

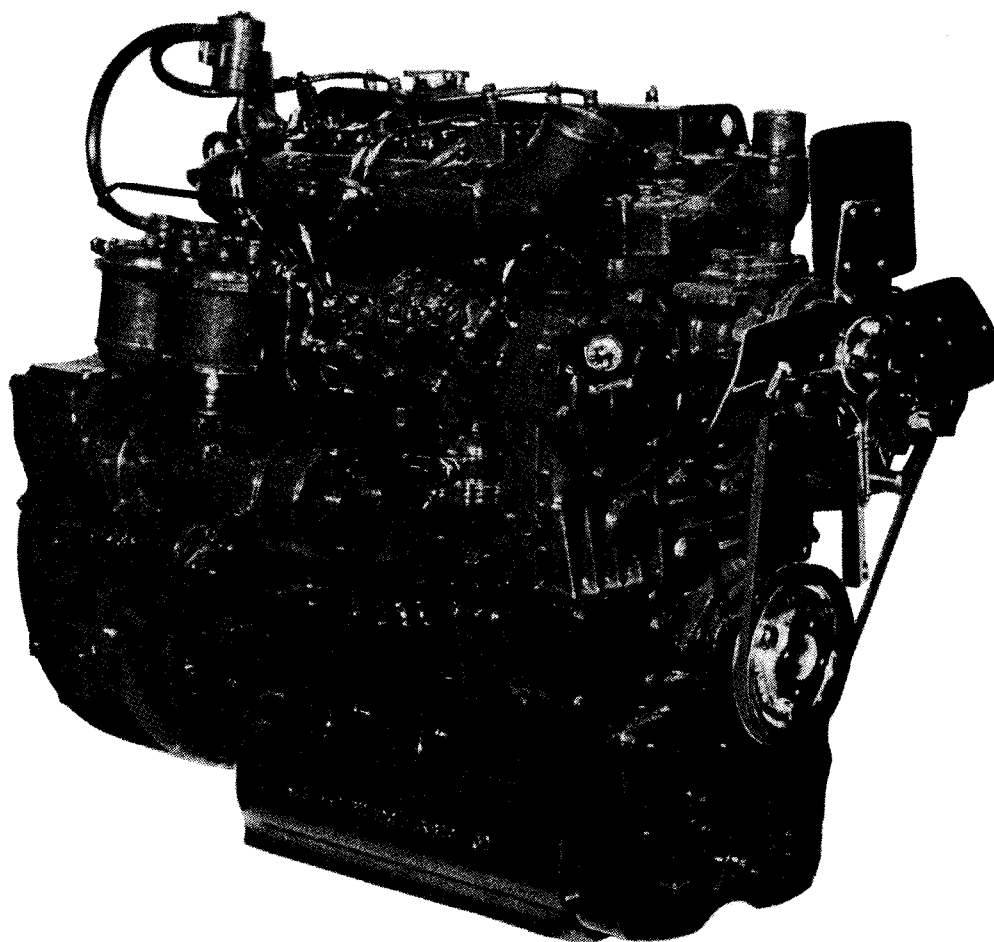


**SSD-327**

**SSD-437**

**SSD-655**

**DIESEL ENGINE  
SERVICE MANUAL**



## INTRODUCTION

This Service Manual provides the service technician with information for proper servicing of SSD Industrial Diesel Engines. Information on service procedures for the SSD-327, SSD-437, and SSD-655 naturally aspirated engines are included.

In general, this manual covers the servicing of the engine and associated standard equipment. In many cases, engines are supplied with accessories and equipment unique to the application. If service information is ever required on such accessories or equipment, it is suggested that the Industrial Engine Operations of Ford Motor Company be contacted. The proper information will either be forwarded or the service technician will be advised where it can be obtained.

The information in this manual is grouped in sections according to the type of work being performed. The various sections are indicated in the index. In addition, each section is subdivided to include topics such as diagnosis and testing, cleaning and inspection, overhaul, removal and installation procedures, disassembly and assembly procedures, and service specifications.

FORD MOTOR COMPANY  
INDUSTRIAL ENGINE OPERATIONS  
FORD PARTS AND SERVICE DIVISION  
300 RENAISSANCE CENTER  
P.O. BOX 43338  
DETROIT, MICHIGAN 48243

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**NOTE:** The recommendations and suggestions contained in this publication are made to assist the distributor in improving his distributorship parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

# SSD ENGINE SERVICE MANUAL

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## PART 1 Basic Engine

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## IDENTIFICATION

An Identification Decal (Fig. 1) is affixed to the top of the engine rocker arm cover. The decal contains the engine serial number which identifies the unit from all

others. Next is the engine displacement which determines the engine specifications, then the model number and SO number which determines the parts or components required on the engine. Use all the numbers when seeking information or ordering replacement parts.

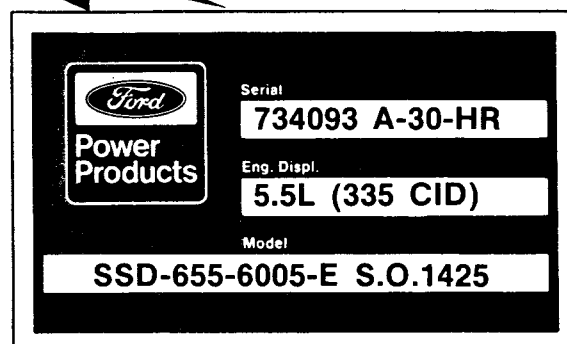
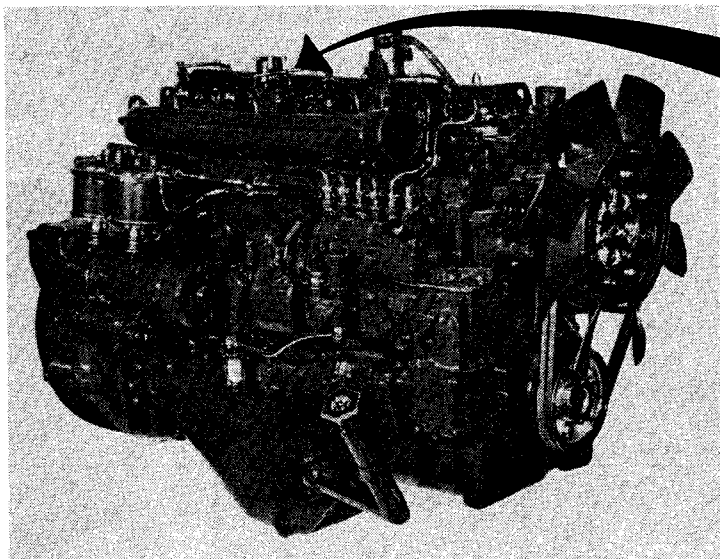


FIG. 1 Ford Power Products Identification Decal

## DESCRIPTION

### GENERAL

The Ford SSD Industrial Diesel Engines covered in this manual include three in-line, naturally aspirated units. The SSD-327 has three cylinders and a displacement of 2.7 Litres (168 CID). The SSD-437 is a four cylinder engine with a displacement of 3.7 Litres (224 CID). The third engine covered in this manual, the SSD-655, is a six cylinder engine with a displacement of 5.5 Litres (335 CID).

SSD engines are direct-injection fueled and operate on a four stroke cycle.

Overhead valves are mounted vertically in replaceable valve guides in the cast iron cylinder head. Valve seats are cut directly in to the cylinder head surface. Valves are operated by rocker arms, push rods, and mechanical tappets actuated by a camshaft. The camshaft is located on the left side of the engine block when viewed from the rear of the engine.

The camshaft is driven at one-half engine speed by a gear coupled to the crankshaft gear through an idler. It is supported by bushings mounted in the camshaft bores in the block. Camshafts in the SSD-327 and SSD-437 are supported by three bushings, the SSD-655 engine camshaft by four. If camshaft bushings are replaced, they must be line-reamed to specifications after installation, since service bushings are not pre-sized.

On SSD-327 and SSD-437 engines, a helical gear, machined integral with the camshaft, drives the oil pump. Camshaft thrust is taken up by a thrust plate bolted to the engine block through the timing gear case. The camshaft drive gear is pressed onto the camshaft and located by a key.

The forged crankshaft runs in four large diameter main bearings in the SSD-327 engine, five in the SSD-437, and seven in the SSD-655. The main bearings and

connecting rod bearings have removable bearings inserts. Crankshaft end play is controlled by thrust washers installed at each side of the main bearing next to the rear main in all engine models. The SSD-437 engine has a counter-rotating weight type vibration damper assembly installed in the lower crankcase to minimize vibration and ensure balanced engine operation.

Connecting rods are I-beam forgings drilled lengthwise for bearing, piston, and cylinder liner lubrication. Two small holes are drilled perpendicular to the central oil passage just below the piston pin. They improve lubrication between the liner and piston. Another oil hole in the top of the connecting rod emits an oil spray to cool the piston. The piston pin mounts in two steel-backed bronze bushings pressed into the rod.

SSD engines use lightweight aluminum alloy pistons with toroidal swirl chambers machined into their tops. Pistons have three rings and are secured to the connecting rods by full-floating piston pins held in the piston bosses by snap rings. The compression ring in the top groove has a chrome-plated circumference. The center ring (number two) is a compression ring and oil scraper with a step in the bottom of its outer circumference. The number two ring backs up the top ring by controlling the thickness of the oil film on the cylinder wall and keeps excess oil out of the combustion chamber. The bottom ring (number three) is a two-piece oil control ring with a coil spring expander and serrations through which oil returns to the crankcase.

Replaceable dry-type cylinder liners are installed in the block bores. Damaged liners, or liners which exceed the wear limit, may be pressed out from the bottom of the block with a special removal plate. A new liner is pressed into the block from the top with a special installation plate until the installation plate bottoms on the block surface. The top of the liner is machined even with the block surface, if required. Both standard and oversize liners are available as service replacements.

The crankcase assembly is enclosed by a heavy duty sump which bolts to the engine block. A sump cover and gasket is mounted to the bottom of the sump on the SSD-437 engine. The main bearings and connecting rod bearings are accessible by removing the sump bottom cover. During overhaul procedures, the sump must also be removed.

SSD-327 and SSD-437 engines are equipped with a C.A.V. distributor type (rotary) injection pump. The fuel lift pump used on these engines is a diaphragm type which is driven by an eccentric cam operated by a gear in the timing gear assembly. The lift pump is similar to a fuel pump used on automotive gasoline engines. It has a lever which is used for manual priming and bleeding air from the fuel system.

The SSD-655 engine is equipped with an in-line injection pump with a separate pumping element for each injector. The reciprocating plunger type fuel lift pump is operated by a cam and cam follower on the injection pump camshaft. It has an external, manually operated pump for priming and bleeding the fuel system.

