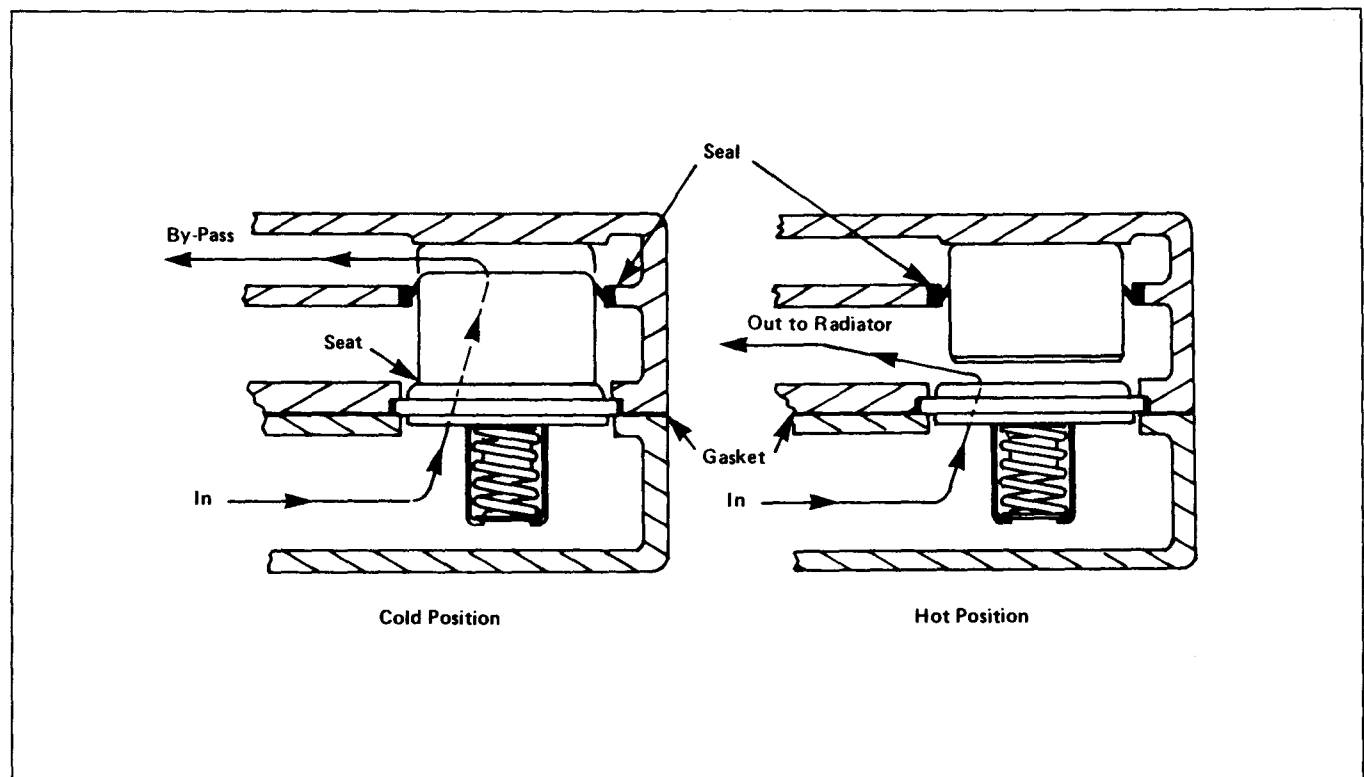


Fig. 8-23, (N10896). By-pass type thermostat

observe minimum opening of 0.375 inch [9.53 mm].

- d. Remove thermostat from water and while sleeve is off of seat inspect seat area for pitting and foreign deposits. Clean as required to assure a tight seal at seat when thermostat closes.
 - e. Discard thermostat if it does not operate as described above.
3. Standard ventless thermostats start opening at 175°F [79°C] (rated) and fully open a minimum travel of 0.375 inch [9.53 mm] at 195°F [91°C].

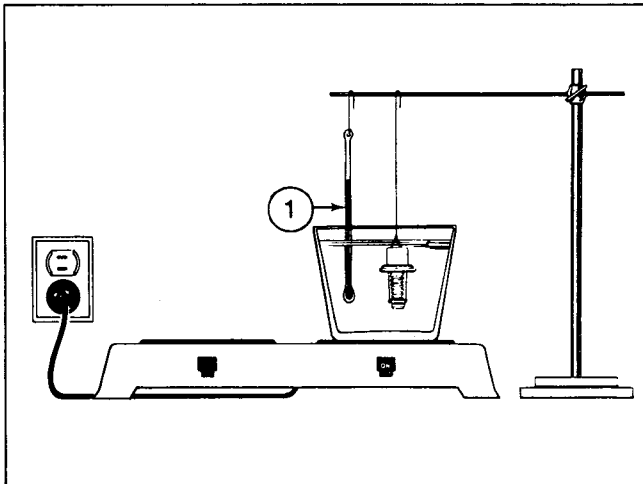


Fig. 8-25, (N10897). Testing thermostats

Assembly

1. Using ST-1225 Seal Mandrel, or equivalent, install new seal in thermostat housing. Seal must be installed with part number or metal flange of seal toward mandrel during installation to insure proper sealing.

Note: Check seal for proper position in thermostat housing, improper seal location may cause by-pass leakage to the radiator when thermostat is in closed position resulting in cold running engine.

2. Install thermostat into housing with sleeve sliding through seal and head facing outward.
3. Assemble thermostat housing using new gasket. Install water outlet connection.

Heat Exchanger

See Support, Pump Mounted or Auxiliary Oil Cooler, Group 7.

Testing Relief Valve

Pressure exchanger to 7 psi [48 kPa]. Replace relief valve if it opens below 7 psi [48 kPa] or fails to open at 7 psi [48 kPa].

Converter Cooler

See Support, Pump Mounted or Auxiliary Oil Cooler, Group 7.

Aftercooler

Disassembly

1. Remove water connection to cooler housing (air intake manifold); lift off connection.
2. Remove element cover and element from cooler housing.

Note: Water supply and discharge connections are secured with "O" rings and gaskets. It may require some force to separate components.

Inspection and Repair

1. Inspect body, cover and sealing surfaces for breaks and distortion, discard all damaged parts.
2. A usual practice is to take cooler element to a radiator shop for cleaning, testing and repair.

Assembly

1. Place aftercooler housing (9, Fig. 8-26) in upright position on work bench.
2. Place cover gasket (7) in position on housing. Lubricate "O" rings (5) with clean engine lubricating oil and position on inlet and outlet fittings of aftercooler core (6). Position aftercooler core into manifold on top of cover gasket.
3. Place water connection gasket (2) on water inlet connection (11) and insert connection through

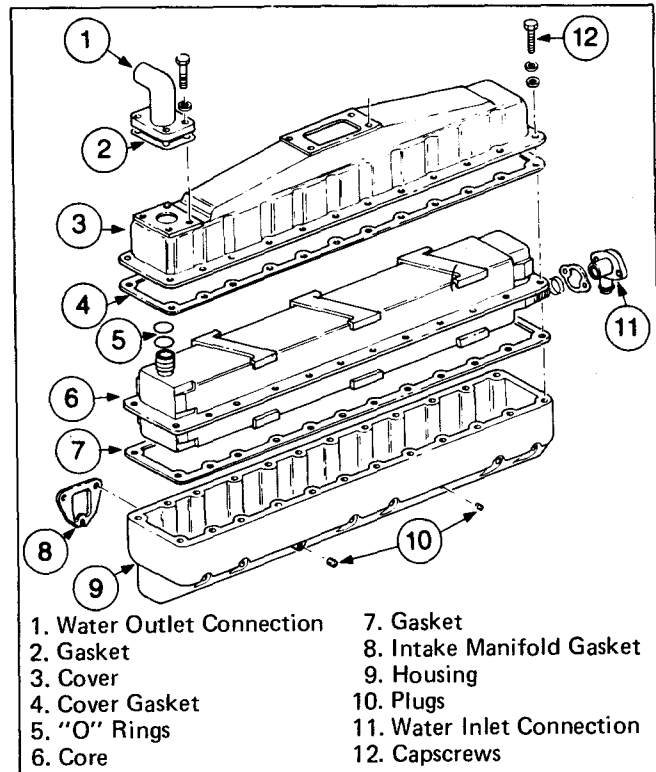


Fig. 8-26, (N10898). Aftercooler — exploded view

manifold and onto inlet fitting of core. Be careful not to damage "O" rings. Install and finger tighten capscrews used to secure connection to manifold.

4. Place other cover gasket (4) over aftercooler core mounting flange. Align capscrew holes of gasket, manifold and core mounting flange. Place aftercooler cover (3) into position and start (serrated washer mating surface) mounting capscrews (12).
5. Position water outlet connection (1), gasket (2) against cover. Using copper washers (13) install and finger tighten three mounting capscrews.

Caution: At this point, determine, if possible, that the "O" ring connections are centered and not under any abnormal "crush".

6. Snug tighten all aftercooler cover mounting capscrews. Tighten two capscrews securing the water inlet to the cast aluminum manifold to 27 to 32 ft-lbs [37 to 43 N•m] torque.
7. Starting at middle of aftercooler and alternating

on either side of cover and either side of center, tighten the cover mounting capscrews to 25 ft-lbs [34 N•m] torque.

8. Tighten capscrews securing the water outlet connection to 15 to 20 ft-lbs [21 to 27 N•m] torque.

Aftercooler (Newest Design)

Assembly

1. Place aftercooler housing (13, Fig. 8-27) in upright position on work bench.

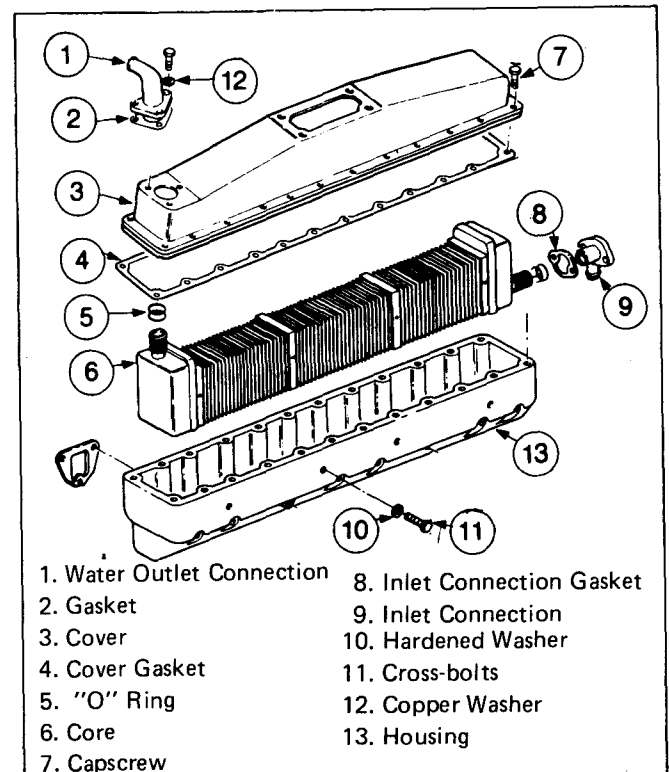


Fig. 8-27, (N10899). Aftercooler — exploded view (new)

2. Lubricate "O" rings (5) with clean engine lubricating oil and position on inlet and outlet fittings of aftercooler core (6). Position the aftercooler core into the housing. Observe that this is a snug fit assembly and may require some gentle hand maneuvering to get the core into the housing. With the core installed and shifted completely toward one side of the housing the

clearance between the core and housing in the cross-bolt area should be 0.003 to 0.013 inch [0.07 to 0.33 mm].

Caution: At this point assure, if possible, that the "O" ring connections are centered and not under any abnormal "crush".

3. Align core and housing holes and start cross-bolts (11) being certain to use hardened washer (10). Starting with the two center capscrews, alternate on either side of center and tighten all capscrews to 15 ft-lbs [21 N•m] torque. Alternate around the housing assembly again and bring the capscrews up to the specified torque of 25 ft-lbs [35 N•m].
4. Place water connection gasket (8) on water inlet connection and insert connection through manifold and onto inlet fitting of core being careful not to damage "O" rings. Install and finger tighten capscrews used to secure connection to manifold.
5. Place cover gasket (4) over aftercooler core to housing mounting flange. Align capscrew holes of gasket, manifold, and place aftercooler cover (3) into position and start serrated mounting capscrews (7).
6. Position water outlet connection (1) and gasket (2) against cover. Using copper washers (12) install and finger tighten three (3) mounting capscrews.

Caution: At this point, determine, if possible, that the "O" ring connections are centered and not under any abnormal "crush".

7. Snug tighten all aftercooler cover mounting capscrews. Tighten two (2) capscrews securing the water inlet to the cast aluminum manifold to 27 to 32 ft-lbs [37 to 43 N•m] torque.
8. Starting at middle of aftercooler and alternating on either side of cover and either side of center, tighten the cover mounting capscrews to 25 ft-lbs [34 N•m] torque.
9. Tighten capscrews securing the water outlet connection to 15 to 20 ft-lbs [21 to 27 N•m] torque.

Raw (Sea) Water Pump

Disassembly

1. Remove raw water pump drive gear or pulley with 3375257 Puller. Remove shaft key (10, Fig. 8-28).
2. Remove snap ring. If belt-driven, rubber seal (14) must be removed before removing snap ring.
3. Remove end cover (1) and gasket (2), rubber plug (3) and rubber impeller (4). If pump is to be reinstalled in same position as removed, note direction of impeller blades to be sure it is reassembled correctly. Fig's. 8-29 and 8-30.
4. Press shaft (9) from pump body and remove slinger.
5. Remove screw from side of housing (7, Fig. 8-31), take out cam (5) and wear plate (6).
6. Remove seal assembly; marcel washer (15), washer (16), ferrule (17) and "O" ring (18), carbon seal (19), seal seat (20) and seal gasket (21).

Inspection

1. Check rubber impeller for deep scratches, cracked or torn impeller fins.
2. Check cam and wear plate surfaces to see that they are smooth and not deeply grooved.
3. Check ball bearing for cracked or broken races, or balls.
4. Discard all unusable parts and replace with new Cummins Replacement Parts.

Assembly

1. Apply high pressure lubricant to shaft and press ball bearing (12), numbered side out, against shoulder of shaft. Press key (10) in shaft.
2. Press oil seal (11) into drive side of housing and insert shaft (9) while holding rubber slinger (8) in position through slot in housing cavity.

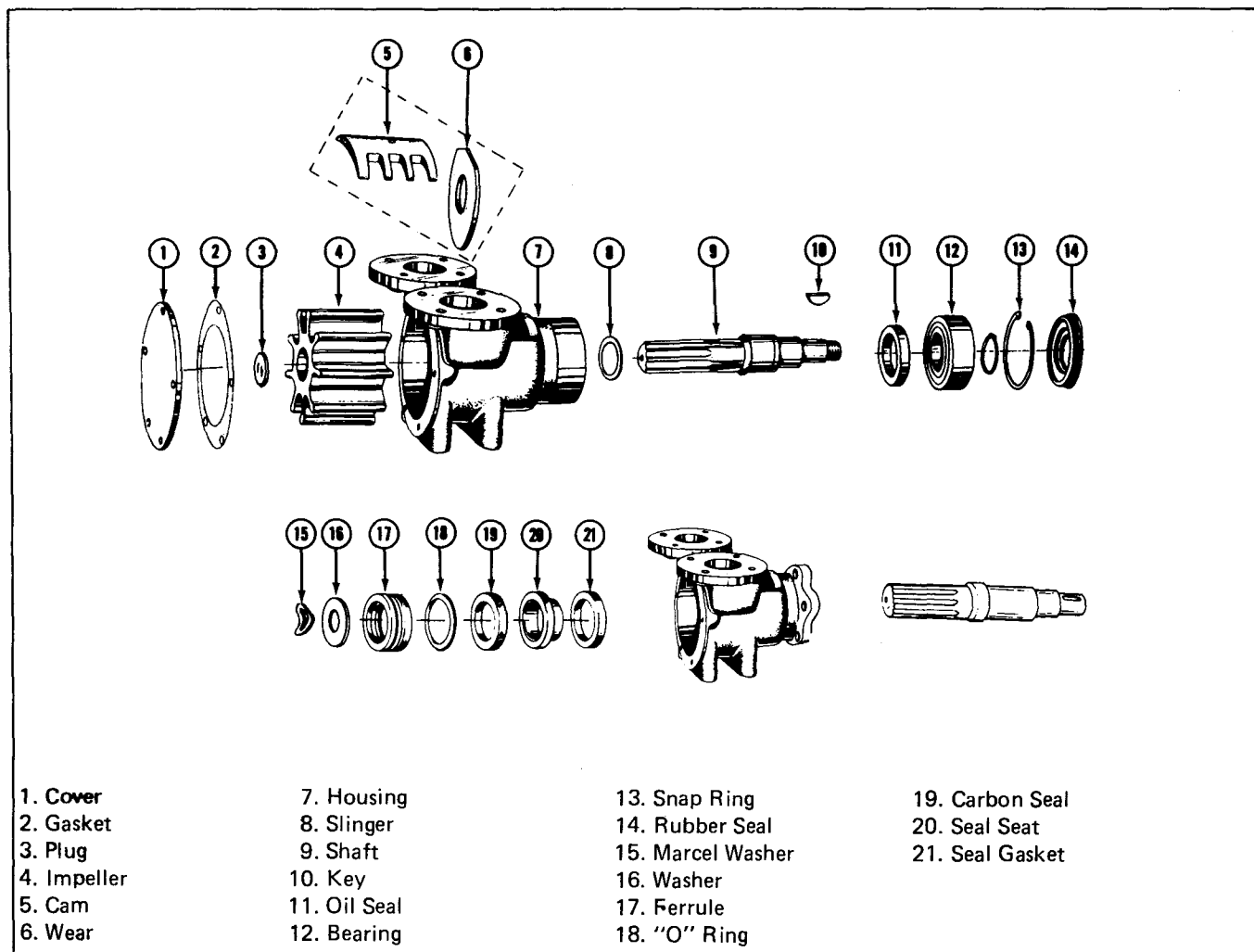


Fig. 8-28, (N10806). Raw (sea) water pump – exploded view

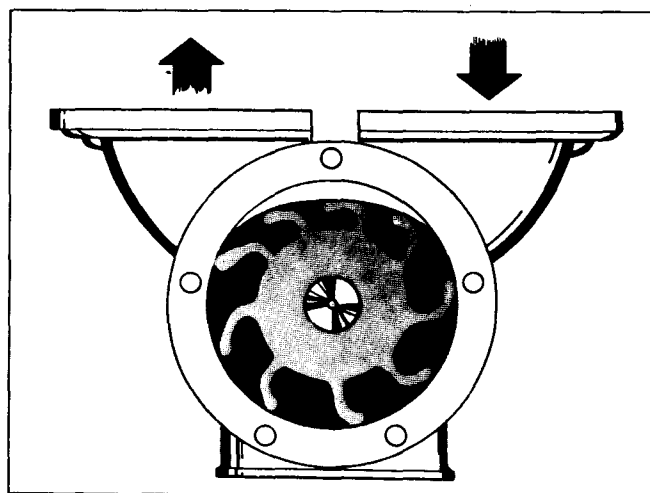


Fig. 8-29, (N20810). Impeller installed for right hand rotation

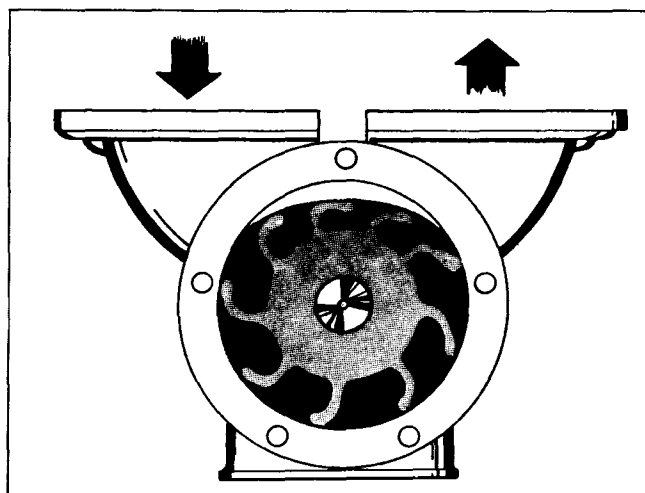


Fig. 8-30, (N20810). Impeller installed for left hand rotation

3. Press ball bearing (12) and shaft assembly into housing bore. Install snap ring.
4. Position seal gasket (21), seal seat (20), carbon seal (19), "O" ring (18) and ferrule (17), washer (16) and marcel washer (15) on shaft and into housing bore.
5. Press oil seal into impeller housing bore. The lip side of seal faces impeller.
6. Install cam (5) and wear plate assembly (6).
7. Heat drive gear in oven to 200°F [93°C].
8. Apply glycerine or soap to impeller fins and insert impeller (4). Insert rubber spline seal (3).
9. Install gasket (2) and end cover (1).

