

ENGINE BALANCE AND BALANCE WEIGHTS

In the balance of two-cycle engines, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds: unbalanced forces and unbalanced couples. These forces and couples are considered as primary or secondary according to whether their frequency is equal to engine speed or twice engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are of small consequence in comparison to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple due to their arrangement on the crankshaft. On a V-type engine, this unbalanced couple tends to move the ends of the engine in an elliptical path; on an In-line engine, it tends to rock the engine from end to end in a vertical plane. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the camshafts (V-type engine) or at the outer ends of the balance shaft and camshaft (In-line engine). This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

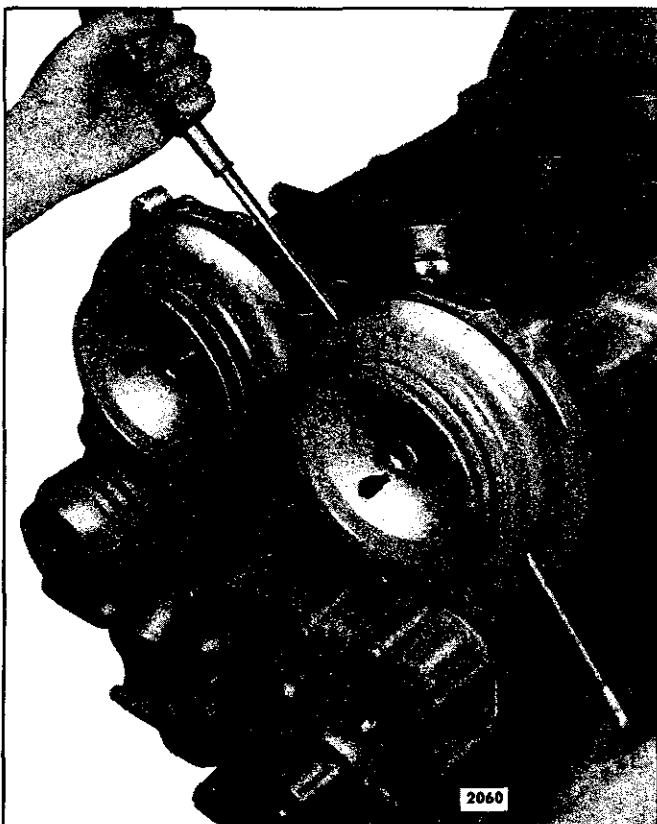


Fig. 1 - Removing Front Balance Weight (Pulley Type)

On the camshafts (V-type engine) or balance shaft and camshaft (In-line engine), each set of weights (weights on the outer ends of each shaft comprise a set) rotates in an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, cancelled. The front balance weights act in a direction opposite to the rear balance weights; therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple.

The balance weights are integral with the gears and the circular balance weights (pulleys) on the shafts. Additional weights are attached to the camshaft and balance shaft gears on two, three and four cylinder engines.

Both the rotating and primary reciprocating forces and couples are completely balanced in the engines. Consequently, the engines will operate smoothly and in balance throughout their entire speed range.

Effective with engine serial numbers 3D-193526, 4D-209292 and 6D-229545 new camshaft front pulleys and weights are used with new bolt-on balance weights which are attached to the rear camshaft gears. When replacing the trunk type pistons with cross-head type pistons in an engine, the new camshaft front pulleys and heavier weights must be used.

When the cross-head pistons are to be installed in an engine built prior to serial numbers 3D-193526, 4D-209292 or 6D-229545, and an in-frame overhaul is desired, a new bolt-on rear balance weight must be used in addition to the existing balance weight attached to the flywheel housing side of each rear camshaft gear. Refer to Section 1.0 for the installation procedure.

Remove Front Balance Weights

1. Remove the nut at each end of both shafts as outlined in Section 1.7.2.
2. Force the balance weight off the end of each shaft, using two screw drivers or pry bars between the balance weight and the upper front cover (Fig. 1).

Install Front Balance Weights

1. Reinstall the Woodruff keys in the shafts, if they were removed.
2. Align the keyway in the balance weight with the key in the shaft, then slide the weight on the shaft. If the weight does not slide easily onto the shaft, loosen the thrust washer retaining bolts at the opposite end of the shaft. Then, to prevent possible damage to the thrust washer, support the rear end of the shaft while tapping the weight into place with a hammer and a sleeve. Retighten the thrust washer retaining bolts to 30–35 lb–ft (41–47 N·m) torque. Install the other weight in the same manner.
3. Wedge a clean rag between the gears. Refer to Section 1.7.2 and tighten the gear retaining nuts to 300–325 lb–ft (407–441 N·m) torque. Then, tighten the front balance weight retaining nuts to 300–325 lb–ft (407–441 N·m) torque. Remove the rag from the gears.

GEAR TRAIN AND ENGINE TIMING

GEAR TRAIN

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the Series 53 engine.

The gear train on an In-line engine consists of a crankshaft gear, an idler gear, a camshaft gear and a balance shaft gear (Fig. 1). The governor drive gear, the upper blower rotor gear for the two and three cylinder engines, and the blower drive gear for the four cylinder engine are driven by the camshaft gear or balance shaft gear, depending upon the engine model.

The gear train on a 6V engine (Fig. 2) or an 8V engine (Fig. 3) consists of a crankshaft gear, an idler gear and two camshaft gears. The accessory drive (fuel pump drive — Section 2.2.1) gear is driven by a camshaft gear.

To reduce the level of engine noise in the Series 53 engines, the pitch and pressure angle of the gear train and accessory drive gears has been changed. This is effective with

engine serial numbers 3D-170683, 4D-180939 and 6D-196535.

This reduction in noise level has been accomplished by changing the gear pitch from 14 to 16 and the pressure angle from 20° to 16°. Identification of the new and former gears can be made by counting the number of teeth in the gears (Table 1).

The former individual 20° angle main gear train gears (crankshaft, idler, balance and camshaft gears) will be available for service until stock is exhausted. Then, when any one gear requires replacement, all of the gears in the gear train must be changed to the 16° angle gears. The former governor, fuel pump, blower rotor and blower drive gears will continue to be serviced, as well as the new gears.

On In-line and 6V engines, the crankshaft gear is pressed on and keyed to the end of the crankshaft. On 8V engines, the crankshaft gear is keyed and bolted to the end of the crankshaft.

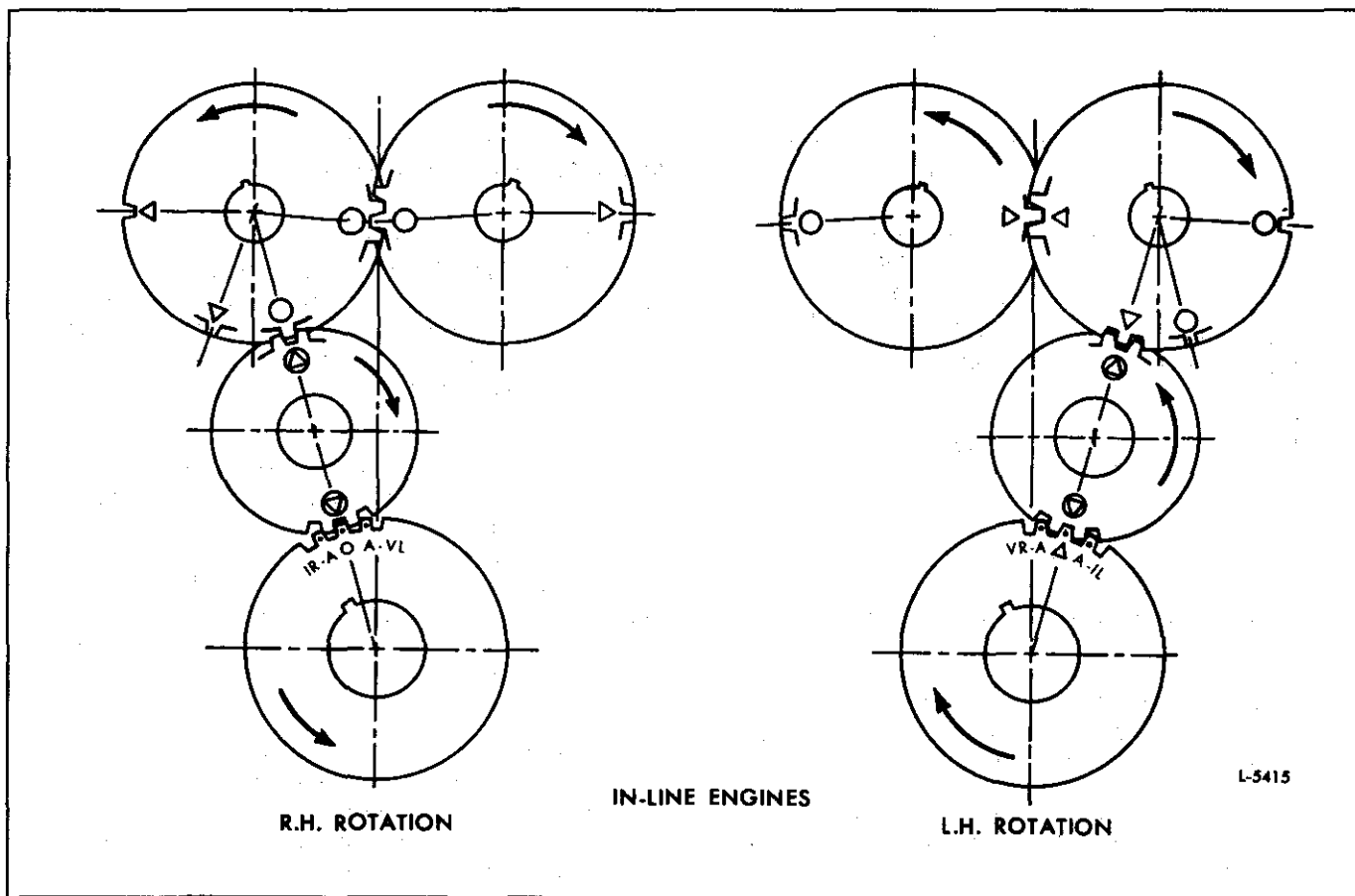


Fig. 1 – In-Line Engine Gear Train Timing Mark (Standard Timing Shown)

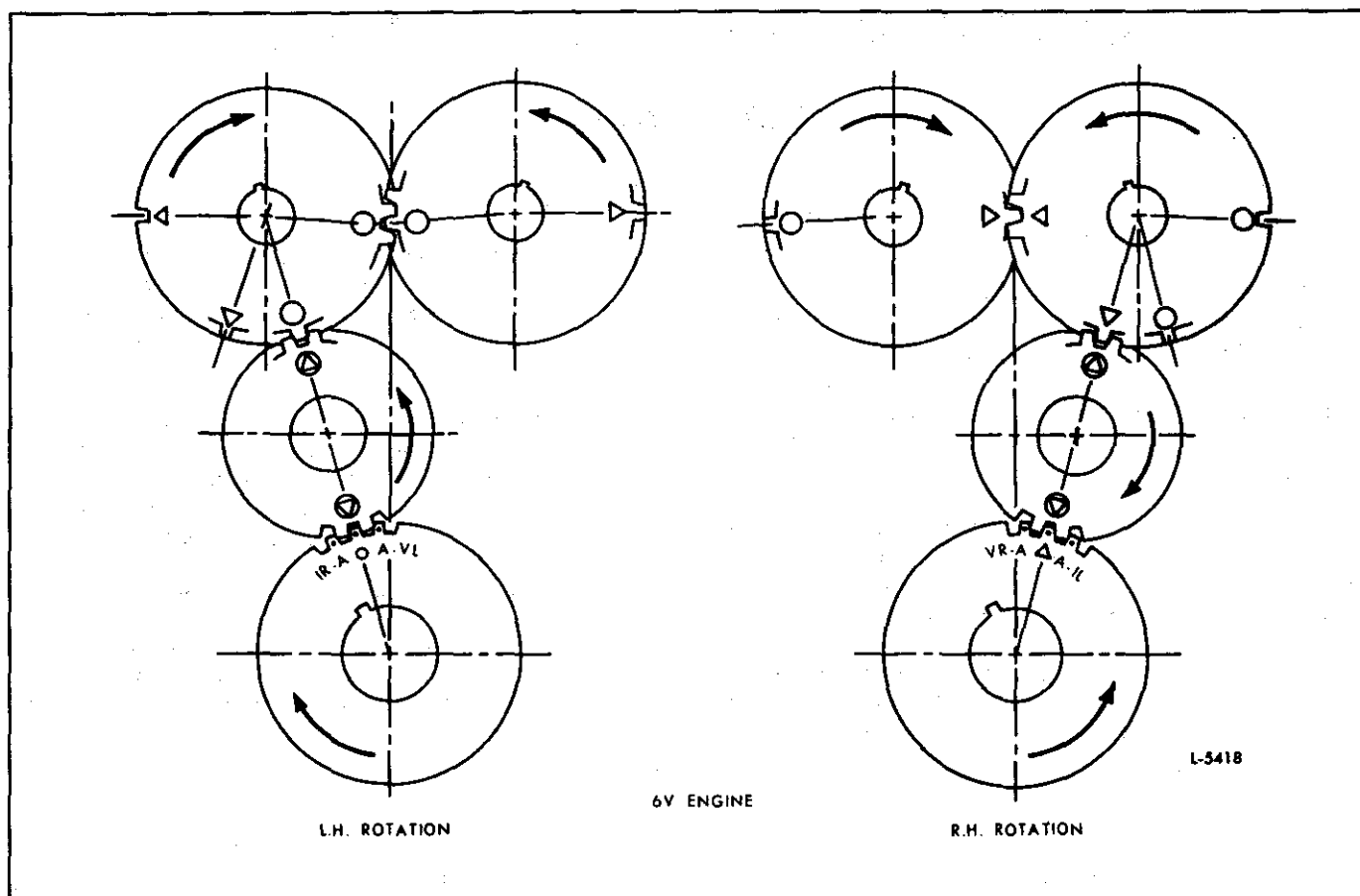


Fig. 2 - 6V Engine Gear Train Timing Marks (Standard Timing Shown)

Gear	Number of Teeth	
	Former	New
Crankshaft	97	111
Balance and Cam	97	111
Idler	72	82
Blower Drive	39	45
Blower Rotor	39	45
Governor Drive	49	56
Fuel Pump Drive	49	56

TABLE 1

The idler gear rotates on a stationary hub.

The camshaft and balance shaft gears on In-line engines and the camshaft gears on 6V and 8V engines are pressed on and keyed to their respective shafts and each gear is secured by a retaining nut and lock plate.

The crankshaft, idler, camshaft and balance shaft gears on In-line and 6V engines are completely interchangeable with each other. However the 8V crankshaft gear, idler gear and camshaft gears are not interchangeable with the In-line and 6V engine gears.

Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage. The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

On In-line engines, the camshaft and balance shaft gears have additional weights attached to the rear face of each gear. Different size weights are used on the three and four cylinder engines. These weights are important in maintaining perfect engine balance. Additional balance weights are not required on 6V camshaft gears. On early 8V engines, the camshaft gears have additional weights attached to the rear face of each gear. On current 8V engines, additional balance weights are not required.

The camshaft and balance shaft gears on an In-line engine, and the two camshaft gears on 6V and 8V engines, mesh with each other and run at the same speed as the crankshaft gear. Since the camshaft gears must be in time with each other, and the two as a unit in time with the crankshaft gear, timing marks have been stamped on the face of the gears to facilitate correct gear train timing.

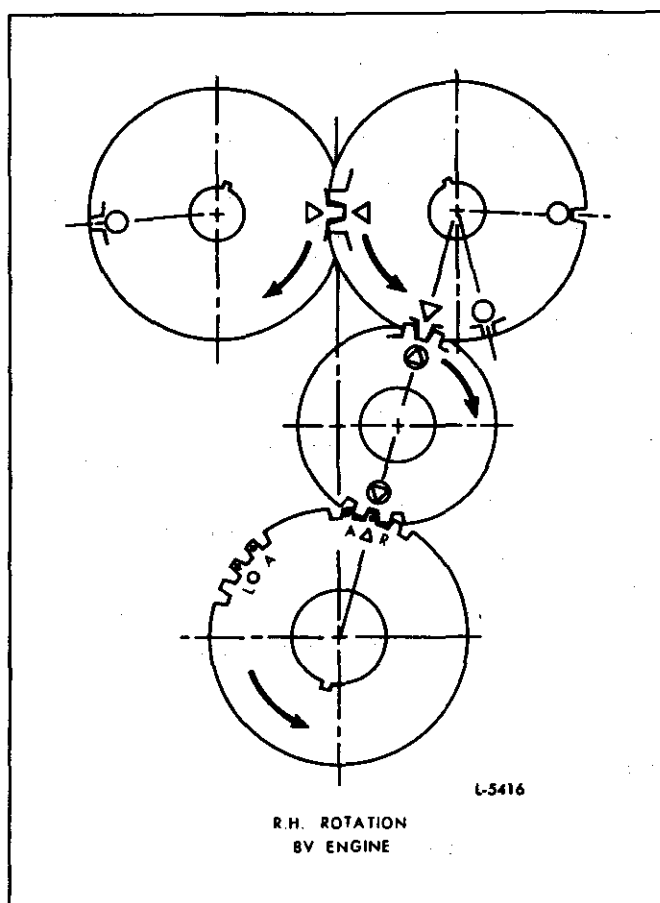


Fig. 3 - 8V Engine Gear Train Timing Marks
(Standard Timing Shown)

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, it is important to remember the engine rotation. Then, working from the crankshaft gear to the idler gear and to the camshaft and/or balance shaft gear in that order, line up the appropriate circle symbols on the gears or the appropriate triangles as each gear assembly is installed on the engine. Refer to Figs. 1, 2 and 3 for a typical gear train timing arrangement.

It is advisable to make a sketch indicating the position of the timing marks *before* removing or replacing any of the gears in the gear train.

The circle and the triangle are the basic timing symbols stamped on the gears. The letters stamped on the crankshaft gears identify the proper timing marks for the particular engine: "I" represents "In-line" engine, "V" represents V-type engine, "R" represents right-hand rotation engine, "L" represents left-hand rotation engine and "A" represents advanced timing.

Effective with engine serial numbers 3D-64404, 4D-65954, 6D-66099 and 8D-3826, all Series 53 vehicle engines are built with advanced timing. The timing is

advanced by aligning the proper "A" timing mark on the crankshaft gear with the circle-triangle timing mark on the idler gear.

IN-LINE ENGINE:

The camshaft and balance shaft gears are positioned so that the circle timing marks are adjacent to each other (Fig. 1).

1). One circle-triangle timing mark on the idler gear is aligned with the second "circle" on the mating camshaft (or balance shaft) gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "IR-A" on the left side of the circle timing mark for a right-hand rotation engine (Fig. 1). For *standard timing*, the circle on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" adjacent to the "IR" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

The crankshaft timing gear is stamped "A-IL" on the right side of the triangle timing mark (Fig. 1) for a left-hand rotation engine. For *standard timing*, the "triangle" on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" adjacent to the "IL" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

6V ENGINE:

The camshaft gears are positioned so that the triangle timing marks are adjacent to each other (Fig. 2). One circle-triangle timing mark on the idler gear is aligned with the second "triangle" on the mating camshaft gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "VR-A" on the left side of a triangle timing mark for a right-hand rotation engine (Fig. 2). For *standard timing*, the "triangle" on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advance timing*, the "A" adjacent to the "VR" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

The crankshaft timing gear is stamped "A-VL" on the right side of a circle timing mark for a left-hand rotation engine (Fig. 2). For *standard timing*, the "circle" on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" adjacent to the "VL" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

8V ENGINE:

The camshaft gears are positioned so that the triangle timing marks are adjacent to each other (Fig. 3). One circle-triangle timing mark on the idler gear is aligned with

the second "triangle" on the mating camshaft gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped "A-triangle-R". For *standard timing*, the triangle on the crankshaft gear is aligned with the circle-triangle on the idler gear. For *advanced timing*, the "A" on the crankshaft gear is aligned with the circle-triangle on the idler gear.

Refer to the *General Information* section for the various gear train arrangements.

There are no timing marks on the governor drive gear, blower rotor gears, blower drive gear or the accessory drive (fuel pump) gear. Therefore, it is not necessary to align these gears in any particular position when meshing the various gears with the camshaft or balance shaft gears.

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth or excessive bearing wear. Therefore, when noise develops in a gear train, remove the flywheel housing and inspect the gear train and

its bearings. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

The backlash between the various mating gears in the gear train (former and current) should be .0005" to .005", except the blower rotor gears which should be .0005" to .0025". Maximum permissible backlash between worn blower gears is .0035" and should not exceed .007" clearance between all other gears in the gear train.

Lubrication

The gear train is lubricated by the overflow of oil from the camshaft and balance shaft pockets spilling into the gear train compartment. A certain amount of the oil also spills into the gear train compartment from the camshaft and balance shaft end bearings and the idler gear bearing. The blower drive gear bearing on the four cylinder In-line engine is lubricated through an external pipe leading from the cylinder block main oil gallery to the gear hub support. The idler gear bearing and the accessory (fuel pump) drive gear on the 6V or 8V engine is lubricated by oil directly from the cylinder block main oil gallery to the bearing hubs.

ENGINE TIMING

The correct relationship between the crankshaft and camshaft(s) must be maintained to properly control fuel injection and the opening and closing of the exhaust valves.

The crankshaft timing gear can be mounted in only one position since it is keyed to the crankshaft. The camshaft gear(s) can also be mounted in only one position due to the location of the keyway relative to the cams. Therefore, when the engine is properly timed, the markings on the various gears will match (Figs. 1, 2 and 3).

Preignition, uneven running and a loss of power may result if an engine is "out of time".

When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without removing the flywheel and flywheel housing by following the procedure outlined below.

Check Engine Timing

Access to the crankshaft pulley, to mark the top dead center position of the selected piston, and to the front end of the crankshaft or the flywheel for turning the crankshaft is necessary when performing the timing check. Then, proceed, as follows:

1. Clean and remove the valve rocker cover. Discard the gasket(s).
2. Select any cylinder for the timing check.

3. Remove the injector as outlined in Section 2.1 or 2.1.1.
4. Carefully slide a rod, approximately 12" long, through the injector tube until the end of the rod rests on top of the piston. Place the throttle in the *no-fuel* position. Then, turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
5. Select a dial indicator with .001" graduations and a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also, select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.
6. Mount the indicator over the injector tube. Check to be sure the indicator spindle extension is free in the injector tube and is free to travel at least one inch.
7. Attach a suitable pointer to the engine lower front cover. The outer end of the pointer should extend out over the top of the crankshaft pulley.
8. Turn the crankshaft slowly, in the direction of engine rotation, until the indicator hand just stops moving.

9. Continue to turn the crankshaft, in the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is .010".
10. Scribe a line on the crankshaft pulley in line with the end of the pointer.
11. Slowly turn the crankshaft, opposite the direction of rotation, until the indicator hand stops moving.
12. Continue to turn the crankshaft, opposite the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is .010".
13. Scribe the second line on the crankshaft pulley in line with the end of the pointer.
14. Scribe a third line on the pulley half way between the first two lines. This is top dead center.

If the crankshaft pulley retaining bolt loosened up, tighten it to the torque specified in Section 1.0.

15. Remove the dial indicator and rod from the engine.
16. Install the injector as outlined in Section 2.1 or 2.1.1. Then, refer to Section 14 and adjust the exhaust valve clearance and time the fuel injector.
17. Turn the crankshaft, in the direction of rotation, until the exhaust valves in the cylinder selected are completely open. Reinstall the dial indicator so the indicator spindle rests on the top of the injector follower. Then, set the indicator on zero. Next turn the crankshaft slowly, in the direction of rotation, until the center mark on the pulley is in line with the pointer.
18. Check the front end of the camshaft for an identification mark. For identification purposes, a

camshaft with no designation on the ends or a "7" stamped on the ends is a high-velocity high-lift camshaft. A camshaft metal stamped with a "V" or "V7" is a low-velocity high-lift camshaft. Effective with engines 4D-112278 and 6D-60777, new camshafts metal stamped "V7L" are used, intermittently in the 4-53 and 6V engines. These are low velocity low-lift camshafts. Note the indicator reading and compare it with the dimensions listed in Table 2 for the particular camshaft in the engine.

19. Remove the dial indicator. Also, remove the pointer attached to the front of the engine.
20. Use new gasket(s) and install the valve rocker cover.

Engine	*INDICATOR READING		
	Correct	Retarded 1-Tooth	Advanced 1-Tooth
	STANDARD TIMING		
(1) 2,3,4 & 6V	.228"	.204"	.245"
(2) 3,4,6V & 8V	.206"	.179"	.232"
ADVANCED TIMING			
(2) 3,4,6V & 8V	.232"	.206"	.258"

* Indicator readings shown are nominal values. The allowable tolerance is $\pm .005$ in.

(1) High velocity type injector cam.

(2) Low velocity type injector cam.

TABLE 2

CAMSHAFT, BALANCE SHAFT AND BEARINGS

The camshaft and balance shaft used in the In-line engines, or the two camshafts used in the V-type engines, are located just below the top of the cylinder block. The camshaft and balance shaft in the In-line engines may be positioned on either side of the engine as required by the engine rotation and accessory arrangement. The camshafts in the V-type engine are positioned according to engine rotation.