The injection pump on SSD-327 and SSD-437 engines is lubricated by the fuel itself. The in-line injection pump on the SSD-655 engine is lubricated by engine oil from the main oil gallery.

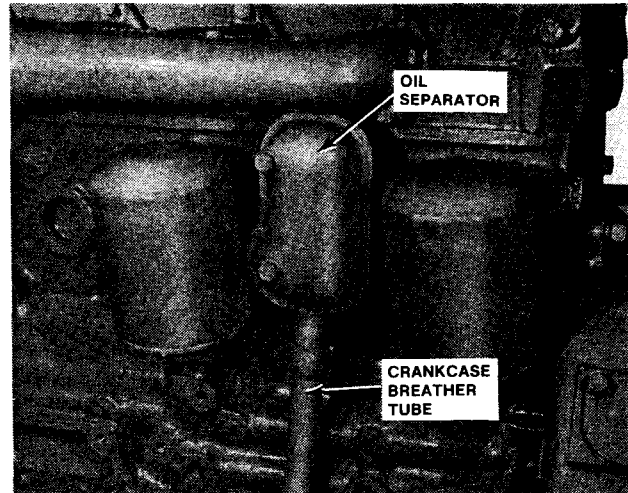


FIG. 2 Crankcase Breather Tube

SSD engines use four different types of injectors.

The crankcase on SSD engines is ventilated by a breather tube. The breather tube contains an oil separator mounted at the junction of the breather tube and the engine (Fig. 2).

## DIAGNOSIS AND TESTING

### CAMSHAFT LOBE LIFT

Check the lift of each lobe in consecutive order and make a note of the readings.

1. Remove the valve rocker arm cover.
2. If only one camshaft lobe is to be checked, loosen the valve rocker arm adjusting screw. Slide the rocker arm assembly serving the camshaft lobe to be checked to one side. Secure it in this position. Repeat this procedure on other lobes to be checked.
3. Make sure the push rod is in the valve lifter socket. Install a dial indicator so that the indicator tip is in the push rod socket and in the same plane as the push rod movement (Fig. 3).
4. Connect an auxiliary starter switch in the starting circuit. Crank the engine with the stop control in the "Stop" position. Bump the crankshaft over until the tappet or lifter is on the base circle of the camshaft lobe. At this point, the push rod will be in its lowest position

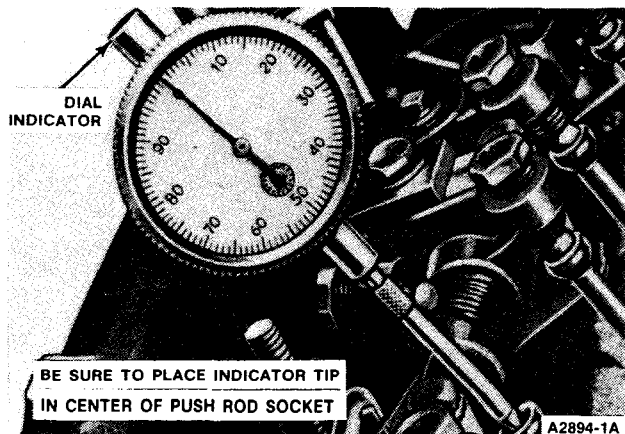


FIG. 3 Measuring Camshaft Lobe Lift—Typical

5. Zero the dial indicator. Continue to rotate the crankshaft slowly until the push rod is in the fully raised position.
6. Compare the total lift recorded on the indicator with specifications.
7. To check the accuracy of the original indicator reading, continue to rotate the crankshaft until the indicator reads zero. If the lift on any lobe is below specified wear limits, the camshaft and the valve lifter(s) operating on the worn lobe(s) must be replaced.
8. Remove the dial indicator and auxiliary starter switch.
9. Install the rocker arms and adjust the valve clearance as detailed under ENGINE ASSEMBLY in this section.
10. Install the valve rocker arm cover.

### CRANKSHAFT END PLAY

1. Force the crankshaft toward the rear of the engine.
2. Install a dial indicator so that the indicator tip rests against the front face of the crankshaft and the plunger is parallel to the crankshaft centerline (Fig. 4).

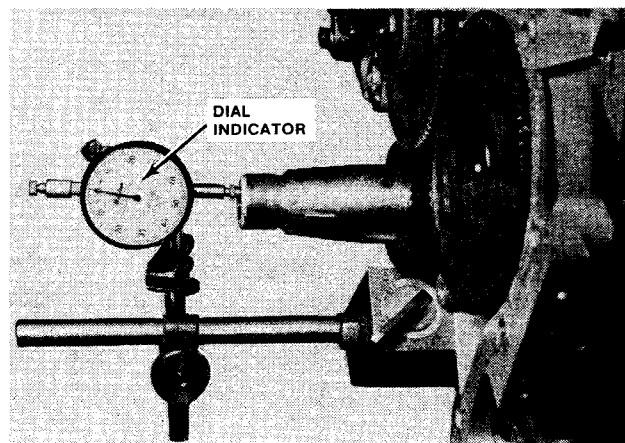


FIG. 4 Checking Crankshaft End Play—Typical

3. Zero the dial indicator. Push the crankshaft forward and note the reading on the dial indicator.
4. If end play exceeds the wear limit specification, replace the thrust washers. If the end play is less than the minimum limit, inspect the thrust washer faces for scratches, burrs, nicks, or dirt.

### FLYWHEEL FACE RUNOUT

Install a dial indicator so that the indicator tip bears against the flywheel face. Turn the flywheel making sure that it is full forward or rearward so that crankshaft end play will not be indicated as flywheel runout.

If the clutch face runout exceeds specification, remove the flywheel and check for burrs between the flywheel and the face of the crankshaft mounting flange. If no burrs exist, check the runout of the crankshaft mounting flange. Replace the flywheel or machine the crankshaft-flywheel mounting face sufficiently to true up the surface if the mounting flange runout exceeds specification.

### CAMSHAFT END PLAY

Prying against the camshaft gear with the valve train load on the camshaft can damage the gear. Therefore, the rocker arm adjusting screws must be backed off, or the rocker arm and shaft assembly must be loosened sufficiently to free the camshaft. After checking the camshaft end play, adjust the valve clearance as detailed under ENGINE ASSEMBLY in this section.

## OVERHAUL

### CYLINDER HEAD

**NOTE:** Before removing any valve assemblies, thoroughly clean the cylinder head as detailed under CLEANING AND INSPECTION in this section.

Place the cylinder head on a work bench or install in a workstand, with valve spring assemblies uppermost. Compress the upper valve cup and valve spring with a valve spring compressor tool (Fig. 6). Remove the two valve locks to release the valve. Remove the upper and lower valve cups and valve spring.

Repeat this procedure for each valve assembly. Keep the components for each valve assembly together so that they can be installed in the same position upon reassembly.

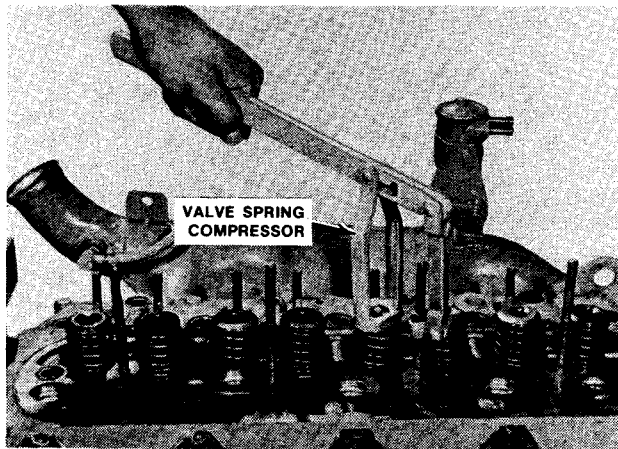


FIG. 6 Removing Valve Assembly

Push the camshaft toward the rear of the engine. Install a dial indicator so that the indicator tip is on the camshaft gear attaching screw (Fig. 5). Zero the dial indicator. Position a large screwdriver between the camshaft gear and the block. Pull the camshaft forward and release it. Compare the dial indicator reading with specifications.

If the end play is excessive, check the thrust plate for correct installation before it is removed. If the thrust plate is correctly installed, it must be replaced.

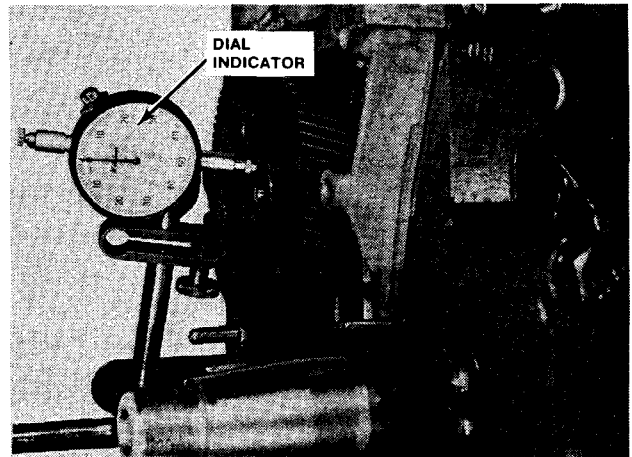


FIG. 5 Checking Camshaft End Play—Typical

Complete cleaning and inspection procedures on the cylinder head and components as detailed in CLEANING AND INSPECTION.

### VALVE GUIDES

If valve stem play is excessive and the valve stem is in good condition with the specified O.D., drive the valve guide out from the underside of the cylinder head. Drive the new valve guide into the cylinder head from the top until the retaining ring contacts the cylinder head. Be sure that the valve guide is fully seated. If the standard replacement guide is a loose fit, ream the block and install an oversize valve guide.

After installation, ream the valve guide to the specified I.D. (Fig. 7) and reface the valve seat.

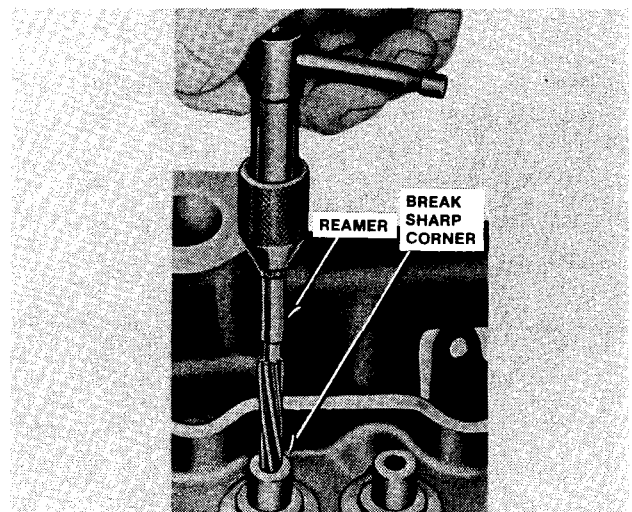


FIG. 7 Reaming Valve Guide I.D.