Table 8-1: Specifications – Inch [mm]

Ref. No.	Dimension Locations	New Minimum	New Maximum	Worn Limit
	Housing Bearing Bores	2.4408 [61.996]	2.4414 [62.012]	2.4494 [62.215]
	Housing Bore	1.5000 [38.100]	1.5200 [38.608]	
1.	Shaft Diameter Impeller End	0.6262 [15.905]	0.6267 [15.918]	
2.	Shaft Diameter Seat Location	0.6262 [15.905]	0.6267 [15.918]	
3.	Shaft Diameter Inner Bearing	0.9843 [25.001]	0.9847 [25.011]	
4.	Shaft Diameter Outer Bearing	0.9843 [25.001]	0.9847 [25.011]	
5.	Shaft Diameter Pulley End	0.6693 [17.000]	0.6696 [17.008]	
6.	Impeller Bore	0.624 [15.85]	0.625 [15.88]	
	Impeller Vane to Body Clearance			
	(Cast Iron)	0.020 [0.51]	0.040 [1.02]	
	(Phenolic)	0.030 [0.76]	0.050 [1.27]	
	Pulley Bore Diameter	0.6663 [16.924]	0.6673 [16.949]	
	Minimum Press-Fit Between			
	Shaft and Impeller	0.001 [0.03]		
	Shaft and Pulley	0.001 [0.03]		

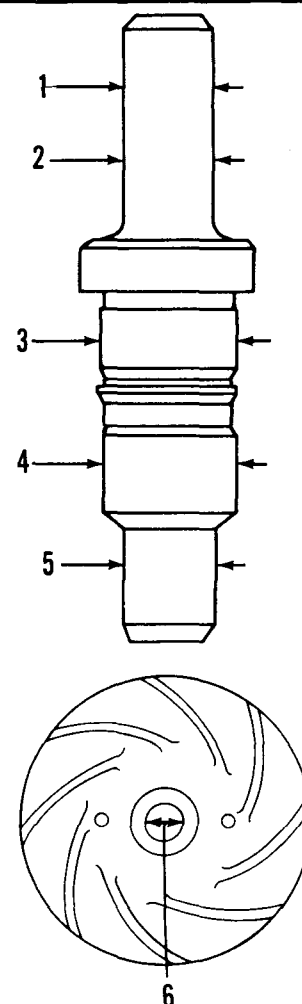
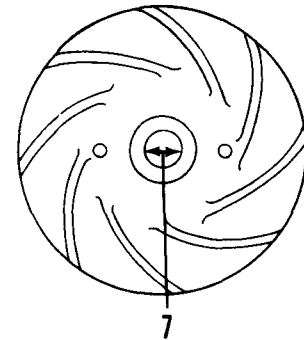
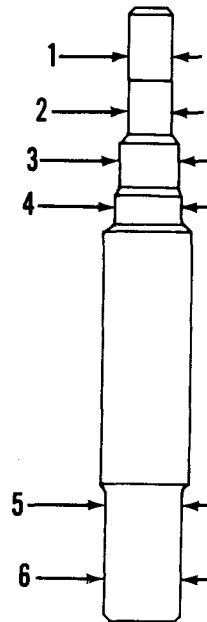


Table 8-2: Specifications – Inch [mm]

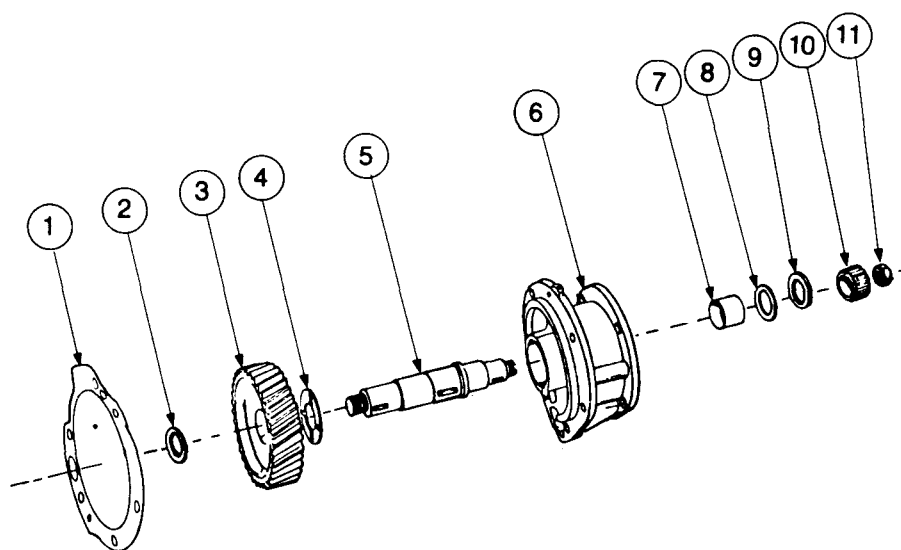
Ref. No.	Dimension Locations	New Minimum	New Maximum	Worn Limit
	Housing Bore	2.8345	2.8351	2.8431
	Outer Bearing	[71.996]	[72.012]	[72.215]
	Housing Bore	2.0471	2.0477	2.0557
	Inner Bearing	[51.996]	[52.012]	[52.215]
	Housing Bore	1.435	1.436	
	Carbon Face Seal	[36.45]	[36.47]	
	Housing Bore	2.9985	3.0015	
	Outer Seal	[76.162]	[76.238]	
	Housing Bore	1.374	1.376	
	Inner Seal	[34.90]	[34.95]	
1.	Shaft Diameter Impeller End	0.6262	0.6267	
2.	Shaft Diameter Seat Location	0.6262	0.6267	
3.	Shaft Diameter Inner Seal	0.872	0.878	
4.	Shaft Diameter Inner Bearing Surface	0.9842	0.9846	
5.	Shaft Diameter Outer Bearing Surface	1.1810	1.1814	
6.	Shaft Diameter Pulley End	1.1810	1.1814	
7.	Impeller Bore	0.624	0.625	
	Impeller Vane to Body Clearance	0.020	0.040	
		[0.51]	[1.02]	
	Pulley Bore	1.1787	1.1798	
		[29.939]	[29.967]	
	Wear Sleeve O.D.	2.2540	2.2560	
	Outer Seal Surface	[57.252]	[57.302]	
	Minimum Press-Fit Between			
	Shaft and Impeller	0.001		
		[0.03]		
	Shaft and Pulley	0.001		
		[0.03]		



Group 9

The drive unit is used to transmit power from the crankshaft, through the camshaft gear; to drive a compressor, fuel pump, water pump and other assemblies. Repair consists of replacing oil seals, bearings or bushings.

Drive Unit



- 1. Gasket
- 2. Oil Slinger
- 3. Drive Gear
- 4. Thrust Washer
- 5. Shaft
- 6. Housing

- 7. Bushing
- 8. Thrust Washer
- 9. Coupling

- 10. Locknut

Fig. 9-1, (N10910). Fuel pump drive — exploded view

Service Tools (Or Equivalent) Required

Service Tool Number	Tool Name
---------------------	-----------

ST-1249	Puller
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Standard Tools

Arbor Press
Grease Gun
Bearing Packer
Feeler Gauge Set
0-1, 1-2, 2-3 Micrometers
Telescoping Gauges

General

Bores in Housing

Bearings or bushings must not turn in housing retaining bore. If old bearing has turned and ruined housing, the housing must be scrapped. Bore of housing must be clean before pressing bearing in place.

Oil Seals

Effectiveness of the seal depends on surface where seal seats. Always check hub sleeve surface for wear and replace sleeve if necessary before install-

ing new seal. Immediately before installing seals, always lubricate with clean lubricating oil.

Thrust Washers

In installation of thrust washers on accessory drives, thrust side of washers is installed away from housing. Thrust side is identified by grooves. Steel backing against the cast iron housing will reduce the possibility of thrust washers' turning. Improper installation of these washers will result in excessive wear and increased end play, which causes early failure of accessory drive assembly.

Fuel Pump or Compressor Drive

Disassembly

1. Remove drive shaft locknut (10, Fig. 9-1) using ST-1249 Coupling Puller; pull coupling (9) from shaft (5).
2. Press shaft and gear assembly from housing (6), press shaft (5) from gear (3), and remove keys from shaft.

Note: A splined coupling is used on air compressor drive. A buffer type coupling is used on fuel pump drive.

Inspection

1. Check bushing in drive housing. Replace if worn beyond specifications as shown in Table 9-1.
2. Check shaft for wear distortion or galling a bushing mating surfaces. Outside diameter of shaft must not be worn more than 1.310 inch [33.27 mm].
3. Replace thrust washers if worn or damaged.
4. Clean all parts in an approved cleaning solvent and blow dry with compressed air.

Assembly

1. Install shaft (5) through housing (6) and bushing (7). Slip on larger thrust washer (4) with face up.
2. Install key and press drive gear on shaft.

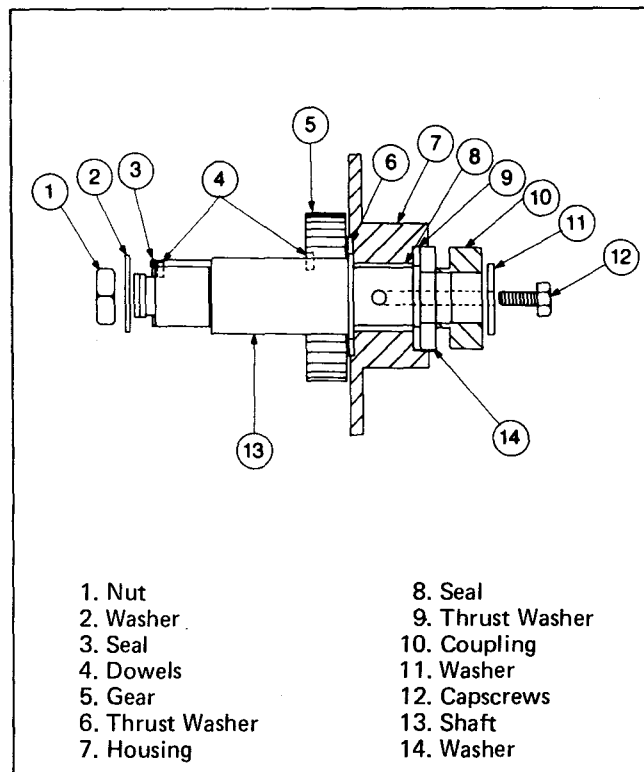


Fig. 9-2, (N10911). Dowel pin shaft accessory drive

3. Turn assembly over; slip on small thrust washer (8) (face up) and clamp washer. Install coupling key.
4. Press on coupling (9), hub end down. Secure with locknut (10) or washer and capscrew.
5. Install slinger (2) over gear end of shaft.

Note: Check end clearance with unit assembled. It should be as listed in Table 9-1 (33).

Dowel Pin Shaft

Can be used to replace 121940 and 199969 Accessory Drive Shafts.

Assembly

1. Remove excess oil from dowel hole. Install dowel (4, Fig. 9-2) in gear mounting diameter of shaft, rounded end in shaft (13).
2. Align gear (5) keyway with dowel (4), install gear on shaft, rear face of gear contacting shoulder on shaft.

3. Place front thrust washer (6) over rear of shaft, bearing face of washer contacting back of gear. Inside diameter of thrust washer over outside diameter of trunnion on shaft.
4. Check bushing and drive housing oil hole alignment.
5. Install shaft, gear and thrust washer assembly (13, 5 and 6) through drive housing (7) from front side. Steel backing of thrust washer (6) contacting drive housing at front of bushing bore.
6. Place rear thrust washer (9) on drive shaft, steel backing of thrust washer facing front of drive shaft.
7. Install thrust washer (14) on drive shaft, front of thrust washer contacting bearing face of rear thrust washer (9).
8. Install coupling (10), trunnion end to front of shaft, retain coupling with washer (11) and capscrew (12). Tighten capscrew 30 to 35 ft-lbs [41 to 47 N•m] torque.

Fuel Pump/Hydraulic Governor Drive

Disassembly

1. Remove governor drive assembly, snap ring (11, Fig. 9-3), ball key and collar (13).

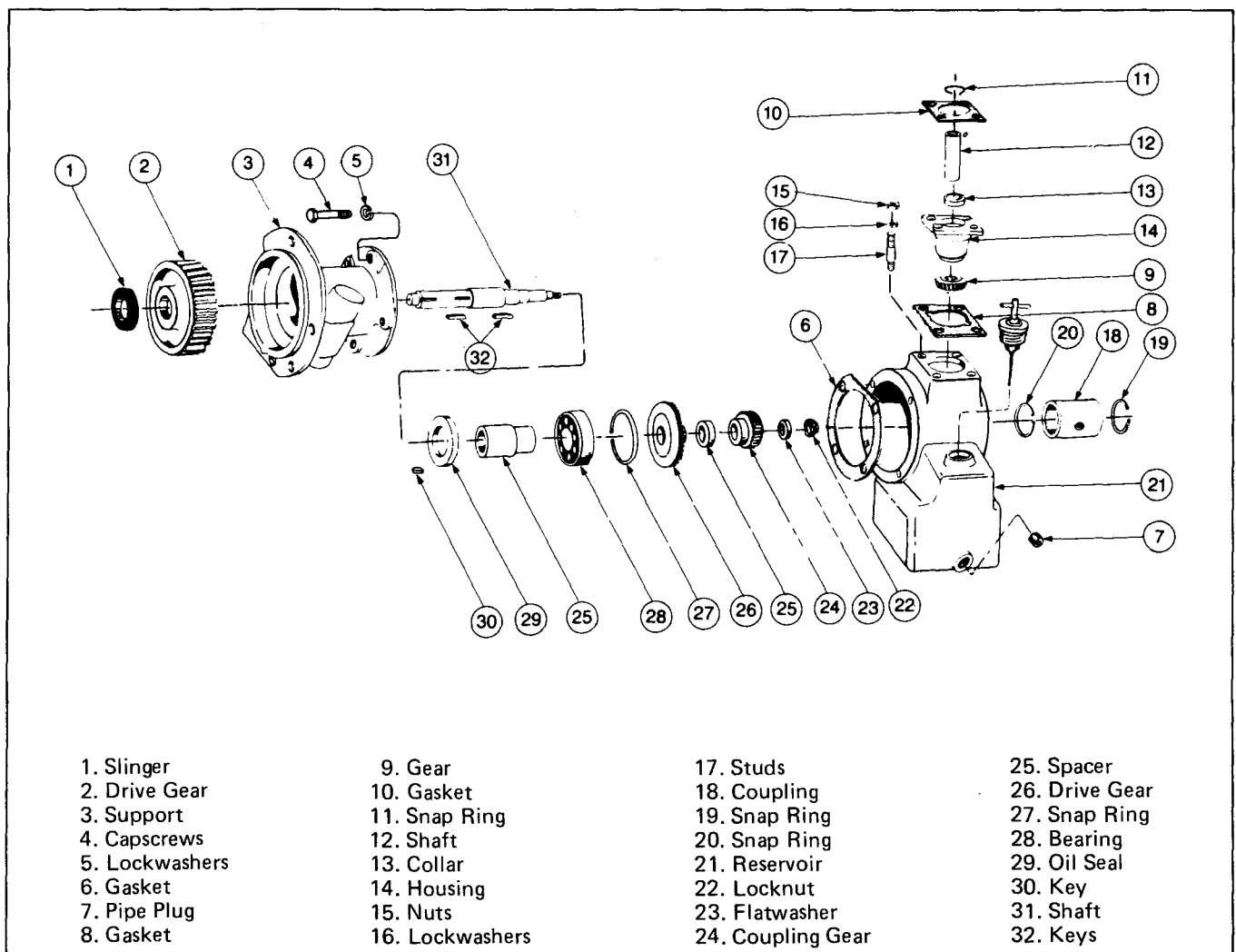


Fig. 9-3, (N10912). Fuel pump, hydraulic governor drive (Woodward Governor)

2. Press on shaft (12) opposite gear end to remove all units from housing (14), separate drive gear (2) and support assembly from reservoir (21); then remove drain plug, dipstick, vent plug and elbow.
3. Remove shaft locknut (22) and washer (23) from drive shaft (31) and use ST-1249 Puller to remove coupling (24). Lift out key (30). Remove spacer (25) and governor drive gear (26).
4. Press on small end of shaft to remove shaft from support (3) and large end of shaft to remove drive gear (2). Remove keys (32) from shaft keyway and snap ring (27) from support. Invert support and press out rear bearing (28) and oil seal (29).

Inspection

1. Check bearing for worn race or rough action, gears for chipped or broken teeth or uneven wear and governor shaft housing oil holes to make certain they are open.
2. Inspect support and reservoir for cracks, breaks or rough mating surfaces. Replace as necessary.

Assembly

1. Lubricate outside of oil seal (29) and press into support from large end. Open end of seal must be down. Lubricate rear bearing (28) and press into support. Insert snap ring (27), flat side down.
2. Lubricate shaft (31) and place key (32) in shaft. Press shaft into flat side of gear (2) until shoulder seats on gear face.
3. Press small end of shaft assembly into large end of support. Press governor drive gear (26) onto shaft until it bottoms on bearing.
4. Insert key (30) and press on coupling (24). Shoulder of coupling goes against gear unless a spacer (25) is used. Install flatwasher (23) and shaft locknut (22).
5. Position reservoir (21) in vise with governor drive studs (17) up. Install dipstick, vent plug, weatherhead fitting and drain plug.

6. On governors with 2:1 gear ratio:

- a. Install shaft (12) in housing (14) with splined end up. Drop collar (13) into housing.
- b. Lubricate ball key and insert in drive shaft; install snap ring (11). Line up ball key with collar (13). Invert assembly and press on gear (9). Allow end clearance of 0.003 to 0.006 inch [0.08 to 0.15 mm].

7. On governor with 3:1 gear ratio:

- a. Press governor two-piece drive shaft (12) into washer flush with bottom side. Note relief in washer to start shaft.
- b. Press shaft assembly into cylinder until shoulder on shaft is flush with end of cylinder. Slide this assembly into governor drive housing so flatwasher rests on bronze bushing.
- c. Invert assembly and install ball key, collared washer (13) and snap ring (11). Press on end of cylinder until flatwasher is against bronze bushing.
- d. Press gear into position allowing end clearance of 0.003 to 0.006 inch [0.08 to 0.15 mm].

8. Place gaskets (8) and install drive gear and housing assembly to serial number side of reservoir. Large oil hole in housing must be at top. Install slinger (1) over gear end of shaft.

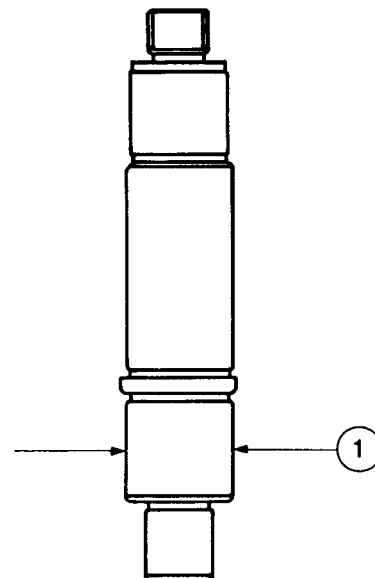
Drive Pulleys

Inspection

1. Check for cracks and chips in hub, web and groove areas.
2. Check for wear in grooves and oil seal sleeve.
3. On two-piece pulleys, check for stripped or distorted threads on sheave and in capscrew holes.
4. Clean in an approved cleaning solvent and dry with moisture free compressed air. Discard all

Table 9-1: Drive Unit Specifications – Inch [mm]

Ref. No.	Measurement	Worn Limit	New Minimum	New Maximum
1.	Shaft			
	Outside Diameter (Bushing Location)	1.310 [33.27]	1.3115 [33.312]	1.312 [33.32]
	Bushing			
	Inside Diameter	1.321 [33.55]	1.316 [33.43]	1.319 [33.50]
	Outside Diameter		1.449 [36.80]	1.450 [36.83]
	Out-of-Round	0.002 [0.05]		
	Press-Fit Between Housing and Bushing		0.002 [0.05]	0.0045 [0.11]
	Accessory Drive			
	End Clearance NH/NT		0.002 [0.05]	0.012 [0.26]
	End Clearance NTC		0.004 [0.10]	0.024 [0.61]
	Hydraulic Governor Drive			
	End Clearance		0.003 [0.08]	0.006 [0.15]



parts that do not meet inspection criteria.

Repair

If wear on sleeve is visible:

1. Remove worn oil sleeve by splitting with chisel. Do not damage pulley hub.
2. Press new sleeve onto pulley hub with mandrel, until it is flush to 0.015 inch [0.38 mm] below face of hub. Consult latest Parts Catalog for correct pulley/sleeve combination.

Group 10

The intake air system group consists of intake manifolds, connections, air cleaners, piping, cold-starting aids, and turbochargers. The turbochargers are covered in separate manuals.

Intake Air System

Intake Manifolds and Connections

Cleaning and Inspection

1. Clean intake manifold or air connection with steam.
2. Inspect for chips, cracks, distortions and damaged threads. Discard unusable parts.
3. Damaged threads may be repaired by installing Heli-Coils.

Cold-Starting Aids

Preheater

Due to the lower compression ratio of turbocharged engines, they may not start unaided below 50°F [10°C]. For this reason, the glow plug cold-starting aid is supplied as standard on these engines.

This aid uses engine fuel which is pressurized by a hand pump and atomized in a nozzle in the intake system. The atomized spray is ignited by the glowing coil of the glow plug and provides sufficient heat for combustion of fuel in the cylinders.

Fuel supply should be obtained from fuel tank.

Preheater Servicing

1. Remove preheater adapter (6, Fig. 10-1) and glow plug (1) from intake manifold.
2. Remove nozzle (2) and clamping washer (5) from adapter (6).

3. Clean adapter and nozzle with Bendix carburetor cleaner, or equivalent. Be sure nozzle screen (3, Fig. 10-1) and spray holes are open and clean. Check "O" ring (4) for damage.
4. Check glow plug on 6-volt or 12-volt source, as applicable.

Caution: 6 and 12-volt plugs are not interchangeable.

5. Assemble clamp washer (5, Fig. 10-1) and nozzle (2) to adapter (6).
6. Tighten nozzle to 15 to 20 ft-lbs [20 to 27 N•m] and bend washer over one of hexagonal sides of nozzle.
7. Install assembled adapter in intake manifold.

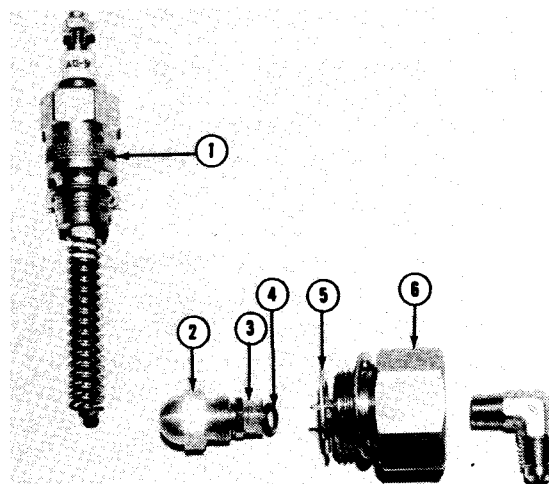


Fig. 10-1, (N21019). Glow plug preheater adapter spray nozzle

Ether-Starting Aids

A pressurized spray can or a rag wet with ether will usually provide quick starting as low as -10°F [-23°C]. Below this temperature, some means of injecting a carbureted ether vapor directly intake manifold is necessary.

Warning: Do not attempt to use ether compound type starting aids near heat, open flame or on engines equipped with glow plug system as explosion or fire may result.

Air Cleaners and Piping

Oil Bath Type Servicing

1. Disassemble cleaner.
2. Steam clean exterior of cleaner to remove any large dirt concentrations.
3. Wash parts with solvent and dry with compressed air as described in Section 0, Engine Disassembly and Cleaning.

Caution: Failure to remove solvent may cause engine to overspeed until all solvent is sucked from cleaner.

4. If air cleaner is to be stored, dip in lubricating oil to prevent rusting of screens. If screens cannot be thoroughly cleaned at this time or if body has been pierced or otherwise severely damaged, replace air cleaner.
5. Clean all hose, clamps and piping. Inspect for cracks or other damage.
6. Assemble cleaner.

Note: Fill oil cup to level indicated by bead on its side with clean oil before operating engine. Oil of the same grade as that in crankcase should be used in cleaner; in extremely cold weather a lighter grade may be necessary. Detergent or additive oils may be used as long as foaming is not encountered. NEVER USE CRANKCASE DRAININGS.

Dry Type Servicing

1. Disassemble cleaner. Clean element with compressed air.

2. Wipe out housing with clean cloth.
3. Inspect gasket, replace if not reusable.
4. Install new or cleaned element.
5. Assemble cleaner.