The accurately ground cams ensure efficient, quiet cam follower roller action. They are also heat treated to provide a hard wear surface.

Both ends of the shafts are supported by bearings (bushing type) that are pressed into bores in the cylinder block. The balance shaft is supported by front and rear bearings only, whereas the camshaft is supported by end, intermediate and center bearings. Two end bearings (front and rear), two intermediate bearings and a center bearing are used in the 4-53 and 8V-53 engines to support the camshafts. The camshafts in the 3-53 and 6V-53 engine are supported by two end bearings and two intermediate bearings.

To facilitate assembly, letters signifying the engine models in which a shaft may be used are metal stamped on the ends of the shaft. The letters on the timing gear end of the camshaft must correspond with the engine model. For example, the letters RC are stamped on a camshaft used in an RC model engine. For additional identification, a camshaft with no designation on the ends or a "7" stamped on the ends is a high-velocity high-lift camshaft. A camshaft metal stamped with a "V" or "V7" is a low-velocity high-lift camshaft. Effective with engines 4D-112278 and 6D-60777, new camshafts metal stamped "V7L" are used intermittently in the 4-53 and 6V-53 engines. These are low-velocity low-lift camshafts.

On 4-53 and 6V-53 engines the present low-lift camshaft must be used in conjunction with the new exhaust valve springs. Failure to change the exhaust valve springs could result in broken springs and engine failure. Refer to Section 1.2.2.

The low-lift camshaft which provides a maximum valve cam lobe lift of .276" is stamped "V7L" on both ends.

To provide proper camshaft end thrust, a new front camshaft pulley spacer is being used and the oil slinger has been eliminated, effective with engine serial numbers 3D-158108, 4D-164682 and 6D-180763. Engines built prior to 1968 were built with an oil slot broached in the camshaft end bearing. With pressure oil from this slot flowing directly on the upper front cover oil seal, the seal required the protection of an oil slinger. Even though the slot was eliminated in 1968 the use of the slinger was continued. With the elimination of the oil slinger, a new .025" longer

spacer is used to make up for the removal of the slinger. Therefore, when removing the oil slinger(s) from an engine built prior to the above serial numbers, it will be necessary to replace the shorter spacer(s) with the new .025" longer spacer. Removal of the oil slinger on former engines is not mandatory. The former short spacer and slinger are for engines built prior to 1968 (engine serial numbers 2D-23442, 3D-44069, 4D-48900 and 6D-41029).

The new spacer is identified with a black oxide finish, the same part number also incorporates an optional material (powered metal) which is identified with an indent in the top surface below the chamfer.

A method of identifying a camshaft with the cylinder head still installed is as follows:

1. Put a dial indicator on the rocker arm clevis.
2. Bar the engine over 360° and the indicator will give a reading directly relative to the maximum amount of lift on the high point of the camshaft exhaust lobe.
 - a. The 4-53 low-lift camshafts have a .276 maximum lift.
 - b. The 4-53 high-lift camshafts have a .327 maximum lift.
3. The above can be accomplished with the cylinder head removed by placing the dial indicator directly on the exhaust valve lobe of the camshaft. A reading of the maximum camshaft lift can be taken at the high point of the lobe.

● New camshafts, balance weights, and accessory drive pulleys are used in turbocharged industrial engines equipped with crosshead pistons and bypass blowers, effective with unit serial numbers 3D193526, 4D209292, 6D0229545. The camshafts feature a revised cam lobe surface finish. To conform with the increased weight of the crosshead pistons, new rear balance weights and front cam and balance shaft pulleys are also required. The new weights and pulleys assist in maintaining an acceptable level of engine vibration.

NOTICE: Do not mix trunk style and crosshead style piston assemblies in the same engine. Do not mix former and new balance weights in the same engine or use a former camshaft with a new camshaft in the same 6V-53 engine. Failure to observe these precautions can result in serious engine damage.

Lubrication

Lubrication is supplied under pressure to the camshaft and balance shaft end bearings via oil passages branching off from the main oil gallery direct to the camshaft end bearings.

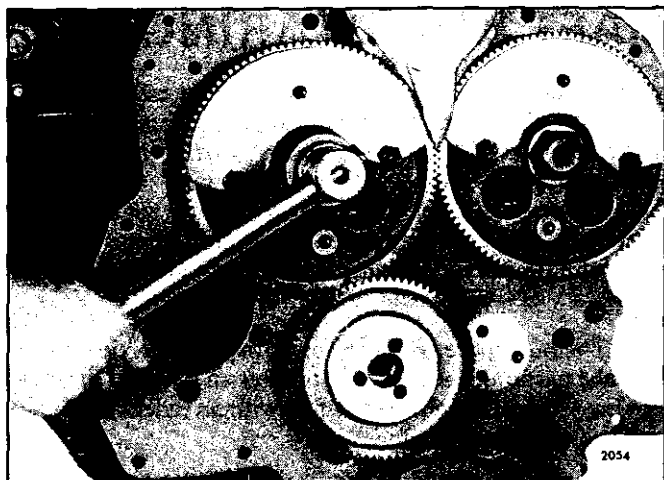


Fig. 1 – Removing or Installing Nut on Camshaft or Balance Shaft

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. On the current camshafts, the intermediate journal oil grooves were eliminated and a chamfer added to the intermediate journal oil holes. When replacing a former camshaft with a current camshaft, always use new bearings.

All of the camshaft and balance shaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

Remove Camshaft or Balance Shaft

Whenever an engine is being completely reconditioned or the bearings, thrust washers or the gears need replacing, remove the shafts from the engine as follows:

Refer to *Shop Notes* in Section 1.0 to install a cup plug in the front end of the camshaft.

1. Drain the engine cooling system.
2. Remove all accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand (See Section 1.1).
3. Mount the engine on an overhaul stand. *Be sure the engine is securely mounted on the stand before releasing the lifting sling.*
4. Remove the cylinder head(s). Refer to Section 1.2.
5. Remove the flywheel and the flywheel housing as outlined in Sections 1.4 and 1.5.
6. Remove the bolts which secure the gear nut retainer plates (if used) to the gears, then remove the retainer plates.

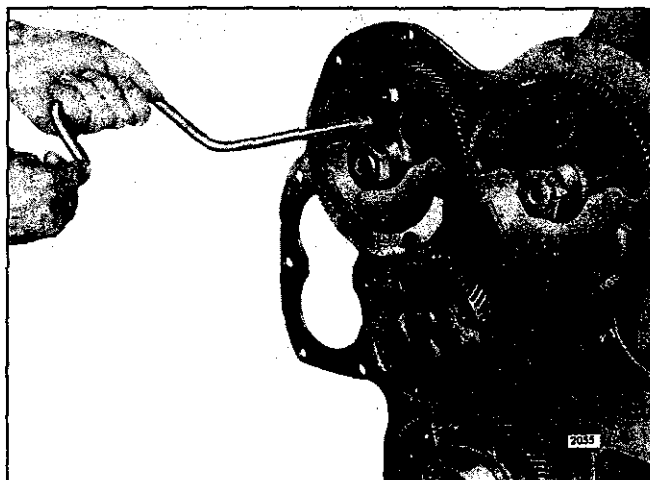


Fig. 2 – Removing or Installing Thrust Washer Retaining Bolts

7. Wedge a clean rag between the gears and remove the nuts from each end of both shafts with a socket wrench (Fig. 1).
8. Remove the balance pulleys from the front end of the shafts as outlined in Section 1.7.
9. Remove the upper engine front cover (Section 1.7.8).
10. Remove the oil slinger from the front end of both shafts.
11. Remove the two retaining bolts that secure the camshaft or balance shaft thrust washer to the cylinder block by inserting a socket wrench through a hole in the web of the gear (Fig. 2).
12. Withdraw the shaft, thrust washer and gear as an assembly from the rear end of the cylinder block.

Remove Camshaft (Flywheel Housing and Transmission in Place)

A camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission, if there is space enough to slide the shaft out through the front of the engine.

1. Drain the cooling system.
2. Remove the accessories and assemblies with their attaching parts that are necessary to facilitate the removal of the flywheel housing hole cover over the camshaft and the upper engine front cover (if used).
3. Remove the cylinder head.
4. Remove the gear nut retainer plates (if used).

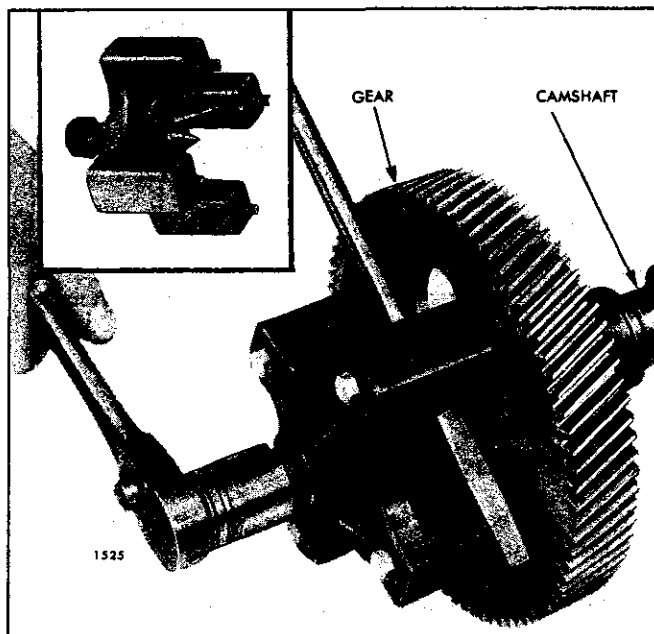


Fig. 3 – Removing Camshaft Gear with Tool J 1902-01

5. Wedge a clean rag between the gears and remove the gear retaining nut from each end of the camshaft (Fig. 1).
6. Remove the camshaft front balance pulley.
7. Remove the upper engine front cover (if used).
8. Remove the woodruff key from the camshaft and then remove the oil slinger.
9. Install the camshaft gear puller J 1902-01, four spacers J 6202-2 and camshaft gear puller adaptor plate J 6202-1 on the camshaft gear (Fig. 3).
10. Turn the center screw of the puller clockwise to disengage the camshaft gear. Do not remove the puller or the adaptor plate until the camshaft is reinstalled. The adaptor plate, secured to both the flywheel housing and the camshaft gear will hold the gear securely in place and in alignment which will aid in the reinstallation of the camshaft.
11. Pull the camshaft from the cylinder block.

Disassemble Camshaft or Balance Shaft

1. Remove the gear from the shaft. Refer to Section 1.7.3.
2. Remove the end plugs from the camshaft, to facilitate the removal of any foreign material lodged behind the plugs, as follows:

- a. Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.
- b. Make an indentation in the center of the camshaft end plug with a $31/64$ " drill (carbide tip).
- c. Punch a hole as deeply as possible with a center punch to aid in breaking through the hardened surface of the plug.
- d. Then, drill a hole straight through the center of the plug with a $1/4$ " drill (carbide tip).
- e. Use the $1/4$ " drilled hole as a guide and redrill the plug with a $5/16$ " drill (carbide tip).
- f. Tap the drilled hole with a $3/8$ "-16 tap.
- g. Thread a $3/8$ "-16 adaptor J 6471-2 into the plug. Then, attach a slide hammer J 2619-5 to the adaptor and remove the plug by striking the weight against the handle.
- h. Insert a length of $3/8$ " steel rod in the camshaft oil gallery and drive the remaining plug out.

If a steel rod is not available, remove the remaining plug as outlined in Steps "a" through "g".

Inspection

Soak the camshaft in clean fuel oil. Then, run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the oil gallery and the oil holes with compressed air. Clean the gears, camshaft bearings and related parts with fuel oil and dry them with compressed air.

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

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam rollers as outlined in Section 1.2.1.

If there is a doubt as to the acceptability of the camshaft for further service determine the extent of cam lobe wear as follows:

The camshaft can be in or out of the engine during this inspection.

1. With a tapered leaf set of feeler gages (.0015"-.0100") and a piece of square hard material $1/8$ " x $3/8$ " x 1" measure the flat on the injector rise side of the cam lobes (Fig. 4).

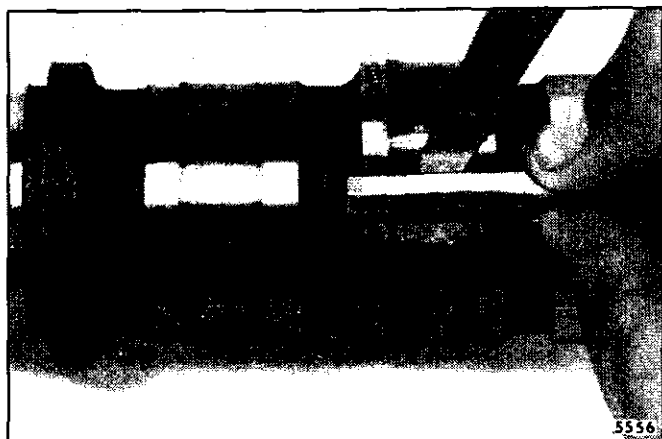


Fig. 4 - Checking Cam Lobe Wear

2. If the flats measure less than .003" in depth and there are no other defects the camshaft is satisfactory for service.
3. A slightly worn lobe still within acceptable limits, may be stoned and smoothed over with a fine crocus cloth.

Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces. Runout should not exceed .002".

Examine both faces of the thrust washers. If either face is scored or if the thrust washers are worn excessively, replace the washers. New thrust washers are .208" to .210" thick.

Also, examine the surfaces which the thrust washers contact; if these surfaces are scratched but not severely scored, smooth them down with an oil stone. If the score marks are too deep to be removed, or if parts are badly worn, use new parts. If a new camshaft is to be installed, thoroughly clean it to remove the rust preventive and blow out the oil passages with compressed air.

The clearance between new shafts and new bearings is .0035" to .007", or a maximum of .008" with worn parts. Excessive clearance between the shafts and the bearings will cause low oil pressure and excessive backlash between the gears.

Bearings are available in .010" and .020" undersize for use with worn or reground shafts.

Oversize camshaft and balance shaft bearings are available in sets, .010" oversize on the outside diameter, to permit reuse of a cylinder block having one or more scored block bearing bores. To use the oversize bearings, the camshaft and balance shaft block bores must be carefully line-bored (machined) to the dimensions shown in Table 1.

CAMSHAFT AND BALANCE SHAFT CYLINDER BLOCK BORE MACHINING CHART

(Oversize Camshaft Bearings)

Engine	Bearing Location	Dimension	
		Minimum	Maximum
2,3,4,6V & 8V	End	2.385"	2.386"
2,3,4,6V & 8V	Intermediate*	2.375"	2.376"
4 & 8V	Center	2.365"	2.366"

*Center Bearing 2-53 Engine Only

TABLE 1

Remove Bearings

The end bearings must be removed prior to removing the intermediate bearings.

NOTICE: When removing the bearings be sure to note the position of the bearings in the bore with respect to the notch in the bearings. Replacement bearings must be installed in the same position.

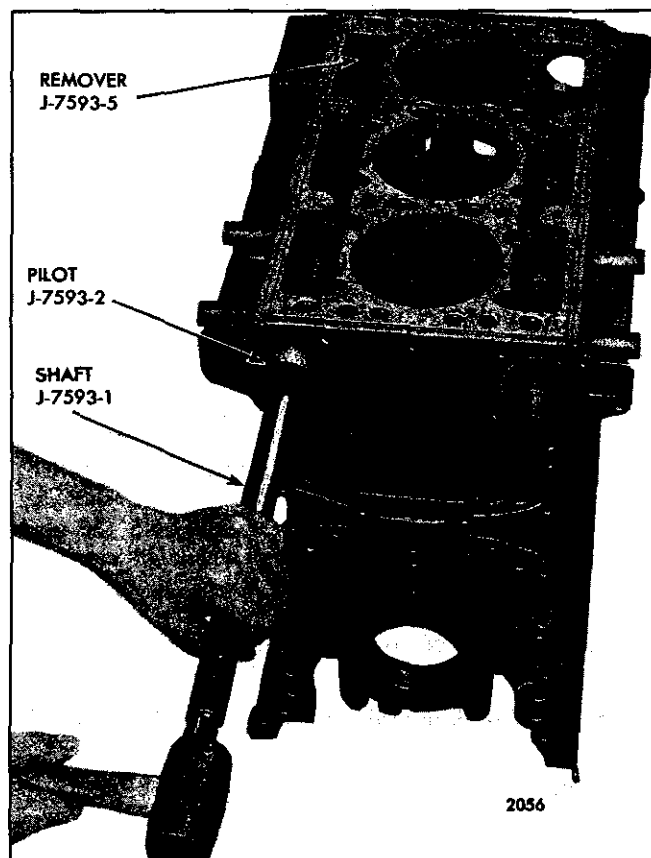


Fig. 5 - Removing End Bearing with Tools J 7593-1, J 7593-2 and J 7593-5

1. Remove all accessories and assemblies with their attaching parts as is necessary so that tool set J 7593-03 may be used as shown in Fig. 5 and in A of Fig. 6.

Tool set J 7593-03, designed for use with standard size bearings, may be used to remove and install .010" undersize and .020" undersize bearings by reducing the pilot diameter of the pilot J 7593-2, installer J 7593-3, remover J 7593-5, installer J 7593-6 and installer J 7593-15.

The pilot diameter of these tools should be reduced by .020". This reduction in tool diameter does not materially effect usage on standard size bearings. If the tools are used frequently, however, it may be

advisable to purchase additional standard pieces. Reduced diameter tools have not been released.

2. Insert the small diameter end of the pilot J 7593-2 into the end bearing.
3. Then, with the unthreaded end of the shaft J 7593-1 started through the pilot, push the shaft through the block bore until the end of the shaft snaps into the remover J 7593-5.
4. Now drive the end bearing out of the cylinder block. The nearest intermediate and/or center bearings can be removed now in the same manner. The large diameter end of pilot J 7593-2 will fit into the camshaft bore and is used when removing the other end bearing and any remaining bearings.

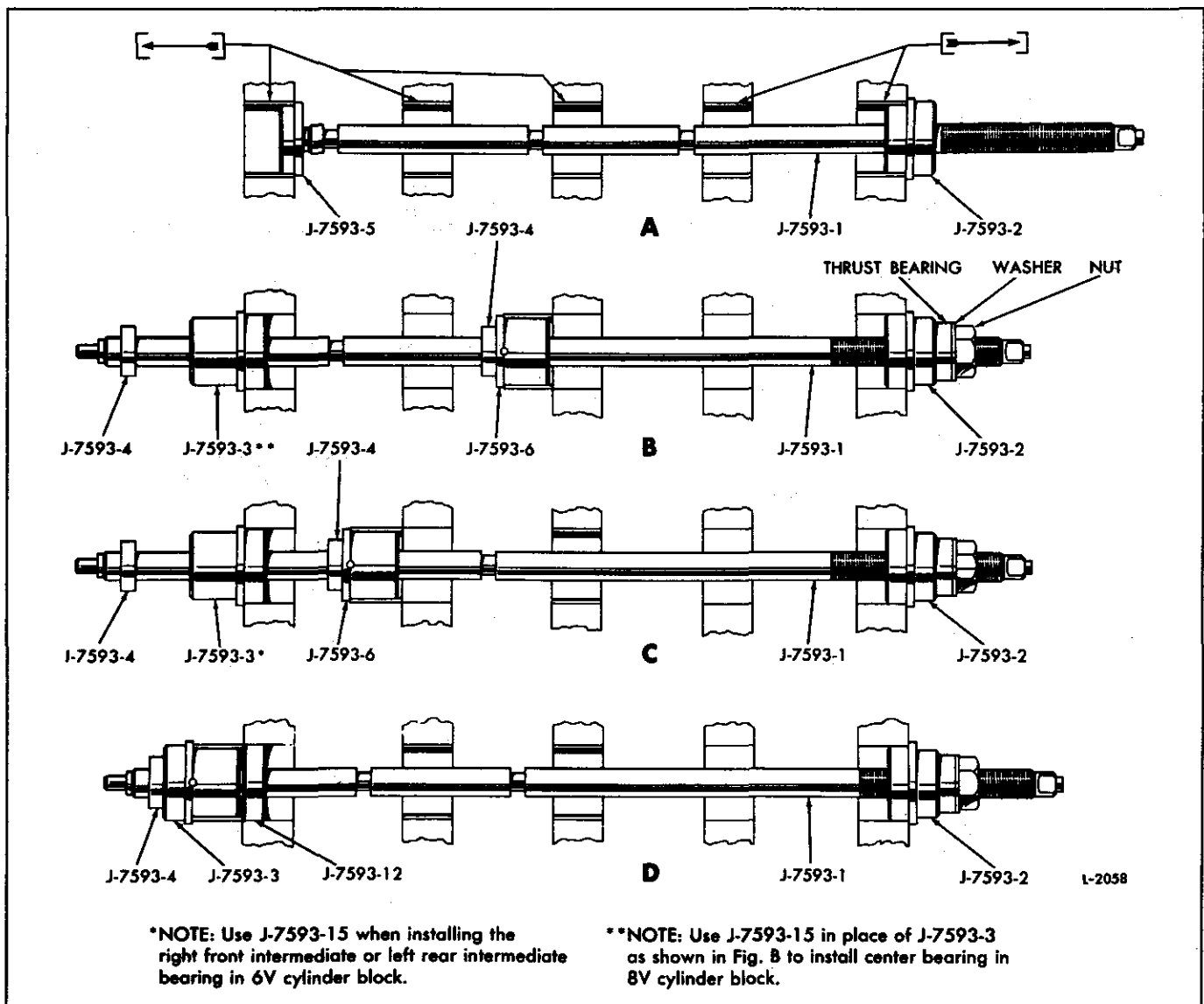


Fig. 6 - Removing and Replacing Camshaft or Balance Shaft Bearings with Tool Set J 7593-03

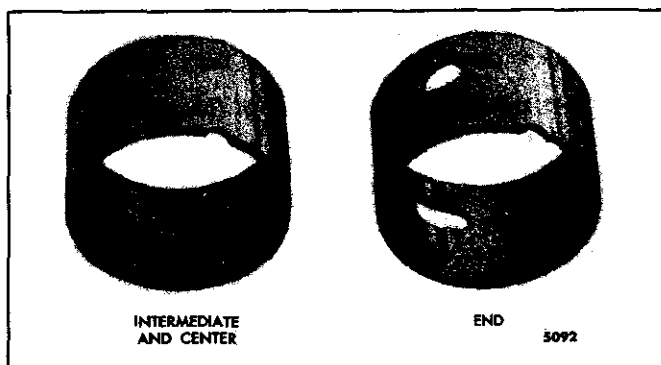


Fig. 7 - Camshaft and Balance Shaft Bearing Identification

Install Intermediate and/or Center Camshaft Bearings

Camshaft center and intermediate bearings must be installed prior to installing the camshaft end bearings. On the 4-53 and 8V engine, the center, rear intermediate and rear bearings are installed in that order by pressing the bearings from the rear to the front of the block. The front intermediate and front bearings are installed by pressing the bearings from the front to the rear of the block. Bearings are similarly installed in the 3-53 and 6V engine except that there is no center bearing. Current bearings incorporate lubrication grooves on the inner bearing surface (Fig. 7).

To properly install the camshaft and balance shaft bearings, refer to Fig. 8 for location of the notch in the bearing in relation to the camshaft or balance shaft bore centerline in the cylinder block.

Also, to facilitate assembly, the camshaft and balance shaft bearings are color coded on the side and/or end (Table 2).

1. Insert pilot J 7593-2 in the bore of the block (Fig. 9). Use the small end of the pilot if an end bearing has been installed. Refer to B and C of Fig. 6.
2. Insert the new intermediate or center bearing into the camshaft bore and position it correctly. Install the center bearing first.
3. Then, with the unthreaded end of shaft J 7593-1 started through the pilot, push the shaft through the entire length of the block bore.
4. Slide installer J 7593-6 on the shaft until the locating pin registers with the notch in the bearing. Then, slide installer J 7593-3 or J 7593-15 on the shaft with the large diameter inserted into the end of the block bore. Refer to C and NOTE of Fig. 6.