## VALVE SEAT REFACING

If inspection shows that the valve seats are pitted or burned, if valves must be refaced, or new valve guides are to be installed, valve seats should be refaced. Valve seats in all SSD engines are integral with the cylinder head. Valve and valve seat angle specifications are listed in Section 8.

Valve seat refacing should be closely coordinated with valve refacing so that the finished seat and valve face will be concentric and the interference fit will be maintained. It is important that a valve and seat have a compression-tight fit. Be sure that the refacer grinding wheels are properly dressed.

Grind all valve seats to a true  $45^\circ$  angle. Remove only enough stock to clean up any pits and grooves or to correct valve seat runout. After the seat has been refaced, use a seat width scale or a machinist's scale to measure the seat width.

If the valve seat width is too great, remove only enough stock from the top edge and/or bottom edge of the seat to reduce its width.

The finished valve seat should contact the approximate center of the valve face. It is a good practice to determine where the valve seat contacts the face. To do this, coat the seat with Prussian Blue and set the valve in place. Rotate the valve with light pressure. If the blue is transferred to the center of the valve face, contact is satisfactory. If the blue is transferred to the top edge of the valve face, lower the valve seat. If the blue is transferred to the bottom edge of the valve face, raise the valve face.

## REFACING VALVES

The valve refacing operation should be closely coordinated with valve seat refacing so that the finished angles of the valve face and the valve seat will be to specifications and provide a compression-tight fit. Be sure that the refacer grinding wheels are properly dressed.

If valve face runout is excessive or if pits and grooves must be removed, reface the valve to a true  $45^\circ$  angle. Remove only enough stock to correct runout or to clean up any pits and grooves. If the edge of the valve is less than  $1/32$  in. (.031 mm) thick after grinding, it will cause the valve to run too hot in the engine. Replace the valve if the edge measurement does not meet specification. Pay close attention to valve critical dimensions.

**NOTE: Do not lap out valve and seat interference fit.**

After valve seats and valve faces are reground, measure the valve recess in the cylinder head.

## INJECTOR SLEEVES

If inspection shows that a fuel injector sleeve has a compression leak, or if injector protrusion into the cylinder head (Fig. 8) is greater than specification, replace the injector sleeve.

To remove, tap the injector sleeve with an appropriate tap, using the burnishing tool guide. Install a puller, and pull the injector sleeve out from the top of the cylinder head (refer to Fig. 40).

Thoroughly clean the groove at the bottom of the injector sleeve bore in the cylinder head. Install new O-rings on the replacement sleeve. Press the sleeve into the cylinder head until seated (Fig. 9). Burnish the sleeve after installation with the special service tool (Fig. 10). Ream the sleeve seat to provide proper injector protrusion (Fig. 11).

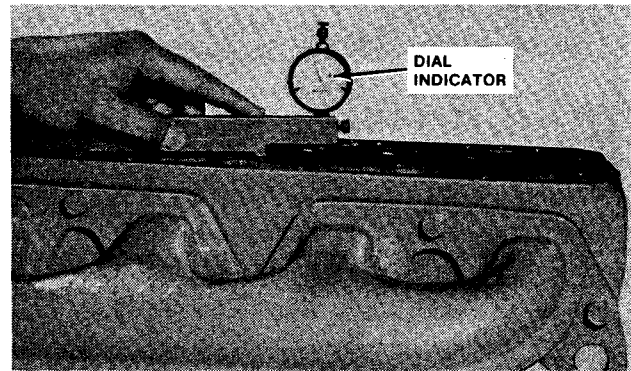


FIG. 8 Checking Injector Protrusion

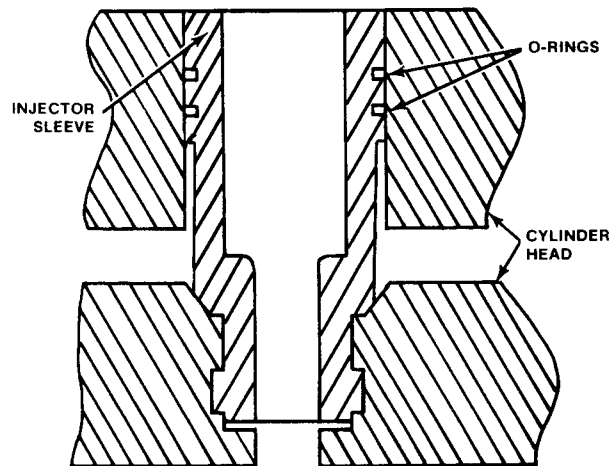


FIG. 9 Injector Sleeve Installation

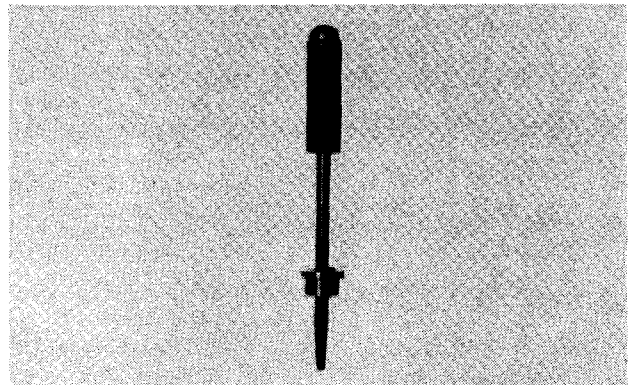


FIG. 10 Injector Casing Burnishing Tool

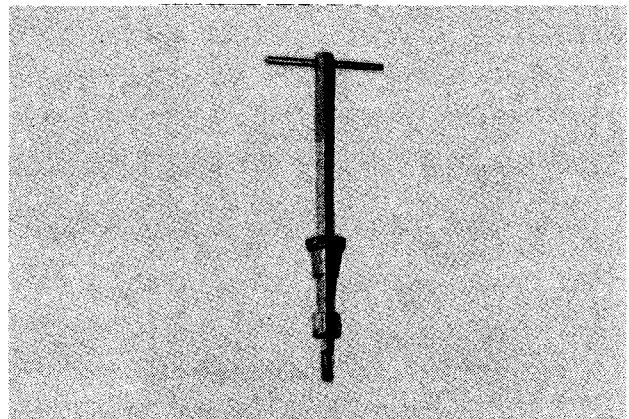


FIG. 11 Injector Casing Reamer and Miller

## CAMSHAFT REPAIR

Remove light scuffs, scores, or nicks from the machined surfaces of the camshaft lobes and journals with a smooth oil stone.

## CAMSHAFT BUSHINGS

Proceed as follows to replace camshaft bushings (camshaft removed). Drive out the front and intermediate bushings with a driver. Drive out the expansion plug at the rear bushing with a suitable bar through the block. Drive out the rear bushing with a driver.

When installing new camshaft bushings, be sure that bushing lubrication passages are aligned with the block lubrication passages. Install intermediate bushing(s) first. Then install front and rear bushings with the driver. When camshaft bushing installation is complete, line-ream the bushings to specified dimensions.

## PUSH RODS AND TAPPETS

Be sure that tappets run in their bores without binding or excessive play. Stone off all nicks, scores, and scratches from the tappet head where it rides on the cam lobe.

If tappets must be replaced because of excessive wear, ream the housing bores and install appropriate oversize tappets (Fig. 12).

**NOTE:** Tappets are slightly barrel shaped; center O.D. is larger than end O.D.

If inspection shows that push rods are not perfectly straight, or if the concave seat contacting the rocker arm adjustment screw is excessively worn, replace the push rod.

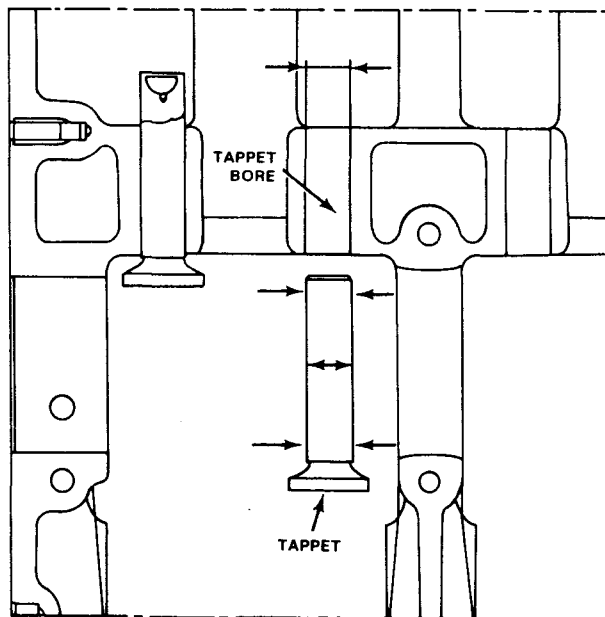


FIG. 12 Tappet and Tappet Bore Measuring Points

## CRANKSHAFT AND SEALS

Crankshaft main bearing and connecting rod journals may be ground undersize if inspection shows this to be necessary. When grinding crankshafts, be sure to maintain the dimensions of the fillet radii and lubrication holes.

After grinding, polish main and rod journals with fine lapping paper to produce a good surface finish. Both grinding and polishing should be against the direction of crankshaft rotation.

To ensure an oil tight seal at the front and rear ends of the crankshaft, two double-lip rubber seals with metallic cores and springs are used. The front oil seal is installed in the timing gear case cover. The rear oil seal is installed in the flywheel housing.

If inspection shows that the working surface of the seal is worn, if the metallic core and spring is broken, or if the surface is rough or out-of-round, the seal must be replaced. Proceed as follows to replace crankshaft oil seals.

### Front Seal

Press or drive the old seal out of its seat in the timing gear case cover. Wipe off all traces of oil and dry the seal seat thoroughly. Press or drive the new seal into its seat so that uniform pressure is applied to the seal ring. Be sure that the seal is bottomed in the seat. Lubricate the seal lip with grease or heavy oil to prevent dry contact with the crankshaft when the engine is started.

### Rear Seal

Remove the flywheel housing from the back of the block (Fig. 13). Pry the old seal out and discard. Clean the housing thoroughly. Press the new seal into the housing until it is flush with the rear surface. Lubricate the seal lip with grease or heavy oil where it contacts the crankshaft flange. Install the flywheel housing.