Heavy Duty Single and Dual Type Servicing

1. Wipe dirt from cover and upper portion of cleaner.
2. Disassemble cleaner and remove element.
3. Blow out element from clean air side using compressed air of not more than 30 psi [207 kPa].
4. Wash element with non-sudsing detergent and warm water. Dry with compressed air not exceeding 30 psi [207 kPa].
5. Inspect element for holes.
6. Install new or cleaned element.
7. Check air restriction indicator, if air restriction is excessive, disassemble air cleaner, remove wing nut and replace safety element.
8. Reassemble air cleaner.

Cartridge Type Air Cleaner Servicing

1. Disassemble cleaner. Remove dirty Pamic cartridge by inserting fingers in cartridge opening. Loosen all four corners, one at a time by pulling straight out.
2. Clean pre-cleaner or moisture eliminator (where applicable). Wipe out housing with clean cloth.
3. Inspect housing and all other parts. Replace if defective.
4. It is not recommended to clean and reuse cartridge.
5. Install a new cartridge; hold cartridge in same manner as when removing from housing. Insert

clean cartridge into housing; avoid hitting cartridge tubes against sealing flange on edges of air cleaner housing.

6. The cleaner requires no separate gaskets for seals; therefore, care must be taken when inserting cartridge to ensure a proper seat within air cleaner housing. Firmly press all edges and corners of cartridge with fingers to effect a positive air seal against sealing flange of housing. Under no circumstances should cartridge be pounded or pressed in center to effect a seal.
7. Assemble cleaner.

Cleaner Restriction Indicator

1. The restriction indicator signals when to change cartridges. The red flag (1, Fig. 10-2) in window gradually rises as cartridge loads with dirt. Do not change cartridge until flag reaches top and locks in position. When locked, flag will remain up after engine is shut down. After changing cartridge, reset indicator by pushing re-set button (2). Push button all the way in firmly; then release. If button sticks, repeat pushing slowly.
2. A second method is utilization of a vacuum gauge and warning light that performs the same function as described in Step 1. Components for vacuum gauge include electrical source (1, Fig. 10-3) air piping (2), vacuum switch (3) and red warning light (4).

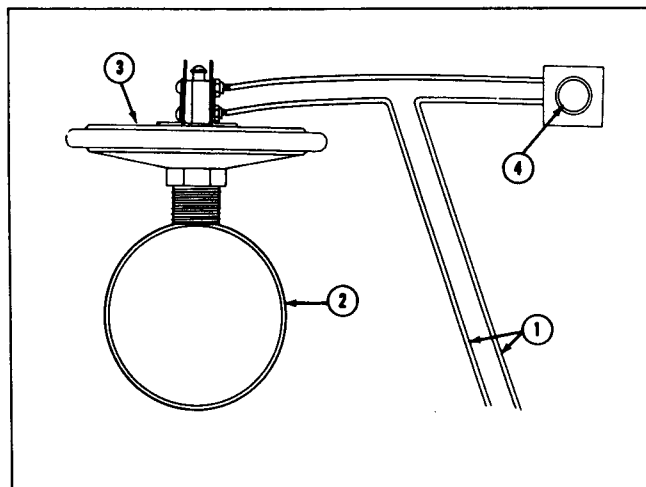


Fig. 10-3, (N21905). Air cleaner restriction vacuum switch diagram

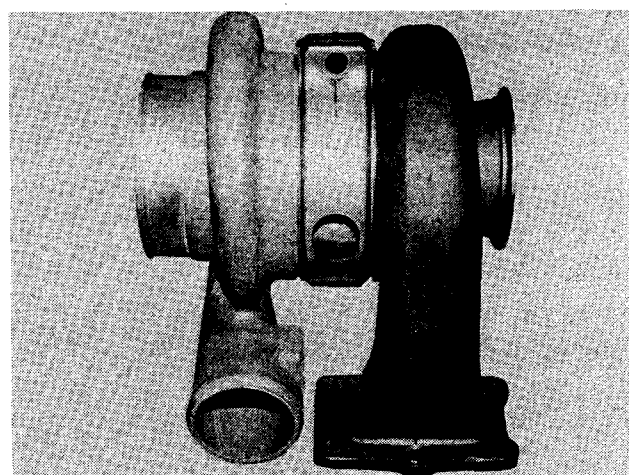


Fig. 10-4, (T-176). T-50 Turbocharger

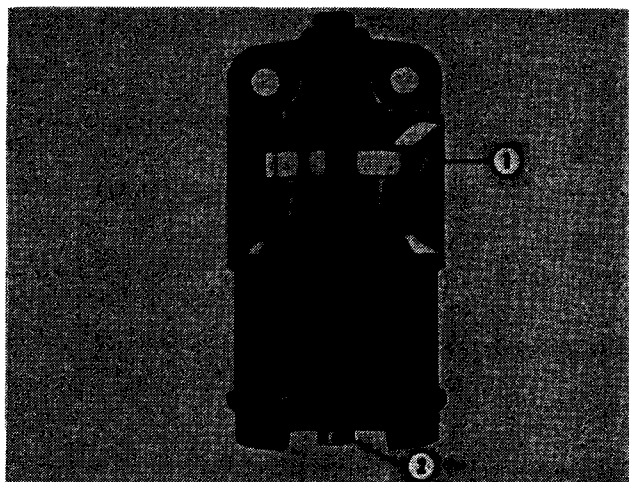


Fig. 10-2, (CGS-20). Air cleaner restriction indicator

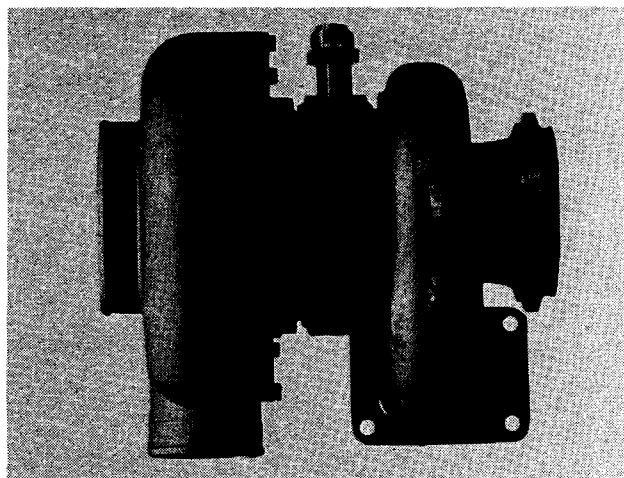


Fig. 10-5, (T-3100). VT-50 Turbocharger

Turbochargers

Three models of Cummins Turbochargers are used on NT Series Engines. The T-50 (Fig. 10-4), VT-50 (Fig. 10-5) and ST-50 Turbochargers, are all covered in Bulletin No. 3379091. Copies may be obtained from your distributor or ordered directly. See order form in back of book.

Group 11

The exhaust system group consists of engine exhaust manifolds, piping and mufflers or silencers.

Exhaust System

Exhaust Manifolds (Dry Type)

Inspection

Inspect exhaust manifold for cracks and distortions; discard defective parts.

When ordering replacement parts, order same part as presently used.

Exhaust Manifolds (Wet Type)

Inspection

1. The exhaust manifold is a combination water header and water-cooled exhaust manifold. Clean as outlined in Group 0, Disassembly and Cleaning. Water test at 30 to 80 psi [207 to 552 kPa].
2. Remove inspection plate from exhaust manifold and inspect for cracks and distortions. Replace manifold if necessary.
3. Install inspection plate and gasket to exhaust manifold. Do not run engine without coolant in water-cooled exhaust manifold.

Caution: Do not run engine without coolant in water-cooled exhaust manifold.

Mufflers and Piping

System Restrictions (Back Pressure)

1. When engine pistons must act against a back

pressure in exhaust system to expel exhaust gas, usable output of engine is lowered; since air-fuel ratio will be reduced because of incomplete scavenging of cylinder, fuel economy is reduced and exhaust temperatures will increase. Although turbocharged engines are effected to a lesser degree than naturally aspirated engines due to positive pressure in intake manifold, it is essential exhaust system for all engines be designed to offer least possible restriction to exhaust flow.

2. High pressure indicates restrictions caused by foreign objects, excessive bends or small sizes of piping. The lowest pressure obtainable is desired.
3. If exhaust back pressure exceeds those values listed in Step 9, early engine failure and poor performance may be expected.
4. The point of measurement must be as close as possible to the manifold or turbocharger outlet flange (1, Fig. 11-1) in an area of uniform flow such as a straight section of pipe at least one pipe diameter from any changes in flow area or flow direction.
5. Where it is impossible to locate the point of measurement in a straight section, it is permissible to measure on the side of a bend where flow is uniform and equivalent to flow along the centerline. Do not measure on inside or outside of bend as flow is not uniform at these points.
6. At the point selected, weld a 1/8 inch [3.18 mm] pipe coupling to the exhaust tubing. Drill through tubing with a 1/8 inch [3.18 mm] drill.

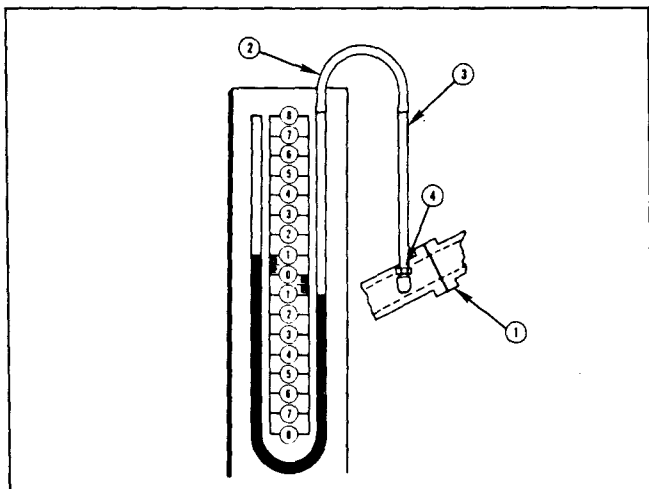


Fig. 11-1, (V11101). Measuring back pressure

Remove all burrs. Mount 90 degree Weather-head fitting (4) to coupling. Then use 3 ft [0.9 m] of 1/8 inch [3.18 mm] inside diameter copper tubing (3) plus 10 ft [3 m] of 3/16 inch [4.76 mm] inside diameter soft rubber hose (2) to manometer. (See note.) The manometer may be mercury filled or water filled.

Note: It is important that line to manometer be as specified to minimize variation in reading due to a standing wave phenomenon which occurs in manometer line. A change in length or material of this line can significantly change reading obtained.

7. Start engine and operate until oil temperature reaches 140°F [60°C].
8. Take back-pressure readings when engine is developing its maximum horsepower at maximum engine speed.
9. Add reading of mercury in both columns for final figure. Fig. 11-1.

Example: If mercury is 1 inch [25.4 mm] high in left column and 1 inch [25.4 mm] low in right column, there is 2 inches [50.8 mm] of pressure. If the mercury is 1 inch [25.4 mm] high in right column and 1 inch [25.4 mm] low in the left column, there is 2 inches [50.8 mm] of vacuum. Maximum permissible back pressure is 3 inches [76.2 mm] Hg or 40.7 inch [1 m] of water.

Group 12

The air equipment group consists of Cummins air compressors, check valve, vacuum pump and piping; it also includes the air-actuated cranking motors, which are sometimes used on Cummins engines.

Air Equipment

Air Compressor

Cummins air compressors are used on all models of Cummins Engines and are covered from a servicing standpoint in Bulletin No. 3379056.

Optional units, such as Bendix-Westinghouse, Wagner and others are covered by publications available from the manufacturer or authorized service station.

Vacuum Pump

Cummins vacuum pump is an adaptation of the compact Cummins air compressor and is covered in Bulletin No. 3379056.

Air Cranking Motor

Air cranking motor servicing is covered by the manufacturer or authorized service station.

Group 13

The principle function of the Electrical System on Cummins Diesel Engines is that of cranking or starting and operating electrical accessories as required by the unit being powered.

Electrical Equipment

Wiring Diagram

A complete collection of wiring diagrams, as applied to all Cummins Engines, is contained in Bulletin No. 3379099. The diagrams are all in the single manual because the same diagram may apply to more than one engine model or series. This bulletin may be obtained from a local Cummins Distributor.

Electrical Components

Complete instructions for testing, repairing and adjusting alternators, generators, voltage regulators, cranking motors, batteries, electric cables and connections are available from the local electrical equipment service distributor.

If this service is not available, further specific information can be obtained as follows:

Delco-Remy Equipment

Electrical Equipment Operation and Maintenance Handbook DR-324-1 or -2, -3, -4 and Test Specifications DR-324-S-1 may be purchased from the nearest United Motor Service Station, or the Service Department, Delco-Remy Division, General Motors Corp., Anderson, Indiana.

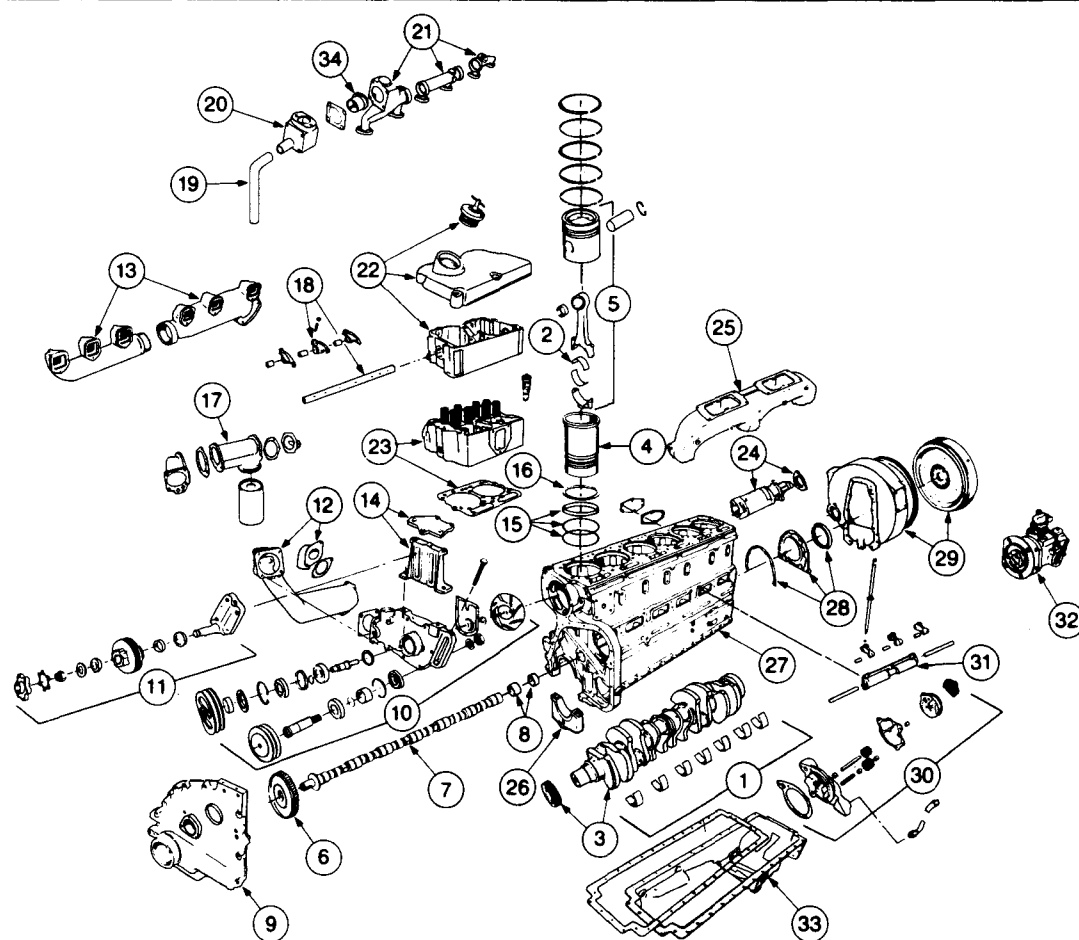
Leece-Neville Equipment

Operation and adjustment information may be obtained from the nearest Leece-Neville distributor or the Service Department of the Leece-Neville Co., 5109 Hamilton Avenue, Cleveland 14, Ohio.

Group 14

The engine assembly section covers assembly of all units and subassemblies to the cylinder block as well as adjustments and engine testing.

Engine Assembly and Testing

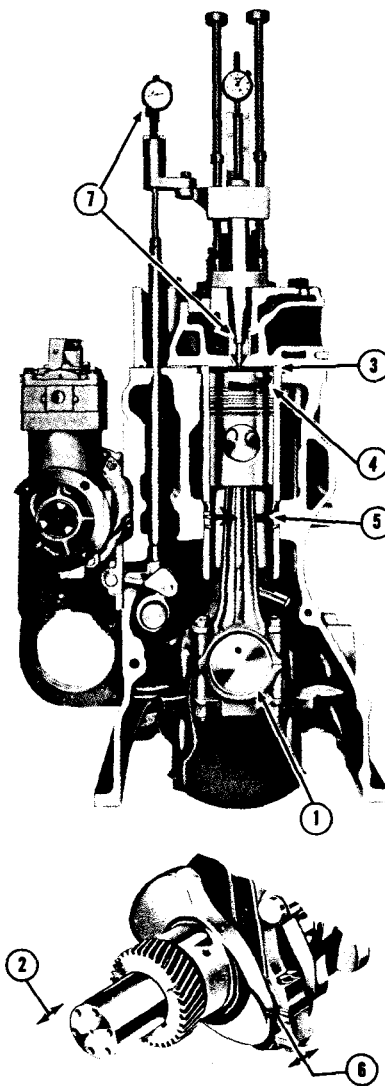


- | | | | |
|----------------------------|-----------------------------|----------------------------|-----------------------------|
| 1. Main Bearings | 10. Water Pump/Idler Assy. | 19. Water By-Pass Tube | 28. Rear Cover Assembly |
| 2. Connecting Rod Bearings | 11. Fan Hub Assembly | 20. Thermostat Housing | 29. Flywheel and Housing |
| 3. Crankshaft and Gear | 12. Water Inlet Connections | 21. Water Manifold Assy. | 30. Lubricating Oil Pump |
| 4. Cylinder Liner | 13. Exhaust Manifolds | 22. Rkr Lvr Hsg. Cover/Cap | 31. Cam Follower/Push Tubes |
| 5. Conn. Rod/Piston Assy. | 14. Fan Hub Mtg. Brkt/Supp. | 23. Cyl. Head and Gasket | 32. Acc. Drive/Fuel Pump |
| 6. Camshaft Gear | 15. Cyl. Liner Pack Rings | 24. Cranking Motor/Spacer | 33. Oil Pan and Gasket |
| 7. Camshaft | 16. Cylinder Liner Shim | 25. Intake Manifold | 34. Thermostat |
| 8. Camshaft Bushings | 17. Lub Oil Cooler/Filter | 26. Main Bearing Cap | |
| 9. Gear Cover | 18. Rocker Levers/Shaft | 27. Cylinder Block | |

Fig. 14-1, (N114235). Engine — exploded view

Table 14-1: Assembly Specifications – Inch [mm] (Reference Fig. 14-1)

Ref. No.	Measurement	Worn Limit	New Minimum	New Maximum
1.	Main Bearing Journal Clearance	0.007 [0.18]	0.0015 [0.38]	0.005 [0.13]
2.	Connecting Rod Bearing Journal Clearance	0.007 [0.18]	0.0015 [0.038]	0.0045 [0.114]
3.	Crankshaft End Clearance	0.022 [0.56]	0.007 [0.18]	0.017 [0.43]
4.	Cylinder Liner Protrusion		0.003 [0.08]	0.006 [0.15]
	Out-of-Round			0.003
	Top One (1) Inch			[0.08]
	Out-of-Round			0.002
	Packing Ring (Lower) area			[0.05]
5.	Connecting Rod Side Clearance		0.0045 [0.114]	0.013 [0.33]
6.	Gear Train (Gear to Gear) Crankshaft, Camshaft, Accessory Drive and Lubricating Oil Pump Backlash	0.020 [0.51]	0.0045 [0.114]	0.0105 [0.267]
7.	Camshaft (With Thrust Plate) End Clearance		0.001 [0.03]	0.005 [0.13]
	(With Outboard Bearing Support) End Clearance		0.008 [0.20]	0.013 [0.33]
8.	Injection Timing Refer to Table 14-4			
9.	Injector, Crosshead and Valve Adjustments Refer to Injector and Valve Adjustment			
10.	Dynamometer Testing Refer to Test Procedure, Table 14-14			
11.	Lubricating Oil Pressure Refer to Table 14-15			
12.	Blow-By Refer to Test Procedure, Table 14-14			
13.	Back Pressure Refer to In-Chassis Run-In			



Crankshaft Flange Capscrew Torque Specifications – ft-lb [N•m]

	Engine Model	Part No.	Minimum	Maximum
14.	NT Series	196653 Capscrew 196654 Retainer	250 [339]	270 [366]
15.	NH Series	140410 Capscrew 140411 Retainer	180 [244]	200 [271]

Service Tools (Or Equivalent) Required

Service Tool Number	Tool Name
ST-1325	Dial Gauge Attachment
ST-435	Pressure Gauge
3375150	Blow-By Checking Tool
ST-547	Gauge Block
ST-593	Timing Fixture
ST-835	“O” Ring Loader
ST-997	Seal and Sleeve Driver
ST-1172	Seal Mandrel
ST-1173	Seal Mandrel
3375162	Piston Ring Compressor Sleeve
ST-1270	Injector Indicator Setting Tool
ST-1182	Valve Spring Spray Nozzle Locator (80 degree Tilt Engine)
ST-1229	Liner Driver
ST-1259	Seal Mandrel (Teflon Seal)
3375151	Seal Pilot (Teflon Seal) (Front)
ST-1263	Seal Pilot (Teflon Seal) (Rear)
3375601	Connecting Rod Guide Pins

Desirable (Or Equivalent) Service Tools

ST-163	Engine Support Stand
ST-386	Pulley Assembly Tool
ST-1232	Drill Reamer Fixture
ST-1317, -A	Engine Rebuild Stand
ST-669	Torque Wrench Adapter
ST-763	Piston Ring Expander
ST-1258	Engine Lifting Fixture
3375013	Block Mounting Plate
ST-1138	Belt Gauge
ST-1184	Cylinder Liner Hold-Down Tool
ST-1190	Fuel Consumption Measuring Device
ST-1294	Smoke Meter
ST-1273	Pressure Gauge (in. hg.)
3375049	Oil Filter Wrench (Spin-On)
3375065	Loctite Pipe Sealant
3375159	Air Compressor Wrench
3375096	Inj./Valve Adjust Kit/with Jacobs Brake
ST-1135	Mini-Filter

Standard Tools – Obtain Locally

0-150 Inch-pound Torque Wrench
0-250 Foot-pound Torque Wrench
0-600 Foot-pound Torque Wrench
Dial Indicator (Starret No. 196A)
Dial Indicator Sleeve (Starret No. 196-L)
Manometer (Mercury or Water)
0-1 Micrometer
Impact Wrench
Engine and/or Chassis Dynamometer
Hoist (Power or Chain)
Straight Edge
Feeler Gauge

Engine Assembly

Mount Cylinder Block to Engine Stand

1. Secure 3375013 Block Mounting Plate to ST-1317 or ST-1317-A Engine Rebuild Stand. Secure water header cover plate adapter and adapter plate to cylinder block.
2. Lift cylinder block and secure to block mounting plate with lockwashers and capscrews.