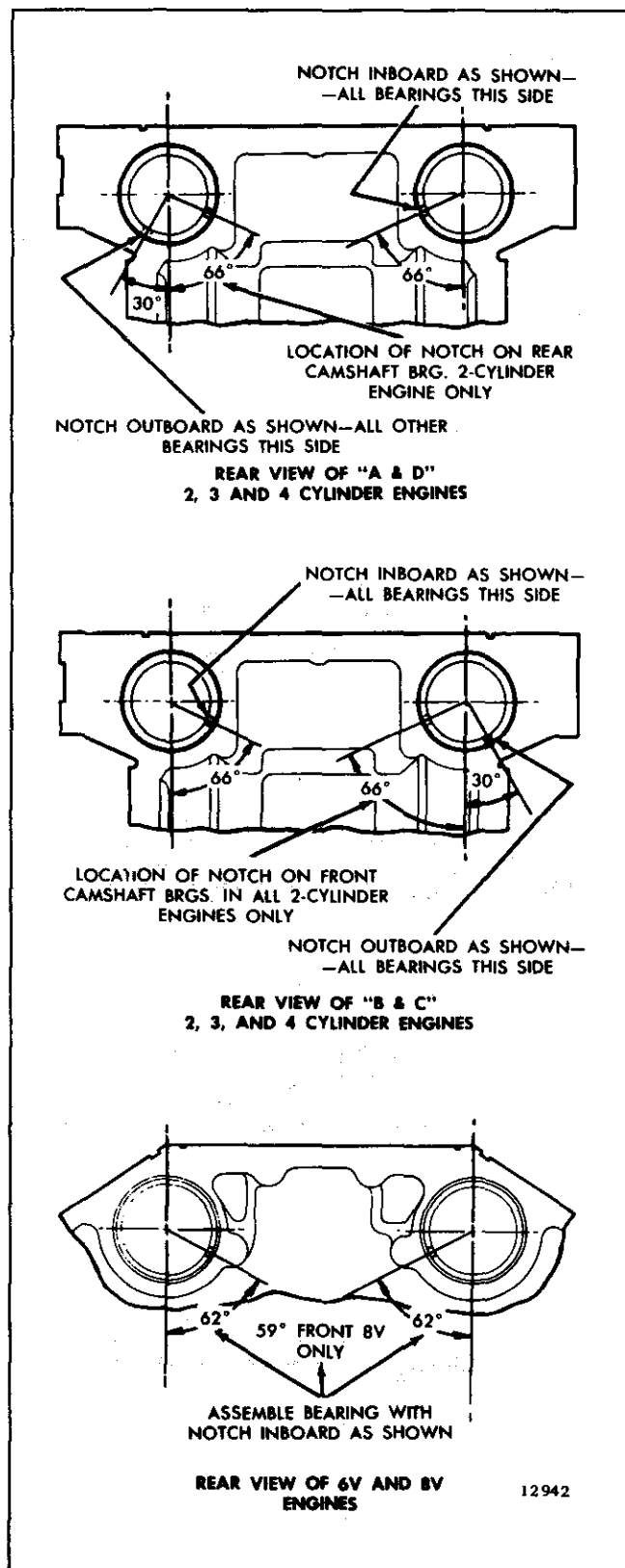


Fig. 8 - Location of Notch in Relation to Shaft Bore Centerline

- Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the puller. The short spacer J 7593-11, shown in Fig. 9, is used on the 3-53 and 6V blocks.
- Align the shaft in such a way that a "C" washer, J 7593-4, can be inserted in a groove in the shaft adjacent to installer J 7593-6.
- Place a "C" washer in the groove near the end of the shaft and, using a suitable wrench on the hex nut, draw the bearing into place until the "C" washer butts up against installer J 7593-3 and prevents the shaft from further movement.

Install End Bearings

Refer to the camshaft and balance shaft color code chart and the cylinder block bore machining dimension chart when installing the end bearings.

- Insert pilot J 7593-2 in the bore of the block as shown in "D" of Fig. 9. Use the small diameter of the pilot if a bearing has been installed.
- Insert support J 7593-12 in the bore in the opposite end of the block; then, with the unthreaded end of the shaft started through pilot J 7593-2, push the shaft through the block and support J 7593-12.
- Place a new end bearing on installer J 7593-3 and align the notch in the bearings with the pin on the installer. Then, slide the installer and the bearing on the shaft. Position the bearing correctly with the groove in the camshaft bore.
- Place "C" washer J 7593-4 in the end notch in the shaft; pull the shaft back until the washer butts against the installer.
- Next, place a spacer (if required), thrust washer, plain washer and hex nut over the threaded end of the shaft as shown in "D" of Fig. 6 and, using a suitable wrench on the hex nut, draw the bearing into place until the shoulder on the installer prevents the shaft from further movement. The bearing is now installed in its correct position.

Install the remaining end bearings in the same manner.

Use of tool set J 7593-03 assures that the bearings are properly spaced in relation to the end of the block. The center bearing (notch end) for a 4-53 and 8V cylinder block is 10.94" from the rear face of the block. The intermediate bearings for the 3-53 and 4-53 block are 5.54" from the rear and front face of the block. The right rear and left front intermediate bearings for the 6V and 8V cylinder block are 5.54" from the rear and front face of the block; and the right front and left rear intermediate bearings are 6.66" from the front and rear face of the block.

CAMSHAFT AND BALANCE SHAFT
BEARING COLOR CODE CHART

Bearing Position	Color Code		Outside Diameter	Inside Diameter
	Current	Former		
End	Brown	Black	Standard	Standard, .010" & .020" U.S. Standard (only)
	Brown	Yellow	.010" Oversize	
Intermediate	Orange	Red	Standard	Standard, .010" & .020" U.S. Standard (only)
	Orange	Blue	.010" Oversize	
Center (4-53-8V)	White	Green	Standard	Standard, .010" & .020" U.S. Standard*
	White	Red	.010" Oversize	

*The former red center bearing of the standard set is also used as the intermediate bearing of the oversize (O.D.) set.

TABLE 2

Assemble and Install Camshaft and Balance Shaft

Refer to Fig. 10 and assemble the camshaft and balance shaft.

- Coat the sides of the camshaft plugs with a light coating of Permatex Hi-Tack® or equivalent.
- Install new end plugs in the camshaft. Press the plugs in to a depth of 1.940" to 2.060" (Fig. 11).
- Install the gears and thrust washers on their respective shafts as outlined in Section 1.7.3.
- Lubricate the bearings and shafts with engine oil and slide the shaft assemblies into the cylinder block being careful not to damage the bearings or the cams and journals. Make sure that the appropriate timing marks on the gears are aligned. Refer to *Gear Train and Engine Timing* in Section 1.7.1.
- Slide an oil slinger on the front end of both shafts.
- Install the upper engine front cover, if used, (Section 1.7.8).
- Secure the thrust washers in place (Fig. 2) and tighten the bolts to 30-35 lb-ft (41-47 N·m) torque.
- Install the front balance weights (Section 1.7).
- Attach the gear nut retainer plates (if used) to the gears with bolts and lock washers and tighten the bolts to 35-39 lb-ft (47-53 N·m) torque.
- Check the clearance between the thrust washer and the gear on both shafts. The clearance should be .005" to .015", or a maximum of .019" with used parts.

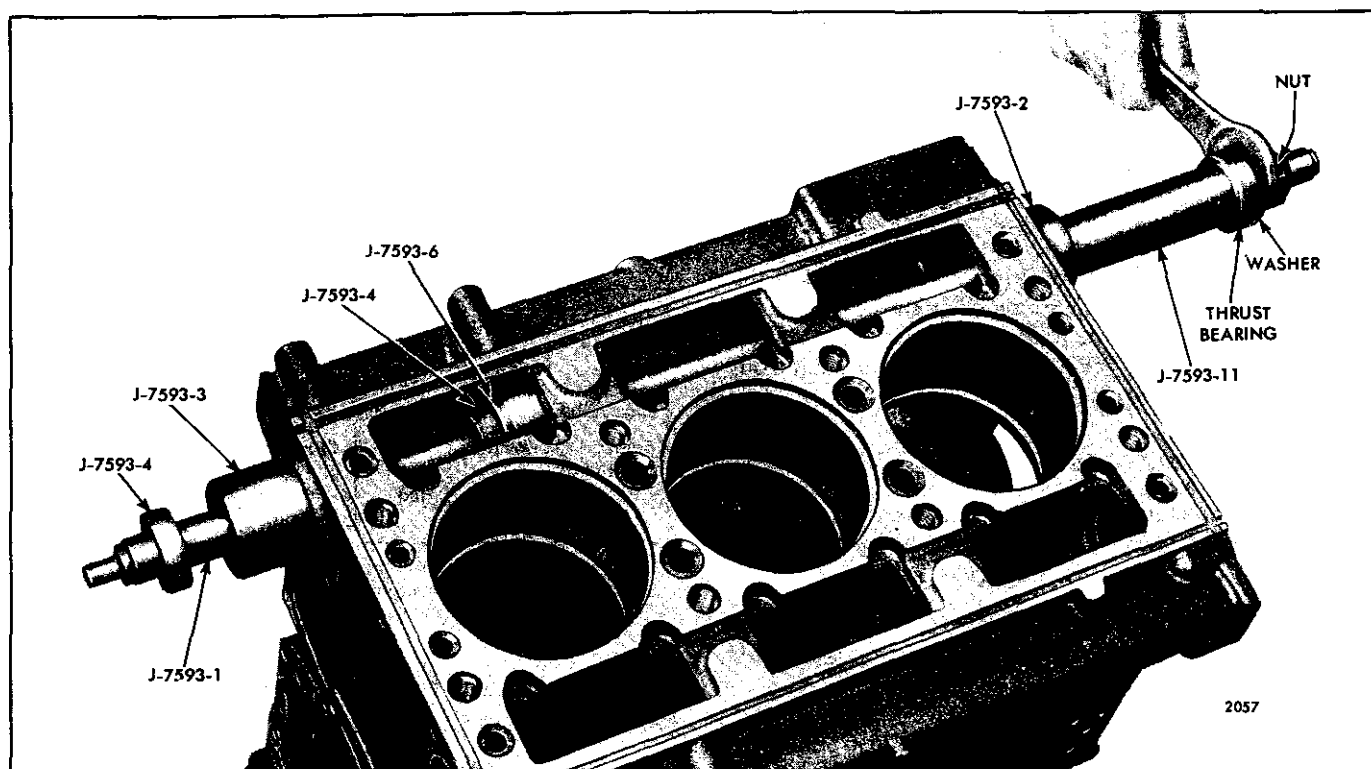


Fig. 9 – Installing Intermediate Camshaft Bearing Using Tool Set J 7593-03

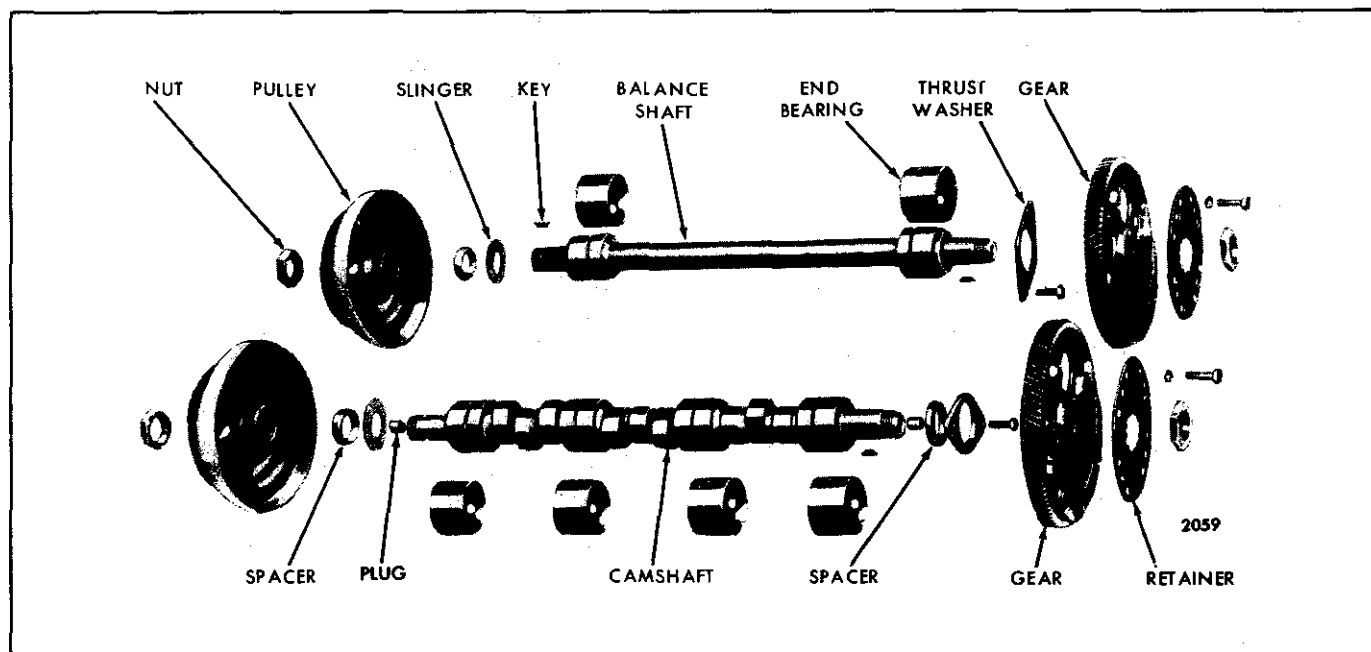


Fig. 10 – Camshaft and Balance Shaft Details and Relative Location of Parts

11. Check the backlash between the mating gears. The backlash should be .0005" to .005" and should not exceed .007" between used gears.
12. Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective sections of this manual.

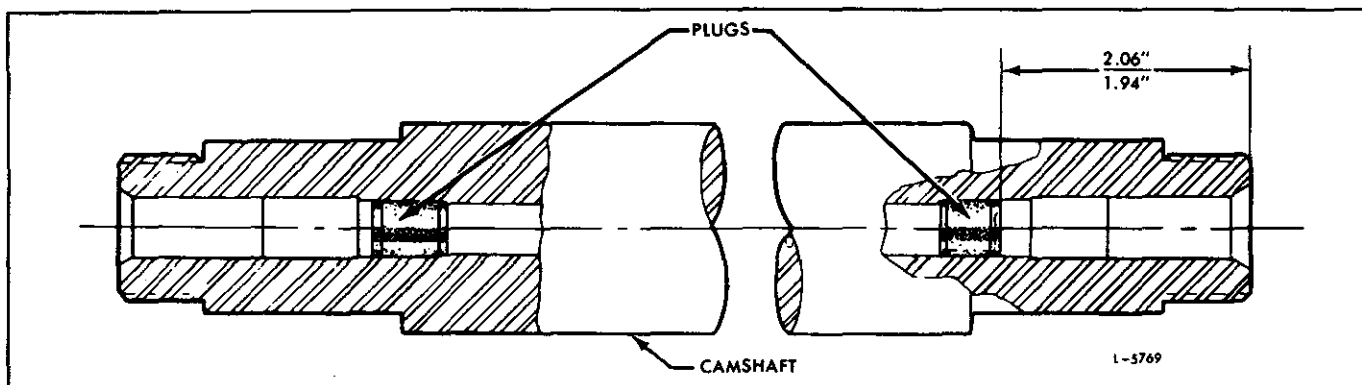


Fig. 11 – Camshaft Plug Installation

Install Camshaft (Flywheel Housing and Transmission in Place)

1. Place the rear camshaft spacer over the end of the camshaft and install the wooruff key in the gear end of the camshaft. Insert this end into position from the front of the engine. Push the shaft in until it slides into the end bearing.
2. Align the key in the shaft with the keyway in the camshaft gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.
3. Remove the camshaft gear puller, spacers and adaptor plate. Finger tighten the gear retaining nut on the shaft.
4. Install the oil slinger on the front end of the camshaft.
5. Install the upper front cover, if used, and slide the spacer over the end of the camshaft and into the oil seal in the cover.
6. Install the camshaft front balance pulley. Finger tighten the pulley retaining nut.
7. With the clean rag wedged between the gears to prevent their rotation, tighten the nut on each end of the camshaft to 300–325 lb-ft (407–441 N·m) torque.
8. Install the gear nut retainers with bolts and lockwashers. Tighten the bolts to 35–39 lb-ft (47–53 N·m) torque.
9. Install the accessories and assemblies that were removed and refill the cooling system.

CAMSHAFT AND BALANCE SHAFT GEARS

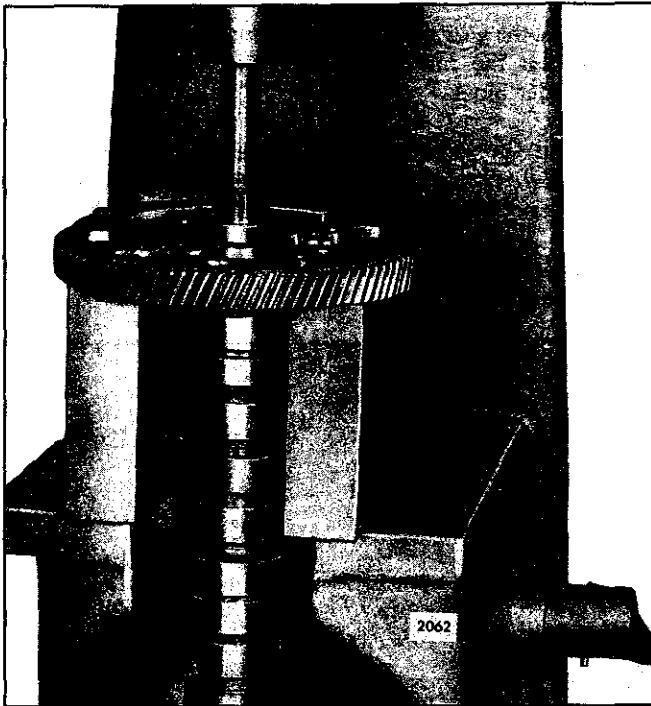


Fig. 1 - Removing Camshaft Gear

The camshaft and balance shaft gears on an In-line engine, and the two camshaft gears on a V-type engine, are located at the flywheel end of the engine and mesh with each other and run at the same speed as the crankshaft.

Since the camshaft and balance shaft gears on In-line engines and the two camshaft gears on V-type engines must be in time with each other, timing marks are stamped on the rim of each gear. Also, since these two gears as a unit must be in time with the crankshaft, timing marks are located on the idler and crankshaft gears (refer to Section 1.7.1 for gear train timing and identification of the new quiet gears and former gears).

Each gear is keyed to its respective shaft and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double hexagon hole in the center, fits over the nut on some engines. The retainer is attached to the gear by bolts threaded into tapped holes in the gear.

On the two, three and four cylinder In-line engines, external weights are attached to the rear face of each gear. Different size weights are used on the two, three and four cylinder engines. The weights are important in maintaining perfect engine balance. Additional weights are not required on the 6V engine camshaft gears or on the 8V engines effective with 8D-127.

When new service gears are used on an In-line engine, or an early 8V engine, the external weights on the old gears must be transferred to the new gears. If the weights are transferred to new gears, tighten the bolts to 45-50 lb-ft (61-68 N·m) torque.

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

When cross-head pistons are to be installed in a turbocharged Series 53 engine built prior to serial numbers 3D-193526, 4D-209292, 6D-229545 and an in-frame overhaul is desired, new bolt-on balance weights must be used.

Remove Camshaft and Balance Shaft Gears

1. Remove the camshaft and the balance shaft from the engine as outlined in Section 1.7.2.
2. Place the camshaft and gear assembly in an arbor press with the gear suitably supported (Fig. 1).
3. Place a wood block under the lower end of the camshaft so the threads will not be damaged when the shaft is pressed from the gear.
4. Place a short piece of 3/4" O.D. brass rod on the end of the camshaft and press the camshaft out of the camshaft gear.
5. Remove the thrust washer, Woodruff key and spacer from the camshaft.
6. Remove the gear from the balance shaft in a similar manner.

Inspection

Clean the gears with fuel oil and dry them with compressed air.

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

Then, examine the gear teeth for evidence of scoring, pitting and wear. Replace the gears, if necessary.

Examine both faces of the camshaft and balance shaft thrust washer and, if either face is worn or scored, replace the washer. Also, examine the surface on the camshaft and balance shaft which the thrust washer contacts. If this surface is scratched, but not severely scored, smooth it up with a fine oil stone.

Install Camshaft and Balance Shaft Gears

1. Note the letters stamped on the end of the camshaft which signify the engine models in which a camshaft may be used. The letters on the timing gear end of the camshaft must correspond with the engine model of the particular engine being assembled. Refer to the front of this manual for engine model identification.
2. Place the rear camshaft spacer over the timing gear end of the camshaft and install the Woodruff key.
3. Lubricate the thrust washer with clean engine oil and place the thrust washer over the gear end of the camshaft and the spacer.
4. Start the camshaft gear over the end of the camshaft with the key in the shaft registering with the keyway in the gear.
5. Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and press the gear tight against the spacer on the shaft (Fig. 2).
6. Measure the clearance between the camshaft thrust washer and the camshaft. This clearance should be

.008" to .015" when new parts are used. With used parts, a maximum clearance of .021" is allowable.

7. Install the gear retaining nut on the camshaft by hand. Tighten the nut after the shaft is installed in the cylinder block.
8. Install the gear on the balance shaft in a similar manner. No rear spacer is used with the balance shaft gear since the gear seats against a shoulder on the shaft.
9. Install the camshaft and balance shaft in the engine as outlined in Section 1.7.2.

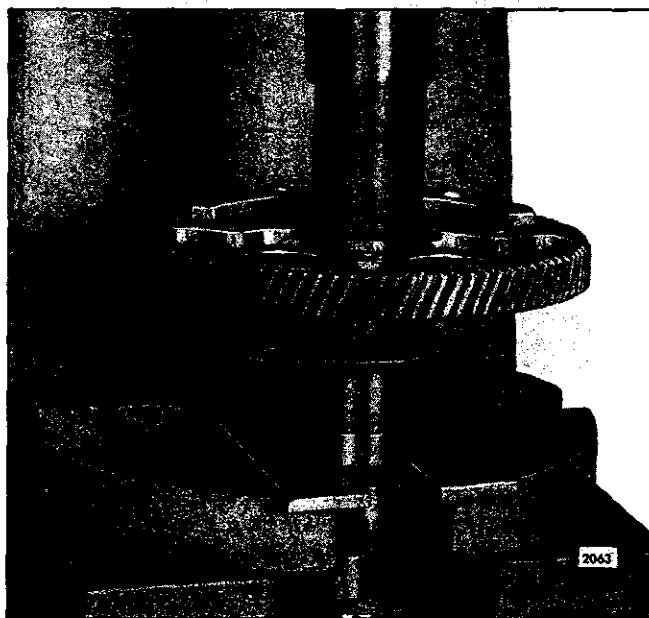


Fig. 2 - Installing Camshaft Gear

IDLER GEAR AND BEARING ASSEMBLY

IN-LINE AND 6V-53 ENGINES

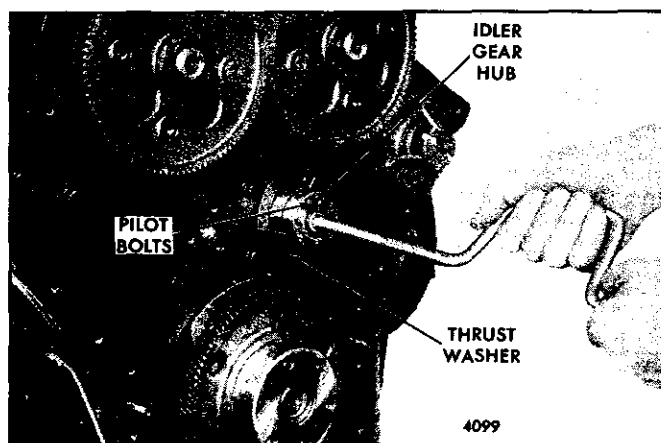


Fig. 1 – Installing Idler Gear Hub

The engine idler gear and bearing assembly, located at the flywheel end of the engine, meshes with the camshaft and crankshaft gears, and rotates on a stationary hub. The hub is secured directly to the cylinder block by a bolt which passes through the hub and three bolts which pass through the flywheel housing, hub and end plate (Fig. 1).

Two timing marks (a triangle within a circle) are stamped on the idler gear diametrically opposite (180°) to one another.

The inside diameter of the idler gear bearing is 2.186" – 2.187" and the outside diameter of the idler gear hub is 2.1825" – 2.1835". Therefore, the clearance between the idler gear hub and the idler gear bearing is .0025" to .0045", with a maximum allowable wear limit of .007".

A thrust washer is provided on both sides of the idler gear and bearing assembly. The standard thickness of the idler gear and bearing assembly is 1.233" to 1.234" and the standard thickness of the two thrust washers is .236" to .240". Therefore, the clearance between the thrust washers and the idler gear is .006" to .013", with a maximum allowable wear limit of .017".

On an In-line engine, the idler gear is positioned on the left-hand side for a right-hand rotating engine and on the right-hand side for a left-hand rotating engine as viewed from the rear. On a 6V engine, the idler gear is positioned on the right-hand side for a right-hand rotating engine and on the left-hand side for a left-hand rotating engine, as viewed from the rear. Refer to *General Description*.

On early engines, an idler gear spacer (dummy hub) was used on the side opposite the idler gear. Currently, the

flywheel housing has an integral cast hub and a .015" thick shim is used between the flywheel housing and the end plate.

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

Remove Idler Gear and Bearing Assembly (Flywheel Housing Removed)

1. Remove the idler gear outer thrust washer from the idler gear hub (Fig. 2).
2. Slide the idler gear straight back off of the idler gear hub.
3. Remove the bolt which secures the idler gear hub to the cylinder block. Then, remove the idler gear hub and the idler gear inner thrust washer as an assembly.

Inspection

Wash the idler gear and bearing assembly, hub and thrust washers thoroughly in clean fuel oil and dry them with compressed air.

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

Examine the gear teeth and bearing for scoring, pitting or wear. If the gear teeth are worn or the bearing is scored, pitted or worn excessively, replace the gear and bearing assembly or install a new bearing in the gear. Examine the outside diameter of the idler gear hub and thrust washers. If scored or worn excessively, replace them.

An idler gear bearing with two oil grooves has been incorporated in the idler gear and bearing assemblies beginning with engine serial numbers 2D-14301, 3D-6773, 4D-9458 and 6D-3334.

When a new bearing (bushing) is installed in the idler gear, it must not protrude beyond the gear face on either side and must sustain an axial load of 2,000 pounds minimum without pushing out of the gear.