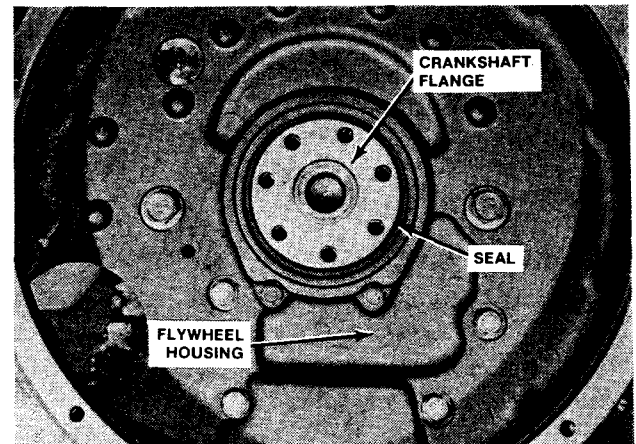


FIG. 13 Crankshaft Rear Oil Seal

## REFINISHING CRANKSHAFT JOURNALS

Dress minor journal scoring with an oil stone. If journals are badly marred or exceed the wear limit, refinish to size for the next undersize bearing. Refinish journals to provide proper clearance for bearing inserts. If the journal will not clean up to the maximum undersize bearing available, replace the crankshaft.

When refinishing crankshafts, always reproduce the same journal shoulder radius that existed originally. Too small a radius will result in crankshaft fatigue failure. Too large a radius will result in bearing failure due to bearing radius ride.

After journals are refinished, chamfer the oil holes; then polish the journal surface with No. 320 grit polishing cloth and engine oil. Crocus cloth may also be used for polishing journals.

## FITTING MAIN AND CONNECTING ROD BEARINGS

Always check main and connecting rod bearing clearance with plastic gauging material. Select gauging material of the proper range and proceed as follows:

1. Clean the crankshaft journals. Inspect journals and thrust faces for nicks, burrs, or bearing pickup that could cause premature bearing wear.
2. Place a piece of plastic gauging material as wide as the bearing cap on the lower bearing insert parallel to the crankshaft centerline and approximately 1/4 in. (6mm) off center (Fig. 14).

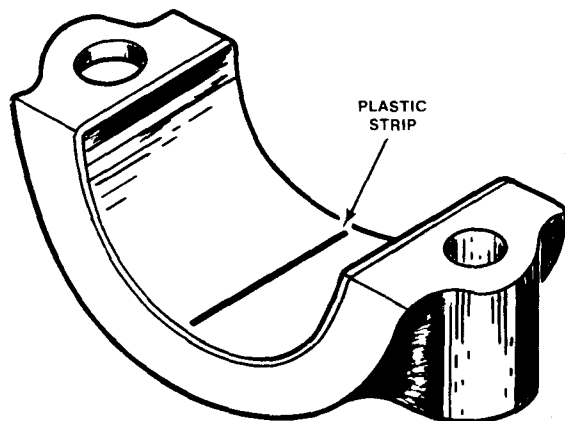


FIG. 14 Installing Plastic Gauging Material in Bearing Insert

3. Install the bearing cap and torque mounting capscrews evenly to specification. Then rock the crankshaft back and forth through a slight arc.
4. Remove the bearing cap and measure the width of the plastic gauging material with the envelope scale (Fig. 15). If clearance is excessive, undersize bearing inserts are required. If one end of the plastic gauging material is wider than the other, a tapered journal is indicated. Width difference between the two ends is approximate journal taper.

Remove all traces of gauging material from the bearing surfaces.

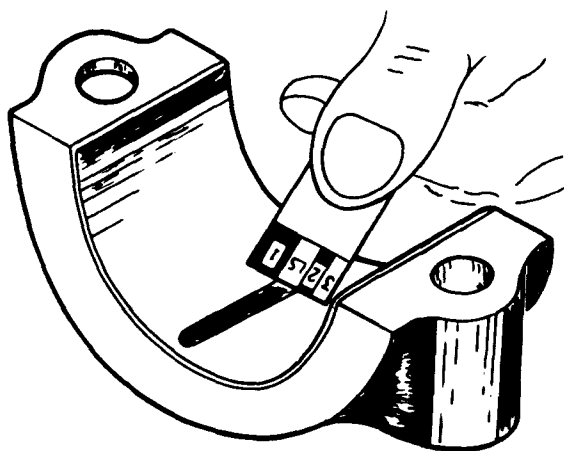


FIG. 15 Measuring Bearing Clearance with Envelope Scale

5. If clearance or taper exceeds specified limits, remove the crankshaft and refinish the journal to eliminate taper or to accommodate the next undersize bearing.

**NOTE: When replacing standard bearings with new bearings, install bearings with minimum specified clearance.**

6. When clearance is within specifications, lightly oil the journal and bearing inserts. Install the bearing cap and torque capscrews to specification. Check bearing side clearance.
7. Repeat procedure for remaining bearings that require replacement.

## CONNECTING RODS

Check piston pin working clearance. If clearance exceeds the allowable maximum specification, replace the bushing.

Each connecting rod is marked on both the body and cap with a number corresponding to the cylinder number to which it belongs. When a connecting rod is replaced, stamp the appropriate cylinder number on both the rod and cap. Never install a cap on a connecting rod to which it is not matched.

## PISTON CLEARANCE

Measure cylinder liner diameter as described under CLEANING AND INSPECTION in this section. Measure piston diameter with an outside micrometer at a point 2 in. (50 mm) up from the base of the piston skirt and at 90° to the piston pin center line (Fig. 16).

Compare the piston and liner diameters. If clearance between any piston and liner is greater than the allowable maximum specification, bore the liners to the appropriate oversize and install oversize pistons and rings, or replace the liners.

**NOTE: Standard size pistons and rings may be used if standard size liners are installed.**

Standard size and four oversize pistons are available as service replacements in SSD engines. Refer to the specifications in Section 8 for available oversize pistons. If a piston must be replaced, be sure that the maximum weight difference is within 0.34 oz. (10 gr).

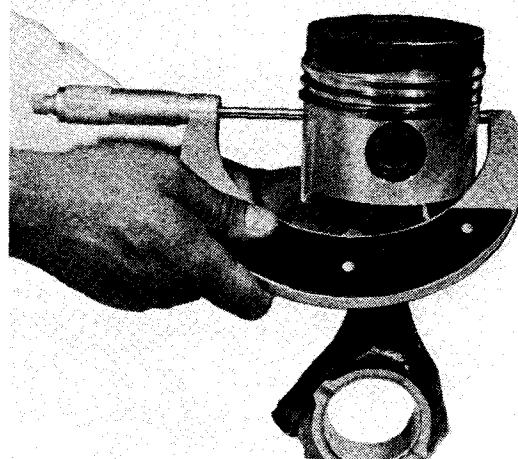


FIG. 16 Measuring Piston Diameter

## PISTON RINGS

Select the proper size ring set for the pistons being used (standard or oversize). Position each ring in the cylinder bore in which it is to be used. Push the ring down into the bore with an inverted piston into an area where normal ring wear is encountered. Be careful not to damage the ring or cylinder wall when inserting the ring. Be certain that the ring is square with the cylinder wall.

Measure the gap between the ring ends with a feeler gauge (Fig. 17). Refer to the specifications in Section 8 for ring end gap. Correct end gap is critical, since too small a gap will allow ring ends to butt together, while too large a gap will increase cylinder leak-down.

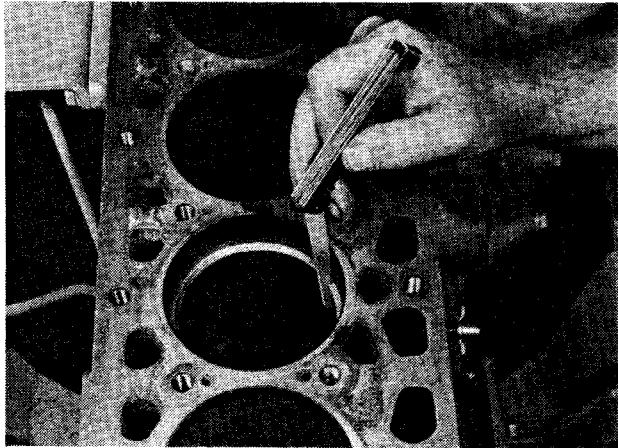


FIG. 17 Checking Piston Ring End Gap

If the end gap is too small, grind the ring ends to meet specification. If the end gap is too large, replace the ring with a new one of the same type and recheck the end gap.

Install the rings on the piston using a ring expander tool. Check the ring groove side clearance of the No. 1 and No. 2 rings with a feeler gauge inserted between the ring and the lower land (Fig. 18). Be sure that the ring is installed in its groove right side up. The manufacturer's name will be on the top side of the ring or the ring will be stamped "TOP". Check specifications to be sure that clearance is within limits. The feeler gauge should slide freely around the entire ring circumference without binding. Any wear that occurs to the groove will form a step on the inner portion of the lower land. If the lower lands have high steps, replace the piston.

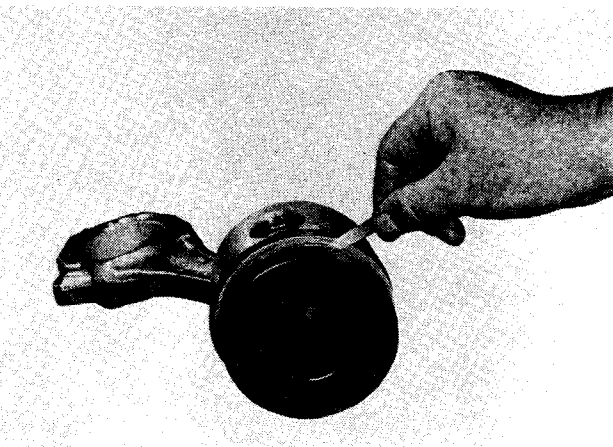


FIG. 18 Checking Ring Groove Side Clearance

## PISTON PINS

If inspection shows that piston pin working clearance in the connecting rod bushing or piston bore exceeds the allowable maximum specification, ream the bore in the piston boss and rod bushing to accept an oversize piston pin.

If bores in the piston bosses or rod bushings must be reamed or honed, use precision honing equipment or an expansion type piloted reamer.

**CAUTION: Do not attempt to ream piston pin bores with a hand-driven reamer. Use a motor-driven reamer, but do not exceed the cutting speed (RPM) recommended by the tool manufacturer.**

The piston pin should be a manual push fit at room ambient temperature of approximately 70°F (21°C). Assemble the piston and connecting rod and press the piston pin in. Secure the pin at each end with a new snap ring. Be sure that the snap rings are fully seated in their grooves.

## ROCKER ARMS AND SHAFT ASSEMBLY

Clean up minor surface defects on the rocker arm shaft with an oil stone. Rocker arm bushings may be honed if cleanup is necessary. If the pad at the rocker arm valve end has a grooved radius, replace the rocker arm.

**CAUTION: Do not attempt to true up the pad surface by grinding.**

Replace rocker arm adjusting screws which have stripped or broken threads. Run an appropriate size tap through the rocker arm adjusting screw end, if necessary, to clean up the threads. If the threads will not clean up, replace the rocker arm.

If bushing working clearance on the rocker arm shaft exceeds the allowable maximum specification, press new bushings into the rocker arms. When installing new bushings into rocker arms, be sure that lubrication ports line up and that bushings are flush with the sides of the rocker arm. Check rocker arms for proper side clearance.