Install Pipe Plugs

1. Wrap pipe plugs with Teflon tape or equivalent.
2. Install pipe plugs in cylinder block. Tighten to 60 to 70 ft-lbs [81 to 95 N•m]. Fig. 14-2.

Cylinder Liners

1. Before installing cylinder liners, check protrusion. If necessary, install shims around liner to maintain 0.003 to 0.006 inch [0.08 to 0.15 mm] protrusion.
2. Just prior to installation, lubricate packing rings

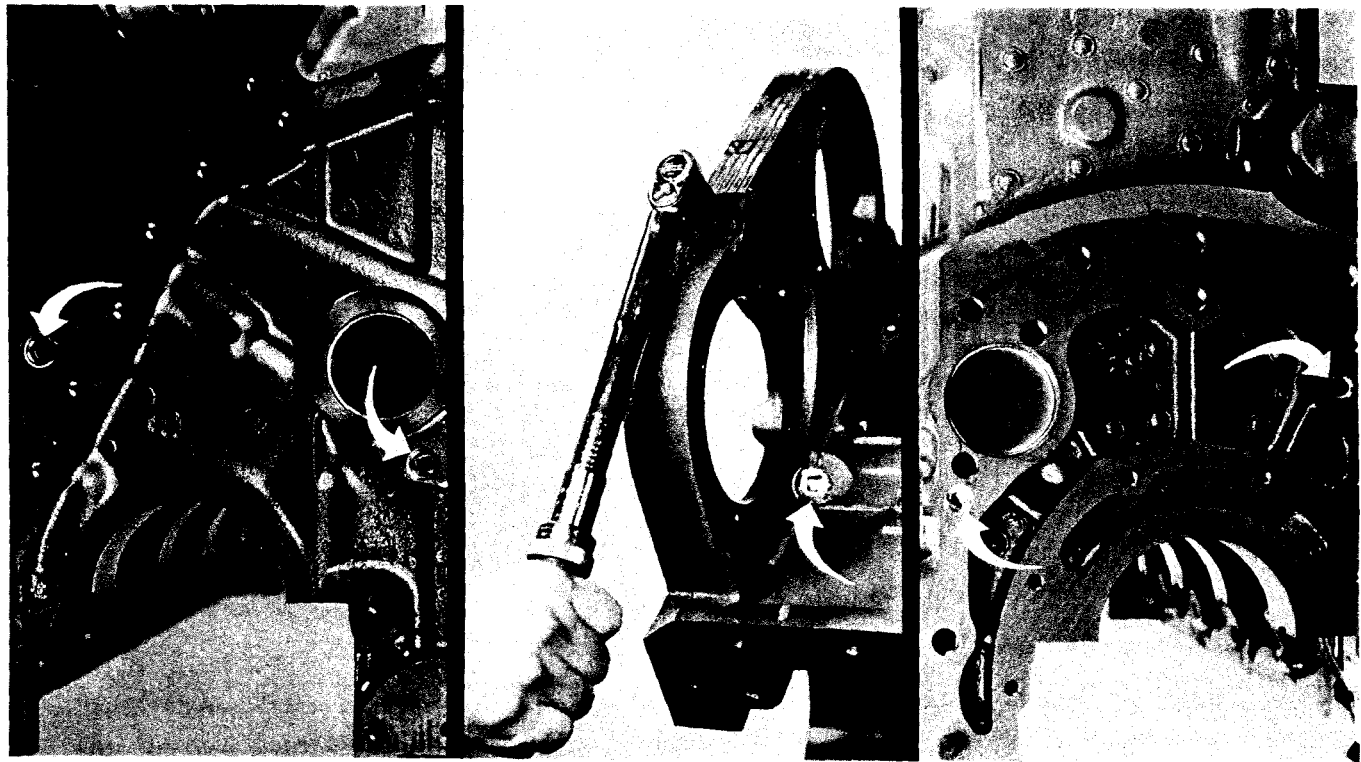


Fig. 14-2, (N114239). Installing pipe plugs

with a light coat of clean lubricating oil. Roll into position and install crevice seal. Using mold mark on ring as guide, straighten as required. Crevice seal (flat) goes in top groove. Black packing ring with yellow stripe goes in center groove and red ring with two blue stripes goes in bottom groove.

Caution: To prevent swelling of "O" rings, lubricate lightly with clean engine lubricating oil just prior to installation. Make sure proper part numbers are used.

3. Make sure liner bore is clean. Lubricate machined portions of block on which rings seat with a light coat of clean engine lubricating oil.
4. Place liner in block by hand, being careful to avoid dislodging "O" rings and crevice seal. Press liner into position. Use ST-1229 Liner Driver to drive liner securely into the block so it fits squarely into block bore. Fig. 14-3.
5. Install ST-1184 Cylinder Liner Hold-Down Tool so foot of tool rests upon wide inner flange on top of liners. Secure tool, space capscrews so

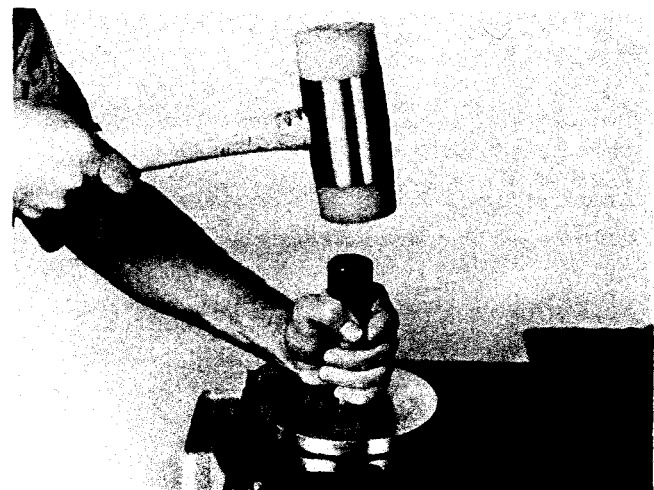


Fig. 14-3, (N114240). Installing cylinder liner

even load will be applied. Tighten capscrews to 50 ft-lbs [68 N•m] torque.

6. Use ST-547 Gauge Block to determine if protrusion meets specifications. Fig. 14-4.
7. Check liner bore with precision dial bore gauge, for roundness at several points within range of

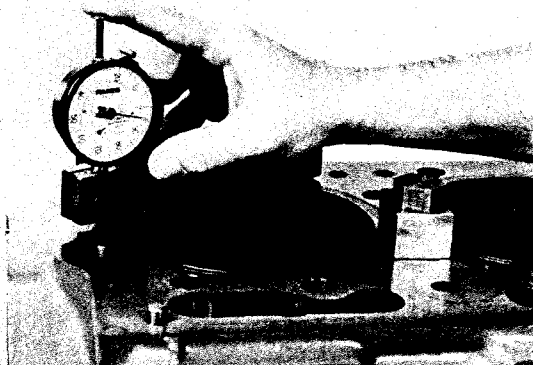


Fig. 14-4, (N114241). Checking cylinder liner protrusion

piston travel. If liner is more than 0.002 inch [0.05 mm] out-of-round in packing ring area, remove liner and check for cause of distortion. It is permissible to have 0.003 inch [0.08 mm] out-of-round at the top 1 inch [25.4 mm] of liner bore.

Crankshaft and Main Bearings

1. Turn cylinder block upside-down.
2. Using a clean rag, wipe main bearing bores and main bearing shells clean. Lay upper main bearing shells in block. All upper main bearing shells are grooved and drilled for lubrication. No's. 1, 3 and 5 are alike and No's. 2, 4 and 6 are alike. No. 7 shell has oil groove off-center. The wide portion of the shell is installed toward flywheel end of block.

Note: Groove on each shell for dowel ring must match with counterbore at capscrow hole on exhaust manifold side of block.

3. Coat upper main bearing shells thoroughly with clean lubricating oil. Install main bearing shells in cylinder block. Fig. 14-5.
4. Install main bearing ring dowels.
5. Lift crankshaft into position, using hooks protected with rubber hose or a rope sling at two crank throws. Check rear counterweight of crankshaft to see if oversize thrust rings are to be used and where installed, front or rear. Roll

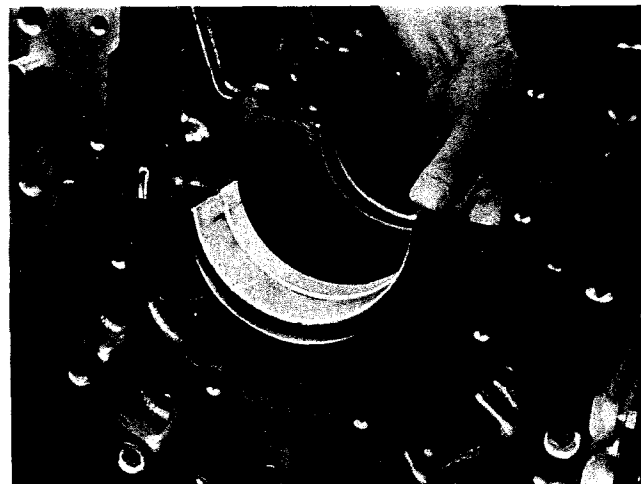


Fig. 14-5, (N114242). Installing upper main bearing shells

upper thrust rings into position, babbitt or grooved sides next to crankshaft flanges. Fig. 14-6. Upper thrust rings are not doweled to block; lower halves are doweled to cap.

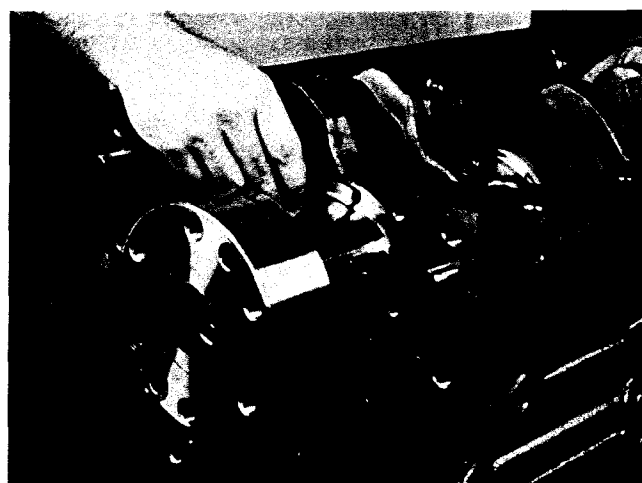


Fig. 14-6, (N114243). Installing thrust ring

6. Coat lower main bearing shells and crankshaft surface with clean lubricating oil. Align bearing shell with ring dowel and snap in opposite side. Fig. 14-7.
7. Lubricate main bearing capscrow threads with clean engine lubricating oil. Coat under head of capscrow and lockplates with SAE 140W gear lubricant.
8. Inspect threads in cylinder block for foreign

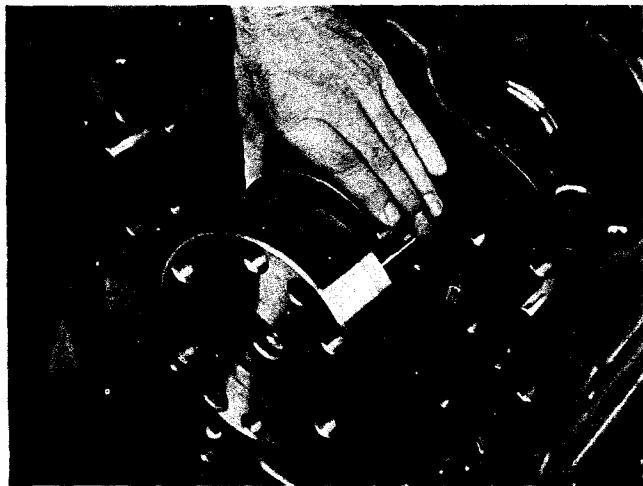


Fig. 14-7, (N114244). Installing lower main bearing shells

material and excess oil. Excess oil should be removed to avoid a hydraulic lock failure.

9. Install main bearing caps with numbers corresponding to those stamped on block on camshaft side of engine.
10. Install lower thrust rings; rings must be located over dowels in No. 7 main bearing cap.
11. Install lockplates and start each capscrew. Tighten alternately and slowly to set caps into position. Tighten main bearing capscrews as follows:
 - a. Tighten main bearing capscrews to 145 to 155 ft-lbs [197 to 210 N•m].
 - b. Continue to tighten capscrews to 300 to 310 ft-lbs [407 to 420 N•m] to "set" shells, caps and lockplates.
 - c. Loosen a minimum of 3 turns; retighten to 140 to 145 ft-lbs [190 to 197 N•m].
 - d. Tighten both capscrews on each cap alternately and evenly to 300 to 310 ft-lbs [407 to 420 N•m] torque.
12. Attach dial indicator gauge securely to rear of cylinder block with contact point of gauge resting on crankshaft flange end face. With a pry bar, pry crankshaft toward front of engine. Remove pry bar and set gauge at "0". Fig. 14-8.

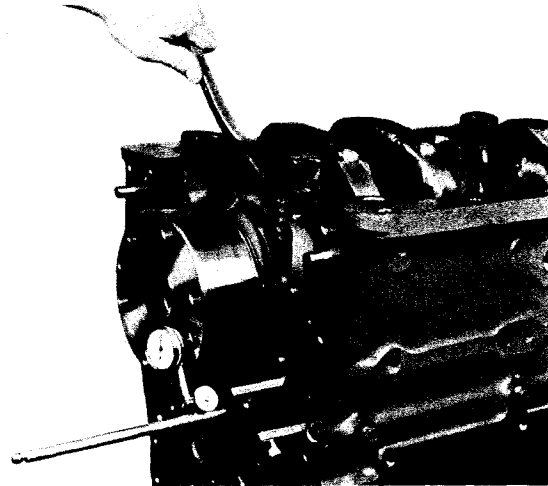


Fig. 14-8, (N114245). Checking crankshaft end play

13. Pry crankshaft toward rear of engine. Total gauge reading should be 0.007 to 0.017 inch [0.18 to 0.43 mm], with a new crankshaft and thrust rings.
14. If reading is less than 0.007 inch [0.18 mm]:
 - a. Loosen bearing cap capscrews slightly.
 - b. Shift crankshaft first toward front and then toward rear of engine.
 - c. Retighten capscrews as described in Step 11.
 - d. Recheck tolerance.
15. If reading is more than 0.022 inch [0.56 mm], crankshaft must be reworked or oversize thrust rings used.
16. Lock tangs of capscrew lockplates. Fig. 14-9.

Connecting Rods and Pistons

1. Install rings on piston with word "TOP" toward top, using ST-763 Piston Ring Expander. Fig. 14-9. Start installation with oil control ring.
2. Over-expanding a piston ring during installation on the piston can cause distortion resulting in damage leading to failure. The ring should only be expanded enough to allow it to pass over the piston.

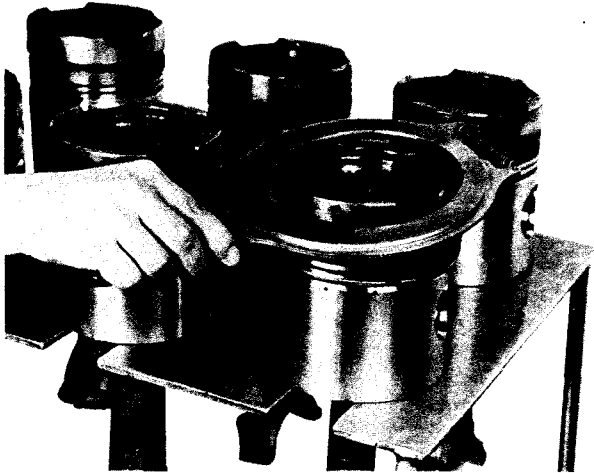


Fig. 14-9, (N114246). Installing piston rings



Fig. 14-10, (N114247). Compressing piston rings

3. A simple formula can be applied to insure that a ring is not over-expanded. The measured gap should not be expanded more than eight (8) times the nominal radial wall thickness of the ring. Stagger ring gaps so they are not in line with each other or piston pin. Press oil ring into groove at the expansion gap. If ring face is not flush with ring land, expander is out of position. Lubricate piston, rings, and liner with clean engine lubricating oil.
4. Slide connecting rod cap from bolts or dowels. Make certain bolt heads are seated squarely on rod shoulder. Keep rod cap with mating connecting rod.
5. Turn engine to vertical position on engine stand and rotate crankshaft so two crank throws are at bottom center position. Coat cylinder liners with clean lubricating oil.
6. Dip piston rod and ring assembly in clean lubricating oil. Compress rings using 3375162 Ring Compressor. Fig. 14-10.
7. Coat connecting rod bearing with clean lubricating oil. Locate tang on bearing to groove in connecting rod and snap into place. Fig. 14-11.
8. Install bearing shell into mating connecting rod cap in the same manner as installing in the connecting rod.
9. Install 3375601 Nylon Guide Screws into con-

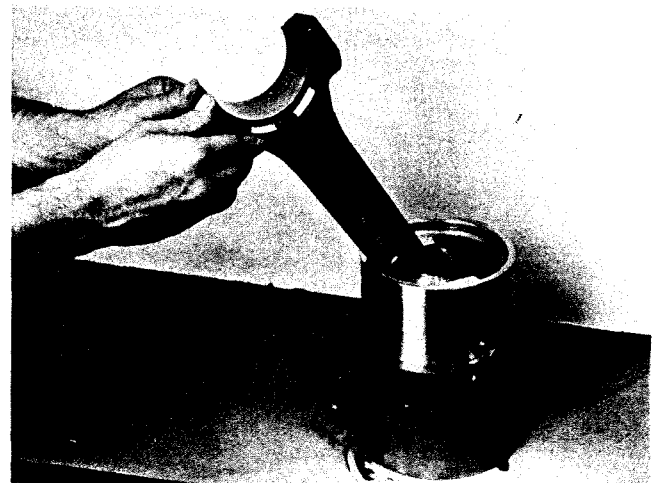


Fig. 14-11, (N114248). Installing connecting rod bearing

necting rod. Fig. 14-12. Insert piston and rod assembly, with tang to camshaft side of engine, into cylinder liner. Push piston and rod assembly through compressor until rings are in cylinder liner. Fig. 14-13. Remove compressor and continue to push piston until rod and bearing seats on crankshaft journal. Fig. 14-14.

Note: As piston and rod is pushed the rod must be guided onto the crank journal to prevent damage to the journal.

Caution: Do not force piston assembly into liner. If piston does not install "freely" in liner, remove and check for broken rings.

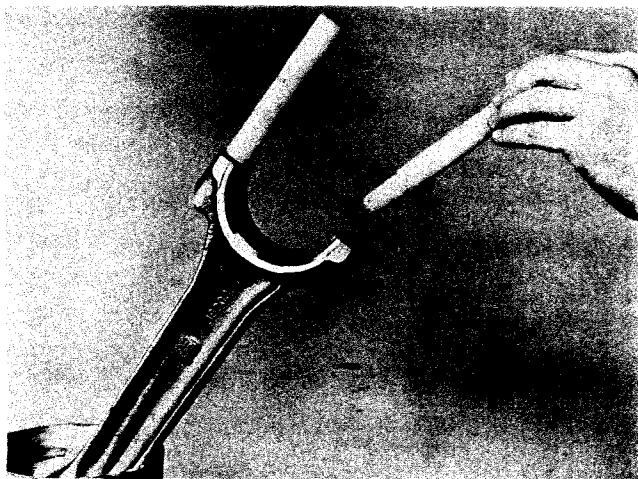


Fig. 14-12, (N114249). Installing nylon guide screws

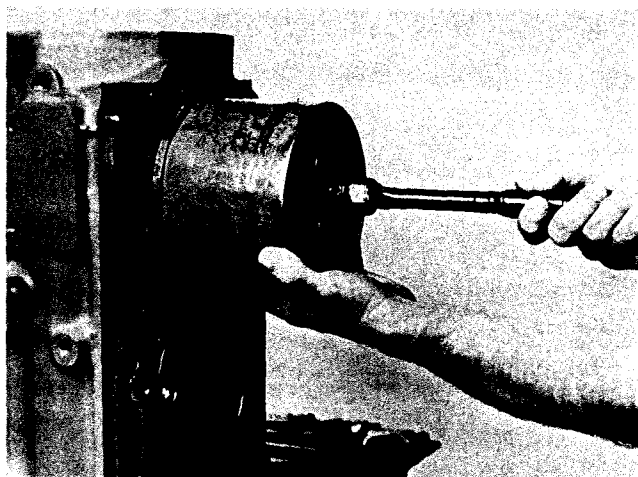


Fig. 14-13, (N114250). Installing piston and connecting rod assembly

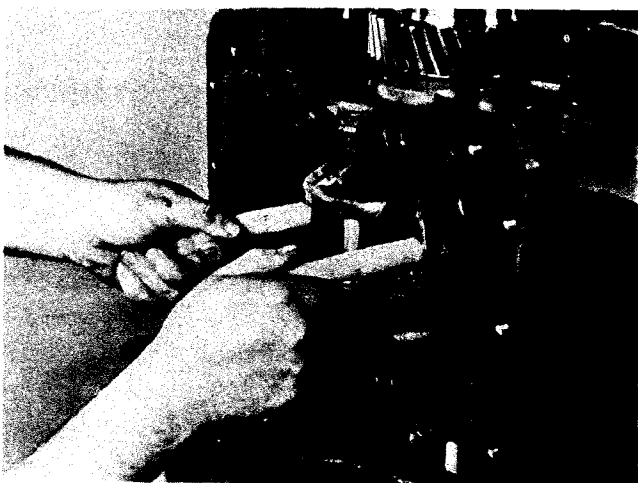


Fig. 14-14, (N114251). Seating connecting rod

10. Remove nylon guides and install rod cap with tang side of cap matching tang side of rod. Fig. 14-15.

Note: Lubricate bolt or capscrew threads with SAE 30W. Lubricate hardened washers (if used) with SAE 140W gear lubricant.

11. Snug capscrews or bolts alternately and evenly to pull cap to rod. Use torque wrench to tighten as in Table 14-2.
12. Tightened rod should be free to move sideways on crank journal with hand pressure. Side clearance is 0.0045 to 0.013 inch [0.114 to 0.33 mm]. If rod is not free, remove cap and check for improper bearing size, dirt, burns, etc.