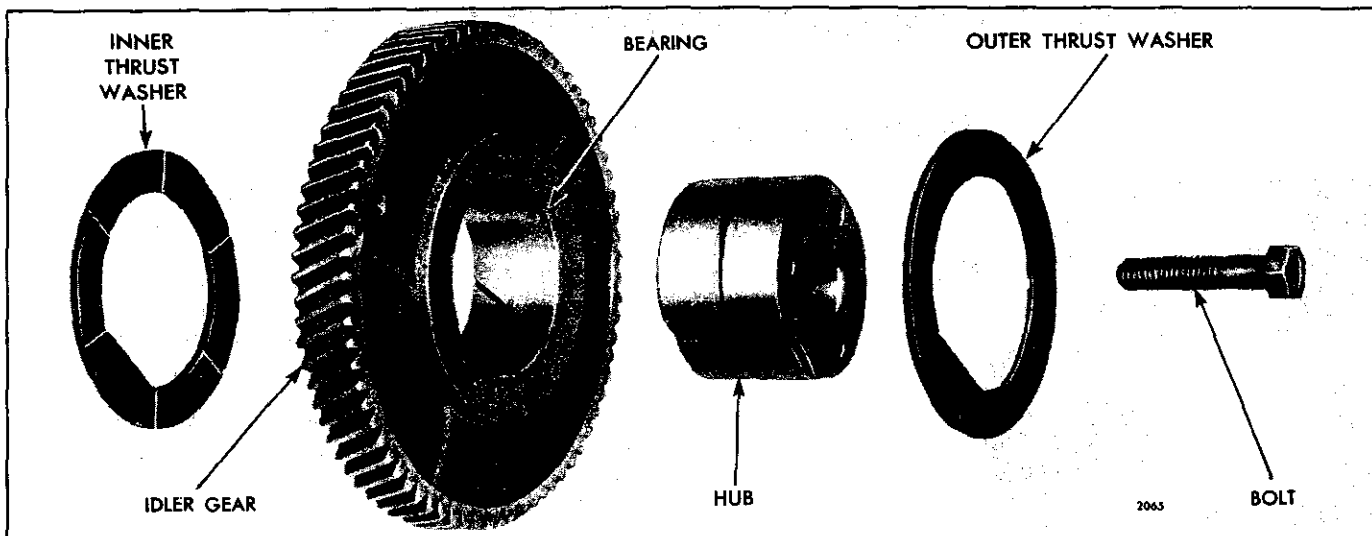


Fig. 2 – Idler Gear Details and Relative Location of Parts

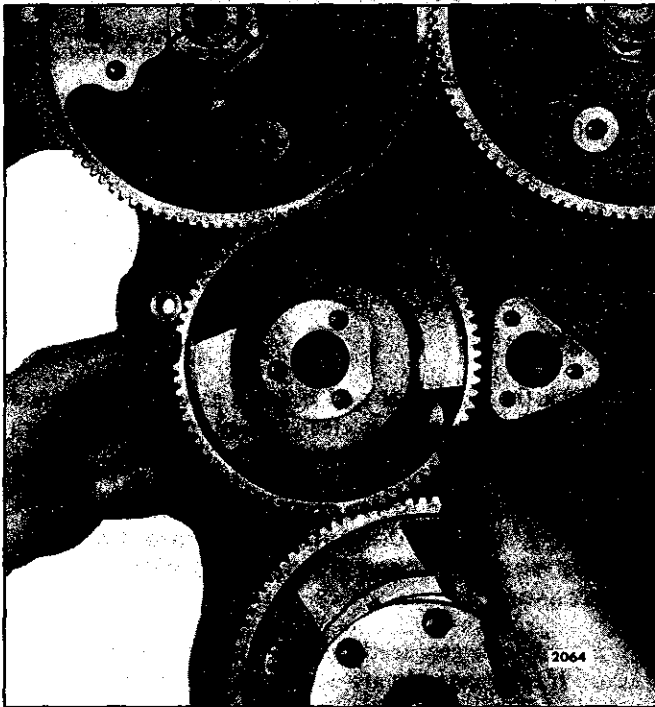


Fig. 3 – Installing Idler Gear

Install Idler Gear and Bearing Assembly

1. Place the inner thrust washer on the forward end of the idler gear hub with the flat in the inner diameter of the thrust washer over the flat on the end of the gear hub and with the oil grooves in the thrust washer facing the idler gear.
2. Place the small protruding end of the idler gear hub through the end plate and into the counterbore in the cylinder block.
3. Insert two 3/8"-16 bolts through the idler gear hub and thread them into the cylinder block (Fig. 1), to be sure the bolt holes will be in alignment when the flywheel housing is installed.
4. Insert the 3/8"-16 x 1-3/4" special bolt through the center of the idler gear hub and thread it into the cylinder block. Tighten the bolt to 40-45 lb-ft (54-61 N·m) torque. Then, remove the two 3/8"-16 bolts previously installed for alignment of the gear hub.
5. Lubricate the idler gear hub and idler gear bearings liberally with clean engine oil.
6. Position the crankshaft gear and the camshaft gear or balance shaft gear so that their timing marks will align with those on the idler gear. Refer to Figs. 1 and 2 and to Table 1 in Section 1.7.1 for identification of the new quiet gears and the former gears.
7. With these timing marks in alignment, install the idler gear (Fig. 2).
8. Apply a thin film of cup grease to the inner face (face with the oil grooves) of the outer idler gear thrust washer. Then, place the thrust washer over the end of the idler gear hub with the oil grooves in the side of the thrust washer facing the idler gear and the flat in the inner diameter of the thrust washer over the flat on the end of the idler gear hub.
9. Check the backlash between the mating gears. The backlash should be .0005" to .005" between new gears and should not exceed .007" between used gears.

8V-53 ENGINE

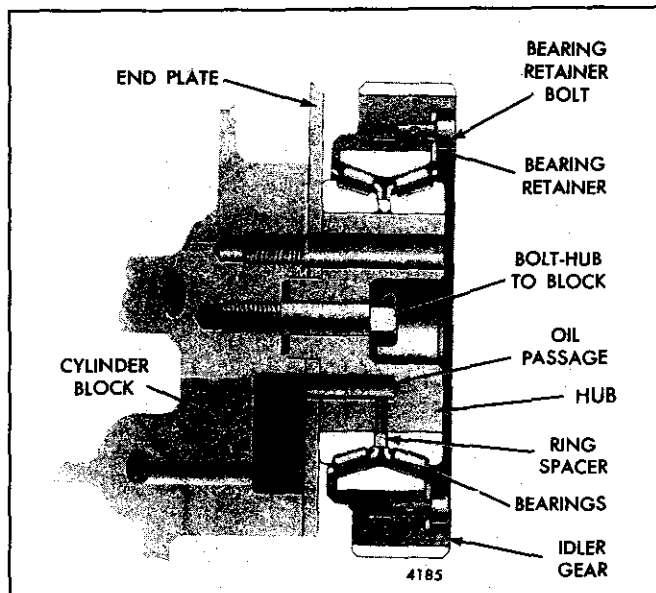


Fig. 4 - Idler Gear Mounting (Former Bearing)

Fig. 4 illustrates the mounting of the roller bearing type idler gear. When replacing any part of the gear assembly, a complete roller bearing type idler gear assembly must be used.

The idler gear is mounted on a double-row, tapered roller bearing which, in turn, is supported on a stationary hub. This hub is secured directly to the cylinder block by a bolt which passes through the hub and rear end plate.

The current idler gear bearing consists of two cups, two cones and an outer and inner spacer ring. The former idler gear bearing consists of a cup, two cones and a spacer ring.

The inner races of the idler gear bearing are pressed on the gear hub and, therefore, do not rotate. A spacer separates the two bearing inner cones. The bearing cup(s) has a light press fit in the idler gear and is held against a flanged lip inside the idler gear on one side and by a bearing retainer secured with six bolts on the other side.

Two timing marks (a triangle within a circle) are stamped on the idler gear, diametrically opposite (180°) to one another.

A dummy hub cast into the flywheel housing is used on the side opposite the idler gear. A shim is used between the dummy hub and the rear end plate. The flywheel housing bears against the inner races of the idler gear bearing and also against the dummy hub. Three self-locking bolts are used to attach the flywheel housing at the idler gear and dummy hub locations.

Remove Idler Gear, Hub and Bearing Assembly (Flywheel Housing Previously Removed)

Remove the hub to cylinder block bolt and withdraw the assembly from the cylinder block rear end plate.

Before removing the idler gear, check the idler gear, hub and bearing assembly for any perceptible wobble or shake when pressure is applied by firmly grasping the rim of the gear with both hands and rocking the gear in relation to the bearing. The bearing must be replaced if the gear wobbles or shakes. If the gear assembly is satisfactory, it is only necessary to check the pre-load before reinstallation.

Disassemble Idler Gear, Hub and Bearing Assembly

While removing or installing an idler gear bearing, the bearing *must* be rotated to avoid the possibility of damaging the bearing by brinelling the bearing cones. Brinelling refers to the marking of the cones by applying a heavy load through the rollers of a non-rotating bearing in such a way that the rollers leave impressions on the contact surfaces of the cones. These impressions may not be easily discerned during normal inspection. For example, a bearing may be brinelled if a load were applied to the inner cone of the bearing assembly in order to force the outer cone into the idler gear bore, thus transmitting the force through the bearing rollers. A brinelled bearing may have a very short life.

Refer to Fig. 4 for the location and identification of parts and disassemble the bearing as follows:

1. Remove the six bolts which secure the bearing retainer to the idler gear.

Component parts of the idler gear bearing are mated. Therefore, matchmark the parts during disassembly to ensure that they will be reassembled in their *original* positions.

2. Clean the idler gear and bearing assembly with fuel oil and dry it with compressed air.
3. Place the idler gear and bearing assembly in an arbor press with the bearing cone or inner race supported on steel blocks (Fig. 5). While rotating the gear assembly, press the hub out of the bearing. Remove the gear assembly from the arbor press and remove the bearing cones and spacer.
4. Tap the bearing cups and spacer (current gear) or bearing cup (former gear) from the idler gear by using a brass drift alternately at four notches provided around the shoulder of the gear (Figs. 6 and 7).

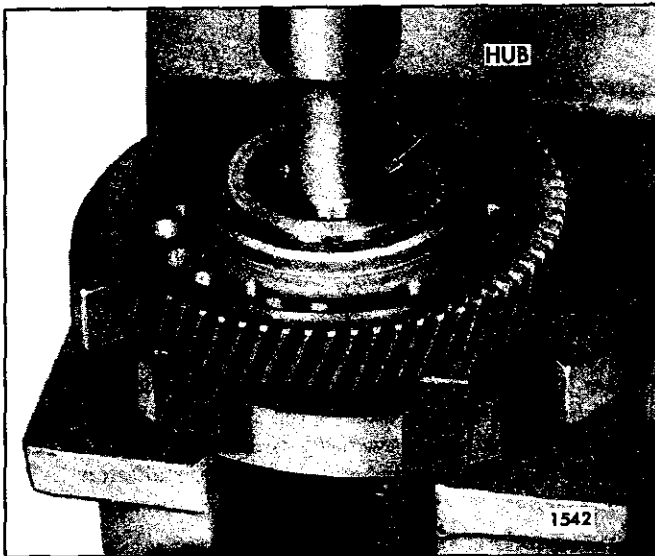


Fig. 5 - Pressing Hub Out of Bearing

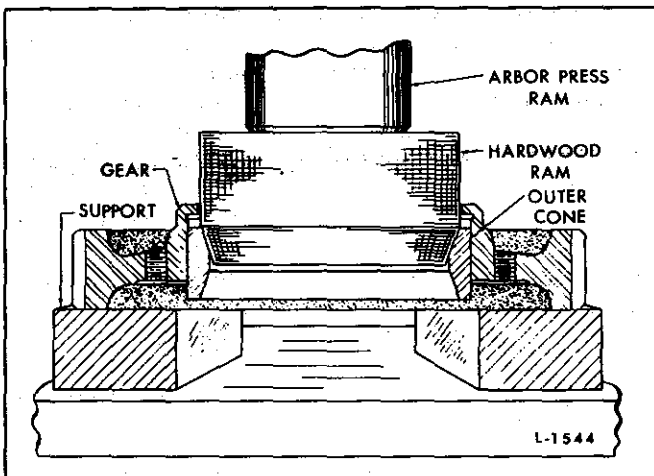


Fig. 6 - Hardwood Ram for Pressing Outer Bearing Race from Gear

Inspection

Wash the idler gear, hub and bearing components thoroughly in clean fuel oil and dry them with compressed air.

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

Check the idler gear hub to ensure that no chips or foreign material is deposited in the holes to cause interference with the flywheel housing attaching bolts.

Inspect the bearing carefully for wear, pitting, scoring or flat spots on the rollers or cones. Replace the bearing if it is defective.

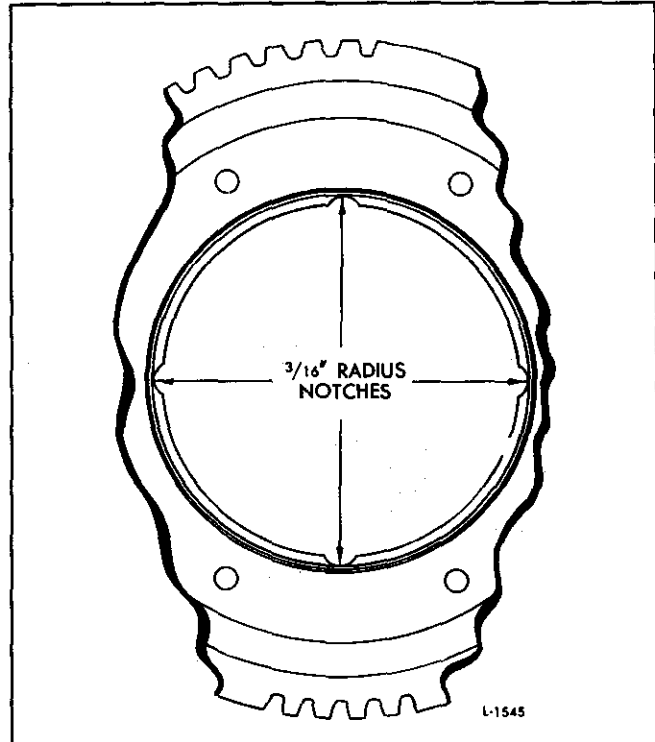


Fig. 7 - Location of Notches in Idler Gear

Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, replace the gear. Also, inspect the other gears in the gear train.

Assemble Idler Gear, Hub and Bearing

CURRENT BEARING

Refer to Fig. 8 and assemble the bearing components in their *original positions* (refer to identification marks made during disassembly) as outlined below:

The current idler gear bearing is a matched assembly. *Do not* mix the components with those of another gear.

1. Support the idler gear, shoulder down, on the bed of an arbor press. Start one of the bearing cups, numbered side up, squarely into the bore of the gear. Then, press the bearing cup against the shoulder of the gear. Use a flat round steel plate (pre-load test plate) between the ram of the press and the bearing cup.
2. Lay the outer spacer ring on the face of the bearing cup.
3. Start the other bearing cup, numbered side down, squarely into the bore of the gear. Then, press the cup tight against the spacer ring. Use a flat round steel plate (pre-load test plate) between the ram of the press and the bearing cup.
4. Press the inner bearing cone (numbered side up) on the idler gear hub, flush with the inner hub mounting face.

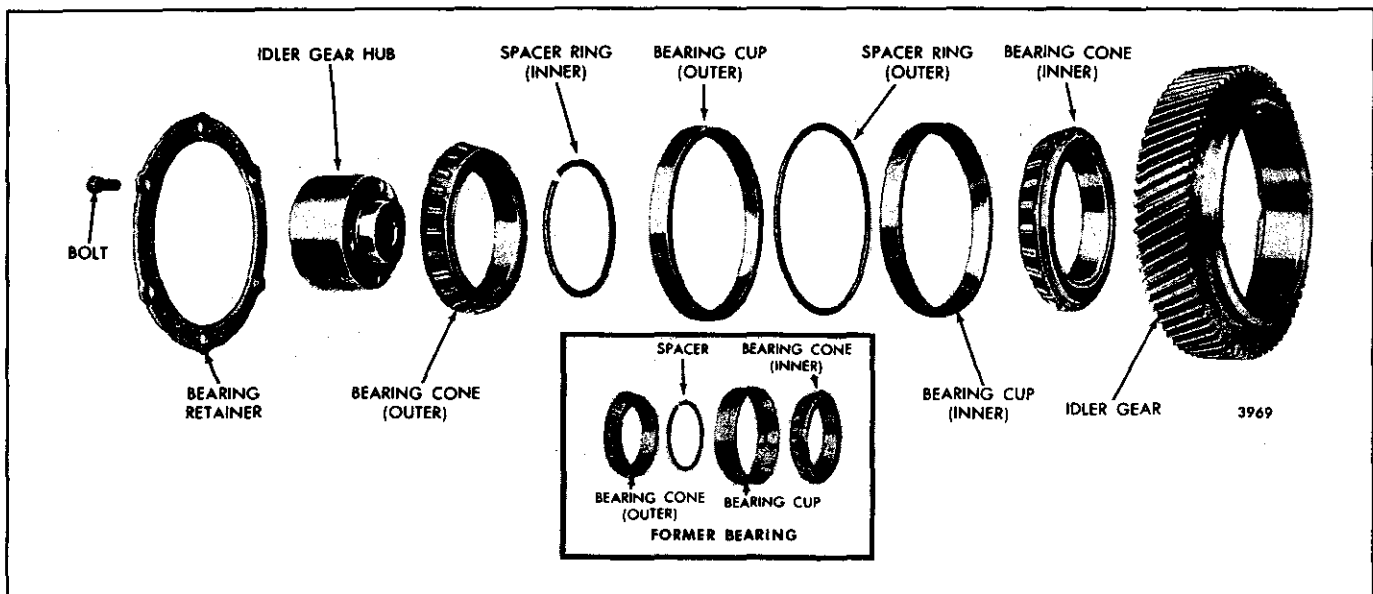


Fig. 8 – Idler Gear Details and Relative Location of Parts (Current Bearing)

Use the pre-load test plate (with the large center hole) between the ram of the press and the bearing.

5. Install the inner spacer ring on the idler gear hub so that the oil hole in the hub is 180° from the gap in the inner spacer ring.
6. Position the gear with both cups over the hub and the inner bearing cone.
7. Press the outer idler gear bearing cone over the hub while rotating the gear to seat the rollers properly between the cones. The bearing cones must be supported so as not to load the bearing rollers during this operation.
8. Before installing the gear and bearing assembly, check the pre-load.

FORMER BEARING

Assemble the bearing components in their *original* positions (refer to the identification marks made during disassembly) as outlined below.

1. Support the idler gear, shoulder side down, on an arbor press and start the outer bearing cone squarely into the bore of the gear. Then, press the bearing cone tight against the shoulder of the gear, using a steel plate between the ram of the press and the bearing cone.
2. Support one bearing cone, numbered side down, on the arbor press and lower the idler gear and bearing cup assembly down over the bearing cone.
3. Place the spacer ring on the face of the bearing cone.

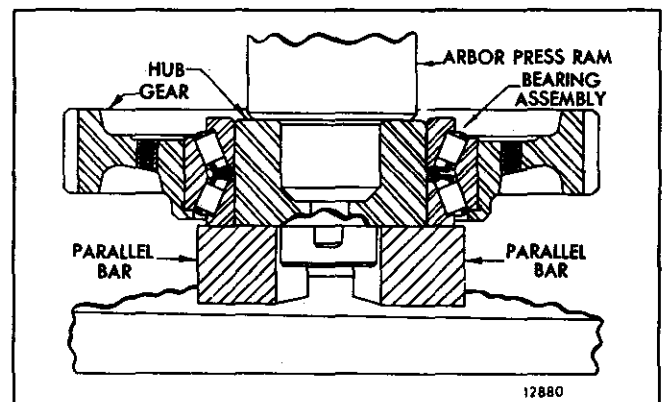


Fig. 9 – Pressing Hub into Bearing

4. Place the second bearing cone, numbered side up, in the idler gear and bearing cup assembly and against the spacer ring.
5. Then, position the idler gear hub over the bearing cones so that the oil hole in the hub is 180° from the gap in the spacer ring.
6. Press the hub into the idler gear bearing cones, while rotating the gear (to seat the rollers properly between the cones), until the face of the hub which will be adjacent to the cylinder block end plate is flush with the corresponding face of the bearing cone. The bearing cones should be supported so as not to load the bearing rollers during this operation (Fig. 9).
7. Prior to installing and securing the bearing retainer, check the pre-load of the bearing assembly as outlined below.

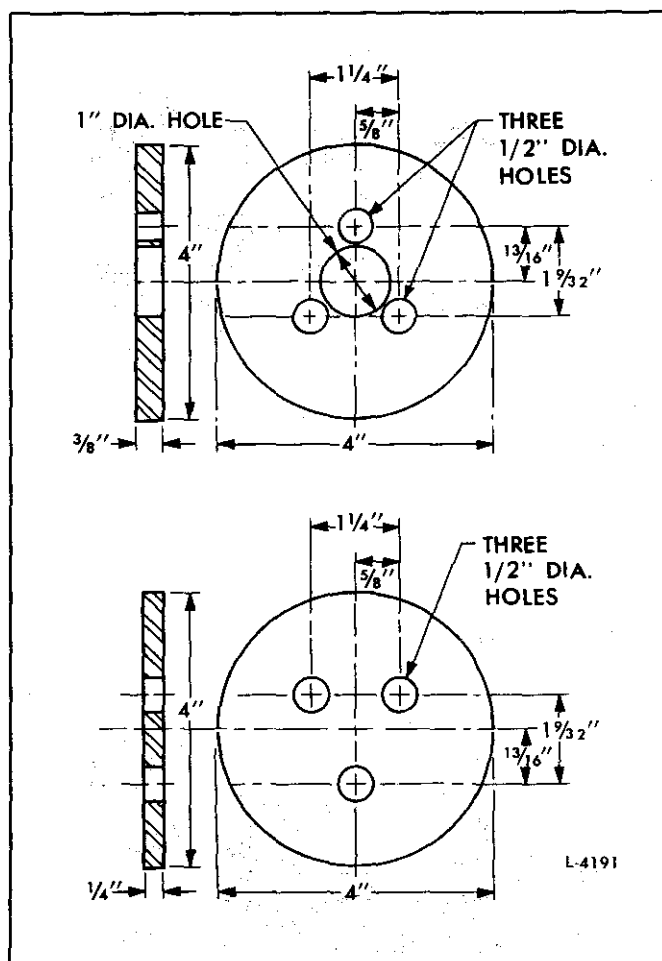


Fig. 10 - Plates for Bearing Test Fixture

Check Pre-Load of Bearing

The rollers of the bearing are loaded between the bearing cup and bearing cones in accordance with design requirements to provide a rigid idler gear and bearing assembly. As the bearing cones are moved toward each other in a tapered roller bearing assembly, the rollers will be more tightly held between the cones and the cup. In the idler gear bearings, a slight pre-load is applied, by means of a selected spacer ring between the bearing cones, to provide rigidity of the gear and bearing assembly when it is mounted on its hub. This method of pre-loading is measured, in terms of "pounds-pull", by the effort required at the outer diameter of the gear to turn the bearing cup in relation to the bearing cones.

Any time an idler gear assembly has been removed from an engine for servicing or inspection, while performing engine overhaul or other repairs, the pre-load should be measured as part of the operation.

The idler gear bearing should be clean and lubricated with light engine oil prior to the pre-load test. Idler gear assemblies which include new bearings should be "worked

in" by grasping the gear firmly by hand and rotating the gear back and forth several times.

After the idler gear, hub and bearing are assembled together, the bearing should be checked to ascertain that the gear may be rotated on its bearing without exceeding the maximum torque specifications, nor be so loose as to permit the gear to be moved in relation to the hub by tilting, wobbling or shaking the gear.

If the mating crankshaft and camshaft gears are not already mounted on the engine, the torque required to rotate the idler gear may be checked by mounting the idler gear in position on the engine, using a round steel plate 4" in diameter (pre-load test plate) against the hub and cone as outlined below.

1. Mount the idler gear assembly on the engine.
2. Install the center bolt through the gear hub and thread it into the cylinder block. Tighten the bolt to 40-45 lb-ft (54-61 N·m) torque.
3. Place the steel plate (lower plate shown in Fig. 10) against the hub and bearing. Insert two 3/8"-16 bolts and one 5/16"-18 bolt through the plate and thread it into the cylinder block. Tighten the two 3/8"-16 bolts to 40-45 lb-ft (54-61 N·m) torque and the 5/16"-18 bolt to 19-23 lb-ft (26-31 N·m) torque.
4. Tie one end of a piece of lintless 1/8" cord around a 1/8" round piece of wood (or soft metal stock). Place the wood between the teeth of the gear, then wrap the cord around the periphery of the gear several times. Attach the other end of the cord to a spring scale, J 8129 (Fig. 11). Maintain a straight, steady pull on the scale, 90° to the axis of the hub, and note the pull, in pounds and ounces, required to start the gear rotating. Make several checks to obtain an average reading. If the pull is within 1-1/4 lb. minimum to 6 lbs. 12 ounces maximum and does not fluctuate more than 2 lbs. 11 ounces, the idler gear and bearing assembly are satisfactory for use.