## CYLINDER BLOCK

Check the top of the block surface with a straightedge and feeler gauge or with a surface plate. If the check indicates distortion which exceeds the maximum allowable specification, true up the top of the block surface with a grinder.

**CAUTION: Take the lightest cut necessary to true up the block surface.**

Check each cylinder liner diameter at three different depths and in two vertical planes as described under CLEANING AND INSPECTION in this section.

In case of light scoring and wear, hone the liner walls to clean up. If scoring is deep, or liner out-of-round or taper is excessive, rebore the liner to the next larger oversize piston before honing. Rebore the liner to a diameter which will ensure the required clearance between the piston and liner wall or replace the liner.

## LINER REPLACEMENT

Remove the old cylinder liner with a hydraulic press and plate. Press the old liner out from the bottom of the block. New liners are pressed in from the top of the block with a hydraulic press and installation plate (Fig. 19). Be sure that the new liner O.D. and block bore diameter is within specification before attempting to press in the liner. Proceed as follows:

1. Coat the liner outside surface and block bore with engine oil.
2. Start the liner in its seat, install plate and begin pressing.
3. Press the liner in 2.75 to 3.50 in. (70 to 90 mm) and check press loading. It should not exceed 3,300 lbs. (1,500 kg).
4. Continue to press the liner into the block bore. Check press loading 0.394 in. (10 mm) before seating liner. Loading should be between 7,937 and 14,330 lbs. (3,600 and 6,500 kg). If press loading does not fall within these limits, remove the liner and install another.
5. Press the liner into the block bore until the installation plate bottoms on the block surface. Machine the top of the liner even with the block surface, if required.

When installation of the liner is complete, the liner I.D. must be bored to the correct size and honed. Replacement liners are supplied with an I.D. slightly smaller than normal size to permit correction of any distortion which may have occurred during installation. Replacement liners are also available in an oversize O.D.

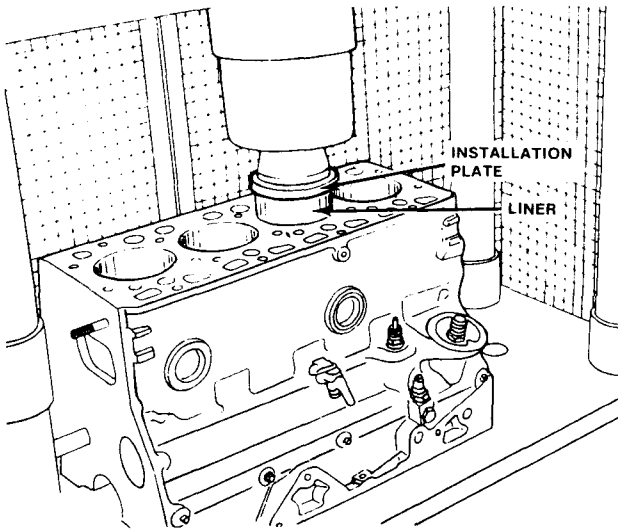


FIG. 19 Installing New Cylinder Liner

## REFINISHING CYLINDER LINERS

Honing the cylinder liner walls is recommended only when the liner has minor scuffs or scratches, or for finishing walls to the specified clearance for oversize pistons. The amount of metal to be removed will determine the grade of hone to be used. If coarse stones are used to start the honing operation, leave enough material for the finishing hone to produce the proper cross-hatch finish pattern.

Liner walls that are badly marred and/or worn beyond the specified limits should be refinished.

**CAUTION:** Before starting to refinish any liner, install all main bearing caps and tighten cap bolts to specifications. This will prevent the crankshaft bearing bores from becoming distorted during the refinishing operation.

Refinish the liner with the most wear first to determine the maximum oversize piston. If the liner will not clean up when refinished to the maximum oversize, replace the liner.

Refinish the liner to approximately 0.0015 in. (0.04 mm) of the required oversize diameter. This will leave enough stock for the final honing step to obtain the correct surface finish and pattern.

Always follow the instructions of the tool manufacturer for proper use of refinishing equipment.

Use a motor-driven, spring-pressure type hone at a speed of from 300 to 500 RPM. Hone stones of 180-220 grit will normally provide the desired bore surface finish of 15/32 RMS. When honing liners, use a lubricant mixture of equal parts of kerosene and SAE 20W engine oil. Operate the hone to produce a cross-hatch pattern finish on the liner surface. The cross-hatch pattern should be at an angle of approximately 30° to the cylinder bore (Fig. 20).

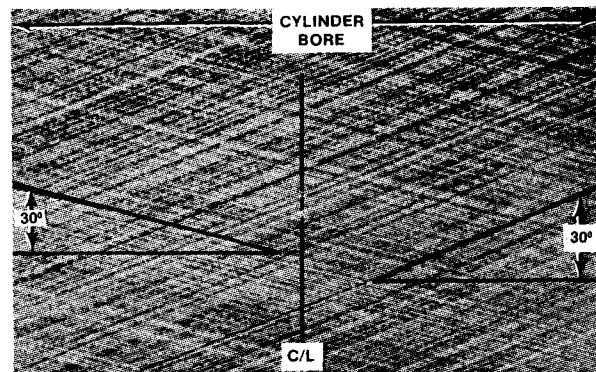


FIG. 20 Liner Cross-Hatch Pattern—Typical

After the final refinishing operation, thoroughly clean and oil the liner walls before checking piston fit. Mark the pistons to indicate the cylinders in which they are to be installed. When the required liners have been refinished, and all pistons have been fitted, thoroughly clean the entire block and again oil the liner walls.

## FLYWHEEL AND RING GEAR

The flywheel is secured to the crankshaft rear flange with self-locking capscrews. Whenever the flywheel is removed, discard the old capscrews and install the flywheel using new ones. Because of the random bolt pattern, the flywheel cannot be improperly installed. The clutch or power take-off must be removed to gain access to the flywheel.

The starter ring gear is mounted to the outer circumference of the flywheel. If the ring gear is to be replaced, it must be cut through and driven off the flywheel. Heat the new ring gear to approximately 176°F (80°C) in an oil bath. Then shrink the ring gear onto the flywheel inner rim with the 60° chamfer facing the engine side.

A clutch pilot bearing is located in the bore machined into the center of the crankshaft rear flange. The size of the pilot bearing bore may vary with the type of clutch or power take-off used.

### DYNAMIC BALANCER (SSD-437 ENGINE)

To overhaul the dynamic balancer assembly, extract the split dowel pins which retain the flyweight shafts from the blind holes at the front of the balancer housing. Drive the flyweight shafts out of the housing with a suitable drift and lift out the flyweights (Fig. 21).

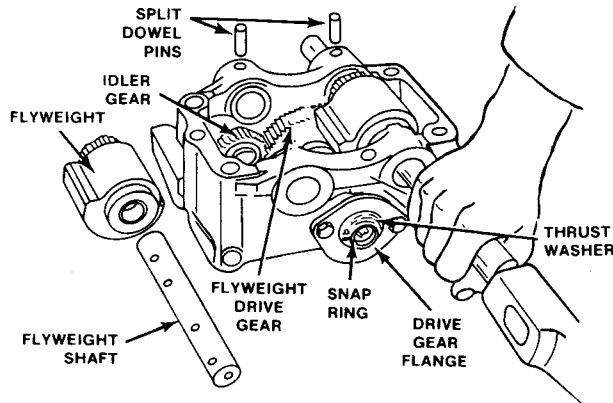


FIG. 21 Removing Flyweight Shafts (SSD-437)

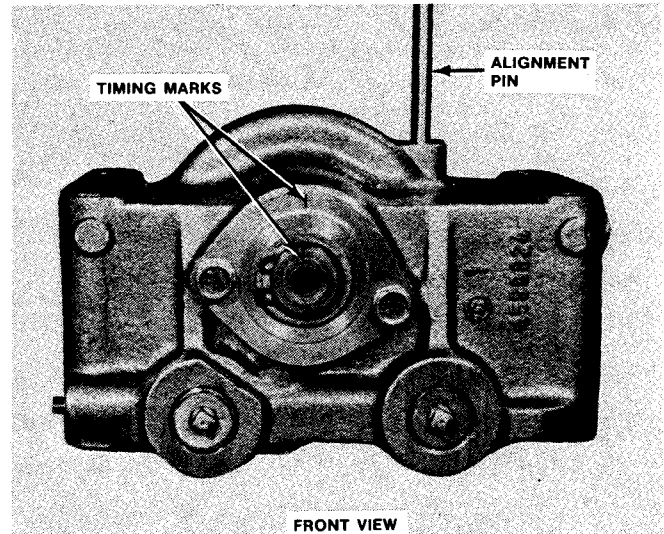
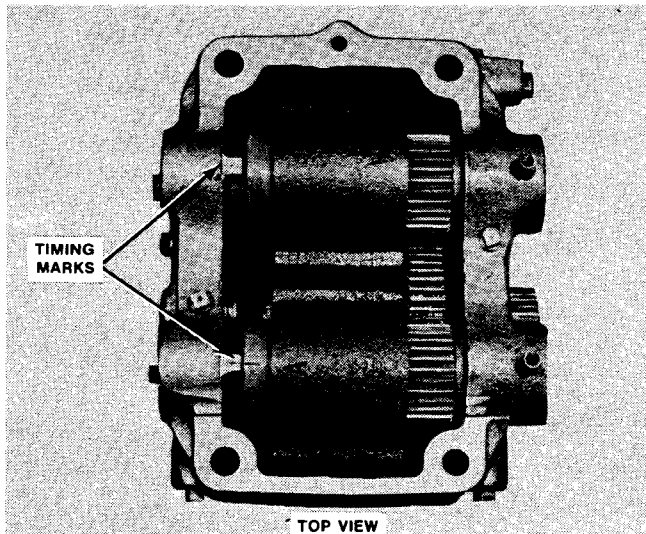


FIG. 22 Flyweight Timing Marks in Alignment (SSD-437)

Remove the flyweight drive gear flange retaining screws, snap ring, and thrust washer. Remove the drive gear flange and drive gear. Remove the flyweight idler gear snap ring, idler gear, and shaft.

Clean and inspect the dynamic balancer assembly as explained under CLEANING AND INSPECTION in this section.

Replace all worn or damaged parts which do not meet specification. If new bushings must be installed in the flyweights, heat the weights in oil at 283° - 320°F (140° - 160°C) before pressing in the new bushings. After installation, ream the bushings to correct specification with an expansion blade reamer.

Reassemble the balancer by reversing the disassembly procedure. When installing the flyweight idler gear, be sure that the longer end faces the housing wall. Align the dowel pin holes in the flyweight shafts with those in the housing and secure the shafts with new split dowel pins.