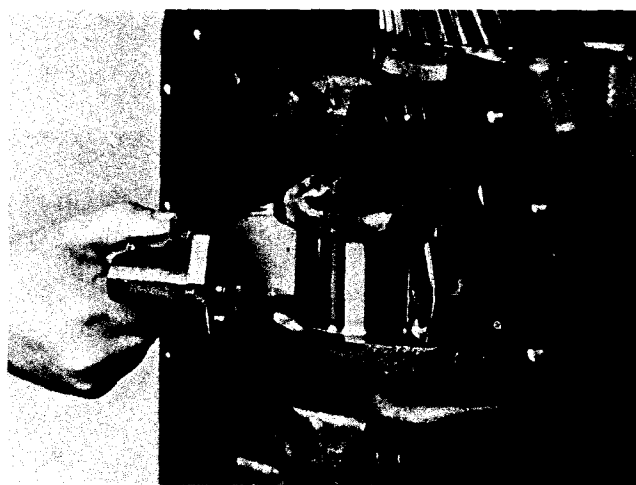


Fig. 14-15, (N114252). Installing connecting rod cap

Table 14-2: Tightening Connecting Rod Nuts

Tightening Sequence With Hardened Washer	Tightening Values Ft-Lb [N•m]
Step 1 Tighten to	70 to 75 [95 to 102]
Step 2 Tighten to	140 to 150 [190 to 203]
Step 3 Loosen all	Completely
Step 4 Tighten to	25 to 30 [34 to 41]
Step 5 Advance to	70 to 75 [95 to 102]
Step 6 Advance to	140 to 150 [190 to 203]

Camshaft and Gear

1. On 2-1/2 inch cam engines, install cup plug seal in cam bore at rear face. Install using 3375153 Cup Plug Driver.
2. Coat both sides of thrust rings with high pressure lubricant and install over end of camshaft with oil grooves toward camshaft gear. Fig. 14-16.

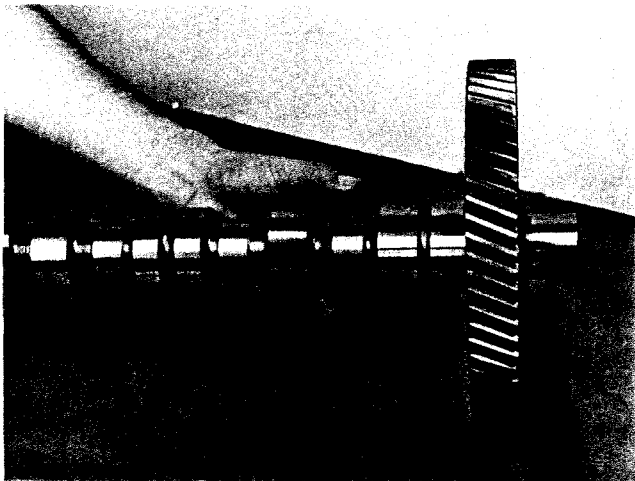


Fig. 14-16, (N114253). Installing camshaft thrust ring

3. Lubricate cam lobes with high pressure lubricant. Install camshaft, rotating slowly. Do not damage lobes or bushings. Use 3375268 Sleeve with 2-1/2 inch cam. Fig. 14-17.
4. Index timing mark on camshaft gear with mark on crankshaft gear. Fig. 14-18.
5. Attach dial indicator gauge to block (Fig. 14-19), check the camshaft to crankshaft gear backlash. Rotate gear as far as it will move; zero the gauge. Rotate gear in opposite direction and read dial.
6. Normal backlash is 0.0045 to 0.0105 inch [0.114 to 0.267 mm] on a new gear, with a minimum of 0.002 inch [0.05 mm].
7. Gears will rattle if backlash exceeds 0.010 inch [0.25 mm]. If noise is not objectionable, do not replace gears unless backlash exceeds 0.020 inch [0.51 mm].

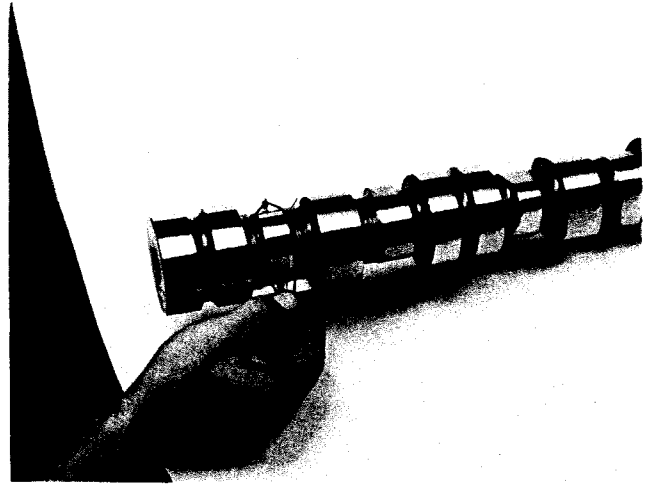


Fig. 14-17, (N114254). Installing camshaft pilot sleeve

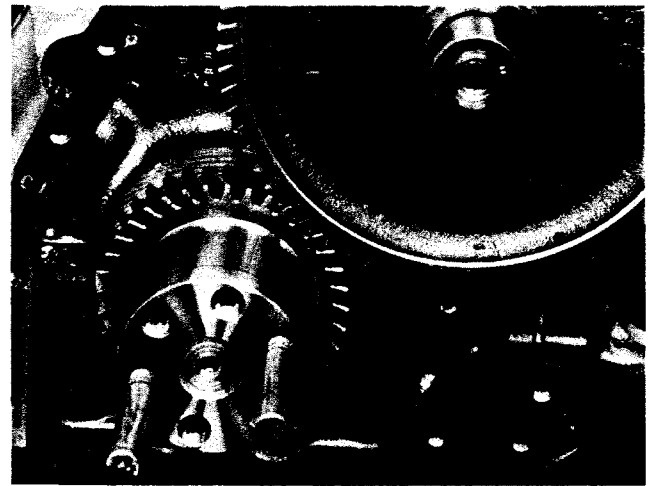


Fig. 14-18, (N114255). Timing marks on camshaft and crankshaft

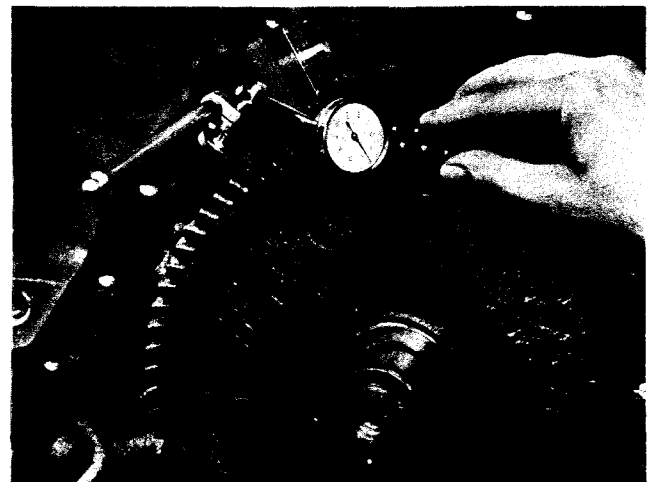


Fig. 14-19, (N114256). Checking gear backlash

Cylinder Heads

1. Plug breather hole on turbocharged engine heads with 1/8 inch [3.18 mm] pipe plug. Breather hole is located at top of head above intake air port. The breather hole has been eliminated on new turbocharged engines.
2. Clean gasket surfaces.
3. Install gasket over dowels so word "TOP" on gasket is visible. Fig. 14-20. Use gasket with standard (white) grommets (0.097 to 0.103 inch [3.8 to 4.1 mm] thick) if water holes are free of erosion. Use service (black) grommets (0.107 to 0.113 inch [4.2 to 4.4 mm] thick) if there is evidence of erosion. No grommet retainers are required. Install ferrels in oil drain holes (if used).

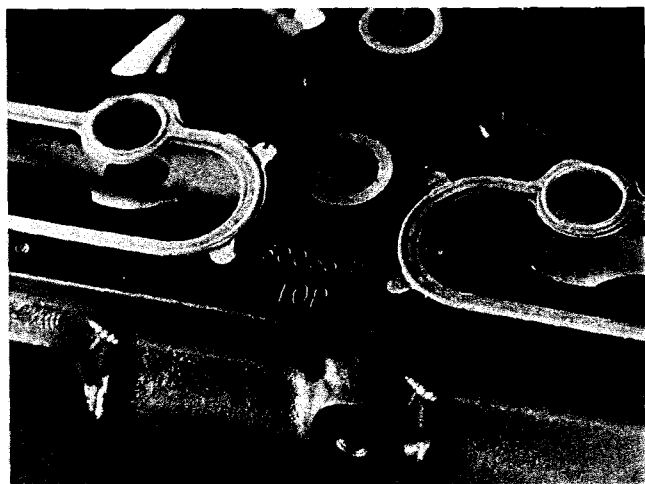


Fig. 14-20, (N114257). Installing cylinder head gasket

4. Insert two guide studs in block and lower head into place on block.

Note: All turbocharged engines must use cylinder head capscrews that have letters NT forged ahead. Do not intermix.

5. Lubricate entire cylinder head capscrew with rust preservative lubricant. Allow excess lubricant to drip from capscrew before installation.

Note: Rust preservative lubricants with 2 percent or higher sulfates ash content must be used.

6. Install washers and capscrews. Torque capscrews to 25 ft-lbs [34 N•m] in sequence shown in Fig. 14-21. Continue torquing in increments of 80 to 100 ft-lbs [108 to 136 N•m] to final torque of 280 to 300 ft-lbs [380 to 407 N•m].

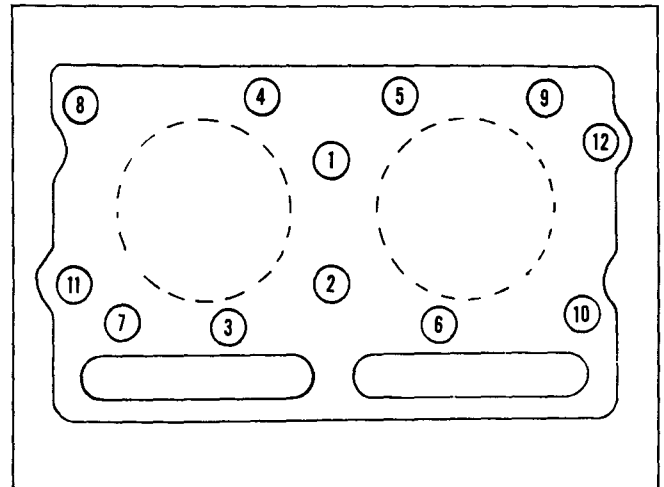


Fig. 14-21, (N11427). Cylinder head torquing sequence

Fuel Cross-Over

Install "O" rings in end of each cylinder head and cross-over; secure cross-over with springtite screws. Tighten with torque wrench and screwdriver adapter to 34 to 38 in-lbs [3.8 to 4.3 N•m]. Fig. 14-22.

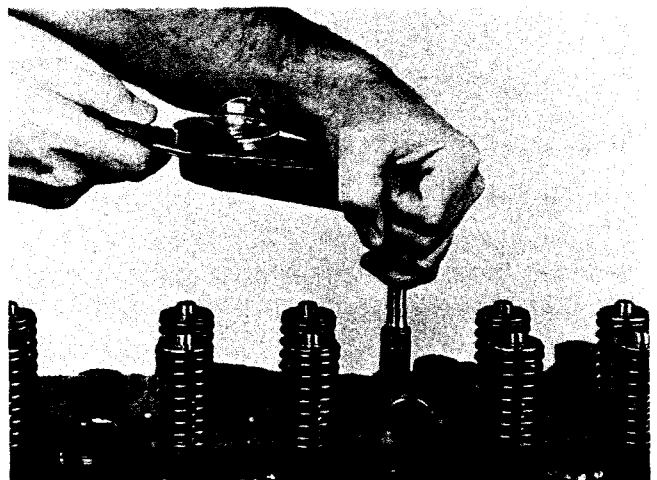


Fig. 14-22, (N114258). Installing fuel crossover

Fuel Fittings and Lines

Coat fuel fittings with sealer. Inlet and drain fittings may be installed either in front of No. 1 head or rear of No. 3 head, as used. Connect tubing to appropriate fitting.

Compression Release Shaft

1. Install new "O" ring over shaft. Insert shaft into cylinder block and secure at rear end of block with copper washer and lockscrew.
2. Using permatex on expansion plug, install plug in counterbore at rear of block, until plug seats in counterbore.

Cam Followers and Push Tubes

1. Install cam follower gaskets. It may be necessary to add or remove gaskets to obtain correct injection timing. Install print-o-seal gasket with seal towards cam follower housing. Fig. 14-23.
2. Position cam follower assembly to block. Fig. 14-24. Torque capscrews in sequence as shown in Fig. 14-25 in increments of 15 to 20 ft-lbs [20 to 27 N•m] to 30 to 35 ft-lbs [41 to 47 N•m].
3. Install push tubes. Injector push tube is largest and fits in middle socket. On engines equipped with compression release, exhaust push tube is

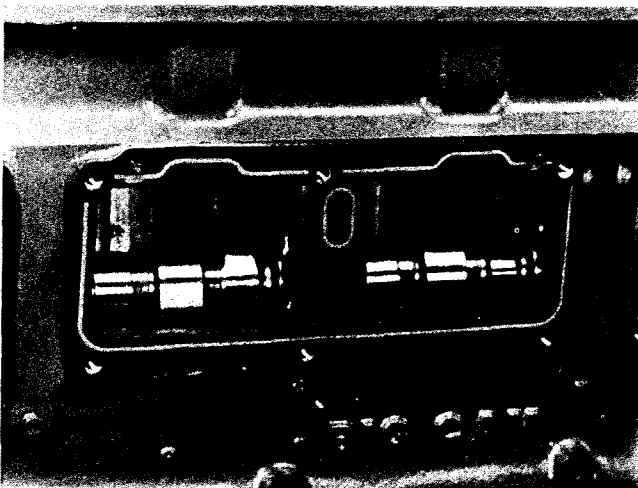


Fig. 14-23, (N114259). Installing cam follower gasket

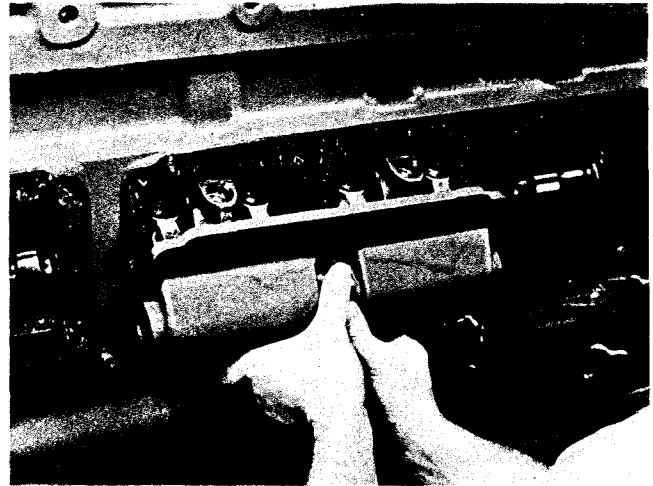


Fig. 14-24, (N114260). Installing cam follower

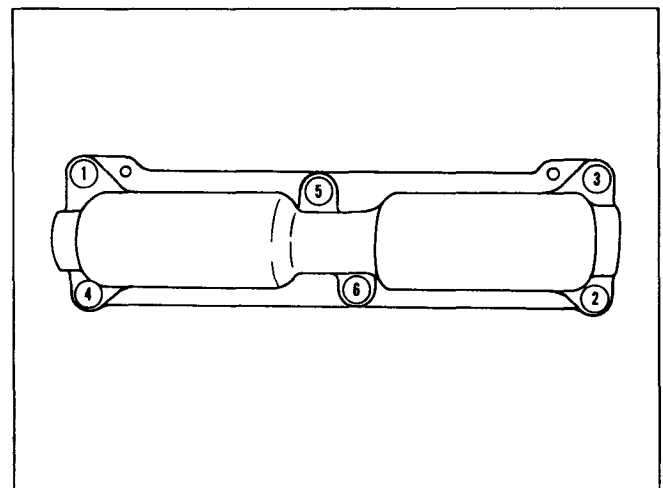


Fig. 14-25, (N114236). Cam follower torquing sequence

equipped with collar to match with milled lift of compression release. On engines without compression release, intake and exhaust tubes are identical.

Note: Injector push tube diameter will be either 3/4 inch [19.05 mm] or 21/32 inch [16.67 mm]. Valve push tubes are 5/8 inch [15.88 mm] in diameter and 0.007 inch [0.178 mm] longer than injector push tubes. Push tubes for 2-1/2 inch cam engine are approximately 1/2 inch shorter. Ref. Table 14-3.

Table 14-3: Push Tube Length — Inch [mm]

	2 Inch Cam	2-1/2 Inch Cam
Injector	18.290 [464.56]	17.775 [451.48]
	18.320 [465.32]	17.805 [452.24]
Valve	18.360 [466.34]	17.880 [454.15]
	18.390 [467.11]	[17.910 [454.91]

Timing the Engine

Use ST-593 to obtain precise timing of push tube travel with piston travel. The travel readings for engine model must be as listed in Table 14-4. Adjustments to timing are made by altering thickness of cam follower housing gaskets.

1. Position ST-593 Timing Tool in injector sleeve. Engage rod of push rod indicator in injector push tube socket. Secure tool in place by tightening knurled hold-downs evenly by hand. Be sure tool is straight in the cylinder. Fig. 14-26.

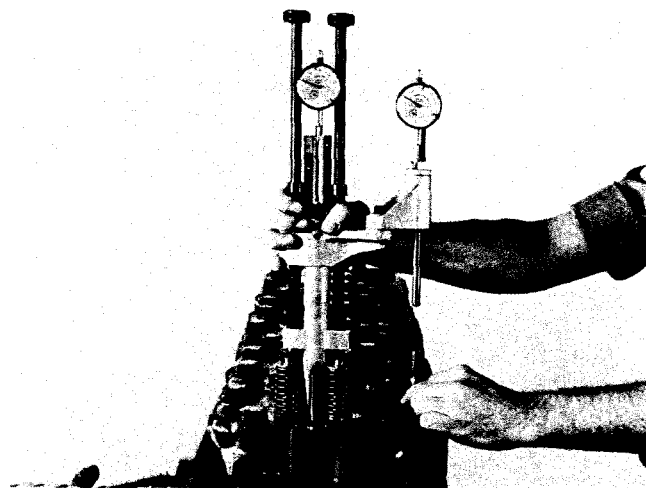


Fig. 14-26, (N114261). Injection timing with ST-593

Note: Each of the two dial indicators used in timing engine must have total travel of at least 0.250 inch [6.35 mm].

2. Loosen both indicator supports. Rotate crankshaft pin direction of engine rotation to TDC (top dead center) (piston travel plunger will be near the full upward position). Adjust both

indicators to their fully compressed position. To prevent damage, raise both indicators approximately 0.020 inch [0.5 mm]. Lock in place with setscrew.

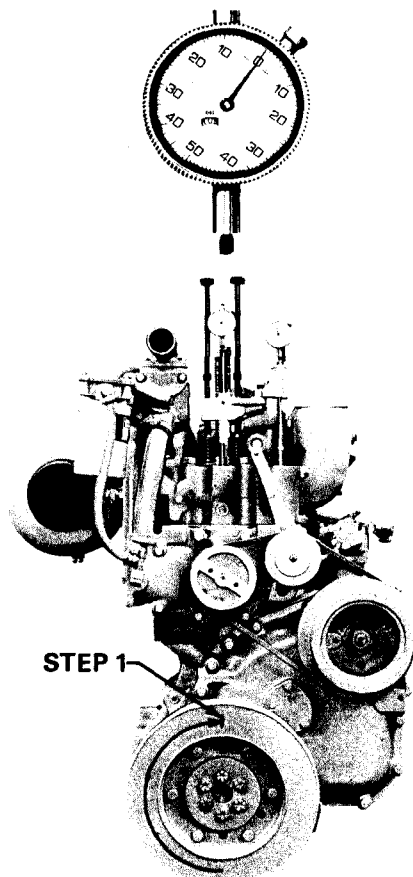
3. Rotate crankshaft back and forth to assure the piston is precisely at TDC on the compression stroke. TDC is indicated by the maximum clockwise position of the piston travel indicator pointer. Turn the piston travel indicator face to align the zero with the pointer. Lock the face with the thumbscrew.

Note: Both indicators move in same direction when cylinder is on proper stroke. If push tube indicator does not move same direction as piston indicator, bar crankshaft one complete revolution to place cylinder on compression stroke. Repeat Step 3.

4. Rotate crankshaft in direction of rotation to approximately 90 degrees ATDC (after top dead center). Turn push tube travel indicator face to align zero with the pointer. Lock face with the thumbscrew.
5. Rotate crankshaft opposite direction of rotation through TDC to 45 degrees BTDC (before top dead center). See Fig. 14-27 and Step 3.
6. Rotate crankshaft in direction of rotation until a reading of 0.2032 inch BTDC is reached on the piston travel indicator. Since exact reading in ten-thousandths must be estimated, exercise care in bringing piston travel indicator to reading.
7. Read push tube travel indicator. It should read the number of thousandths before zero that is called for in Table 14-4.

Note: Never make a change in cam follower gaskets for timing purposes before making following checks:

- a. Be sure cam follower housing capscrews are tightened to 30 to 35 ft-lbs [41 to 47 N•m] torque.
- b. Recheck indicator positioning. Be sure indicators are not bottoming or binding.
- c. Carefully recheck top center position. Be

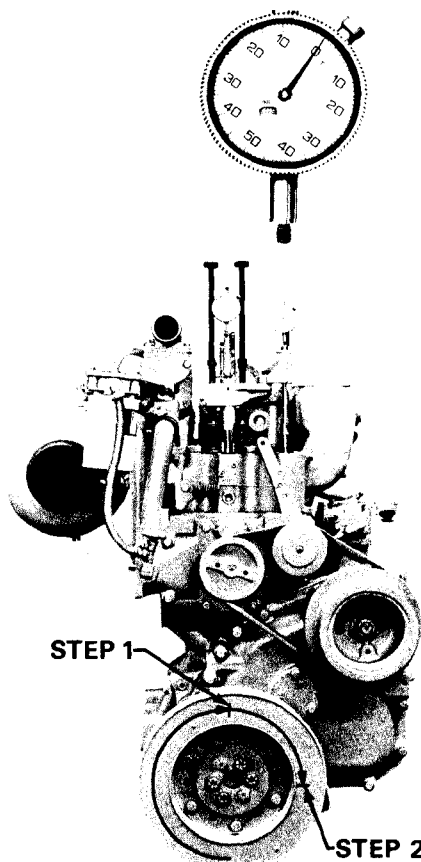


STEP 1

STEP 1 TOP DEAD CENTER (TDC)

Install timing fixture. Rotate crankshaft in direction of engine rotation to TDC. (Piston travel plunger will be near the full upward position). Adjust both indicators on the fixture to their fully compressed position. To prevent damage, raise both indicators approximately 0.020 inch (0.5 mm). Lock in place with set screw. Rotate crankshaft back and forth to assure the piston is precisely at TDC on the compression stroke. (Both indicators move in same direction when piston is on proper stroke). TDC is indicated by maximum clockwise position of the piston travel indicator pointer. Turn piston travel indicator face to align the zero with the pointer. Lock the face with the thumbscrew.