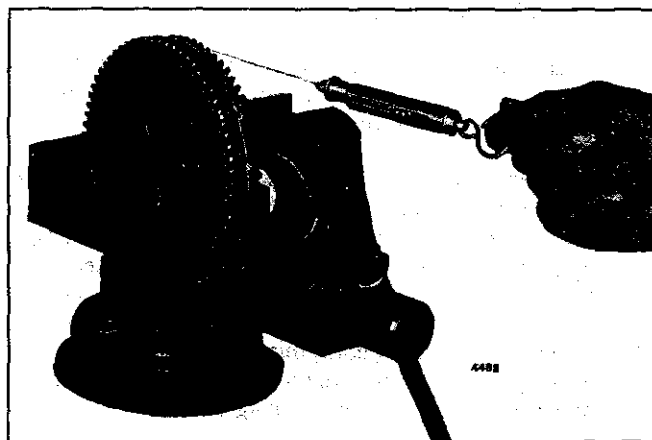


Fig. 11 - Checking Pre-Load of Idler Gear Bearing

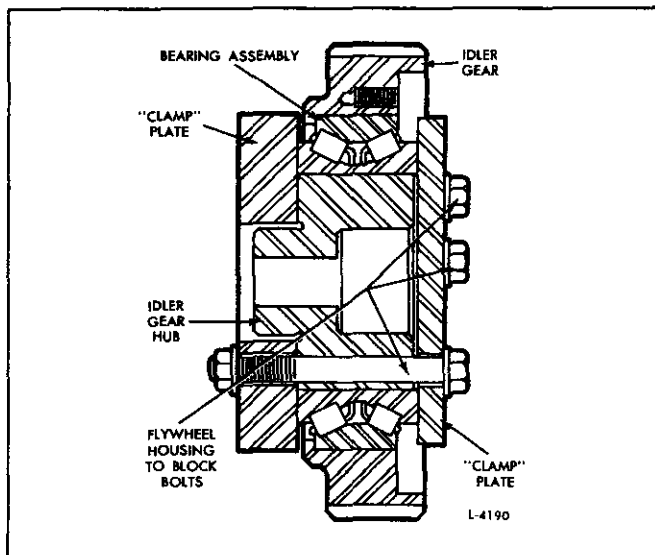


Fig. 12 - Fixture for Testing Bearing Pre-Load

If the crankshaft and camshaft gears are mounted on the engine, a suitable fixture which may be held in a vise can be made with two plates (Figs. 10 and 12). One of the plates is used to take the place of the flywheel housing and the other the cylinder block. *Engine-mounted* conditions are simulated by tightening the 3/8"-16 attaching bolts and nuts to 40-45 lb-ft (54-61 N·m) torque.

Check the pre-load as follows:

1. Clamp the idler gear between the two plates (Fig. 12). Insert the bolts and tighten the three 3/8"-16 bolts and nuts to 40-45 lb-ft (54-61 N·m) torque.
2. Clamp the idler gear assembly and fixture in a vise (Fig. 10).
3. Attach the cord to the idler gear and spring scale and check the pre-load as outlined in Step 4 of the previous method.

If the scale reading is within the specified 1-1/4 to 6-3/4 lbs., but fluctuates more than the permissible 2 lbs. 11

ounces, the idler gear and bearing assembly must NOT be installed on the engine. Fluctuations in scale reading may be caused by the cones not being concentric to each other, damaged cones or rollers, or dirt or foreign material within the bearings. The bearing should be inspected for the cause of fluctuation in the scale readings and corrected or a new bearing installed.

A scale reading which exceeds the specified maximum indicates binding of the bearing rollers or rollers improperly installed. When the scale reading is less than the specified minimum, the bearing is more likely worn and the bearing should be replaced.

After the pre-load test is completed, remove the steel plates. Attach the bearing retainer to the idler gear with six self-locking bolts. Tighten the bolts to 12-15 lb-ft (16-20 N·m) torque.

Install Idler Gear, Hub and Bearing Assembly

1. Position the crankshaft gear and the camshaft gear so that the timing marks will align with those on the idler gear (refer to Section 1.7.1).
2. With these marks in alignment, start the idler gear into mesh with the crankshaft gear and the camshaft gear and simultaneously rotate the gear hub so that the oil hole in the rear end plate is in line with the oil hole in the hub and the three bolt holes are in line.
3. Roll the idler gear into position and gently tap the hub until it seats against the rear end plate.
4. After making sure that the hub is tight against the rear end plate, secure the idler gear assembly in place with the 3/8"-16 x 1-3/4" special bolt. Tighten the bolt to 40-45 lb-ft (54-61 N·m) torque.
5. Lubricate the idler gear and bearing liberally with clean engine oil.
6. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between used gears.

CRANKSHAFT TIMING GEAR

IN-LINE AND 6V-53 ENGINES

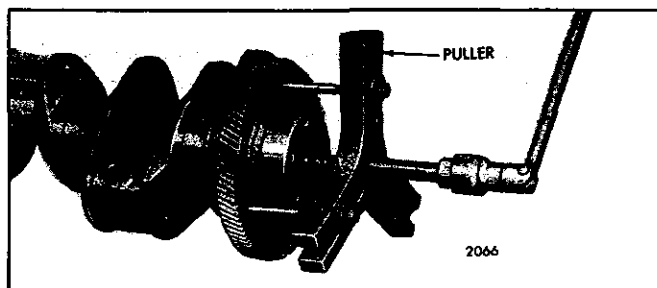


Fig. 1 - Removing Crankshaft Timing Gear with Puller J 4871

The crankshaft timing gear is keyed and pressed on the crankshaft and drives the camshaft gear (In-line or 6V-53 engines) or balance shaft gear (In-line engines) through an idler gear. A quiet gear train was introduced in 53 Series engines effective with engines 3D-170683, 4D-180939 and 6D-196535.

Since the camshaft must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (refer to Section 1.7.1 for gear train timing and identification of the new quiet gears and the former gears).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The former crankshaft timing gear is a .001" to .003" press fit on the crankshaft. The current 111 toothed gear is a .0015" to .0035" press fit on the crankshaft. The crankshaft diameter at this point is 4.060" to 4.061". Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.
2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.
3. Attach bar type puller J 4871 to the crankshaft gear with three long bolts or hooks, flat washers and nuts through the holes in the gear (Fig. 1).
4. Turn the center screw of the puller to pull the crankshaft gear off of the crankshaft.

Inspection

Clean the gear with fuel oil and dry it with compressed air.

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

Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also, check the other gears in the gear train.

Install Crankshaft Timing Gear

Before the crankshaft timing gear is installed, measure the inside diameter of the gear and outside diameter of the butt end of the crankshaft to assure the correct press fit.

- The inside diameter of the current 111 tooth gear is 4.0575" to 4.0585". The former 97 tooth gear inside diameter is 4.0580" to 4.0590".
- The outside diameter of the butt end of the crankshaft is 4.060" to 4.061".

If either the crankshaft or gear are beyond specifications, replace the gear or the crankshaft.

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

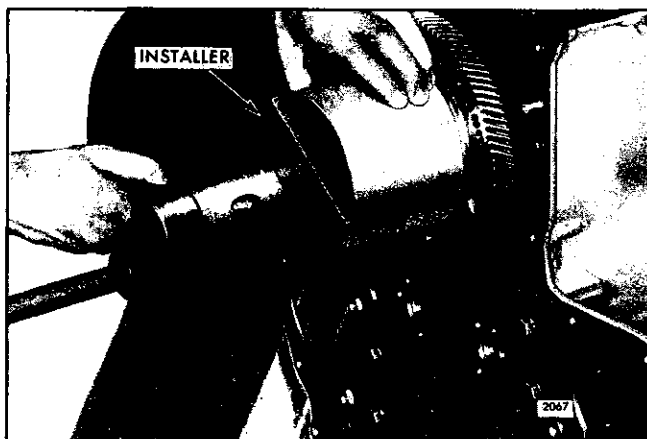


Fig. 2 - Installing Crankshaft Timing Gear Using Installer J 7557

1. If removed, install the Woodruff key in the keyway in the crankshaft.
2. Start the timing gear over the end of the crankshaft with the timing marks on the outer rim of the gear facing out and the keyway in the gear in alignment with the Woodruff key in the crankshaft.
3. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).

When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

4. Place a heavy hammer against the head of the bolt in the front end of the crankshaft. Place installer J 7557 against the rear face of the timing gear and drive the gear up against the shoulder on the crankshaft (Fig. 2).
5. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between used gears.
6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

8V-53 ENGINE

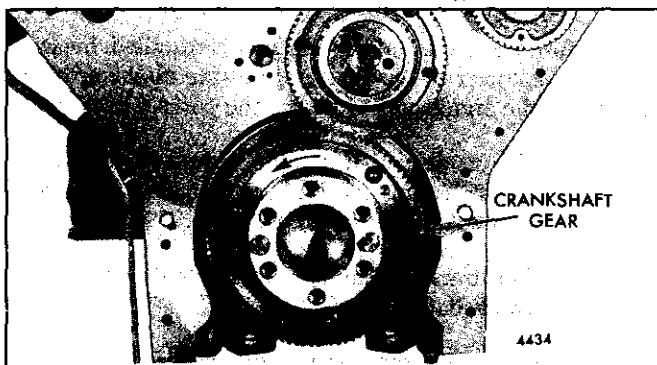


Fig. 3 - Crankshaft Timing Gear Mounting
(R.H. Rotation Engine Shown)

The crankshaft timing gear on an 8V-53 engine is keyed and fastened to the crankshaft with three 3/8"-24 x 3/4" socket head bolts (Fig. 3).

Since the camshafts must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft gears (refer to Section 1.7.1).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft timing gear is a .001" to .003" press fit on the crankshaft. The crankshaft diameter at this point is 4.060" to 4.061". Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve,peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the crankshaft.
2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its *original* position.
3. Remove the three socket head bolts securing the gear to the crankshaft.

4. Provide a base for the puller screw by placing a steel plate across the cavity in the end of the crankshaft. Then, remove the gear with a suitable puller (J 4871).

Inspection

Clean the gear with fuel oil and dry it with compressed air.

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

Examine the gear teeth for evidence of scoring, pitting or wear. If severely damaged or worn, install a new gear. Also, check the other gears in the gear train.

Install Crankshaft Timing Gear

1. If removed, install the Woodruff key in the keyway in the crankshaft.
2. Start the timing gear over the end of the crankshaft with the timing marks on the outer rim of the gear facing out and the keyway in the gear in alignment with the Woodruff key in the crankshaft.
3. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Section 1.7.1).

When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

4. Start the three 3/8"-24 socket head bolts into the crankshaft. Then, slowly draw the gear tight against the shoulder on the crankshaft by tightening the bolts uniformly to 35-39 lb-ft (47-53 N·m) torque.
5. Check the backlash between the mating gears. The backlash must be .0005" to .005" between new gears and should not exceed .007" between used gears.
6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Section 1.3.2.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

4-53 AND 6V-53 ENGINES

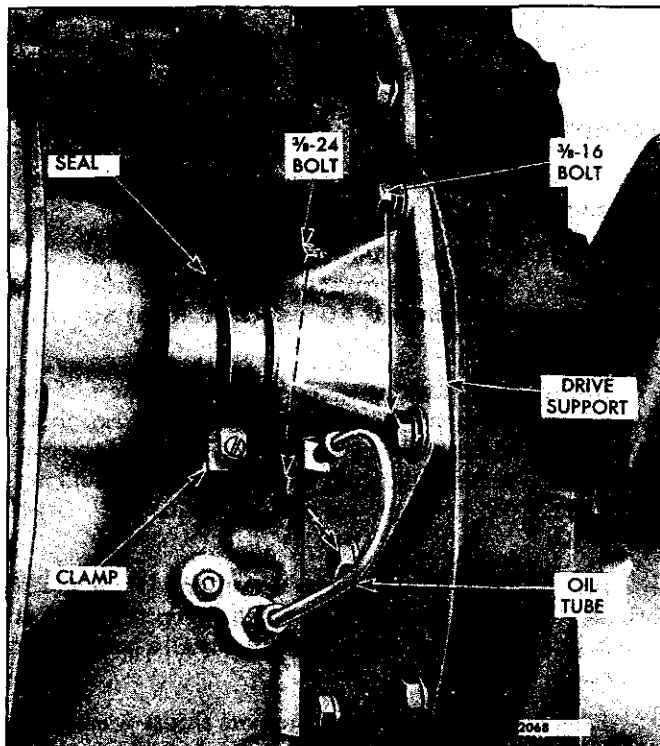


Fig. 1 - Blower Drive Support Mounting on 4-53 In-line Engine

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

Effective with engine serial numbers 4D-201579 and 6D-220736, new carbonitride-hardened blower drive shaft and a new steel induction-hardened blower coupling cam are being used in naturally aspirated and turbocharged engines. Carbonitride hardening results in added resistance to shaft and coupling spline wear. To distinguish the new shafts from the former, one end of each new shafts is stamped with the letter "H". The non-counterbored face of the new cam is stamped with the letter "S". The former and the new components are not interchangeable, and only the new components will be serviced.

To reduce the level of engine noise in the Series 53 engines, the pitch and pressure angle of the gear train and accessory drive gears has been changed (refer to Section 1.7.1).

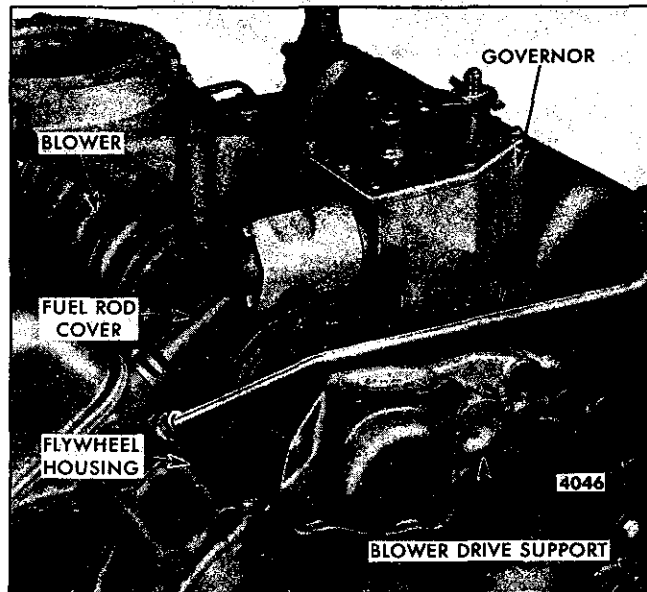


Fig. 2 - Blower Drive Support Mounting on 6V-53 Engine

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

NOTICE: Do not mix the former and the current hardened gears on the same engine. Mixing the gears will result in excessive gear wear and may lead to serious engine damage.

The hardened gears are used on 3-53 turbocharged industrial and 6V turbocharged automotive engines. This change became effective with engine serial numbers 3D-193516 and 6D-229616.

Remove and Install Blower Drive Shaft

1. Remove the air inlet housing from the blower (refer to Section 3.3).
2. Refer to Fig. 1 and loosen the blower drive seal clamp.
3. Slide the clamp and seal off of the blower drive support.
4. Remove the four blower-to-block bolts. Then, carefully lift the blower away from the blower drive support and the cylinder block so the serrations on the blower drive shaft are not damaged.
5. Withdraw the blower drive shaft from the blower drive support.
6. Install the shaft by reversing the removal procedure.



Fig. 3 – Pressing Blower Drive Gear From Shaft

Remove Blower Drive Support

1. Remove the blower and the blower drive shaft as outlined above.
2. Disconnect the lubricating oil tube from the blower drive support (Fig. 1).
3. Remove the blower drive support attaching bolts.
4. Tap the blower drive support to loosen it, then carefully withdraw the support from the rear end plate so the blower drive gear teeth will not be damaged.

Disassemble Blower Drive Support

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

2. If there are burrs on the edges of the snap ring groove, remove them with a stone. Then, withdraw the gear and shaft from the support.
3. Support the blower drive gear in an arbor press (Fig. 3).
4. Place a short 1-1/8" diameter brass rod on the end of the shaft and press the shaft out of the gear.

Inspection

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

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

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

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

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

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

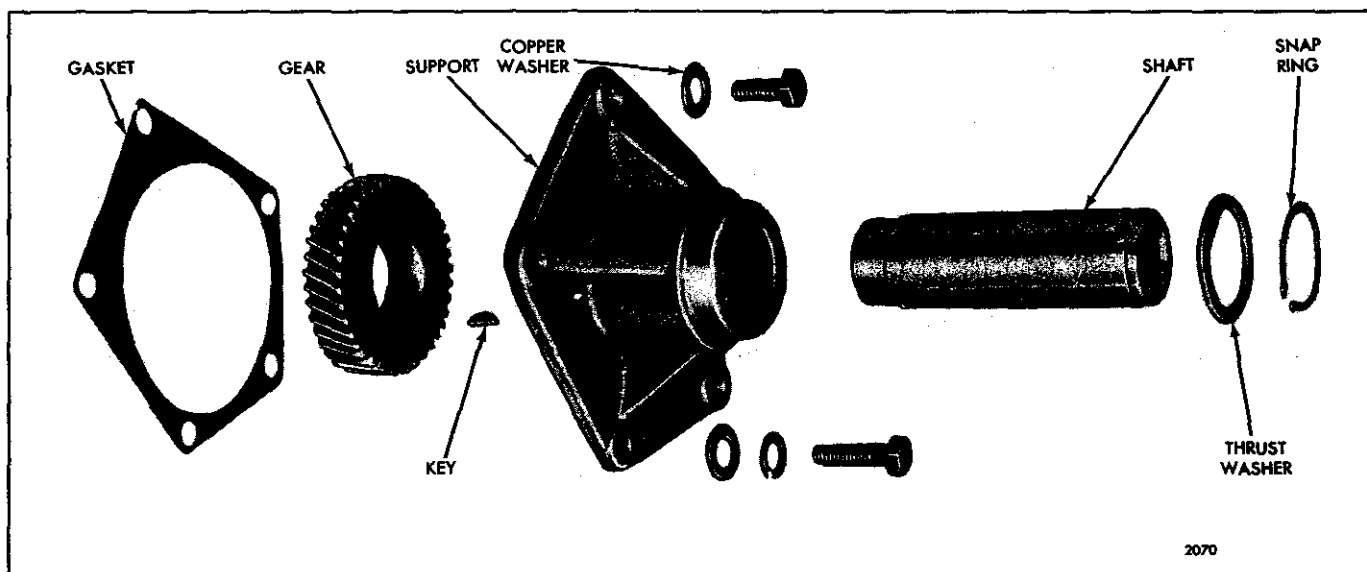


Fig. 4 – Blower Drive Gear and Support Assembly Details and Relative Location of Parts (In-line Engine)

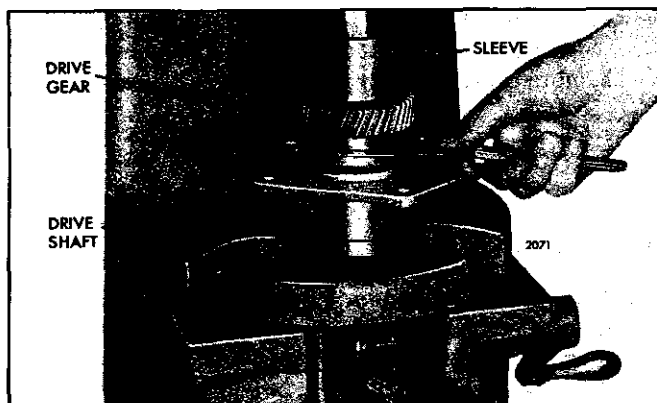


Fig. 5 – Pressing Blower Drive Gear On Shaft

Assemble Blower Drive Support

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

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

2. Assemble the thrust washer and the snap ring on the shaft.
3. Install the key in the shaft, if it was removed.
4. Place the shaft and support in an arbor press.
5. Position the gear on the shaft so the keyway in the gear is in alignment with the key in the shaft. Then, place a sleeve on the gear and press the gear on the shaft until the clearance between the gear and support is .004" to .012" (Fig. 5).

Install Blower Drive Support

1. Affix a new blower drive support gasket to the cylinder block rear end plate.
2. Install the blower drive support assembly by reversing the removal procedure.
3. Tighten the 3/8"-24 support-to-end plate bolts (with copper washers) and the 3/8"-16 support-to-flywheel housing bolts (with plain washers and lock washers) to 35 lb-ft (47 N·m) torque.

8V-53 ENGINE

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

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

Remove And Install Blower Drive Shaft

1. If an air compressor is attached to the rear right-hand face of the flywheel housing, disconnect and remove it from the flywheel housing.
2. Remove the five bolts and lock washers securing the blower drive hole cover to the flywheel housing. Remove the cover and gasket.
3. Remove the two bolts securing the blower drive shaft retainer to the blower drive coupling support, then remove the retainer.

4. Pull the blower drive shaft out of the blower drive hub and cam. If necessary, use a pair of small nose pliers.
5. Install the blower drive shaft by reversing the removal procedure.

Remove Blower Drive Support

1. Remove the blower, governor and drive support assembly from the engine as outlined under *Remove Blower* in Section 3.4.1.
2. Remove the six bolts, lock washers, plain washers and one socket head bolt securing the blower drive support to the blower rear end plate.
3. Tap each end of the blower drive support with a plastic hammer to loosen it from the gasket and dowel pins. Then, remove the drive support assembly and gasket.

Disassemble Blower Drive Support

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

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

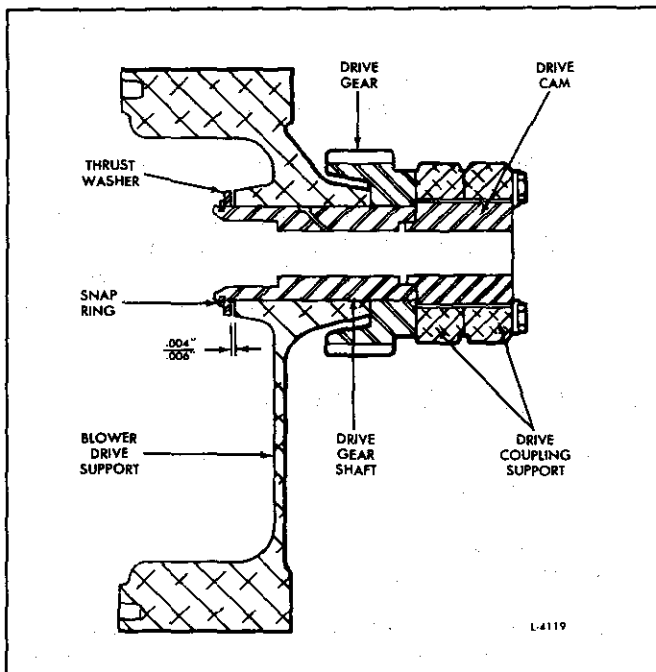


Fig. 6 - Blower Drive Support Assembly

2. If there are any burrs on the edges of the snap ring groove, remove them with a fine stone. Then, withdraw the drive gear and shaft from the support.
3. Support the blower drive gear and shaft, rear face of the gear up, on two wood blocks on the bed of an arbor press.

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

Inspection

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

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

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also, check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and the support should not be less than .002" (with new parts) or more than .007" (with used parts).