When overhaul is complete, align the assembly marks on the flyweights with those on the housing (Fig. 22). Temporarily install a pin or small drift in the housing to keep the flyweights in correct position until after the balancer assembly is installed in the engine.

### CLEANING AND INSPECTION

The cleaning and inspection procedures listed are for a complete engine overhaul. For partial engine overhaul or parts replacement, follow the cleaning or inspection procedure which applies.

#### INTAKE MANIFOLD Cleaning

Remove all gasket material from the machined surfaces of the manifold. Clean the manifold in a suitable solvent and dry it with compressed air.

#### Inspection

Inspect the manifold for cracks, damaged gasket surfaces, or other defects which would make it unsuitable for further service. Replace all studs that are stripped or otherwise damaged.

**CAUTION:** Remove all filings and foreign matter that may have entered the manifold as a result of repairs.

#### EXHAUST MANIFOLD Cleaning

Remove all gasket material from the machined surfaces of the manifold. Remove deposits from the inside of the manifold. Blow out all loose particles with compressed air.

#### Inspection

Inspect the cylinder head joining flanges of the exhaust manifold for evidence of exhaust gas leaks. Replace all studs that are stripped or otherwise damaged.

Inspect the manifold for cracks, damaged gasket surfaces, or other defects that would make it unsuitable for further service.

## ROCKER ARMS AND SHAFT ASSEMBLY

### Cleaning

Clean the components thoroughly in a suitable solvent. Be sure that all oil passages are open and unobstructed.

### Inspection

On rocker arm shaft assemblies, check the clearance between each rocker arm and the shaft by measuring the I.D. of the rocker arm bore and the O.D. of the shaft. If the clearance between any rocker arm and the shaft exceeds the wear limit, replace the shaft and/or the rocker arm. Inspect the shaft and the rocker arm bore for nicks, scratches, scores, or scuffs.

Inspect the pad at the valve end of the rocker arm for indications of scuffing or abnormal wear. If the pad is grooved, replace the rocker arm.

**CAUTION:** Do not attempt to true this surface by grinding.

Check the rocker arm adjusting screws and the push rod end of the rocker arms for stripped or broken threads. Check the ball end of the adjusting screw for nicks, scratches, or excessive wear.

## PUSH RODS

### Cleaning

Clean the push rods in a suitable solvent.

### Inspection

Check the ends of the push rods for nicks, grooves, roughness, or excessive wear.

The push rods can be visually checked for straightness while they are installed in the engine by rotating them with the valve closed. They also can be bench-checked with a dial indicator (Fig. 23).

If the push rod is visibly bent, it should be replaced.

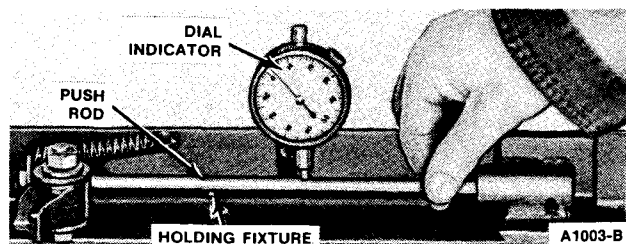


FIG. 23 Checking Push Rod Straightness

## CYLINDER HEAD

### Cleaning

**CAUTION:** With the valves installed to protect the valve seats, remove deposits from the combustion chambers and valve heads with a scraper and a wire brush. Be careful not to damage the cylinder head gasket surface.

After the valves are removed, clean the valve guide bores with a valve guide cleaning tool. Use cleaning solvent to remove dirt, grease, and other deposits. Clean all bolt holes; be sure the oil transfer passage is clean and unobstructed. Remove all deposits from the valves with a fine wire brush or buffing wheel.

### Inspection

Check the cylinder head for cracks and inspect the gasket surface for burrs and nicks. Replace the head if it is cracked.

The following inspection procedures are for a cylinder head that is to be completely overhauled. For individual repair operations, use only the pertinent inspection procedure.

When a cylinder head is removed because of gasket leaks, check the flatness of the cylinder head gasket surface (Fig. 24) for conformance to specifications.

**CAUTION:** If it is necessary to refinish the cylinder head gasket surface, do not plane or grind off more than 0.020 in. (0.5mm).

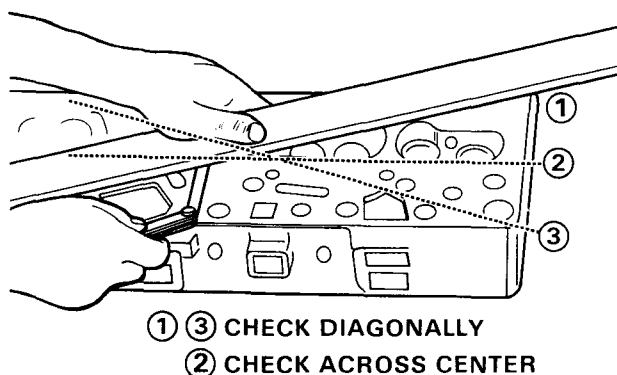


FIG. 24 Checking Cylinder Head Flatness

Check the valve seat runout with an accurate gauge (Fig. 25). Follow the instructions of the gauge manufacturer. If the runout exceeds the wear limit, reface the valve and valve seat. Measure the valve seat width. Reface any valve seat if its width is not within specification.

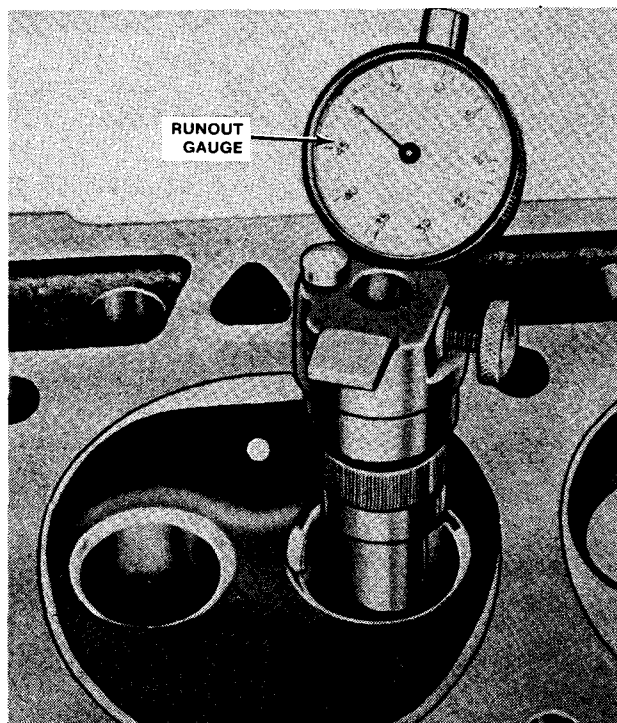


FIG. 25 Checking Valve Seat Runout—Typical

Inspect the valve face and the edge of the valve head for pits, grooves, scores, or other damage. Inspect the stem for a bent condition and the end of the stem for grooves or scores. Check the valve head for signs of burning, erosion, warpage, and cracking. Minor pits, grooves, etc., may be removed. Replace valves that are severely damaged.

Inspect the valve spring, valve spring retainers, locks, and sleeves for wear or damage. Replace any component that appears damaged.

Check the valve stem to valve guide clearance of each valve in its respective valve guide with a dial indicator and tool as shown in Fig. 26. Use a flat end indicator tip.

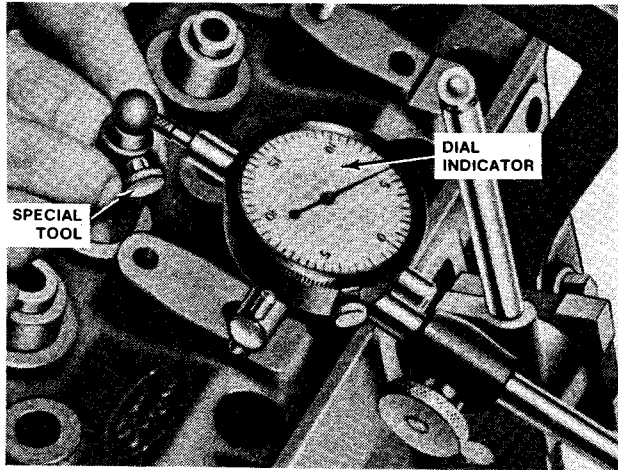


FIG. 26 Checking Valve Stem-to-Guide Clearance—Typical

Install the tool on the valve stem until it is fully seated and tighten the knurled set screw firmly. Permit the valve to drop away from its seat until the tool contacts the upper surface of the valve guide.

Position the dial indicator with its flat tip against the center portion of the tool's spherical section at approximately 90° to the valve stem axis. Move the tool back and forth in line with the indicator stem. Take a reading on the dial indicator without removing the tool from the valve guide upper surface.

Check the valve springs for proper pressure (Fig. 27) at the specified spring lengths using a valve spring tester. Weak valve springs cause poor engine performance. Replace any spring not within specification.

**NOTE:** Manually rotating the valve spring assemblies while installed in the engine must not be used to determine valve spring condition.

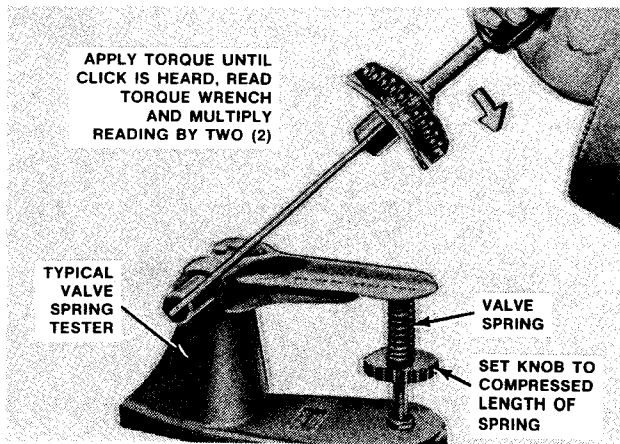


FIG. 27 Checking Valve Spring Pressure

Check each valve spring for squareness using a steel square (Fig. 28). Stand the spring and square on-end on a flat surface. Slide the spring up to the square. Revolve the spring slowly and observe the space between the top coil of the spring and the square. A valve spring which exceeds the maximum out-of-square specification should be replaced.

**NOTE:** Follow the same procedure to check new valve springs before installation.

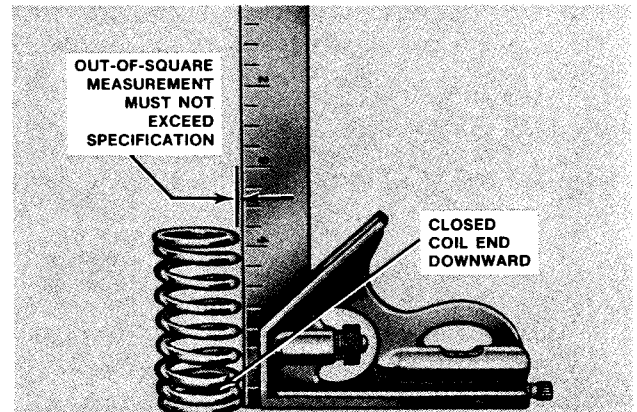


FIG. 28 Checking Valve Spring Squareness

## TIMING GEARS Cleaning

Clean the gears in a suitable solvent and dry them with compressed air.