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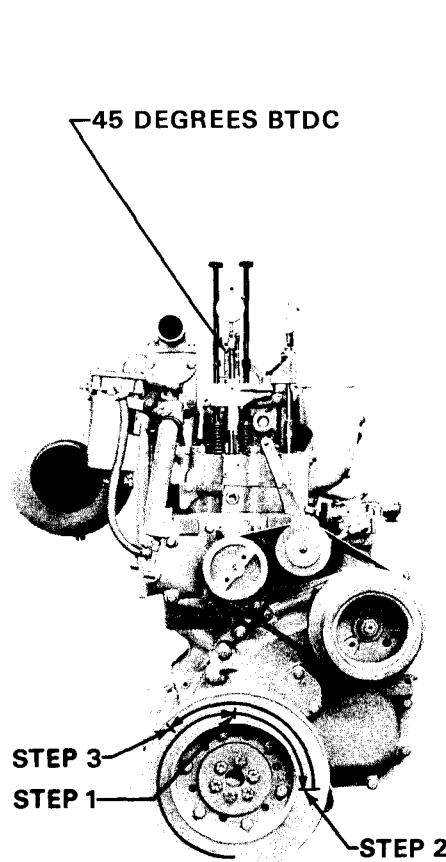


STEP 1

STEP 2

STEP 2 90 DEGREES AFTER TOP DEAD CENTER (ATDC)

Rotate crankshaft in direction of engine rotation to 90 degrees ATDC. (Piston travel plunger will be near the bottom of its travel.) Turn push tube travel indicator face to align zero with the pointer. Lock the face with the thumbscrew.



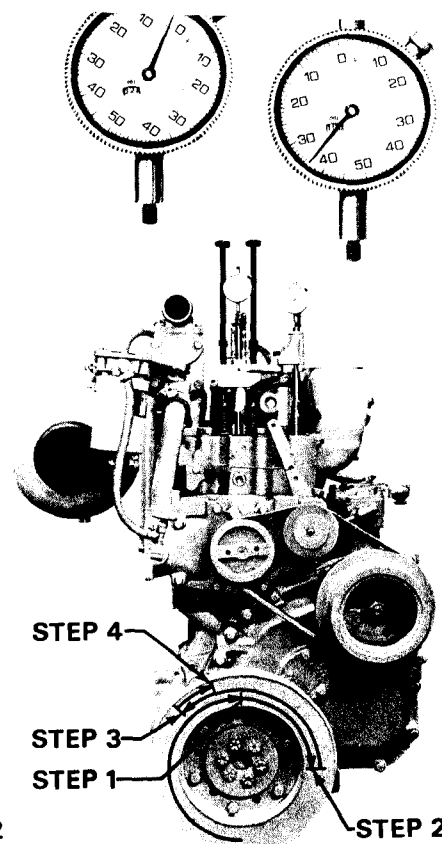
STEP 3

STEP 1

STEP 2

STEP 3 45 DEGREES BEFORE TOP DEAD CENTER (BTDC)

Rotate crankshaft opposite direction of engine rotation through TDC to 45 degrees BTDC. (Piston travel plunger will be as indicated in illustration.) This step is necessary to remove gear train lash and provide more accurate indicator readings on the following step.



STEP 4

STEP 3

STEP 1

STEP 2

STEP 4 19 DEGREES BEFORE TOP DEAD CENTER (BTDC)

Rotate crankshaft in direction of engine rotation until a reading of -0.2032 inch BTDC is reached. At this position compare the reading of the push tube travel indicator to specifications listed for that timing code or CPL in the engine shop manual. Readings should fall within these specifications. If not, correct by adding gaskets to advance injection timing (Decrease the push tube travel indicator reading) or removing gaskets to retard injection timing. (Increase push tube travel indicator reading)

NOTE: RIGHT HAND ENGINE ROTATION ONLY

NH/NT ENGINE INJECTION TIMING

sure each step is carried out as described.

8. If push tube travel is greater than limits indicated in Table 14-4, engine timing is slow; if push tube travel is less, timing is fast. Injection timing may be advanced or retarded by adding or removing cam follower gaskets. Remove gasket on right hand engine to retard timing. Add gaskets on left hand engines to retard timing.

Note: The timing operation must be performed on one cylinder per head.

Fuel Pump/Compressor Drive/Accessory Drive

Bar engine to No. 1 cylinder, TDC position (firing stroke), continue rotating to 90 degrees ATC. In this position, the two center-punched marks on drive gear will mesh or index with two dash marks on camshaft gear. Fig. 14-28. This timing is required so external timing marks on accessory drive pulley will be properly aligned with timing mark on gear case to show valve and injector adjustment positions, keyway of drive shaft will be at top. Secure drive to cylinder block.

1. Attach a dial indicator gauge to the block with plunger on accessory drive gear tooth. Fig. 14-29. Rotate gear as far as it will move to take up backlash, zero indicator.
2. Rotate gear in opposite direction and read backlash on dial gauge. Backlash should be 0.0045 to 0.0105 inch [0.114 to 0.267 mm].

Air Compressor

For balance of engine and air compressor reciprocating force, the coupling driven air compressor must be timed to engine firing order.

1. Bar engine to "A" or "1-6" valve set mark.
2. Rotate air compressor crankshaft so timing mark or male splined coupling half keyway will be pointing at "9:30 o'clock" when looking at coupling end of compressor.
3. Assemble splined coupling to air compressor drive shaft.
4. With a new gasket in place, install air compres-

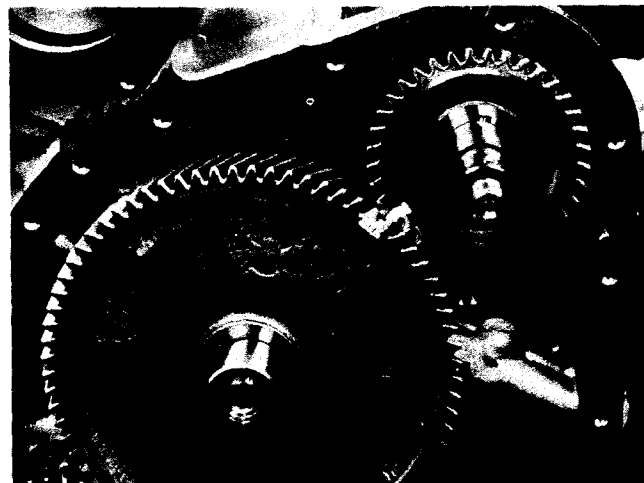


Fig. 14-28, (N114262). Align timing marks.

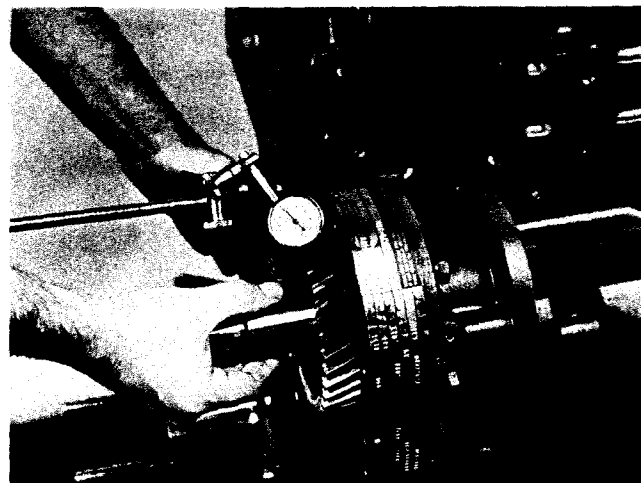


Fig. 14-29, (N114263). Checking accessory drive gear backlash

sor to accessory drive housing. Tighten cap-screws to 40 to 45 ft-lbs [54 to 61 N•m] torque.

Note: Bendix Westinghouse Tu-Flo 500 Compressor air intake may be plumbed to engine intake manifold on NHCT-270, NHCT-CT, NTC-290, NTC-335, NTC-350 and NTA-370 engines.

5. Connect air and water lines to compressor. Position and secure air compressor support bracket to block and air compressor.

Lubricating Oil Pump

1. Place lubricating oil pump gasket to gear case.

Table 14-4: Injection Timing

Timing Code	Piston Travel (Inches)	Push Rod Travel (Inches)		
		Nominal	Fast	Slow
A	-0.2032	-0.0415	-0.0395	-0.0435
B	-0.2032	-0.0295	-0.0275	-0.0315
C	-0.2032	-0.0335	-0.0315	-0.0355
D	-0.2032	-0.036	-0.034	-0.038
E	-0.2032	-0.029	-0.028	-0.030
Y	-0.2032	-0.039	-0.037	-0.041
Z	-0.2032	-0.026	-0.024	-0.028
AA	-0.2032	-0.031	-0.030	-0.032
AC	-0.2032	-0.028	-0.027	-0.029
AF	-0.2032	-0.045	-0.044	-0.046
AH	-0.2032	-0.035	-0.034	-0.036
AI	-0.2032	-0.034	-0.033	-0.035
AK	-0.2032	-0.041	-0.040	-0.042
AN	-0.2032	-0.046	-0.045	-0.047
AQ	-0.2032	-0.042	-0.041	-0.043
AS	-0.2032	-0.036	-0.035	-0.037
AT	-0.2032	-0.030	-0.029	-0.031
AU	-0.2032	-0.049	-0.048	-0.050
AV	-0.2032	-0.050	-0.049	-0.051
AW	-0.2032	-0.060	-0.059	-0.061
AX	-0.2032	-0.055	-0.054	-0.056
AY	-0.2032	-0.040	-0.039	-0.041
AZ	-0.2032	-0.059	-0.058	-0.060
BA	-0.2032	-0.028	-0.027	-0.029
BB	-0.2032	-0.100	-0.099	-0.101
BC	-0.2032	-0.024	-0.023	-0.025
BD	-0.2032	-0.095	-0.094	-0.096
BH	-0.2032	-0.052	-0.051	-0.053
BI	-0.2032	-0.105	-0.104	-0.106

Note: Reference engine dataplate for timing code.

Make certain oil passages are open.

2. Mesh drive gear teeth with camshaft gear as pump is installed. Secure pump.
3. Use same procedure to check pump gear backlash (Fig. 14-30), as used for checking accessory drive gear backlash.

Note: If power steering pump is driven by lubricating oil pump, position coupling to shaft, install power steering pump.

4. When used, secure oil filter can with new element and sealing "O" ring to lubricating oil

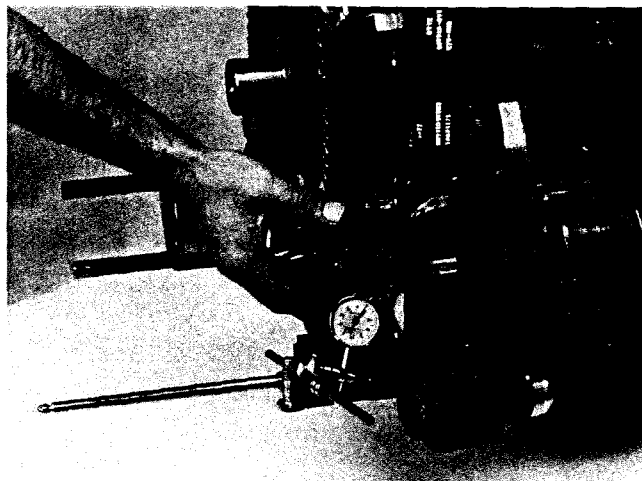


Fig. 14-30, (N114264). Checking lubricating oil pump gear backlash

pump by torquing center bolt to 25 to 35 ft-lbs [34 to 47 N•m].

Gear Case Cover

1. Shellac new gasket to gear case cover. Check current Parts Catalog for correct gear case cover and gear case cover gasket part numbers.
2. Install gear cover in place over dowels. Torque capscrews to 45 to 50 ft-lbs [61 to 68 N•m] trim off excess gasket material at pan flange mounting area.
3. Make sure that bottom surface of cover is

within ± 0.004 inch [0.10 mm] of flush with oil pan surface of block.

4. Check concentricity of oil seal bore in relation to crankshaft. If total indicator reading exceeds 0.010 inch [0.25 mm] remove, clean and relocate gear cover (Fig. 14-31).
5. Install crankshaft oil seal with ST-1259 Mandrel and 3375151 Pilot (Fig. 14-32). Use ST-1172 Mandrel for tapered nose crankshaft. Install accessory drive seal with ST-1173 Mandrel and ST-386 Pulley Assembly Tool. ST-1173 Mandrel will seat seal to required depth (Fig. 14-33).

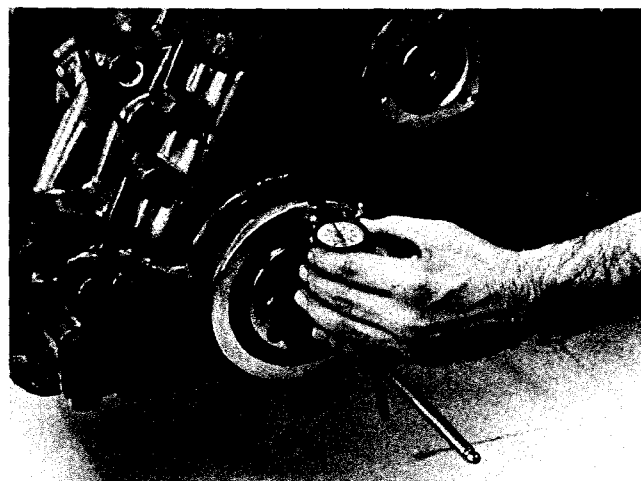


Fig. 14-31, (N114265). Checking concentricity of crank seal bore



Fig. 14-32, (N114266). Installing crank oil seal

Caution: LDL (Laydown Lip) TFE oil seals must be installed with seal lip and outside diameter of shaft clean and dry to prevent premature leakage.

- a. Check clearance between seal and shoulder on gear case cover bore, if so equipped. Minimum clearance is 0.030 inch [0.76 mm]. Seal must not bottom on shoulder of bore.

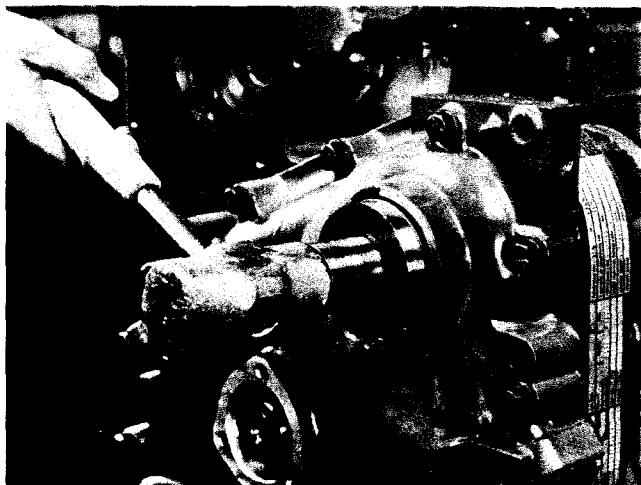


Fig. 14-33, (N114267). Installing accessory drive oil seal

- b. Front face of oil seal must be square with crankshaft axis within 0.010 inch [0.25 mm] total indicator reading.
6. Install camshaft thrust plate or support bearing.
 - a. Remove "O" ring seal and spacers. Push plate or support against camshaft so camshaft rests against thrust washers. Measure dimension between thrust plate and gear case cover with feeler gauge. Fig. 14-34.
 - b. Using micrometer, select enough spacers to provide 0.001 to 0.005 inch [0.03 to 0.13 mm] camshaft end clearance for engines with camshaft thrust plate, 0.008 to 0.013 inch [0.20 to 0.33 mm] for engines with camshaft outboard bearing support.
 - c. Install spacers and "O" ring seal; secure thrust plate to gear case cover.
 - d. Install accessory drive shaft pin. Fig. 14-35.



Fig. 14-34, (N114268). Checking camshaft thrust plate clearance



Fig. 14-35, (N114269). Installing accessory drive shaft pin

Accessory Drive Pulley

Note: Remove pipe plug in gear cover; check to make sure timing marks are lined up. Replace pipe plug. Tighten to 35 to 45 ft-lbs [47 to 61 N•m].

1. Install oil slinger over accessory drive shaft with key and key seal, if used, on accessory drive shaft. Lubricate shaft with clean lubricating oil, start accessory drive pulley over shaft and key; use ST-386 to position pulley on shaft. Fig. 14-36.
2. Remove ST-386; install flatwasher and pulley nut. Torque nut to 90 to 110 ft-lbs [122 to 149 N•m]. Currently built engines are equipped with a flanged nut to retain the accessory drive

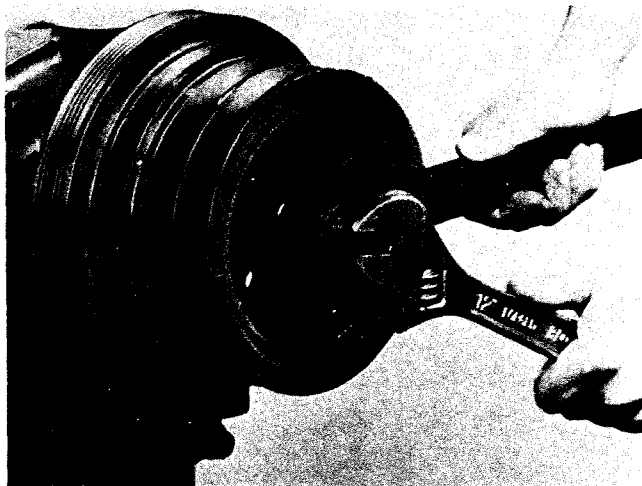


Fig. 14-36, (N114270). Installing accessory drive pulley

pulley. Tighten the flanged retaining nut to 300 to 310 ft-lbs [407 to 420 N•m] torque. The flanged retaining nut may be used to bar the engine.

Crankshaft Flange and Vibration Damper

Lapping

Each time the crankshaft flange or pulley is removed or replaced, it must be lapped to the crankshaft to provide maximum contact area between mating parts.

1. Insure that all mating surfaces are free of burrs, nicks and fretting. Do not attempt lapping until all imperfections have been removed.
2. Inspect flange with a magnetic particle process for cracks or inclusions.
3. Coat inside diameter of flange with Grade A (280 grit) lapping compound and lap by turning flange one-fourth (1/4) to one-half (1/2) turn each way until both crank nose and flange inside diameter are mated.
4. Clean all compound from flange and crankshaft nose; allow no compound to reach seal or enter engine.

Contact Check

1. Apply a light even coat of Prussian Blue on nose of crankshaft. Hold flange or pulley perpendicular to centerline of crankshaft and position on

nose, turn flange one-eighth (1/8) turn and pull straight off.

2. Contact area should be 100 percent for a distance of 1/2 inch [12.70 mm] at large diameter of crank nose, remainder of taper must have 70 percent to 100 percent of bluing contact.
3. Clean all Prussian Blue from the crank nose and flange.

Installation

Caution: Lubricate crankshaft nose in flange area with SAE 30 rust preservative lubricant with 2 percent or higher sulfated ash content. **DO NOT** use lubricant when cast iron flanges 115562, 115563, 175183 or 175185 are used.

1. Install crankshaft flange over end of crankshaft if used. Center line of keyway in flange and keyway in crankshaft should be aligned within plus or minus 1/8 inch [3.18 mm].
2. Install retainer and capscrew, check current Parts Catalog for correct capscrew and retainer, torque to specifications listed in Table 14-1.
3. With dial gauge mounted to gear case cover, check crankshaft flange eccentricity and wobble. Eccentricity must not exceed 0.004 inch [0.10 mm] total indicator reading; wobble must not exceed 0.003 inch [0.08 mm] measured at 2-3/4 inch [69.85 mm] radius. Fig. 14-37.

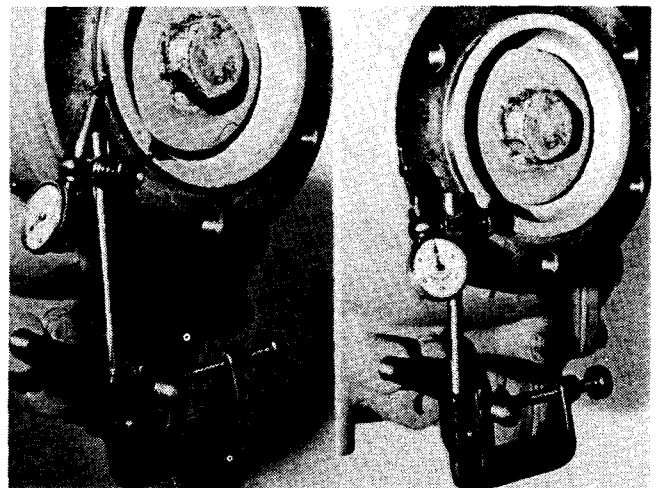


Fig. 14-37, (N114156). Checking crankshaft flange eccentricity and wobble

4. Install vibration damper to crankshaft flange with lockplates and capscrews. Torque to 60 ft-lbs [81 N•m] and lock in place.
5. Position a dial gauge to gear case cover and rest arm on outer machined surface at point (A, Fig. 14-38) to check eccentricity and at point (B) on inner machined surface of outer member to check wobble. Run-out must not exceed 0.0025 inch [0.064 mm] per one (1) inch radius of damper (as measured from center of damper). Crankshaft must be kept at front or rear limit of thrust clearance while wobble is being checked.

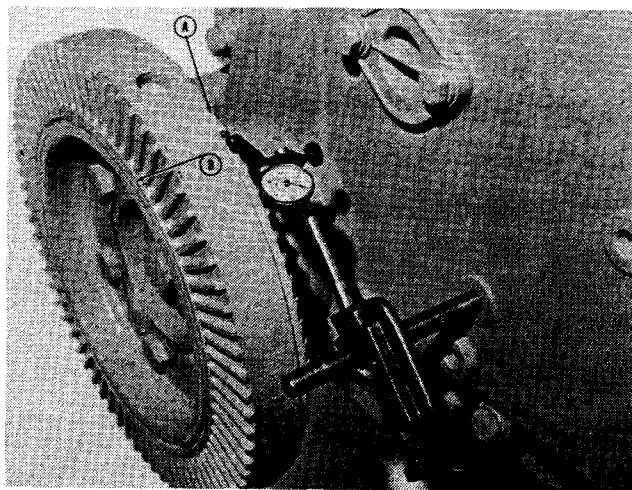


Fig. 14-38, (N114140). Checking vibration damper run-out

Vibration Damper and Pulley

1. Position front engine support to block, if used, maintain a minimum of 1/32 inch [0.79 mm] clearance between support and gear case cover. Tighten capscrews to 55 ft-lbs [75 N•m] torque.