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

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

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

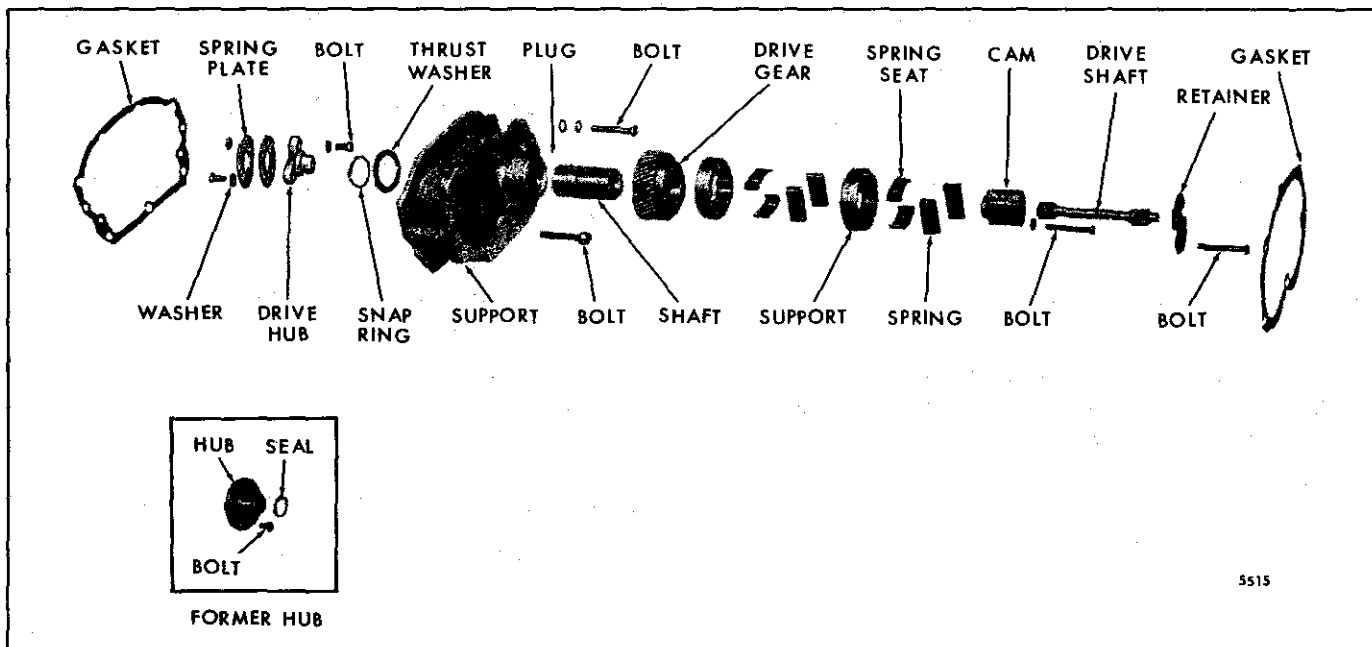


Fig. 7 - Blower Drive Support Details and Relative Location of Parts (8V-53 Engine)

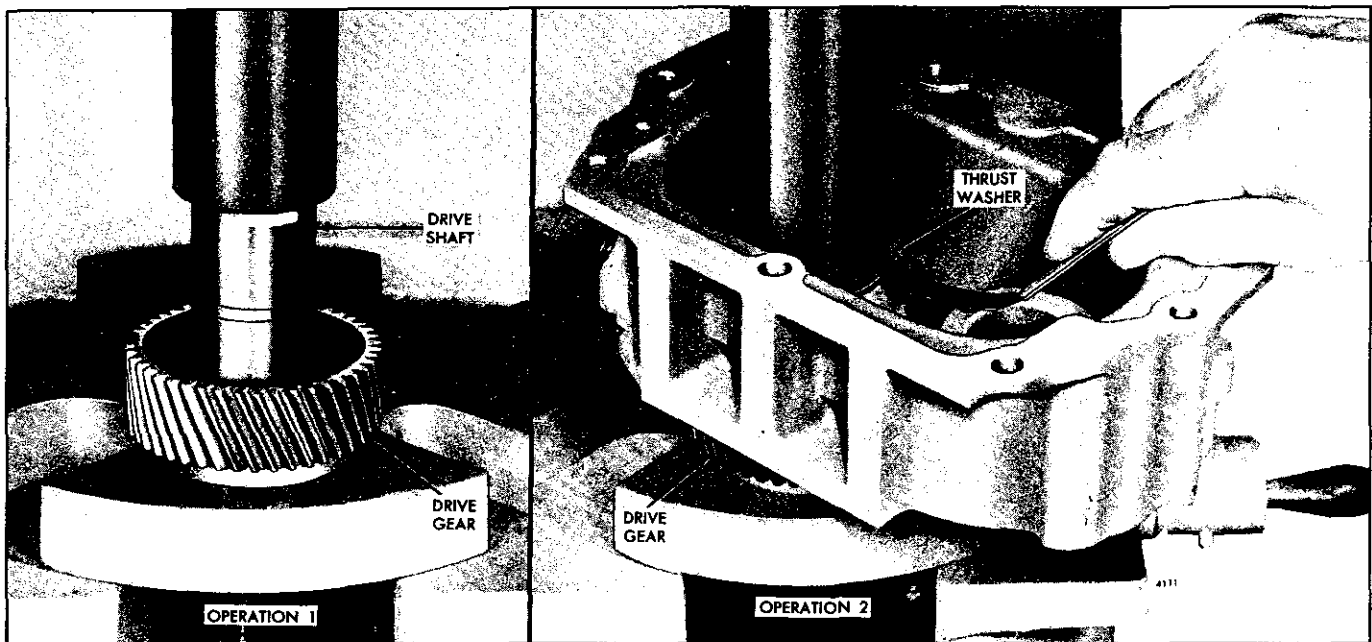


Fig. 8 – Installing Blower Drive Gear Shaft in Drive Gear

Assemble Blower Drive Support

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

1. Lubricate the drive gear end of the blower drive gear shaft with engine oil. Then, start the shaft straight into the shaft bore in the drive gear from the recessed side.
2. Place the blower drive gear and shaft on the bed of an arbor press (Fig. 8, Operation 1). Then, press the shaft straight into the drive gear approximately one half inch.
3. Lubricate the blower drive gear shaft with engine oil. Then, insert the shaft into the shaft bore in the support.
4. Place the thrust washer, oil groove side facing the support, on the blower drive gear shaft. Then, install the snap ring in the groove in the shaft.
5. Support the blower drive gear, shaft and support on the bed of an arbor press (Fig. 8, Operation 2). Then,

press the drive gear shaft into the drive gear until the clearance between the thrust washer and the support is .004" to .012" (Fig. 6).

Install Blower Drive Support

1. Affix a new blower drive support gasket to the forward face of the support.
2. Place the blower drive support assembly over the two dowel pins in the blower rear end plate and against the gasket.
3. Install the six bolts, lock washers, plain washers and one socket head bolt. Tighten the bolts to 20–24 lb–ft (27–33 N·m) torque.
4. Install the blower, governor and drive support assembly on the engine as outlined under *Install Blower* in Section 3.4.1.

1. The first part of the document is a list of names and addresses of the members of the committee. The names are listed in alphabetical order, and the addresses are listed below each name. The list includes the names of the members of the committee, the names of the members of the sub-committee, and the names of the members of the advisory committee. The addresses are listed in the same order as the names.

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ACCESSORY DRIVES

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

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

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

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

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

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

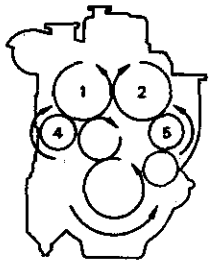
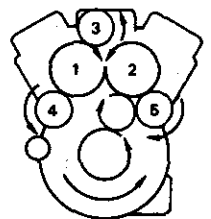
	ACCESSORY DRIVE POSITION	DRIVE RATIO
	1	1:1
	2	1:1
	4 BLOWER GOV.	2.47:1
	5 BLOWER GOV.	1.98:1
	5 BLOWER GOV.	2.47:1
	1	1:1
	2	1:1
	3	*2.47:1
	4	1.98:1
	5	1.98:1
*2.20:1 ON 8V ENGINE		

Fig. 1 - Accessory Drive Locations

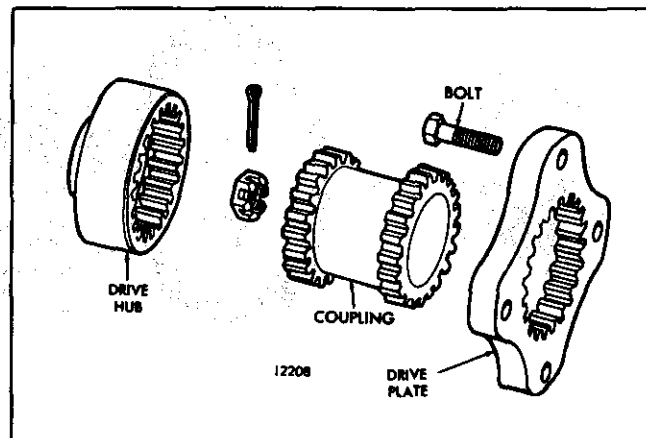


Fig. 2 - Air Compressor Drive

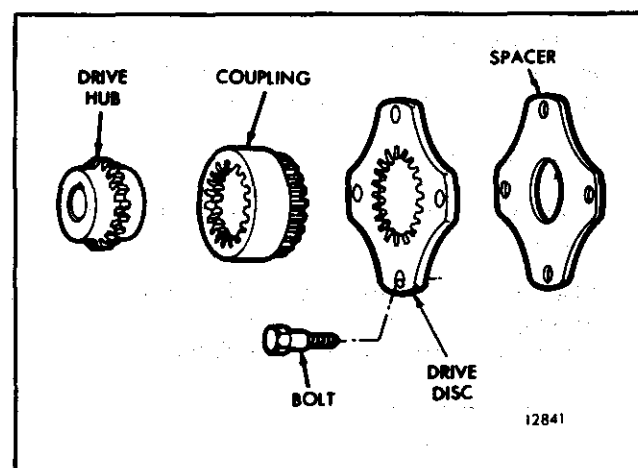


Fig. 3 - Hydraulic Pump Drive

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

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

Remove Accessory Drive

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

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

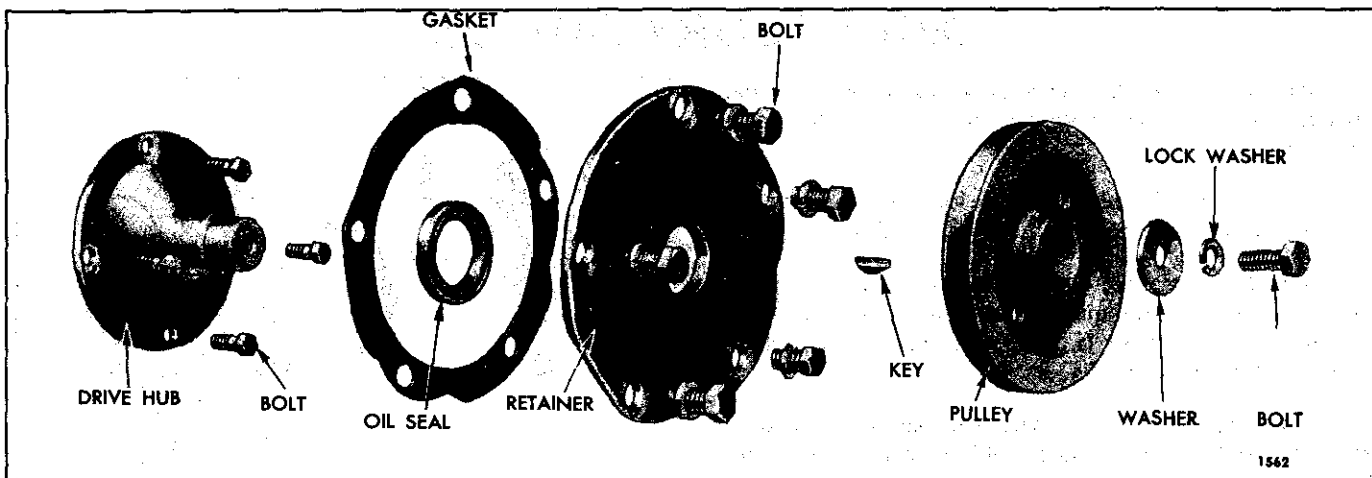


Fig. 4 – Components of Accessory Drive for Belt-Driven Accessory (Drive Hub Type)

2. Remove the five bolts and lock washers attaching the accessory to the flywheel housing. Pull the accessory straight out from the flywheel housing.
3. Remove the drive coupling.
4. Remove the drive hub from the accessory shaft, if necessary.
5. Place a clean, lintless cloth in the flywheel housing opening, underneath the accessory drive plate, to prevent bolts from accidentally falling into the gear

train. Remove the lock wires, if used. Then remove the four bolts (and lock washers, if used) and remove the accessory, the drive plate and the spacer, if used.

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

1. Remove any external piping or connections to the accessory.
2. Loosen the accessory and slide it toward the drive pulley. Then remove the drive belt and accessory.

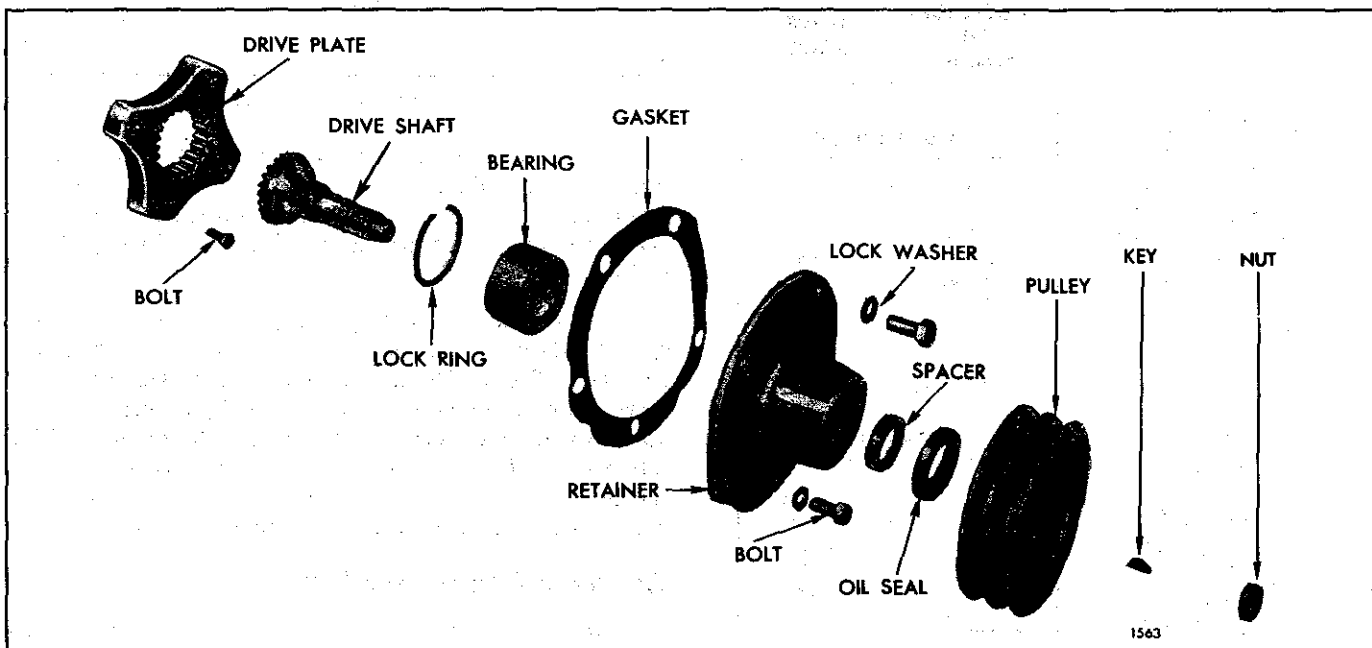


Fig. 5 – Components of Accessory Drive for Belt-Driven Accessory (Drive Plate Type)

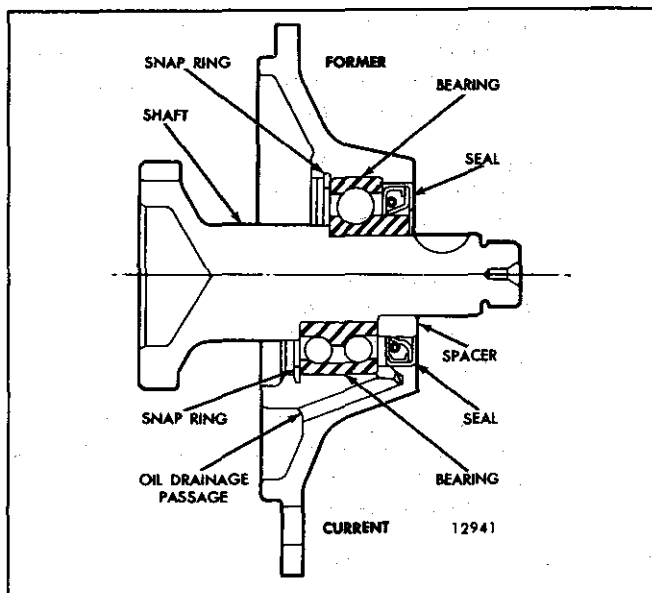


Fig. 6 - Former and Current Drive Plate Type Accessory Drive

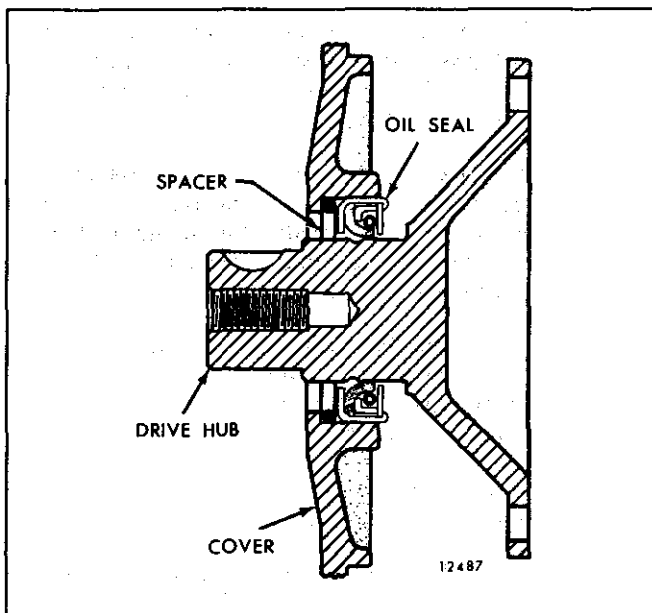


Fig. 7 - Location of Oil Seal Spacer

3. Remove the bolt and washer (Fig. 4), or nut (Fig. 5), retaining the pulley on the drive shaft.
4. Use a suitable gear puller to remove the pulley from the drive shaft. Remove the Woodruff key.
5. Remove the five bolts and lock washers which attach the drive retainer assembly to the flywheel housing. Remove the retainer assembly.
6. Remove the accessory drive shaft, drive plate and spacer (Fig. 5), or drive hub (Fig. 4), in a manner

similar to that outlined in Step 5 under removal of the direct gear-driven type accessory drive.

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

Inspection

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

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

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

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

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

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

Install Accessory Drive

1. Remove old gasket material from the flywheel housing. Use care so that no gasket material falls into the gear train compartment.
2. Insert a clean, lintless cloth in the flywheel housing opening to prevent bolts from accidentally falling in the gear train. Align the bolt holes in the accessory drive plate and spacer (if used), or the accessory drive hub, with the tapped holes in the camshaft or balance shaft gear. Then secure the plate and spacer, or drive hub, with four bolts (and lock washers or lock wire, if used). Remove the cloth from the flywheel housing opening.
3. If a gear-driven accessory is used as shown in Figs. 2 and 3, install the accessory drive coupling. When replacing the drive hub on the accessory shaft, drive

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

- a. Place a new gasket on the flange and align the holes in the gasket with the bolt holes in the flange. Use a light coat of grease to retain the gasket in position.
 - b. Place the accessory in position against the flywheel housing, rotating it, if necessary, to align the teeth of the accessory hub with those in the drive coupling. Secure the accessory to the flywheel housing with five bolts and lock washers.
4. If the accessory drive shown in Figs. 5 or 6 is used, assemble as follows:
- a. Install the accessory drive plate and spacer as outlined in Steps 1 and 2 above.
 - b. Place the drive shaft retainer on the bed of an arbor press, with the mounting flange side up. Press the double-row ball bearing straight in until the bearing contacts the shoulder in the bore of the retainer. Install the snap ring.
On former accessory drives (Fig. 6), install the bearing with the protruding face of the inner race towards the retainer.
 - c. Turn the retainer over and press the oil seal into the bore of the retainer with the lip of the seal toward the bearing.
 - d. Turn the retainer over again, bearing side up, and press the accessory drive shaft in the bearing until the shoulder on the shaft contacts the bearing.
 - e. Apply a light coat of grease to the mounting flange of the retainer and place a new gasket in position against the flange. Align the holes in the gasket with the bolt holes in the flange.
 - f. Place the retainer and drive shaft assembly against the flywheel housing, rotating the shaft slightly, if necessary, to permit the teeth of the drive shaft to mesh with the teeth in the drive plate. Secure the retainer assembly to the flywheel housing with five bolts and lock washers.
 - g. On current accessory drives, install the spacer over the shaft and against the bearing.
- h. Install the Woodruff key in the drive shaft. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.
- i. Thread the 3/4"-16 pulley retaining nut on the end of the drive shaft and tighten it to 120-140 lb-ft (163-190 N·m) torque.
- j. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.
- When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.*
5. Assemble the accessory drive shown in Fig. 4 as follows:
- a. Press a new oil seal in the oil seal retainer, if the seal was removed.
 - b. Coat the mounting flange of the retainer lightly with grease and place a new gasket against the flange. Align the holes in the gasket with the bolt holes in the flange.
 - c. With the accessory drive hub in place (see Step 2 above), slip the retainer and oil seal assembly over the end of the shaft. Use care not to damage the oil seal. Secure the retainer to the flywheel housing with five bolts and lock washers.
 - d. Install the Woodruff key. Start the pulley straight on the shaft, aligning the keyway in the pulley with the key on the shaft. Use a soft hammer to tap the pulley on the shaft.
 - e. Install the washers and the pulley retaining bolt and draw the bolt up tight.
 - f. Install the accessory on the engine and slip the drive belt over the pulleys. Position the accessory to provide the proper tension on the belt and secure it in place.
- When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.*

ENGINE FRONT COVER (Upper)

In-Line and 6V Engines

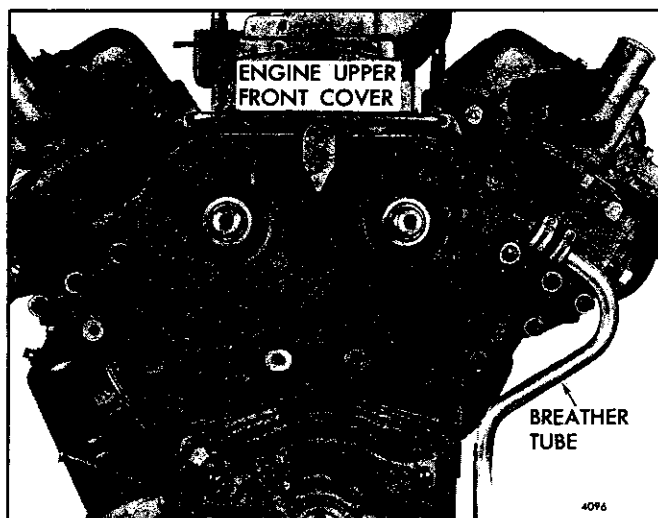


Fig. 1 - 6V Engine Upper Front Cover Mounting

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

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

Remove Cover

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

If necessary, remove the engine cover as follows:

1. Remove the various parts and subassemblies from the engine as outlined in their respective sections of this manual.

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

Inspection

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

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

Remove Oil Seals

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

Install Oil Seals

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

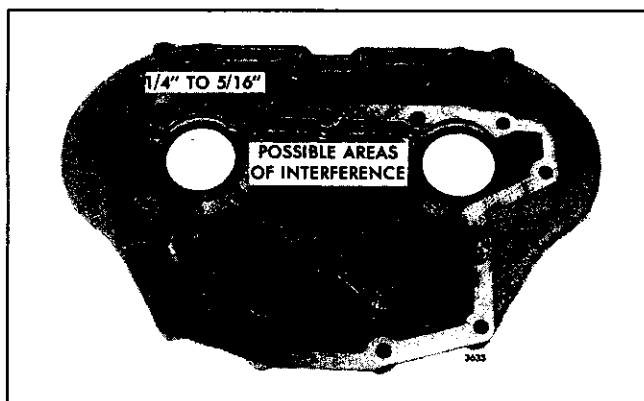


Fig. 2 - In-Line Engine Upper Front Cover

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

Install Cover

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

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

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

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

SHOP NOTES - TROUBLESHOOTING - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

CHECKING BEARING CLEARANCES

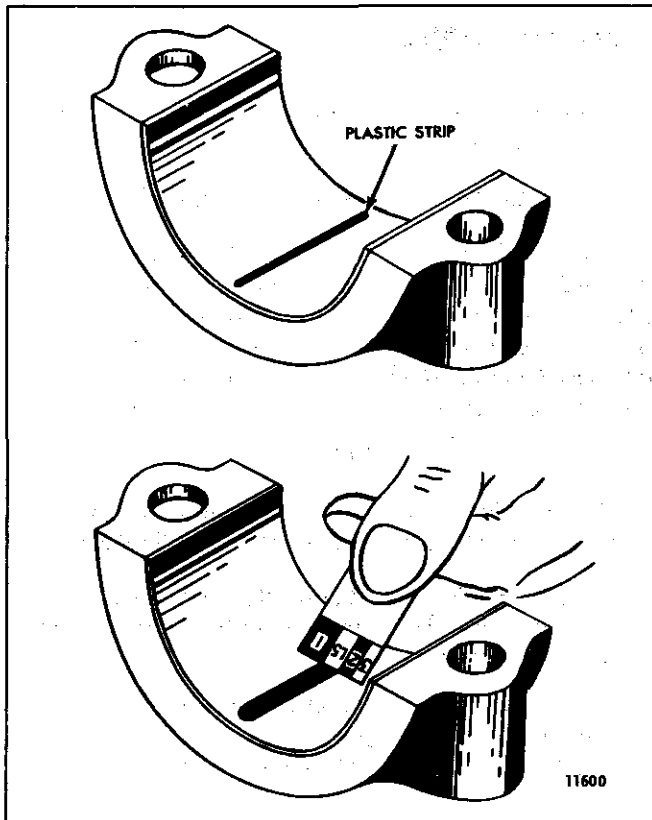


Fig. 1 - Using Plastic Strip to Measure
Bearing-to-Crankshaft Clearance

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

The strip is a specially molded plastic "wire" manufactured commercially and is available in three sizes

and colors. Type PG-1 (green) has a clearance range of .001" to .003", type PR-1 (red) has a range of .002" to .006" and type PB-1 (blue) has a range of .004" to .009".