## Inspection

Inspect the gear teeth for scores, nicks, etc. Note the condition of the tooth contact pattern. If the teeth are chipped or scored, replace the gears.

## CAMSHAFT Cleaning

Clean the camshaft in a suitable solvent and wipe it dry.

## Inspection

Inspect the camshaft lobes for scoring and signs of abnormal wear. Lobe wear characteristics may result in pitting in the general area of the lobe toe. This pitting is not detrimental to the operation of the camshaft; therefore, the camshaft should not be replaced unless the lobe lift loss has exceeded 0.005 in. (0.127 mm).

The lift of the camshaft lobes can be checked with the camshaft installed in the engine or on a bench using gauge blocks. Refer to Camshaft Lobe Lift detailed under DIAGNOSIS AND TESTING in this section.

Check the oil pump drive gear on SSD-327 and SSD-437 engines for broken or chipped teeth. Replace the camshaft if this condition exists.

## CRANKSHAFT Cleaning

Handle the crankshaft with care to avoid possible fractures or damage to the finished surfaces. Clean the crankshaft with a suitable solvent, then blow out all oil passages with compressed air.

## Inspection

Inspect the main and connecting rod journals for cracks, scratches, grooves, or scores. Inspect the crankshaft oil seal surfaces for nicks, sharp edges, or burrs that may damage the oil seals during installation or cause premature seal wear.

Measure the diameter of each journal in at least four places to determine if an out-of-round, taper, or undersize condition exists (Fig. 29).

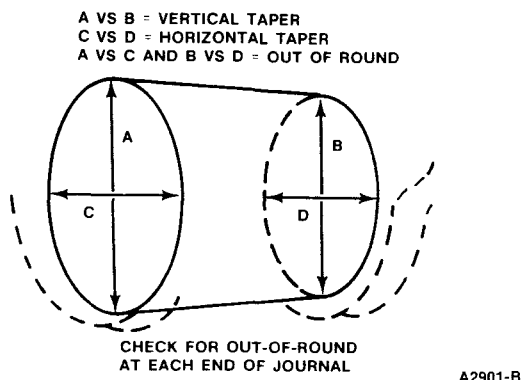


FIG. 29 Journal Diameter Measuring Points

The crankshaft should be magnafluxed for stress points. Place the crankshaft on gauge blocks to check alignment using a dial indicator (Fig. 30). Check the alignment of the main and connecting rod bearing journals with the crankshaft centerline. Check flywheel flange runout and flange eccentricity against specification. Correct minor discrepancies by machining the crankshaft to specifications. Replace the crankshaft if it is excessively worn or out of alignment.

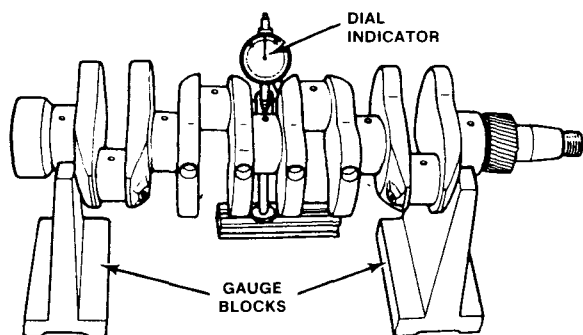


FIG. 30 Checking Alignment of Main and Connecting Rod Bearing Journals

## FLYWHEEL Cleaning

Clean the flywheel in a suitable solvent and dry with compressed air.

## Inspection

Inspect the flywheel for cracks, heat checks, or other damage that would make it unsuitable for further service. Machine the friction surface of the flywheel if it is scored or worn. If it is necessary to remove more than 0.045 in. (1.143 mm) of stock from the original thickness, replace the flywheel.

Inspect the ring gear for worn, chipped, or cracked teeth. If the teeth are damaged, replace the ring gear. Refer

to Flywheel and Ring Gear detailed under OVERHAUL in this section.

With the flywheel installed on the crankshaft, check the flywheel face runout, following the procedures under DIAGNOSIS AND TESTING in this section.

## CONNECTING RODS

### Cleaning

Remove the bearings from the rod and cap. Identify the bearings if they are to be reused. Clean the connecting rod, including the rod bore and the back of the inserts in a suitable solvent. Blow out all oil passages with compressed air.

**CAUTION:** Do not use a caustic cleaning solution.

### Inspection

The connecting rods and related parts should be carefully inspected and checked for conformance to specifications. Various forms of engine wear caused by these parts can be readily identified:

- A shiny surface on either pin boss side of the piston usually indicates that a connecting rod is bent.
- Abnormal connecting rod bearing wear can be caused by either a bent connecting rod, worn or damaged crankpin, or a tapered connecting rod bore.
- Twisted connecting rods will not create an easily identifiable wear pattern, but badly twisted rods will disturb the action of the entire piston, rings, and connecting rod assembly and may be the cause of excessive oil consumption.

Inspect the connecting rods for signs of fracture and the bearing bores for out-of-round and taper. If the bore exceeds the specified limits and/or if the connecting rod is fractured, it must be replaced.

Check the I.D. of the connecting rod piston pin bore. If the pin bore in the connecting rod exceeds specification, a new bushing must be installed. Replace damaged connecting rod nuts and bolts.

Check the connecting rods for bend or twist on a suitable alignment fixture (Fig. 31). Follow the instructions of the fixture manufacturer. If the bend and/or twist exceeds specification, the connecting rod must be replaced.

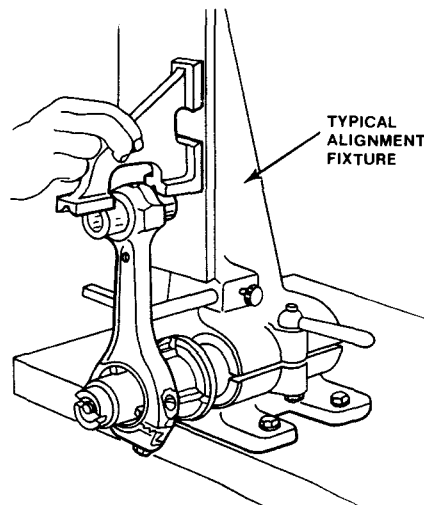


FIG. 31 Checking Connecting Rod Alignment

## PISTONS, PINS AND RINGS

### Cleaning

Remove deposits from the piston surfaces. Clean gum or varnish from the piston skirt, piston pins, and rings with a suitable solvent.

**CAUTION: Do not use a caustic cleaning solution or a wire brush to clean pistons.**

Clean the ring grooves with a ring groove cleaner (Fig. 32). Make sure the oil ring slots (or holes) are clean.

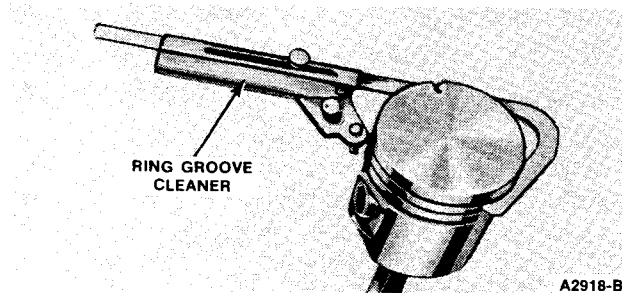


FIG. 32 Cleaning Piston Ring Grooves

### Inspection

Carefully inspect the pistons for fractures at the ring lands, skirts, and pin bosses, and also for scuffed, rough, or scored skirts. If the lower inner portions of the ring grooves have a high step, replace the piston. The step will interfere with ring operation and cause excessive ring side clearance.

Spongy, eroded areas near the top edge of the piston are usually caused by detonation or pre-ignition. A shiny surface on the thrust surface of the piston, offset from the centerline between the piston pin holes, can be caused by a bent connecting rod. Replace pistons that show signs of excessive wear, wavy ring lands, or fractures or damage from detonation or pre-ignition.

Check the piston to cylinder bore clearance by measuring the piston and bore diameters. Refer to specifications for the proper clearance. Refer to Cylinder Block detailed under INSPECTION in this section for the bore measurement procedure.

Measure piston O.D. with an outside micrometer at 90° to the piston pin bore and 2 in. (50 mm) up from the base of the piston skirt. Check the ring groove side clearance. Refer to the overhaul procedures detailed under Piston Clearance and Piston Rings in this section.

Replace piston pins showing signs of fracture, etching, or excessive wear. Check the piston pin fit in the piston and rod. Refer to the overhaul procedures detailed under Piston Pins in this section.

Check the O.D. of the piston pin and the I.D. of the pin bore in the piston. Replace any piston pin or piston that is not within specifications.

Replace all piston rings. Check the ring end gap and side clearance. Refer to the overhaul procedures detailed under Piston Clearance and Piston Rings in this section.

**CAUTION: Used rings should not be transferred from one piston to another regardless of mileage or hours.**

## MAIN AND CONNECTING ROD BEARINGS

### Cleaning

Clean the bearing inserts and caps thoroughly in a suitable solvent and dry them with compressed air.

**CAUTION: Do not scrape gum or varnish deposits from the bearing shells.**

### Inspection

Inspect each bearing carefully. Bearings that have a scored, chipped, or worn surface should be replaced. Typical examples of unsatisfactory bearings and their causes are shown in Fig. 33. The copper-lead bearing base may be visible through the bearing overlay. This does not necessarily mean that the bearing is worn. It is not required to replace the bearing if the bearing clearance is within recommended limits. Check the clearance of bearings that appear to be satisfactory with plastic gauging material as detailed under Fitting Main and Connecting Rod Bearings in the OVERHAUL section.