Caution: Do not use any lubricant on pulley or crankshaft mating surfaces. Wipe with clean dry cloth.

2. Align capscrew holes and install pulley and vibration damper assembly to crankshaft, tap into position with soft hammer. Coat capscrews with clean lubricating oil, secure pulley and damper assembly to crankshaft and torque to 85 ft-lbs [115 N•m].

Note: Check capscrew marking, if 1/2 inch Grade 8

capscrews are used, tighten capscrews to 115 to 125 ft-lbs [156 to 170 N•m] torque. If 5/8 inch Grade 8 capscrews are used, tighten to 180 to 200 ft-lbs [244 to 271 N•m] torque. If 5/8 inch Grade 5 capscrews are used, tighten to 150 to 170 ft-lbs [203 to 231 N•m] torque. See Capscrew Markings and Torque Values, Section 18.

3. If vibration damper was removed from pulley, wipe mating surface of damper and pulley clean, position damper to pulley, install and torque capscrews to 85 ft-lbs [115 N•m].
4. Check damper for eccentricity and wobble as described in Step 5 preceding.

Fan Bracket and Water Pump (Old Style)

1. Install water pump support and gasket (Fig. 14-39), tighten to 30 ft-lbs [41 N•m] torque.
2. Install water pump and clamp ring or fan bracket. Secure loosely with lockwashers and capscrews. Turn water pump to low point of its eccentricity.
3. Assemble belt on water pump pulley and drive pulley. Insert a large screwdriver in holes provided in water pump; turn pump in its eccentric counterclockwise to tighten belt. Use ST-1138 to check belt tension.

4. Tighten clamp ring or fan bracket as follows:

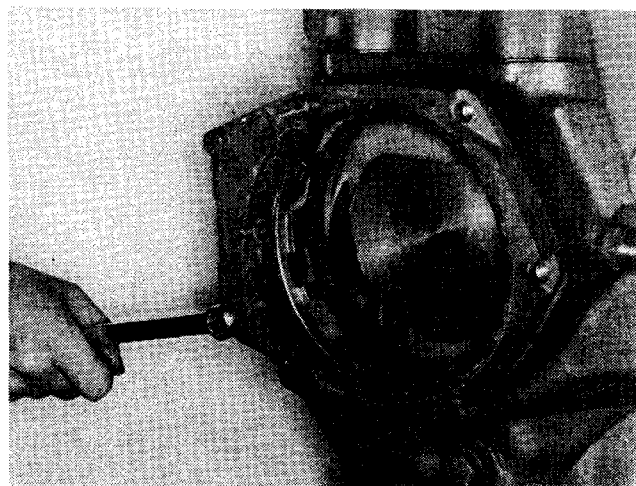


Fig. 14-39, (N114191). Installing fan hub support (NTA Series)

- a. Tighten capscrew farthest from belts on exhaust side, then capscrews above and below it, to 50 ft-lbs [7 N•m] torque.
- b. Tighten capscrew on belt side, then two remaining capscrews to 5 ft-lbs [7 N•m] torque.
- c. Tighten all capscrews alternately and evenly to 12 to 15 ft-lbs [16 to 20 N•m] torque.

Water Pump Cavity Cover Plate and Fan Bracket

1. Install water pump support to block using new gasket. Torque capscrews to 30 ft-lbs [41 N•m].
2. Using new sealing ring, install water pump cavity cover and fan hub bracket. Secure with capscrews. Torque in same procedure as Step 4 preceding.
3. Install bracket support to fan bracket.

Water pump and Idler (FFC Series)

1. Using new gasket, position water pump and idler assembly to block. Fig. 14-40. Torque as follows:
 - a. Torque in rotation to 10 ft-lbs [14 N•m].
 - b. Repeat rotation torque to 20 ft-lbs [27 N•m].

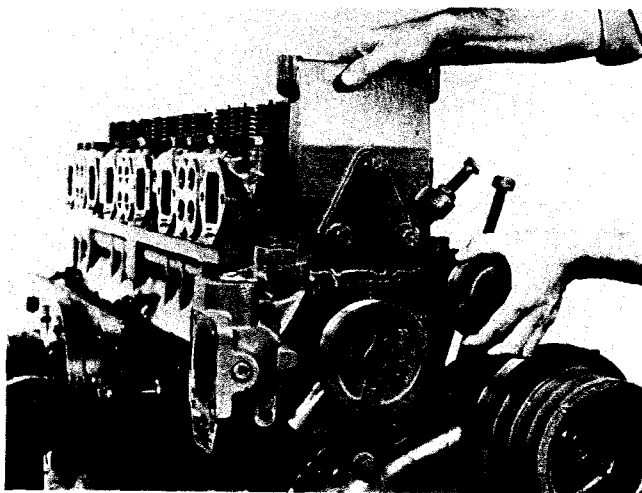


Fig. 14-40, (N114271). Installing water pump and idler.

- c. Final torque in rotation to 30 ft-lbs [41 N•m].

2. Position belts over water pump, idler and accessory drive pulleys. Tighten idler adjusting screw to obtain 120 to 140 lb [534 to 623 N] belt tension using ST-968 or ST-1274 Belt Tension Gauge. Fig. 14-41.
3. Secure idler shaft to bracket with flatwasher and locking nut. Tighten to 50 ft-lbs [68 N•m] torque. Back off adjusting screw 1/2 turn.

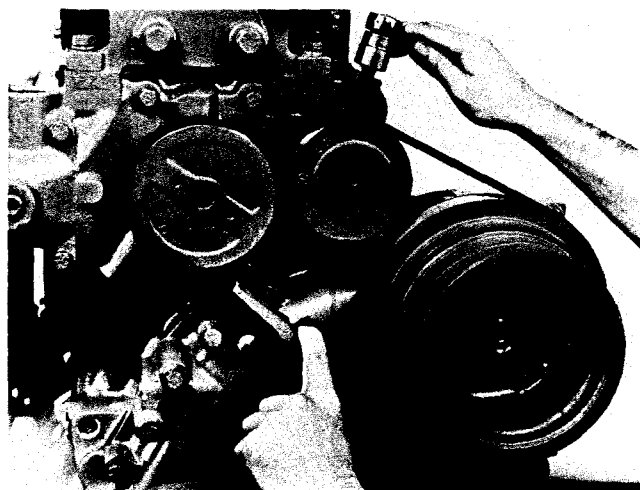


Fig. 14-41, (N114272). Adjusting belt tension

4. If not previously installed, position fan hub assembly to mounting bracket. Tighten capscrews finger tight.
5. Position and secure fan hub assembly and bracket to water pump housing.
6. Secure fan bracket support to fan bracket and install adjusting screw and hardened washer (if used).
7. Position belts over fan hub pulley and accessory drive pulley; tighten fan hub adjusting screw to obtain 90 to 110 lb [400 to 489 N] belt tension using ST-968 or ST-1138 Belt Tension Gauge.
8. Secure fan hub assembly to fan mounting bracket; torque capscrews to 50 ft-lbs [68 N•m].

Fan Hub and Pulley

1. Assemble fan pulley to fan bracket, if not previously installed. Position flatwasher and locking nut on shaft. Start nut on thread; do not tighten.
2. Avoid stretching belts, loosen adjusting screw, position belts over fan hub and drive pulleys.
3. Tighten adjusting screw to obtain proper tension of drive belts.
4. Torque fan hub shaft-to-bracket nut to 400 to 450 ft-lbs [542 to 610 N•m]. Do not over-tighten. Back off adjusting screw 1/2 turn.
5. As an alternate method, tighten nut hand tight; rotate 75 degrees, mark bracket in line with corner of nut and turn one full hex or 60 to 70 degrees.

Belt Tension — Standard Vee Belt

1. Installation:
 - a. When two or more identical belts are used on the same drive, they must be replaced as a matched set.
 - b. Shorten distance between pulley centers and install belt(s). Do not roll or pry belt over pulley.
 - c. Pulley misalignment must not exceed 1/16 inch [1.59 mm] for each foot [0.3 m] of distance between pulley centers.
 - d. Belts should not bottom on pulley grooves, nor should they protrude over 3/32 inch [2.38 mm] above top edge of groove.
 - e. Belt riding depth should not vary over 1/16 inch [1.59 mm] on matched belt sets.
 - f. Do not allow belts to rub against any adjacent part.
2. Adjusting:
 - a. Use ST-1274 for Poly V or 3/8 to 1/2 inch [9.53 to 12.70 mm] width belts. Use ST-1138 for 11/16 to 7/8 inch [17.46 to

22.23 mm] width belts.

- b. When belts are installed, tighten until a reading of 90 to 110 lb force is obtained. New belts will loosen after running for an hour or more and may require readjustment. Recheck belt tension and readjust to 90 to 110 lbs if reading is less than 80 lbs.

Rear Cover Plate and Oil Seal

1. Clean crankshaft seal area with crocus cloth and wipe clean.

Caution: TFE "Laydown Lip" oil seals must be installed with seal lip and shaft outside diameter clean and dry. The use of lubricant of any kind may cause premature leakage.

2. Install rear cover and gasket to cylinder block. Tighten capscrews finger tight so rear cover plate will move for alignment and position sleeve driver over end of crankshaft; rear cover plate should pilot over tool.
3. Snug capscrews so cover can be shifted. Use ST-997 Seal Driver with ST-997-6 Buttons removed to align cover with crankshaft. Rear cover must be aligned within 0.005 inch [0.13 mm] total indicator runout and within 0.004 inch [0.10 mm] flat with pan rail of cylinder block (Fig. 14-42). Tighten cover capscrews to 24 to 29 ft-lbs [33 to 39 N•m] and trim off excess gasket material.
4. Install seal/sleeve assembly tool over end of shaft placing the larger inside diameter portion of the tool toward the engine.

Note: LDL TFE oil seals for service replacement include an assembly sleeve tool (where required) to protect the seal lip during shipment and installation to the engine. Assembly sleeve tools are pre-assembled into the seal lip during processing by the supplier, prior to packaging.

5. Push the seal off of the assembly sleeve tool over the larger outside diameter portion of the tool onto the shaft.
6. Complete installation of the seal into housing

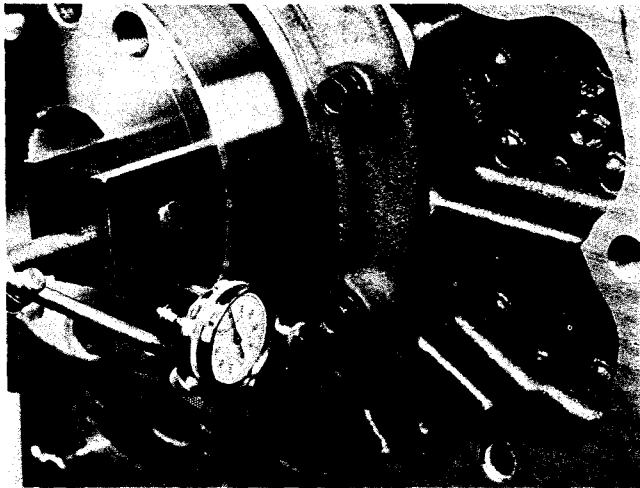


Fig. 14-42, (N114273). Checking rear cover plate run-out

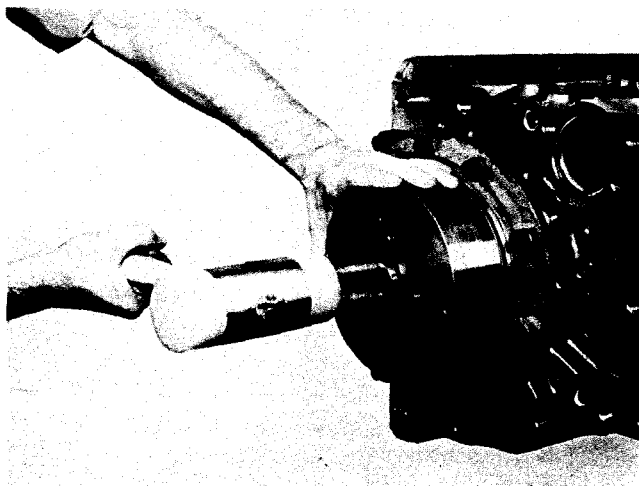


Fig. 14-43, (N114274). Installing rear cover plate oil seal

bore using ST-997 Seal Driver with ST-997-6 Buttons installed (Fig. 14-43).

Dry Type Flywheel Housing

1. Clean mating surface of flywheel housing to block and install new cork camshaft bore gaskets in flywheel housing with gasket cement. Allow sufficient time for drying. Gasket slippage will allow oil to leak from rear of camshaft bore. No gasket is required on engines with cup plug cam seal.
2. If new flywheel housing is being installed, or if dowels are worn, sheared or loose, remove

dowels from block. Snug housing to block with lockwashers and capscrews.

Indicate Flywheel Housing Bore

1. Draw chalk marks at 12, 6, 9 and 3 o'clock. Attach ST-112 and a dial gauge to crankshaft flange. Fig. 14-44.

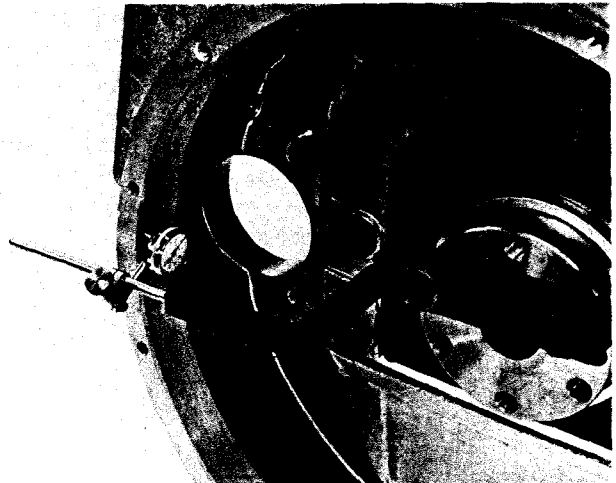


Fig. 14-44, (N114275). Indicating flywheel housing bore

2. Check readings at 9 and 3 o'clock. If run-out exceeds specifications in Table 14-5, move housing one-half of distance to center horizontally.
3. Check readings at 12 and 6 o'clock. If run-out exceeds specifications, move housing to center vertically.

Indicate Flywheel Housing Face

1. Attach ST-1325 and a dial gauge as shown in Fig. 14-45.
2. Push crankshaft forward to take up end clearance and turn crankshaft to obtain readings on housing face. Take up crankshaft end clearance in same direction each time.
3. Total flywheel housing face run-out must not exceed specifications in Table 14-5.
4. If both bore and face run-out readings are within limits and dowels were removed, ream dowel holes to smallest surfaces. Then reinstall,

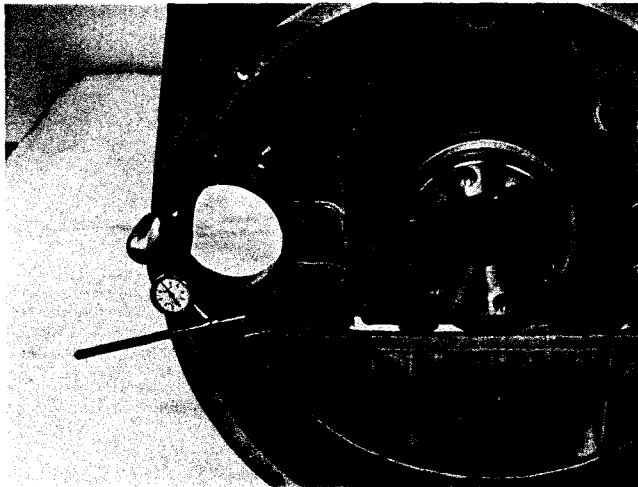


Fig. 14-45, (N114276). Indicating flywheel housing face

realign and dowel. After readings are within limits, tighten capscrews alternately and evenly to 150 ft-lbs [203 N•m].

Flywheel Housings Using Wet Clutch Seal

If engine is to be dynamometer tested, the wet clutch seal must NOT be installed until after test. DRY RUNNING WILL DESTROY THIS SEAL.

1. Mount wet type flywheel housing to block using new "O" rings and capscrews, indicate face and bore (see Indicate Flywheel Housing Face as previously stated). Install oversize dowels.
2. Press new seal into seal carrier with spring loaded sealing lip toward flywheel until it seats in carrier. Refer to Parts Catalog for correct seal number.

Note: Dual lip seals are now available for wet clutch applications.

3. Position seal carrier with new gasket to flywheel housing. Secure snug with Nylok capscrews. Indicate seal carrier to crankshaft, it must be centered within 0.006 inch [0.18 mm] T.I.R.
4. Torque seal carrier to flywheel housing capscrews to 8 ft-lbs [11 N•m]. If access cover plate was removed, reinstall and secure using copper washers and capscrews.

Caution: Do not operate engine without clutch oil in clutch housing. Damage may occur to flywheel housing clutch seal and clutch.

Flywheel

Note: When replacing a flywheel, dowels are to be omitted.

1. Install flywheel:
 - a. Screw two studs, 5/8"-18 x 6" long into crankshaft flange as guides. Install flywheel over studs; match dowel holes in flywheel and crankshaft.
 - b. Remove guide studs and position 200861 Hard Flatwasher on self-locking capscrew; tighten alternately until snug, to pull flywheel up evenly. Tighten to 200 to 220 ft-lbs [271 to 298 N•m] torque. Washers are not used under capscrews with safety wire holes in head. Tighten capscrews with safety wire holes to 190 to 200 ft-lbs [258

Table 14-5: Flywheel Housing Specifications – Inch [mm]

SAE No.	Bore Diameter (For Reference Only)	True Location Tolerance	Face Fun-Out Tolerance
00	31.000 to 31.010 [787.40 to 787.65 mm]	0.012 [0.30 mm] TIR	0.012 [0.30 mm] TIR
0	25.500 to 25.520 [647.70 to 647.95 mm]	0.010 [0.25 mm] TIR	0.010 [0.25 mm] TIR
1/2	23.000 to 23.008 [584.00 to 584.20 mm]	0.010 [0.25 mm] TIR	0.010 [0.25 mm] TIR
1	20.125 to 20.130 [514.27 to 514.40 mm]	0.008 [0.20 mm] TIR	0.008 [0.20 mm] TIR
2	17.625 to 17.630 [447.68 to 447.80 mm]	0.008 [0.20 mm] TIR	0.008 [0.20 mm] TIR
3	16.125 to 16.130 [409.58 to 409.70 mm]	0.008 [0.20 mm] TIR	0.008 [0.20 mm] TIR
4	14.250 to 14.255 [361.95 to 362.08 mm]	0.006 [0.15 mm] TIR	0.006 [0.15 mm] TIR
5	12.375 to 12.380 [314.33 to 314.45 mm]	0.006 [0.15 mm] TIR	0.006 [0.15 mm] TIR
6	10.500 to 10.505 [266.70 to 266.83 mm]	0.006 [0.15 mm] TIR	0.006 [0.15 mm] TIR

to 271 N•m] torque. Refer to Fig. 14-46 for torquing sequence.

2. Indicate clutch pilot bearing bore.

- a. Attach indicator gauge to side of flywheel housing. Fig. 14-47.
- b. Total indicator reading must not exceed 0.005 inch [0.13 mm] in one complete revolution.

3. Indicate flywheel clutch face.

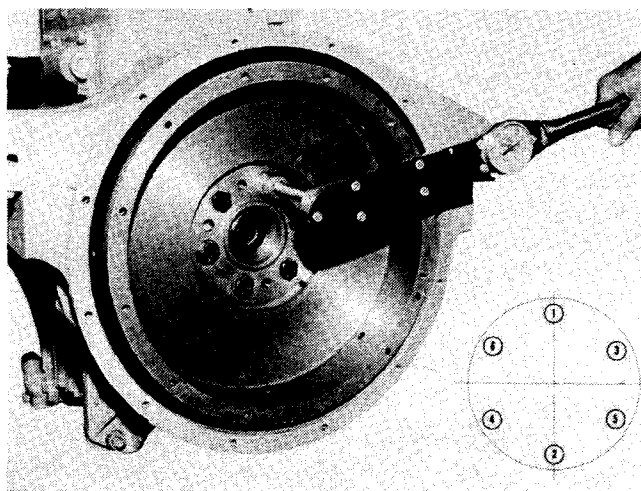


Fig. 14-46, (N11451). Flywheel torquing sequence

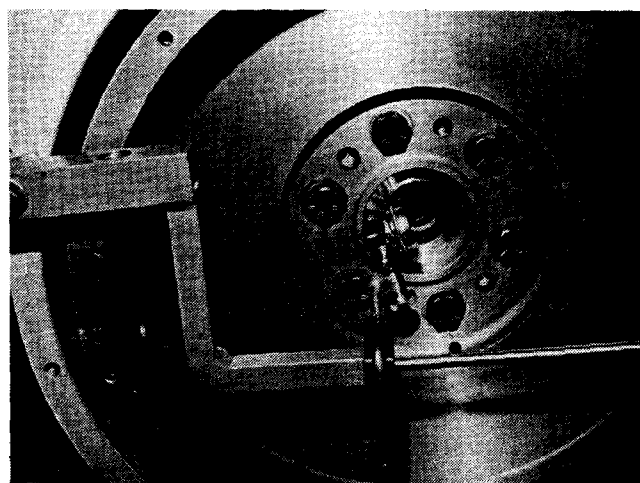


Fig. 14-47, (N114138). Indicating flywheel bearing bore

- a. Shift gauge to clutch face of flywheel. Fig. 14-48.

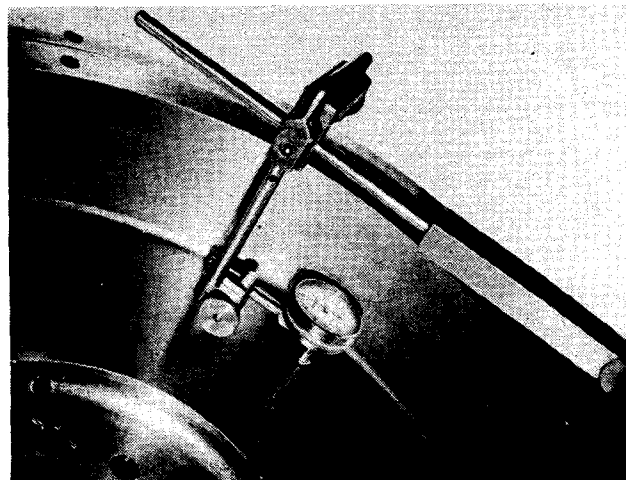


Fig. 14-48, (N114139). Indicating flywheel clutch face

- b. Total indicator reading must not exceed 0.0005 inch [0.013 mm] per inch [25.4 mm] of diameter of outer 1/3 of clutch face radius.

Note: If total indicator readings exceed limits listed in 2b and 3b above remove flywheel; clean flywheel and crankshaft flange faces, reinstate and repeat checks.