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

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

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

2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4" off center (Fig. 1).
3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.
4. Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.
5. Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope (Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

IN-FRAME OVERHAUL

Polyethylene plastic plugs (J 34697) help prevent solvent and debris from entering the crankcase while

cleaning the airbox during in-frame overhaul or cylinder kit replacement.

CAMSHAFT CUP PLUG INSTALLATION

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

Install the cup plug as follows:

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

CYLINDER BLOCK LINE BORING

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

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

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

3. Bore diameters for standard and oversized main bearing shells are shown in the following table:

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

TABLE 1

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

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

• WELDING ENGINE CYLINDER HEADS

The welding of series 53 cylinder heads is not recommended. The welding of cylinder heads has been used as a salvage procedure for several years. As a salvage

procedure, the resultant product has not been considered as good as a new casting.

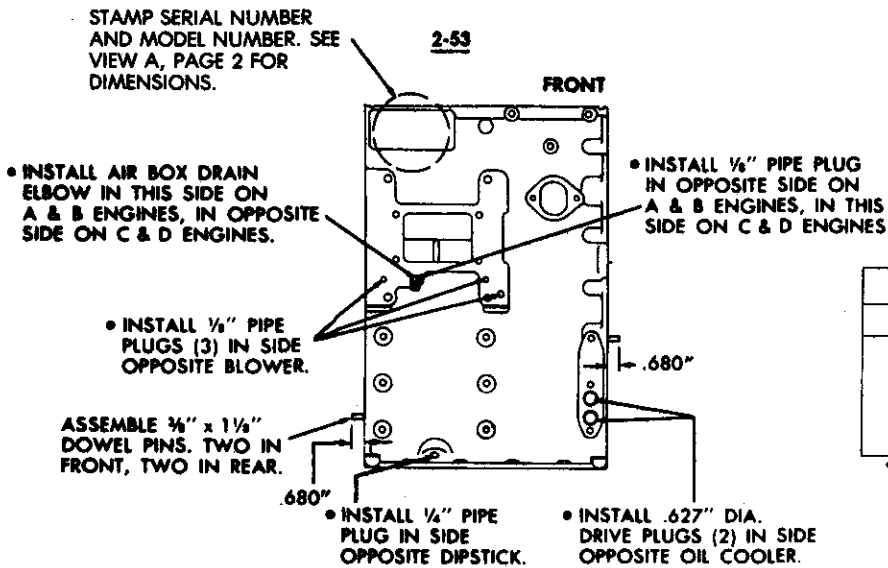
REUSING CROSSHEAD PISTON ASSEMBLY COMPONENTS

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

The crown, pin and bushing of a crosshead piston assembly should be considered as matched. If a crown is replaced, the piston pin and bushing must also be replaced.

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

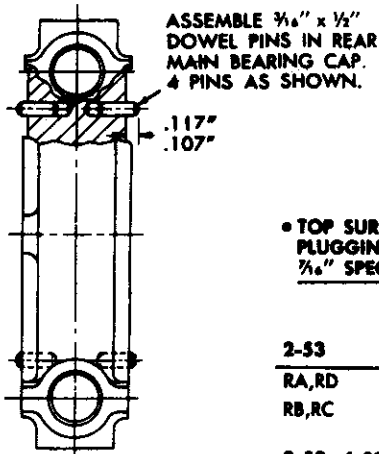
CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)



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

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

CUTAWAY VIEW OF REAR MAIN BEARING CAP



NOTES

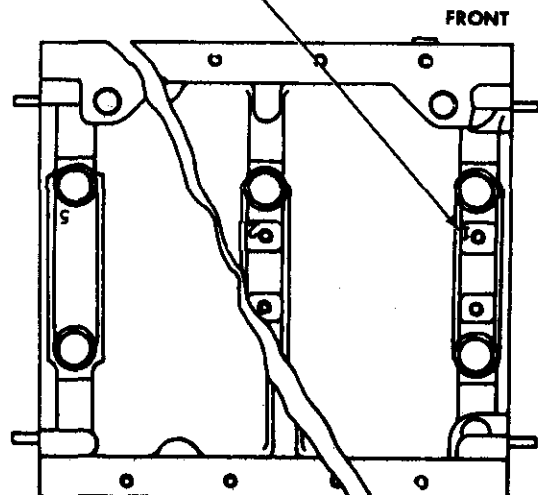
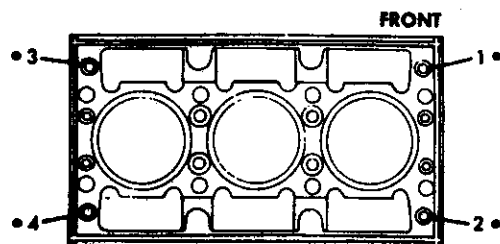
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

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

• TOP SURFACE PLUGGING INSTRUCTIONS
1/8" SPECIAL CUP PLUG

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

STAMP BEARING NUMBERS, 1/8" HIGH FIGURES, FROM FRONT TO REAR.



REV. 9-77

CYLINDER BLOCK PLUGGING INSTRUCTIONS (IN-LINE ENGINES)

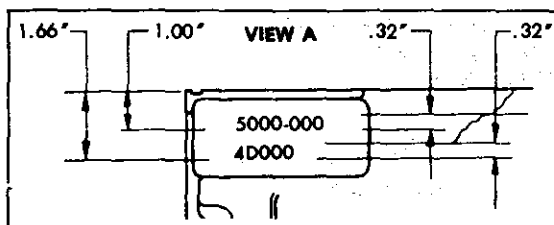
STAMP SERIAL NUMBER AND MODEL NUMBER. SEE VIEW A FOR DIMENSIONS.

3-53

FRONT

- INSTALL $\frac{1}{8}$ " PIPE PLUGS (3) IN SIDE OPPOSITE BLOWER.
- INSTALL AIR BOX DRAIN ELBOW IN THIS SIDE ON A & B ENGINES, IN OPPOSITE SIDE ON C & D ENGINES.
- INSTALL $\frac{1}{8}$ " PIPE PLUG IN OPPOSITE SIDE ON A & B ENGINES, IN THIS SIDE ON C & D ENGINES.
- INSTALL $\frac{1}{8}$ " PIPE PLUG IN SIDE OPPOSITE DIPSTICK.
- INSTALL $\frac{1}{8}$ " PIPE PLUGS (2) IN OPPOSITE SIDE.
- INSTALL $\frac{1}{8}$ " DRAINCOCK IN SIDE OPPOSITE OIL COOLER, $\frac{1}{8}$ " PIPE PLUG IN OIL COOLER SIDE.
- ASSEMBLE $\frac{3}{8}$ " x $1\frac{1}{8}$ " DOWEL PINS. TWO IN FRONT, TWO IN REAR.
- .680"
- INSTALL .627" DIA. DRIVE PLUGS (2) IN SIDE OPPOSITE OIL COOLER.*

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



STAMP SERIAL NUMBER AND MODEL NUMBER. SEE VIEW A FOR DIMENSIONS.

4-53

FRONT

- INSTALL $\frac{1}{8}$ " DRAINCOCK IN EACH SIDE.
- INSTALL AIR BOX DRAIN ELBOW IN THIS SIDE ON A & B ENGINES, IN OPPOSITE SIDE ON C & D ENGINES.
- INSTALL $\frac{1}{8}$ " PIPE PLUG IN OPPOSITE SIDE ON A & B ENGINES, IN THIS SIDE ON C & D ENGINES.
- INSTALL $\frac{1}{8}$ " PIPE PLUGS (2) IN SIDE OPPOSITE BLOWER.
- INSTALL $\frac{1}{8}$ " PIPE PLUG IN SIDE OPPOSITE DIPSTICK.
- INSTALL $\frac{1}{8}$ " PIPE PLUG IN OPPOSITE SIDE.
- INSTALL $\frac{1}{8}$ " PIPE PLUGS (2) IN SIDE OPPOSITE BLOWER.
- ASSEMBLE $\frac{3}{8}$ " x $1\frac{1}{8}$ " DOWEL PINS. TWO IN FRONT, TWO IN REAR.
- .680"
- INSTALL .627" DIA. DRIVE PLUGS (2) IN SIDE OPPOSITE OIL COOLER.

NOTES

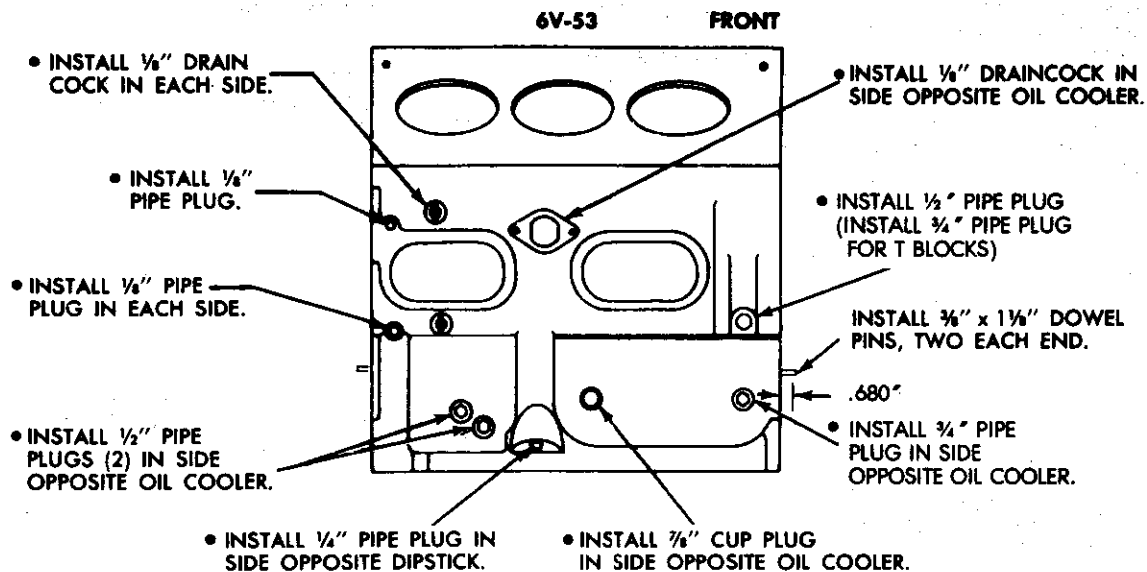
1. INSTALL PLUGS FLUSH TO BELOW TOP OF FINISHED SURFACES OF BLOCK.

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

REV. 9-77

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

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



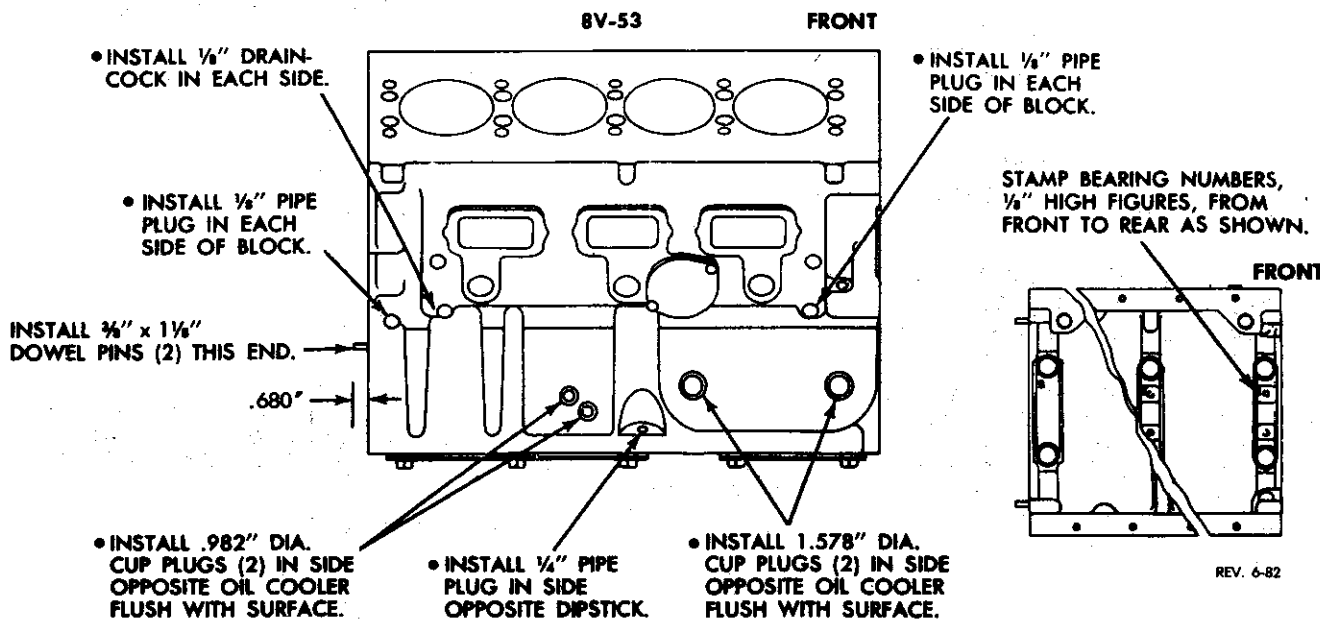
NOTES

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

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

STANDARD PIPE PLUG TORQUE

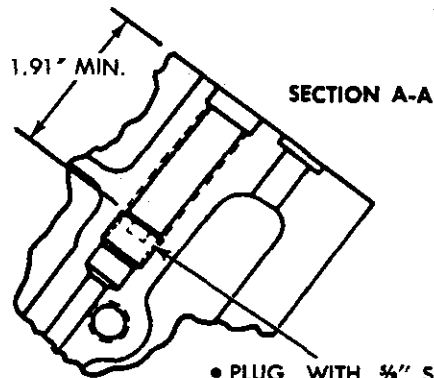
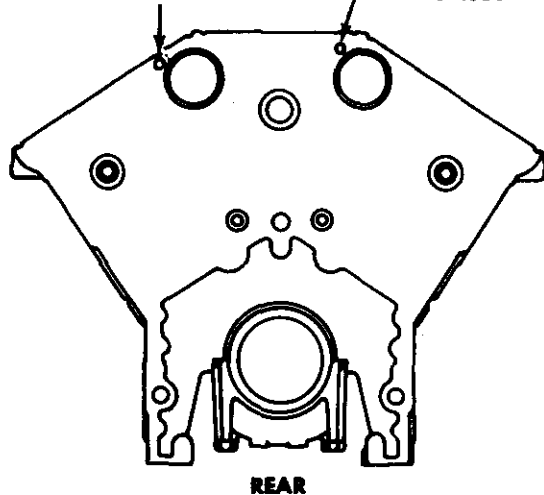
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50



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

INSTALL $\frac{3}{16}$ " x $\frac{1}{2}$ " DOWEL PIN AT EACH END. (COPPER-FLASHED FOR 8V-53, PLAIN FOR 6V-53) FLUSH TO .020" BELOW SURFACE.

- INSTALL $\frac{3}{16}$ " SPEC. CUP PLUG, FRONT AND REAR ON 8V-53, REAR ONLY ON 6V-53 FLUSH TO .030" BELOW SURFACE.

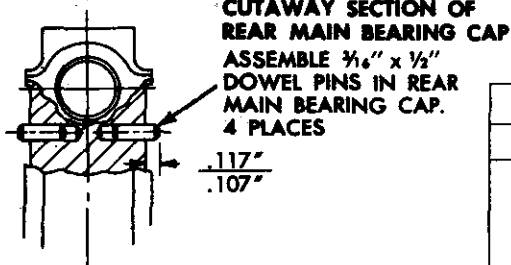


- PLUG WITH $\frac{3}{8}$ " SOCKET CUP SET SCREW RIGHT AND LEFT BANK AT REAR 8V-53 ONLY

NOTES

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

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



CUTAWAY SECTION OF REAR MAIN BEARING CAP ASSEMBLY $\frac{3}{16}$ " x $\frac{1}{2}$ " DOWEL PINS IN REAR MAIN BEARING CAP. 4 PLACES

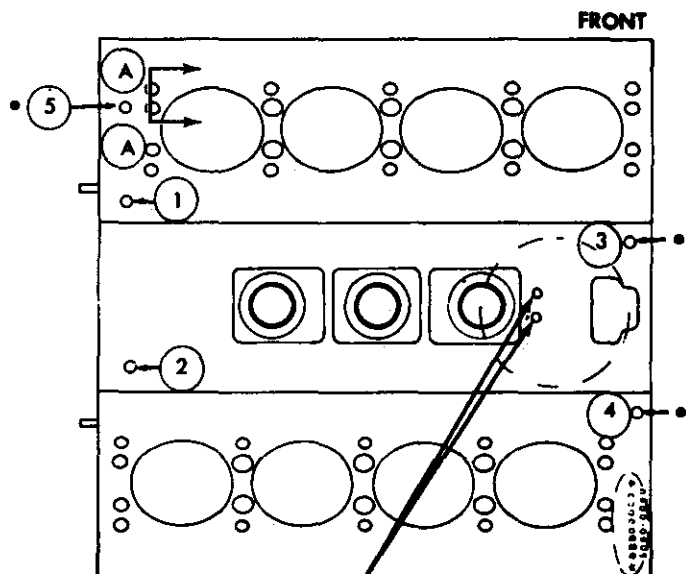
STANDARD PIPE PLUG TORQUE		
PIPE PLUG SIZE	lb-ft	Nm
1/8	10-12	14-16
1/4	14-16	19-22
3/8	18-22	24-30
1/2	23-27	31-37
3/4	33-37	45-50

TOP SURFACE PLUGGING INSTRUCTIONS

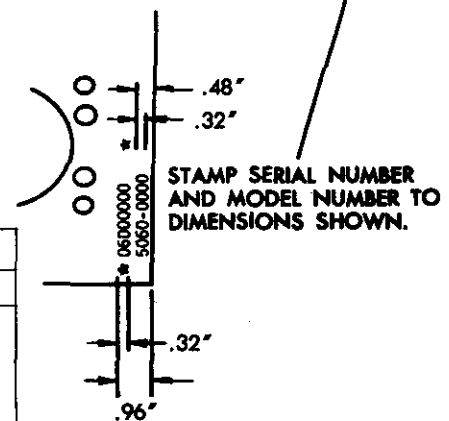
USE $\frac{3}{16}$ " COPPER FLASHED DOWEL PIN EXCEPT WHERE NOTED. INSTALL PINS FLUSH TO .020" BELOW SURFACE.

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

- *NO. 2 HOLE, PLUG WITH $\frac{3}{16}$ " PLAIN DOWEL PIN. NO. 5 HOLE, PLUG WITH $\frac{1}{8}$ " PIPE PLUG FLUSH TO .12" BELOW SURFACE.

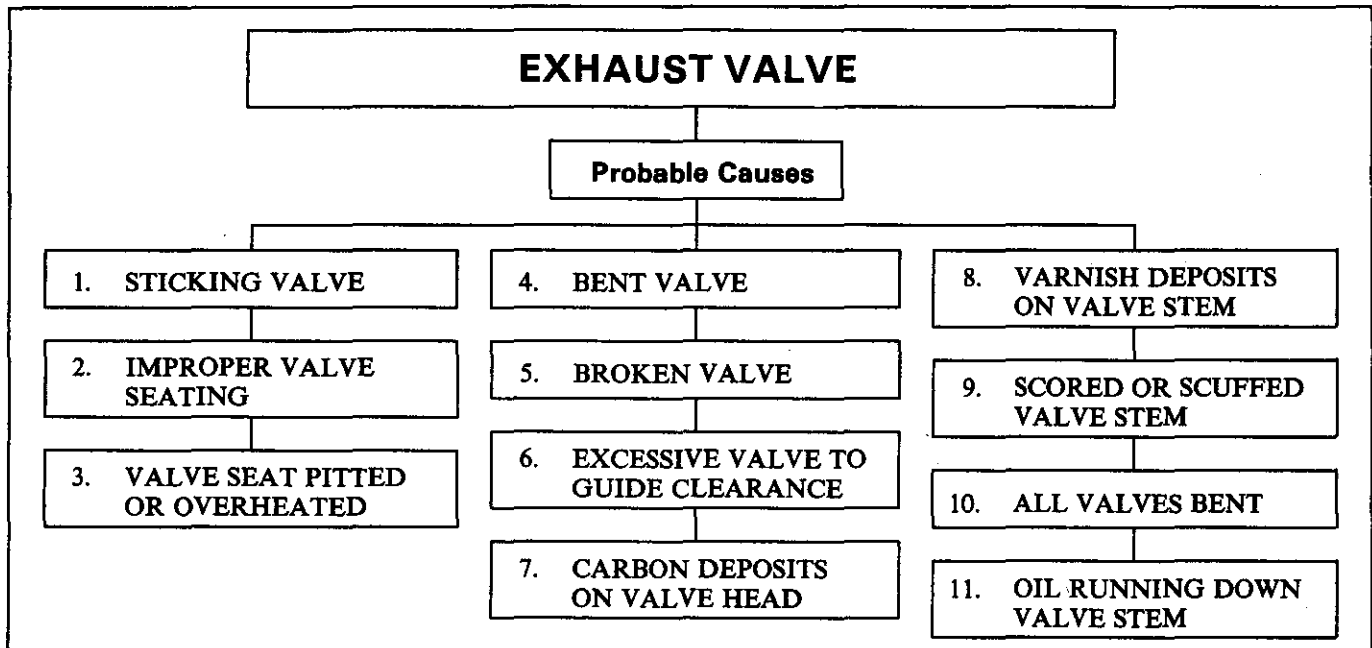


PLUG WITH .075" SPECIAL PLUG BLOCK 5149781 ONLY



REV. 6-82

TROUBLESHOOTING



SUGGESTED REMEDY

- | | |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ol style="list-style-type: none"> 1. Check for carbon deposits, a bent valve guide, defective spring or antifreeze (ethylene glycol) in the lubricating oil. Replace a bent guide. Clean-up and reface the valve. Replace the valve, if necessary. 2. Check for excessive valve-to-guide clearance, bent valve guide or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary. 3. Check the operating conditions of the engine for overload, inadequate cooling or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder-face valve if operating conditions warrant. 4. Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge (four valve head) or a defective spring. Check the valve guide, insert, cylinder head and piston for damage. Replace damaged parts. 5. Check for excessive valve-to-guide clearance, defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder head and piston for damage. Replace damaged parts. 6. Replace a worn valve guide. Check and replace the valve, if necessary. | <ol style="list-style-type: none"> 7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling or improper timing which results in carbonization of the lubricating oil. Clean-up the valves, guides and inserts. Reface the valves and inserts or replace them if they are warped, pitted or scored. 8. Check for a worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace. 9. Check for a bent valve stem or guide, metal chips or dirt, or for lack of lubrication. Clean up the valve stem with crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap DOES NOT scrape the valve stem. 10. Check for a gear train failure or for improper gear train timing. 11. Check the operation of the engine for excessive idling and resultant low engine exhaust back pressure. Install valve guide oil seals. |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits" in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure

satisfactory performance. It should be emphasized that the figures given as "Limits" must be qualified by the personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

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

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

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

* Center land is .0002" - .0008" thinner than adjacent lands.

Runout tolerance given for guidance when regrinding crankshaft. Crankshaft for 2-53 supported on No. 1 and No. 3 journals; runout measured at No. 2 journal. Crankshaft for 3-53 supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 4-53 supported on No. 1 and No. 5 journals; runout measured at No. 2, 3 and 4 journals. Crankshaft for 6V supported on No. 1 and No. 4 journals; runout measured at No. 2 and No. 3 journals. Crankshaft for 8V supported on No. 1 and No. 5 journals; runout measured at No. 2, 3, 4 and outboard journals.

When the runout on adjacent journals is in the opposite direction, the sum must not exceed .003" total indicator reading. When in the same direction, the difference must not exceed .003" total indicator reading. When high spots of runout on adjacent journals are at right angles to each other, the sum must not exceed .004" total indicator reading, or .002" on each journal.

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

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

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

STANDARD PIPE PLUG TORQUE SPECIFICATIONS






Use sealing compound on plugs without gaskets or teflon.

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

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

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

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

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

12252

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

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

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

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

SERVICE TOOLS

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

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

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

SECTION 2

FUEL SYSTEM AND GOVERNORS

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FUEL SYSTEM

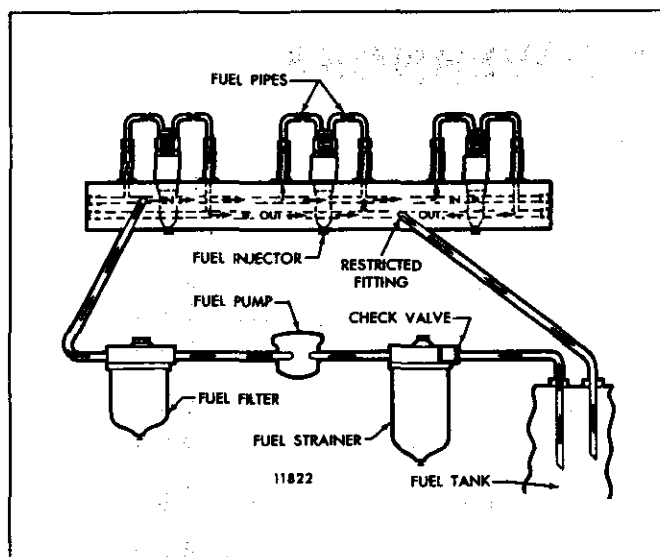


Fig. 1 - Typical Fuel System for In-Line Engines

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

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

The fuel manifolds are identified by the words "IN" (top passage) and "OUT" (bottom passage) which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines. Surplus fuel returns from the

outlet side of the injectors to the fuel return manifold and then back to the supply tank.

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

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

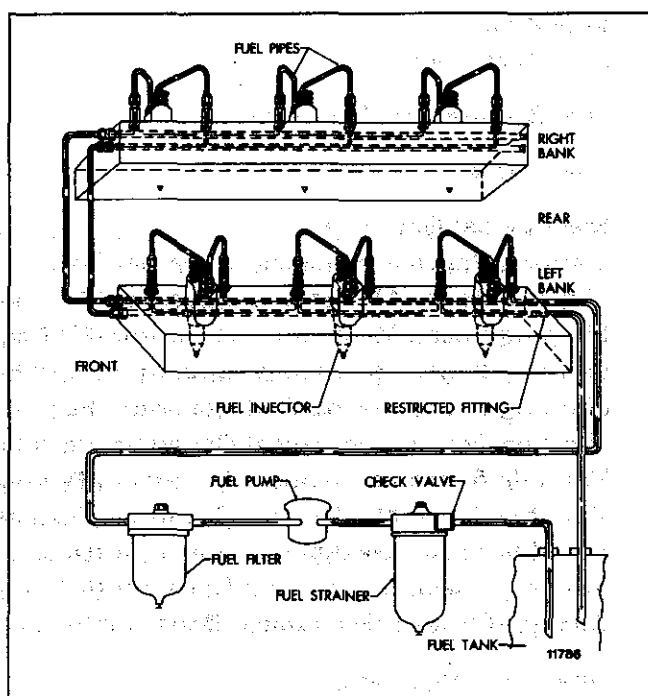


Fig. 2 - Fuel System for 6V-53 Engines

FUEL INJECTOR

MECHANICAL UNIT INJECTOR (MUI)

CROWN VALVE

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

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

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

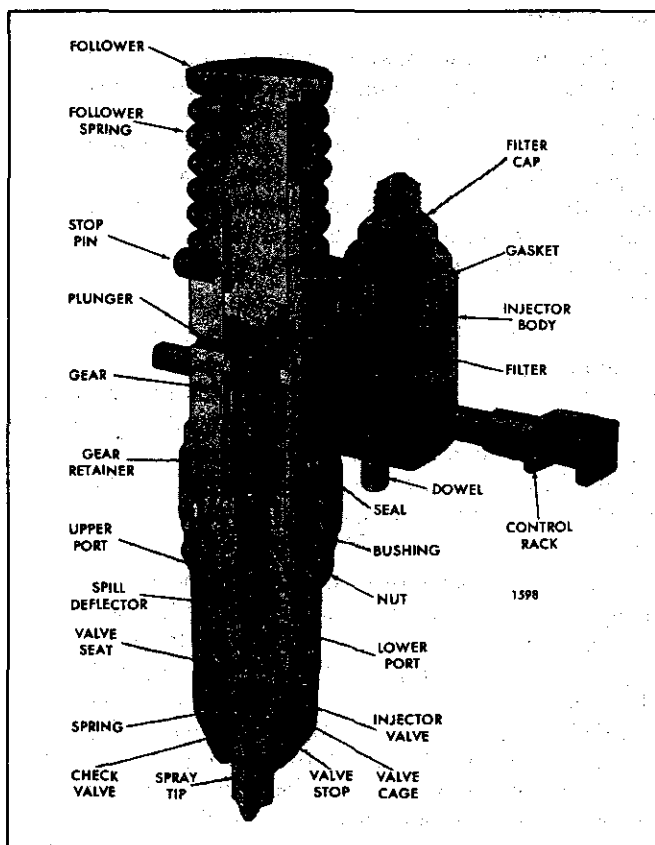


Fig. 1 - Fuel Injector Assembly

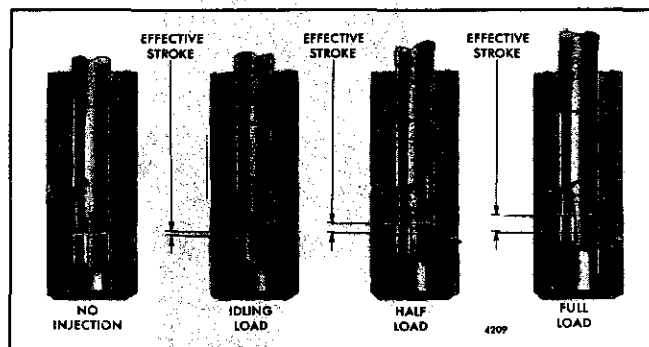


Fig. 2 - Fuel Metering from No Load to Full Load

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

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

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

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

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

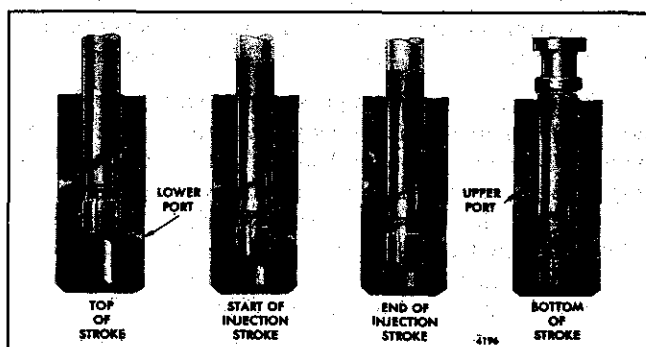


Fig. 3 - Phases of Injector Operation Through Vertical Travel of Plunger

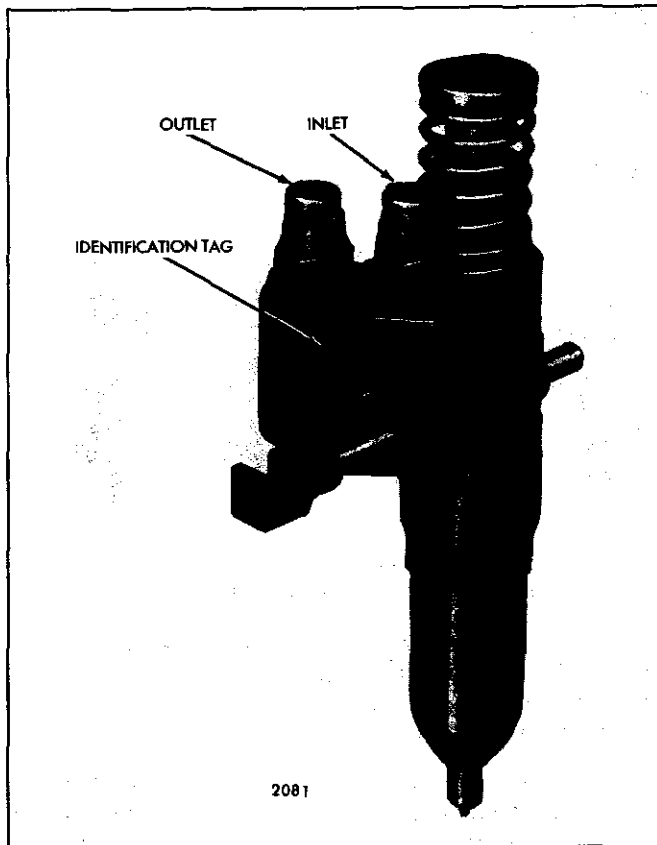


Fig. 4 – Injector Identification

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

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

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

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

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

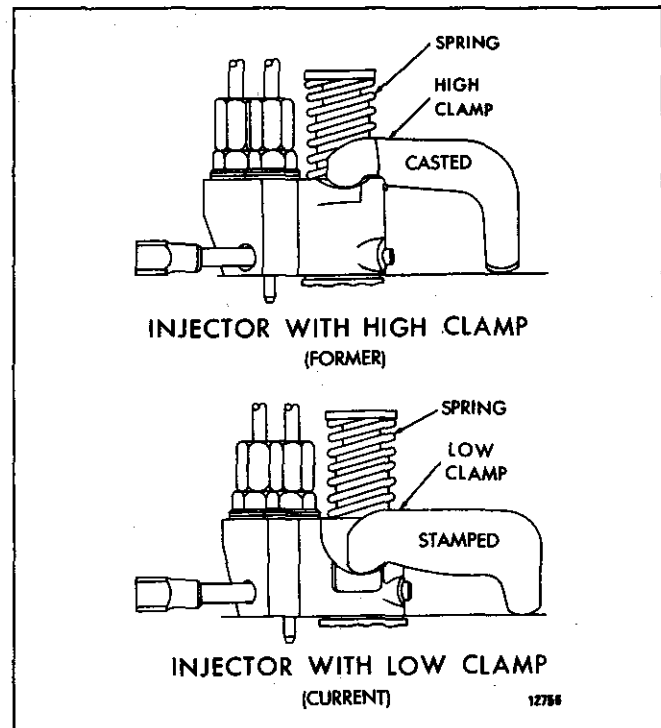


Fig. 5 – Comparison of High Clamp and Low Clamp Injectors

Operation

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

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

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

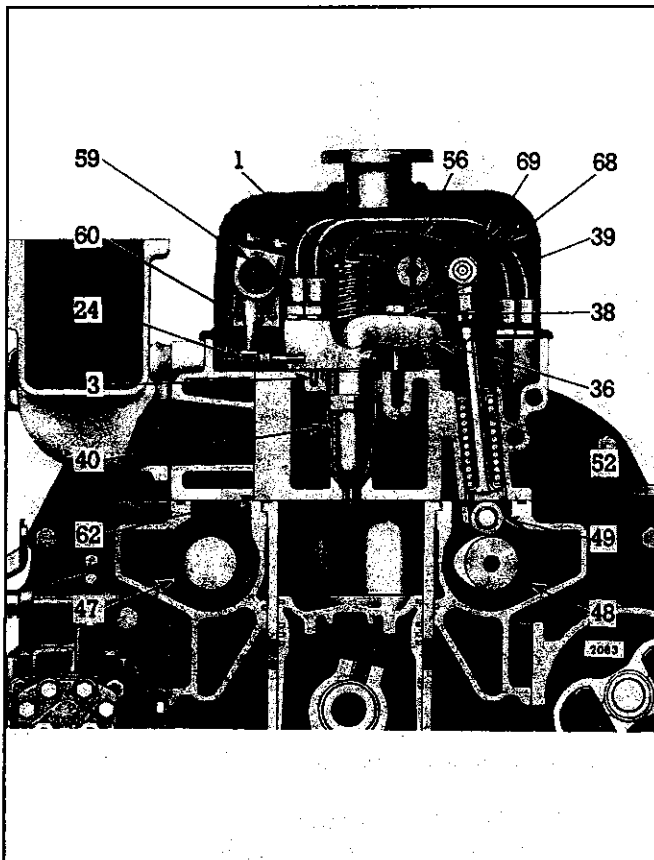


Fig. 6 - Fuel Injector Mounting

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

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

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

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

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

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the

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

General Instructions for Injector Care and Overhaul

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

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

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

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

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

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

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

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

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

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

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

Remove Injector

1. Clean and remove the valve rocker cover. Discard the gasket.
2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

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

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

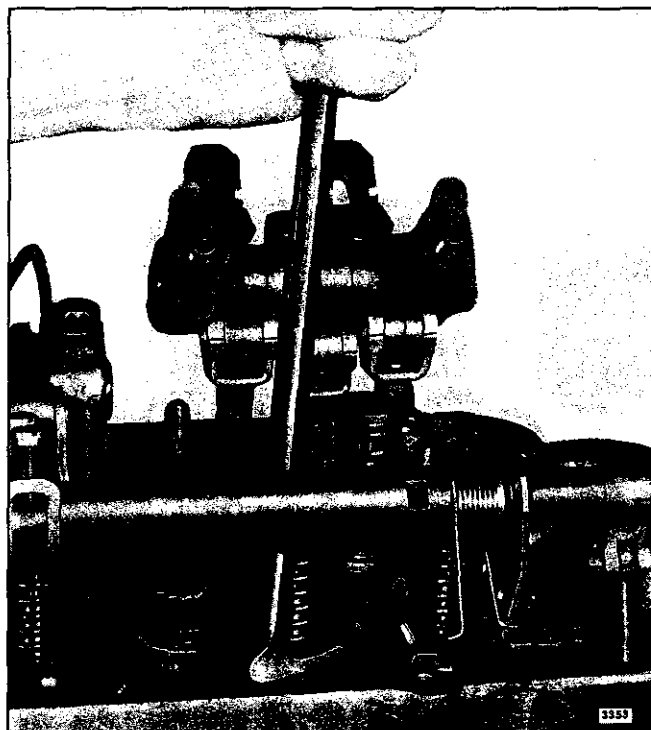


Fig. 7 – Removing Injector from Cylinder Head

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

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).
5. Remove the injector clamp bolt, special washer and clamp.
6. Loosen the inner and outer adjusting screws or adjusting screw and locknut on the injector rack control lever and slide the lever away from the injector.
7. Lift the injector from its seat in the cylinder head (Fig. 7).
8. Cover the injector hole in the cylinder head to keep foreign material out.
9. Clean the exterior of the injector with clean solvent and dry it with compressed air.

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

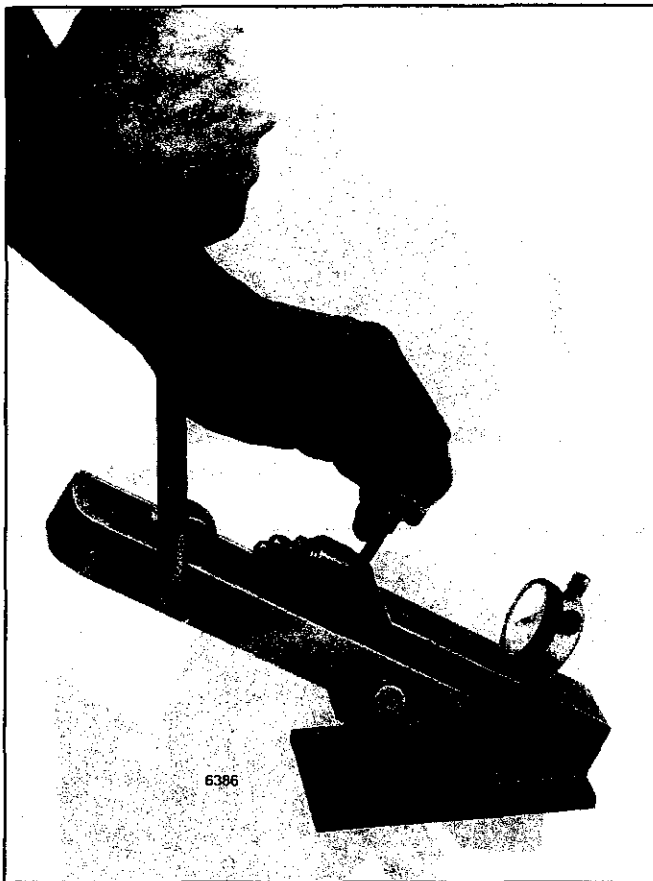


Fig. 8 – Checking Rack for Freeness in Tester J 29584

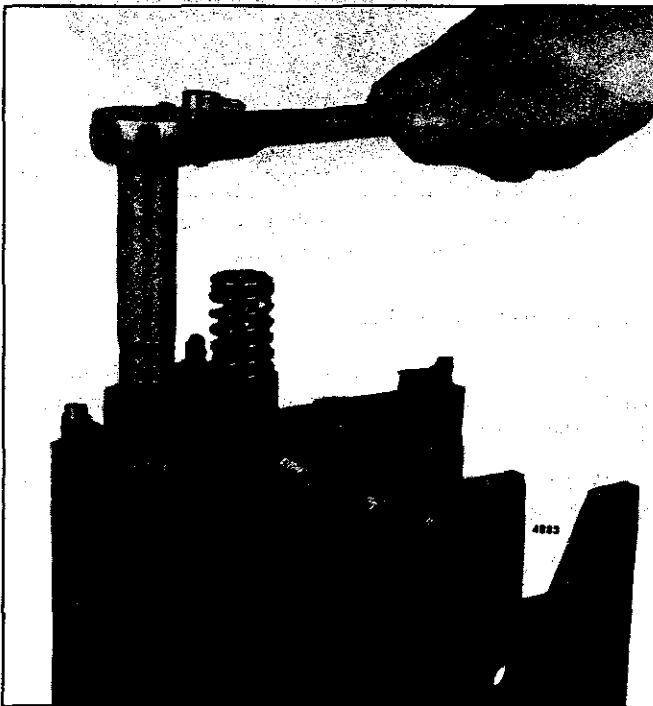


Fig. 9 – Removing Filter Cap

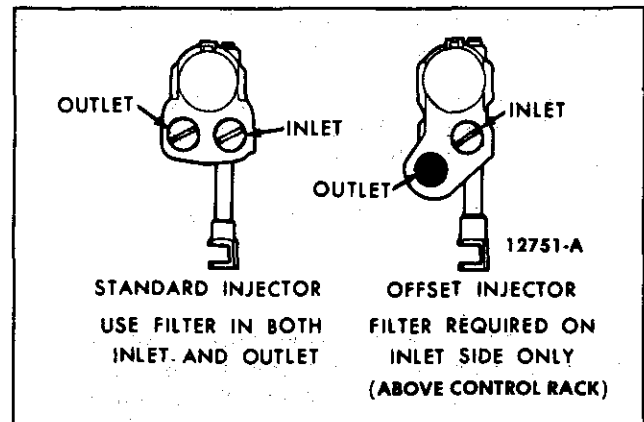


Fig. 10 – Location of Filter in Injector Body

Inspect and Test Prior to Reuse

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

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

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

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

4. Check the injector for leaks using Tester J 23010-A as outlined in Section 2.0 - Shop Notes.
5. Check the spray pattern, atomization and valve opening pressure using Tester J 23010-A as outlined in Section 2.0 - Shop Notes.
6. Perform injector fuel output test using Calibrator J 22410-A as outlined in Section 2.0 - Shop Notes.

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

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

Disassemble Injector

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

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

2. Compress the follower spring (Fig. 11). Then, raise the spring above the stop pin with a screwdriver and withdraw the pin. Allow the spring to rise gradually.
3. Refer to (Fig. 12) and remove the plunger follower, plunger and spring as an assembly.
4. Using socket J 4983-01, loosen the nut on the injector body (Fig. 13).
5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing.

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

6. Refer to (Fig. 15) and remove the spill deflector. Then, lift the bushing straight out of the injector body.
7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.
8. Withdraw the injector control rack from the injector body. Also, remove and discard the seal ring from the body.

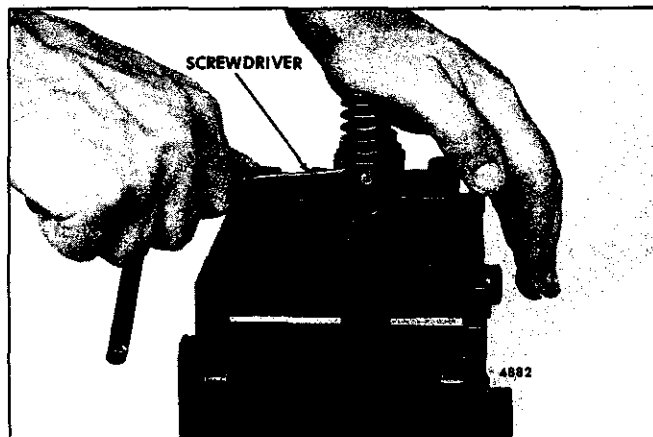


Fig. 11 - Removing Injector Follower Stop Pin



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

Clean Injector Parts

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

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

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

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

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

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

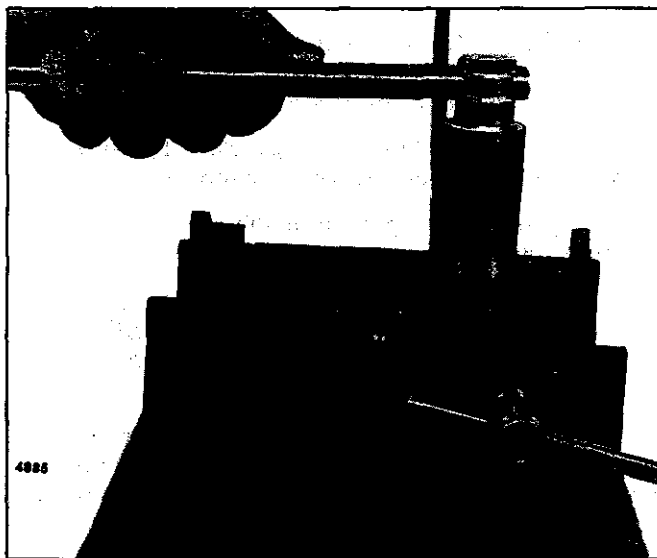


Fig. 13 - Removing Injector Nut Using Tool J 4983-01

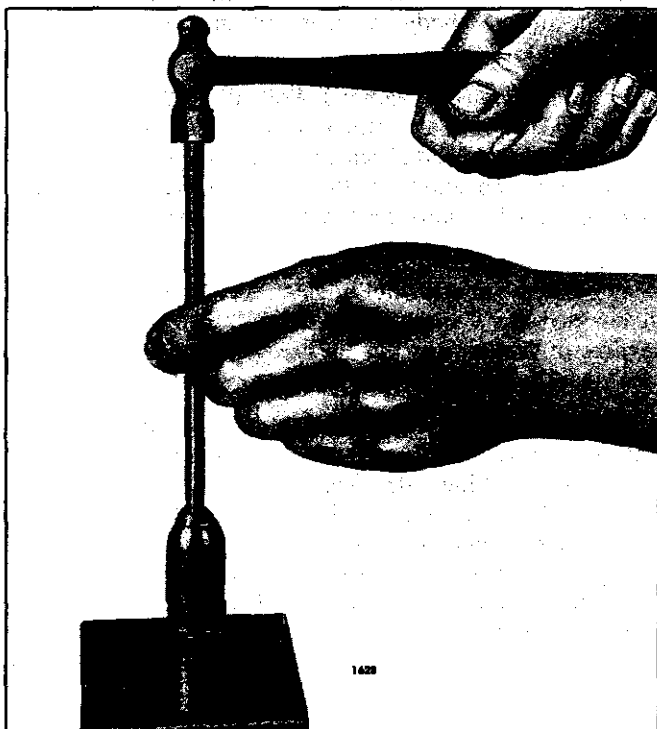


Fig. 14 - Removing Spray Tip from Injector Nut Using Tool J 1291-02

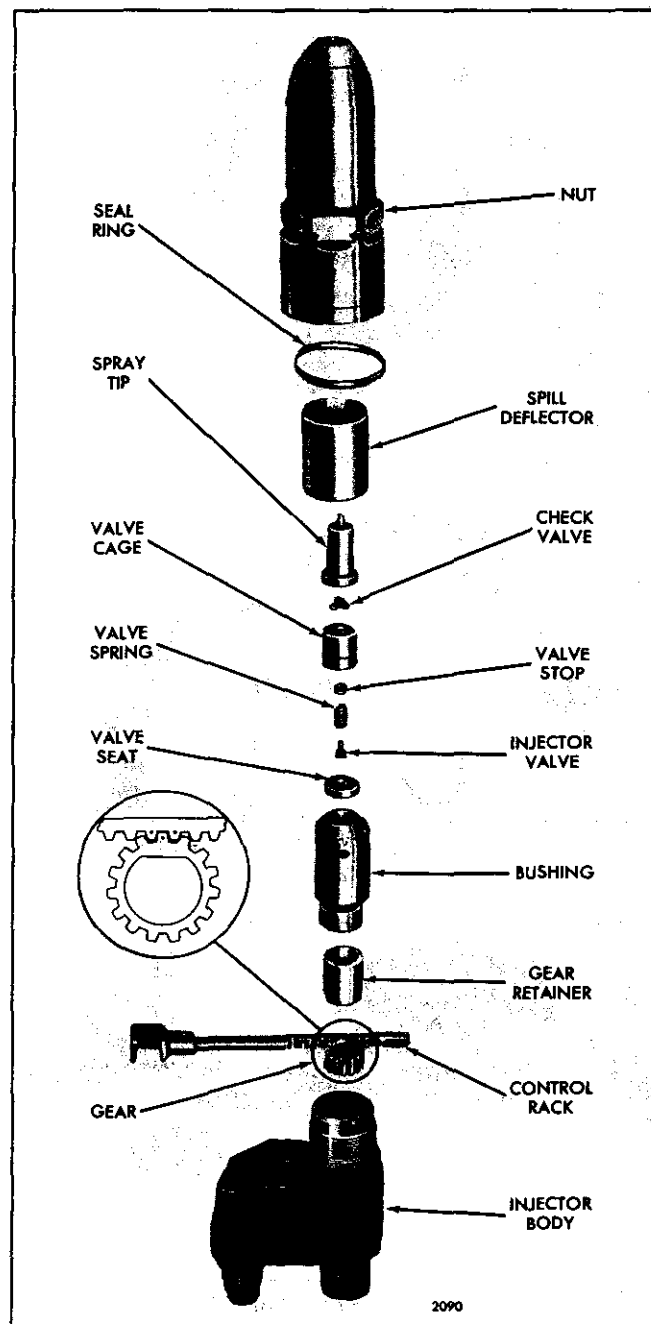


Fig. 15 - Injector Rack, Gear, Spray Tip and Valve Assembly Details and Relative Location of Parts

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

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