Oil Pan (With Body-Fit Bolts)

1. Two oil pan capscrew holes at flywheel end of block are reamed for body-fit bolts. If not previously installed, install bolts in block.
2. Install new oil pan gasket to cylinder block or pan.
 - a. When using new "tab-lock" gasket, paint oil pan flange with lubriplate. Start at either end of oil pan, lay gasket sections on oil pan flange. Proper assembly is assured by matching letter located on end of each gasket section.
 - b. Insert several capscrews through gasket and oil pan flange capscrew holes to line up. When gasket sealing compound dries, remove guide capscrews.
3. Check oil pan screen to make certain that it is properly assembled and that all screws are tight.
4. Assemble pan to block with nuts, lockwashers

and capscrews. On aluminum oil pans, install flat steel washers between pan and lockwashers.

5. If new pan is being installed prior to installing flywheel housing:
 - a. Position so buttress-end of pan is flush with end of block. Check with straight-edge.
 - b. Ream holes to next oversize and install oversize body-fit bolts.

Oil Pan (Less Body-Fit Bolts)

Oil pan currently used on 80 degree tilt engines have bosses drilled to accommodate oil gauge and filter bracket, alternator mounting bracket and lifting eyes. Brackets, lifting eyes and spacers, as used, should be installed during oil pan installation.

Note: Flywheel housing must be on engine.

1. Install guide studs in oil pan flange of block.
2. Shellac new oil pan gasket to oil pan flange of block.
3. Position oil pan over guide studs and start oil pan flange capscrews, flatwashers and lockwashers by hand.
4. Install and tighten middle buttress to flywheel housing capscrews with washers on both sides of oil pan. This pulls pan tight and square with flywheel housing.
5. Lock pan in position by tightening two (2) center capscrews on each side of block.
6. Loosen and remove buttress capscrews assembled and tightened in Step 4. (Capscrews must be removed to provide socket clearance to buttress corner capscrews.)
7. Tighten two (2) rear corner pan flange to block capscrews. This pulls the block and pan flanges together and ensures that pan is pulled firmly into corner by housing and block. Remove guide studs.
8. Insert and tighten all capscrews from 28 to 40 ft-lbs [38 to 54 N•m] torque.

9. Insert pan to rear cover plate flatwashers, lockwashers and capscrews; tighten to 15 to 20 ft-lbs [20 to 27 N•m] torque.

Oil Suction Tube

1. Assemble tube nuts and rubber sleeve lubricated with clean engine lubricating oil, to suction tube. Start nuts on oil pump adapter and oil pan flange, do not tighten.
2. Position oil pan flange with new gasket to oil pan. Do not tighten capscrews.
3. Push tube and sleeve into oil pump adapter until it bottoms and tighten nut 1 to 1-1/4 turn from finger tight. Fig. 14-49.



Fig. 14-49, (N114277). Installing oil suction tube

4. Tighten tube nut on oil pan suction flange finger tight. Torque suction flange to oil pan capscrews to 30 to 35 ft-lbs [41 to 47 N•m]. Tighten tube nut against stop on suction flange.

Fuel Pump

1. Position and secure fuel pump to fuel pump drive or air compressor with new gasket and buffer or spline in place; use same part number as removed. Tighten fuel pump mounting screws to 30 to 35 ft-lbs [41 to 47 N•m]. Fig. 14-50.
2. Install line from fuel pump shut-down valve to

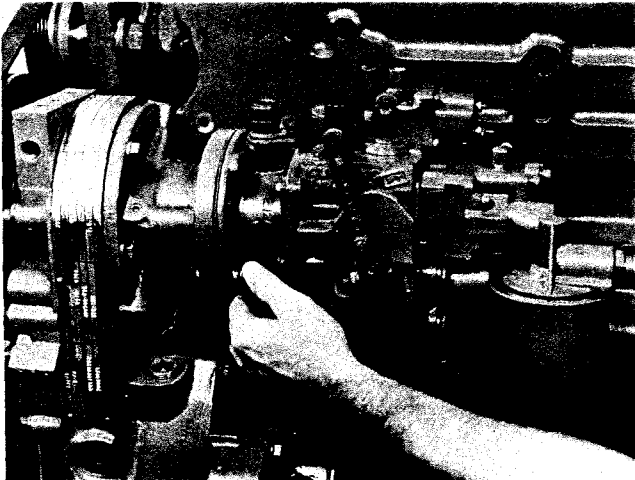


Fig. 14-50, (N114278). Installing fuel pump

cylinder head fuel drilling connection previously installed.

Injector Installation

1. Lubricate the injector body "O" rings with light coat of clean lubricating oil.
2. Start the injector assembly into bore, from intake side of engine. Injectors are to be placed with filter screen at 12 o'clock (PT type D may be turned to any position); guide by hand until injector is aligned.
3. Place ST-448 Valve Spring Compressor on top of injector plunger coupling and "seat" injector by giving a quick, hard push.
4. Place hold-down plate over injector body with counterbore up. Start hold-down capscrews. Do not tighten.
5. Carefully insert injector plunger link. Torque hold-down capscrews to 11 to 12 ft-lbs [15 to 16 N•m] in 4 ft-lb [5 N•m] increments.
6. Raise plunger 1/3 its own length and allow to fall back. If plunger binds or sticks, loosen capscrews and retorquer.

Water Manifold and Thermostat Housing

1. With "O" ring on water manifold connection, slip connection into manifold. Grease new

water manifold and thermostat housing sealing rings and place rings in cylinder heads; position and secure water manifolds to cylinder head.

2. Position and secure assembled thermostat housing to front section of water manifold and install water crossover, if used.

Valve Crosshead Adjustment

1. Position crossheads over guides with adjusting screw toward water manifold. Loosen adjusting screw locknut, back adjusting screw off one turn.

Note: Engines using Jacobs Brake use special crossheads on exhaust side of head. See Group 20.

2. Use light finger pressure at the rocker lever contact surface to hold crosshead in contact with valve stem nearest the push tube. Turn adjusting screw down until it contacts its mating valve stem. Fig. 14-51.



Fig. 14-51, (N114279). Adjusting valve crosshead

Note: With new crossheads and guides, advance adjusting screw one-third of one hex to straighten stem in its guide and to compensate for slack in thread. With worn crossheads and guides, it may be necessary to advance the screw as much as 1/2 hex in order to straighten the stem in its guide.

3. Hold adjusting screw in position and torque locknut to 25 to 30 ft-lbs [34 to 41 N•m]; or, if ST-669 Torque Wrench Adapter is used, tighten to 22 to 26 ft-lbs [30 to 35 N•m].

4. Check clearance between crosshead and valve spring retainer with wire gauge. There must be a minimum of 0.025 inch [0.64 mm] clearance.

Rocker Lever Housing

1. Position new rocker lever housing gasket on cylinder head.
2. Loosen locknuts and back off rocker lever adjusting screws so that there is a maximum of 1-1/4 inch [31.8 mm] between the machined surface at the top of the rocker lever and the top of the ball on the adjusting screw. See Fig. 14-52.

Caution: If the adjusting screw protrudes beyond this given maximum, bending of the push tubes may result as the rocker housing is torqued to the head.

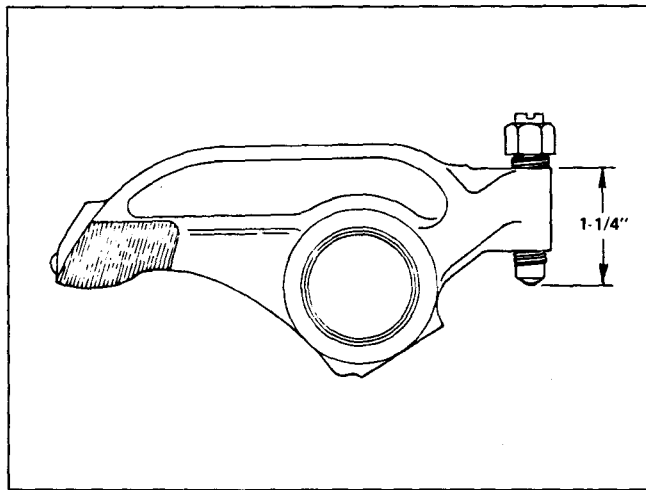


Fig. 14-52, (N114). Rocker lever adjusting screw position

3. Holding rocker levers in place, position housing on heads with ball ends of rocker levers fitting into their respective push tube sockets. Install brackets and fan hub bracket support bell crank, if used.
4. Secure housing, brackets, and support with capscrews. Tighten in sequence (Fig. 14-53), to 55 to 65 ft-lbs [75 to 89 N•m] torque.

Note: On 80 degree tilt engines use ST-1182 Valve Spring Spray Nozzle Locator to check that oil spray nozzles are properly located.

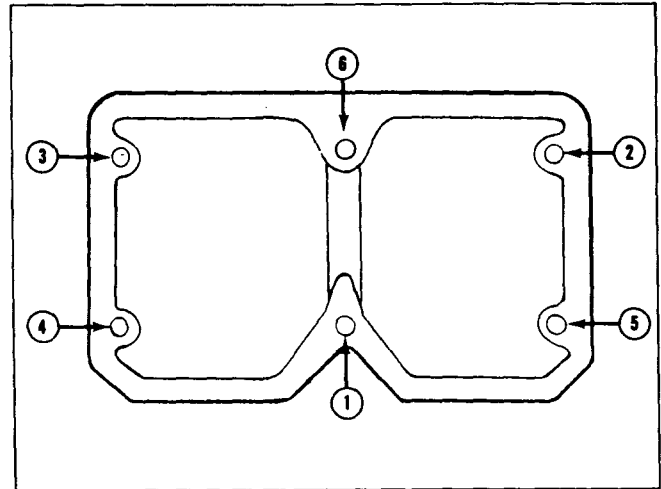


Fig. 14-53, (N11463). Torquing sequence for rocker lever housing

Jacobs Brake

Install Jacobs Brake, if used. See Group 20.

Compression Release Lever

1. Install dowel in cylinder block if removed.
2. Position upper lever and bracket assembly to front rocker arm housing and secure.
3. Using screwdriver in slot in end of compression release shaft, turn shaft clockwise until lifting notch contacts a valve push tube collar. Move compression release shaft lever to middle of travel; secure with clamping screw.
4. Secure spring on cylinder head with capscrew; hook spring in lever on compression release shaft. Attach link to lower and upper lever; secure with cotter pins.

Valve and Injector Adjustment

Adjust Injectors, Crossheads and Valves

Before adjusting injectors and valves be sure to determine if rocker housings are cast iron or aluminum and use appropriate setting.

Two methods of adjusting injectors and valves are described in this manual. The preferred method is Uniform Plunger Travel. This method involves adjusting plunger with ST-1270 Injector Indicator

Kit (consists of ST-1170 Dial Indicator, ST-1193 Actuator and ST-1250 Actuator) to a specified travel. The second method involves setting plunger adjusting screw to a specified torque setting. It is essential that injectors and valves be in correct adjustment at all times.

Temperature Settings

The following temperature conditions provide the necessary stabilization of engine components to assure accurate adjustments.

Cold Setting

Engine must have reached a stabilized temperature (oil and/or component temperature to be within 10° F of ambient air temperature).

Note: At rebuild period this setting is obtained through normal room temperature.

Hot Setting

1. Set injectors and valves immediately after the engine has reached normal stabilized operating oil temperature.
2. If oil temperature gauge is unavailable, set injectors and valves immediately after engine has operated at rated speed and load or at high idle for a period of 40 minutes. If slotted thread adjusting screws are used, 20 minutes is sufficient.

Adjustment After Engine Rebuild

During rebuild, adjust injectors and valves using appropriate values in the "Cold Set" column. The engine must then run until normal oil operating temperature has been obtained to allow stability of structural components as affected by gasket replacements. Recheck injectors and valves. See Engine Test Procedure, Phase 4.

Injector and Valve Adjustment

Dial Indicator Method Using ST-1170

1. If used, pull compression release lever back while barring engine. This allows crankshaft to be rotated without working against compression.

2. Bar engine until "A" or 1-6 "VS" mark on pulley (Fig's. 14-54 and 14-55), is aligned with pointer on gear case cover. In this position, both valve rocker levers for cylinder No. 5 must be free (valves closed). Injector plunger for cylinder No. 3 must be at top of travel; if not,

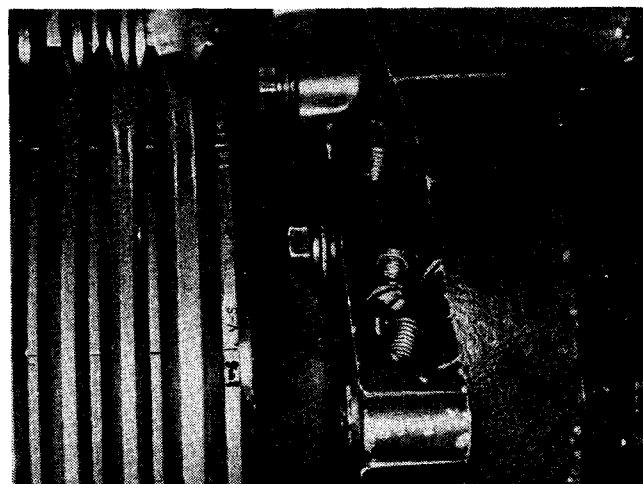


Fig. 14-54, (N114220). Valve set timing marks

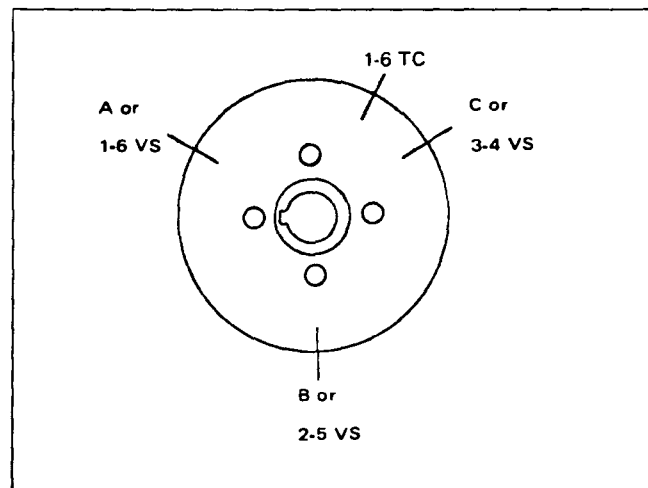


Fig. 14-55, (N114230). Accessory drive pulley markings

bar engine 360 degrees, realign marks with pointer.

3. Turn adjusting screw down on cylinder being adjusted until plunger contacts cup and advance an additional 15 degrees to squeeze oil from cup. Loosen adjusting screw 1/2 turn.
4. Set up ST-1170 Indicator Support with indica-

tor extension on injector plunger top at No. 3 cylinder. Fig. 14-56. Make sure indicator extension is secure in indicator stem and not against rocker lever.

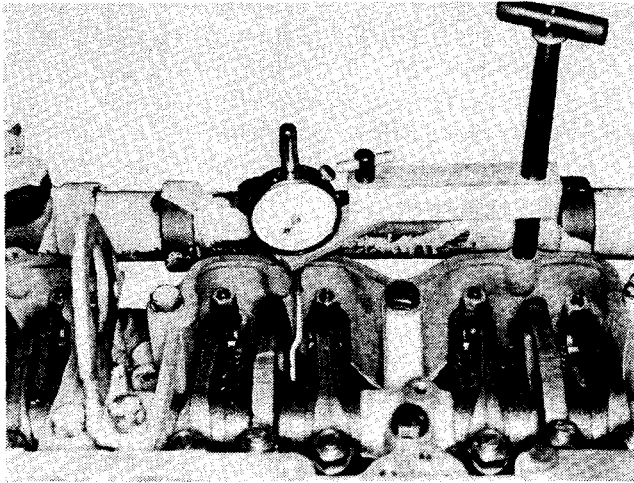


Fig. 14-56, (N114231). Dial indicator in place — extension in contact with plunger

Note: Cylinder No. 3 for injector setting and cylinder No. 5 for valve setting are selected for illustration purposes only. Any cylinder combination may be used as a starting point; see Table 14-6 and firing order Table 14-7.

5. Using ST-1193 Rocker Lever Actuator (Fig. 14-57), or equivalent, bar lever toward injector until plunger is bottomed. Allow injector plunger to rise, bottom again, set indicator at zero

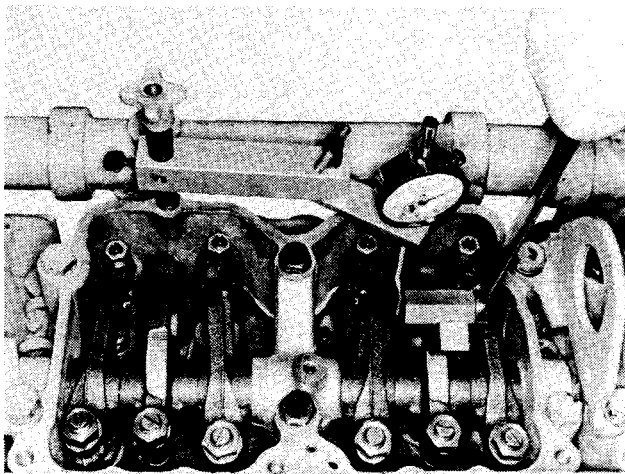


Fig. 14-57, (N114237). Bottoming injector plunger in cup

- (0). Check extension contact with plunger top, turn adjusting screw until Adjustment Value, Table 14-8 is obtained.

6. Bottom plunger again, release lever; indicator must show travel as indicated.

Table 14-6: Injector and Valve Set Position

Bar in Direction	Pulley Position	Set Cylinder	
		Injector	Valve
Start	A or 1-6 VS	3	5
Adv. To	B or 2-5 VS	6	3
Adv. To	C or 3-4 VS	2	6
Adv. To	A or 1-6 VS	4	2
Adv. To	B or 2-5 VS	1	4
Adv. To	C or 3-4 VS	5	1

Table 14-7: Engine Firing Order

Right Hand:	1-5-3-6-2-4	Left Hand:	1-4-2-6-3-5
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Table 14-8: Uniform Plunger Travel Adjustment Limits

Oil Temp.	Injector Plunger Travel		Valve Clearance	
	Inch [mm]		Inch [mm]	
	Adj. Value	Recheck Limit	Intake	Exhaust
Aluminum Rocker Housing				
Cold	0.170 [4.32]	0.169 to 0.171 [4.29 to 4.34]	0.011 [0.28]	0.023 [0.58]
Hot	0.170 [4.32]	0.169 to 0.171 [4.29 to 4.34]	0.008 [0.20]	0.023 [0.58]
Cast Iron Rocker Housing				
Cold	0.175 [4.45]	0.174 to 0.176 [4.42 to 4.47]	0.011 [0.28]	0.023 [0.58]
Hot	0.175 [4.45]	0.174 to 0.176 [4.42 to 4.47]	0.008 [0.20]	0.023 [0.58]

7. Tighten locknut to 40 to 45 ft-lbs [54 to 61 N•m] and actuate injector plunger several times as a check of adjustment. Tighten to 30 to 35 ft-lbs [41 to 47 N•m] when using ST-669 Adapter.

Crosshead Adjustment

1. Loosen valve crosshead adjusting screw locknut and back off adjusting screw (Fig. 14-58) one turn.

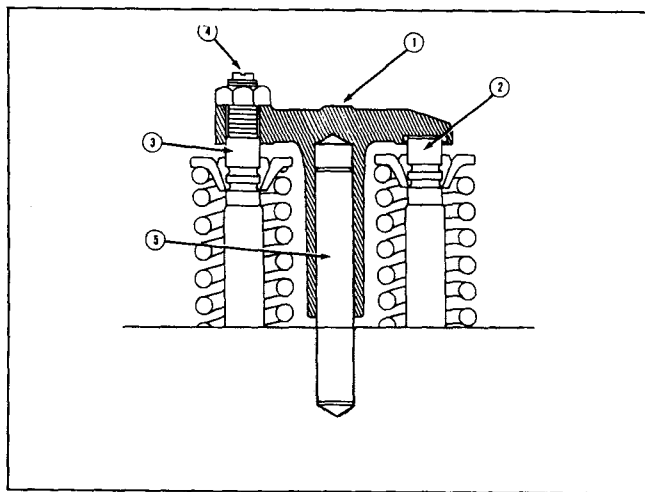


Fig. 14-58, (N21461). Valve crosshead

2. Use light finger pressure at rocker lever contact surface (1) to hold in contact with valve stem (2). Turn down adjusting screw until it touches valve stem (3).
3. Advance setscrew an additional 20 to 30 degrees to straighten stem on its guide. Using ST-669 Torque Wrench Adapter, tighten locknuts to 22 to 26 ft-lbs [30 to 35 N•m]. If ST-669 is not available, hold screws with screwdriver and tighten locknuts to 25 to 30 ft-lbs [34 to 41 N•m].
4. Check clearance between crosshead and valve spring retainer with wire gauge. There must be a minimum of 0.025 inch [0.64 mm] clearance.

Valve Adjustment

The same engine position (VS Mark) used to adjust injectors is used for setting intake and exhaust valves, however, the valves to be adjusted are not the same cylinder as injectors. In this position adjust valves for cylinder No. 5. See Table 14-6.

1. While adjusting valves, make sure compression release, on those engines so equipped, is in running position.

2. Loosen locknut and back off adjusting screw. Insert feeler gauge between rocker lever and crosshead. Valve clearances are shown in Table 14-8. Turn screw down until lever just touches gauge and lock in this position. Tighten locknut to 40 to 45 ft-lbs [54 to 61 N•m] torque. When using ST-669, torque to 35 to 40 ft-lbs [47 to 54 N•m].
3. Always make valve adjustment after injector adjustment. Move to next cylinder as indicated in Table 14-7 and repeat adjustments.

Top Stop Injector Adjustment

When top stop injectors are used, cold set to zero (0) as follows:

1. A zero clearance setting is made at same injector adjustment position as with dial indicator method (inner base of cam lobe).

Caution: Top stop injector plunger travel can only be adjusted when injectors are removed from engine using 3375160 Adjusting Tool.

2. When engine has been set in proper position for injector to be adjusted, tighten adjusting screw until all lash is removed from injector train. Then tighten adjusting screw one additional turn to properly seat links and to squeeze oil from socket surfaces. Back adjusting screw off until spring washer contacts stop. Now adjust zero clearance. Use 3375232 Torque Wrench and tighten screw to 5 to 6 in-lbs [0.56 to 0.68 N•m] torque. Fig. 14-59. Zero clearance is defined as the condition where the link is slightly loaded.

Note: If torque wrench is not available, zero clearance can be set at the point where the link is slightly loaded, but just free enough to be rotated by thumb and forefinger.

3. Hold adjusting screw with screwdriver and tighten locknut to 40 to 45 ft-lbs [54 to 61 N•m]. Tighten to 30 to 35 ft-lbs [41 to 47 N•m] when using ST-669 Adapter.

Adjust Injectors and Valves (Torque Method)

1. If used, pull compression release lever back