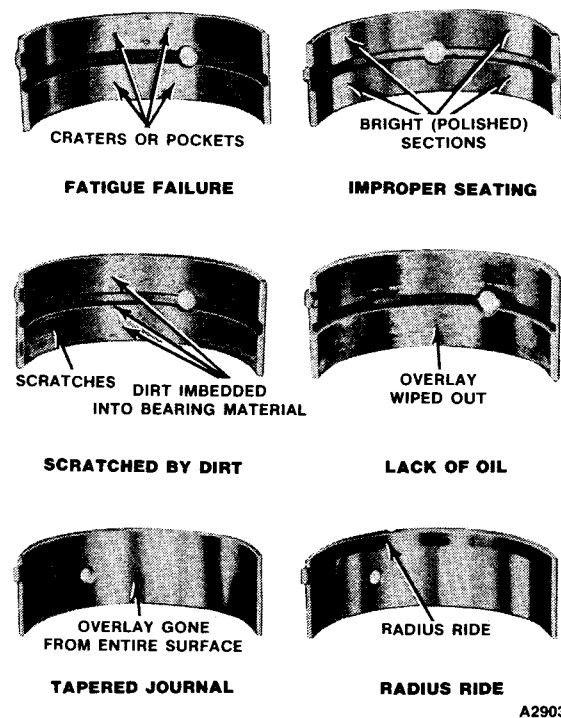


FIG. 33 Typical Bearing Failures

## CYLINDER BLOCK

### Cleaning

After any cylinder bore repair operation, such as honing or deglazing, clean the bore(s) with soap or detergent and water. Then, thoroughly rinse the bore(s) with clean water to remove the soap or detergent, and wipe the bore(s) dry with a clean, lint-free cloth. Finally, wipe the bore(s) with a clean cloth dipped in engine oil. If these procedures are not followed, rusting of the cylinder bore(s) may occur.

If the engine is disassembled, thoroughly clean the block with a suitable solvent. Remove old gasket material from all machined surfaces. Remove pipe plugs that seal oil passages; then clean out all the passages. Blow out all passages, bolt holes, etc., with compressed air. Make sure the threads in the cylinder head bolt holes are clean. Dirt in the threads may cause binding and result in a false torque reading. Use a tap to clean up threads and to remove any deposits. Thoroughly clean the grooves in the crankshaft bearings and bearing retainers.

## Inspection

After the block has been thoroughly cleaned, check it for cracks. Minute cracks not visible to the naked eye may be detected by coating the suspected area with a mixture of 25% kerosene and 75% light engine oil. Wipe the area dry and immediately apply a coating of zinc oxide dissolved in wood alcohol. If cracks are present, the coating will become discolored in that area. Replace the block if it is cracked.

Check all machined gasket surfaces for burrs, nicks, scratches, and scores. Remove minor imperfections with an oil stone.

Replace all expansion plugs that show evidence of leakage.

Inspect the cylinder walls for scoring, roughness, or other signs of wear. Check the cylinder bore for out-of-round and taper. Measure the bore with an accurate bore gauge following the instructions of the manufacturer. Measure the diameter of each cylinder bore at the top, middle, and bottom with the gauge placed at right angles and parallel to the centerline of the engine (Fig. 34).

**NOTE: Use only the measurements obtained at 90° to the engine centerline when calculating the piston to cylinder bore clearance.**

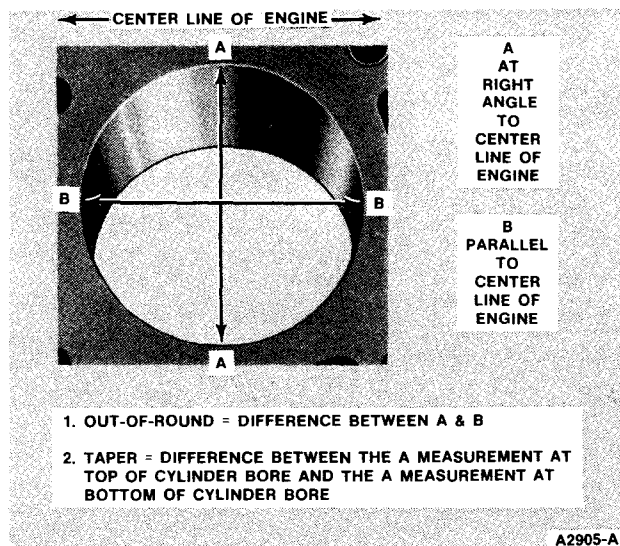


FIG. 34 Measuring Cylinder Bore Diameter

Refinish cylinders that are deeply scored and/or when out-of-round and/or taper exceed the wear limits. If the cylinder walls have minor surface imperfections, but the out-of-round and taper are within limits, it may be possible to remove the imperfections by honing the cylinder walls and installing new service piston rings providing the piston clearance is within specified limits.

## OIL SUMP AND COVER Cleaning

Scrape any dirt or metal particles from the inside of the sump and cover. Scrape all old gasket material from the gasket surfaces. Clean the sump and cover in a suitable solvent and dry them thoroughly.

## Inspection

Check the sump and cover for cracks, holes, damaged drain plug threads, or damaged gasket surfaces.

Inspect the cover for damage (uneven surface) at the bolt holes caused by over-torquing the bolts. Straighten surfaces as required. Repair any damage, or replace the sump or cover if satisfactory repairs cannot be made.

## DYNAMIC BALANCER (SSD-437 ENGINE) Cleaning

After disassembly (refer to Dynamic Balancer Overhaul in this section for procedures), clean all components in a suitable solvent and dry them with compressed air. Clean all lubricant passages to be sure that they are open and unobstructed. Be sure that all foreign matter is removed from the inside of the flyweight assembly housing.

## Inspection

Inspect the gears for worn, chipped, or broken teeth. Replace any gears showing evidence of wear or damage. Inspect the coupling sleeve and drive pinion splines. Check bushings in the gears and flyweights for excessive wear. Replace worn bushings as directed in Dynamic Balancer Overhaul in this section. Install new split dowel pins upon reassembly.

**NOTE: The water pump and adapter housing cannot be removed together as an assembly. The water pump must be removed first to gain access to one adapter housing mounting nut which is located inside the housing.**

- Disconnect and remove the fuel lines, fuel filters, and injector lines.

**NOTE: Plug the lines and fittings to prevent the entrance of foreign matter.**

- Remove all thermostart components. Remove the intake and exhaust manifolds.
- Remove and identify the injectors.

**NOTE: Store the injectors in a clean area.**

## DISASSEMBLY AND ASSEMBLY

### ENGINE DISASSEMBLY

- Install workstand mounting brackets to the engine. Install the engine in a rotary workstand and secure the mounting brackets.
- Drain the engine oil, remove the oil filter(s), and discard.
- Remove the starter motor. Loosen the alternator mounting bolts and remove the drive belt(s). Remove the alternator, cooling fan, and fan hub.
- Remove the water pump, cylinder head coolant outlet, and thermostat. Remove the water pump adapter housing.

8. Remove the rocker arm cover and the rocker arms and shaft assembly. Remove and identify the push rods and valve stem caps.
9. **SSD-327 and SSD-437 Engines** — Remove the injection pump drive gear cover from the front of the timing gear case. Loosen the two bolts retaining the pump flange to the front of the drive gear one or two turns. Remove the injection pump drive gear, using the gear retaining nut as a puller. Remove the injection pump from the flange on the rear of the timing gear case. Remove the fuel lift pump and support housing.
10. Remove the cylinder head bolts. Install a lift cable and hook assembly to the lifting eyes on the cylinder head and remove the head with a chain fall or floor crane. Place the head in a workstand or on support blocks on a bench. Remove the head gasket and discard.
11. Install a holding tool on the flywheel to prevent the crankshaft from rotating.
12. Remove the crankshaft hub pulley. Remove the crankshaft hub nut and tabbed washer. Reinstall the hub nut on the crankshaft and hand-tighten a few turns.
13. Install a puller on the crankshaft hub and loosen the hub from the end of the crankshaft (Fig. 35). Remove the puller, hub nut, and hub.

**WARNING:** The hub will release with considerable force from the tapered crankshaft. Be sure the hub nut is installed as directed so that hub travel will be restricted during the removal operation.

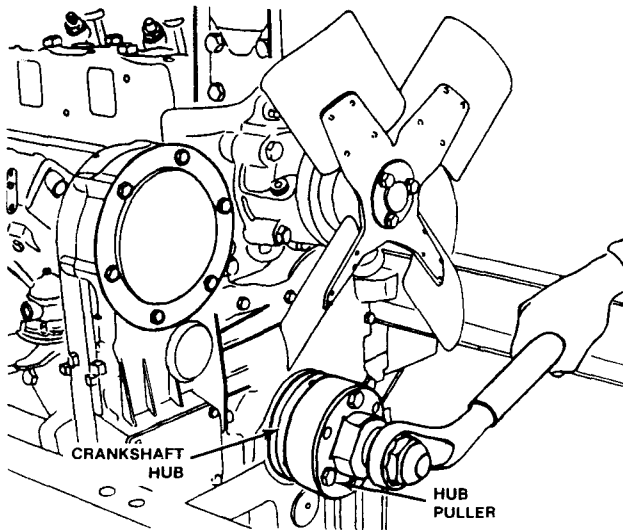


FIG. 35 Removing Hub from Crankshaft

14. Invert the engine in its workstand and proceed as follows to remove the oil sump:
  - **SSD-327 Engine** — Remove the bolts securing the oil sump to the engine block and remove the sump. Remove all gaskets and discard. Remove the oil suction tube and the oil pump from the engine block.
  - **SSD-437 Engine** — Remove the oil sump cover. Remove the cover gasket and discard. Remove the oil suction tube from the oil pump. Remove the bolts securing the dynamic balancer to its supports. Lift the balancer and move it to the rear while disengaging the coupling sleeve from the splined drive pinion (Fig. 36). Remove the coupling sleeve and balancer assembly from the engine. Remove the drive pinion oil tube, drive pinion, and support flange.

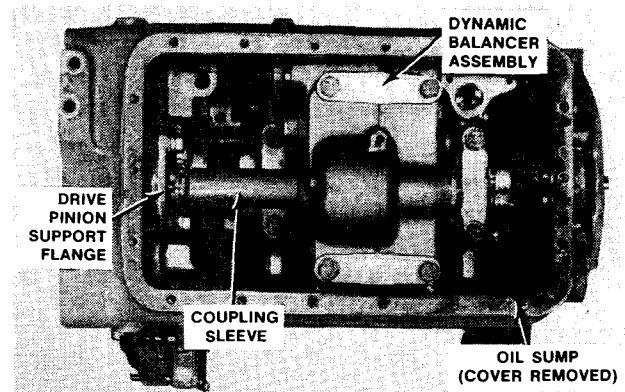


FIG. 36 Dynamic Balancer Assembly (SSD-437)

Remove the bolts securing the oil sump to the engine block and remove the sump using a chain fall or floor crane. Remove all gaskets and discard. Remove the intermediate balancer gear. Remove the oil pump.

- **SSD-655 Engine** — Remove the bolts securing the oil sump to the engine block and remove the sump using a chain fall or floor crane. Remove all gaskets and discard. Remove the oil pickup tube, pressure tube, and the oil pump.
15. Turn the engine upright in its workstand and remove the bolts securing the timing gear case cover to the timing gear case. Remove the gear case cover. Remove all gaskets and seals and discard. Remove the snap ring from the idler gear shaft. Remove the idler gear and the two thrust washers. Remove the P.T.O. drive gear (Fig. 37 and 38).

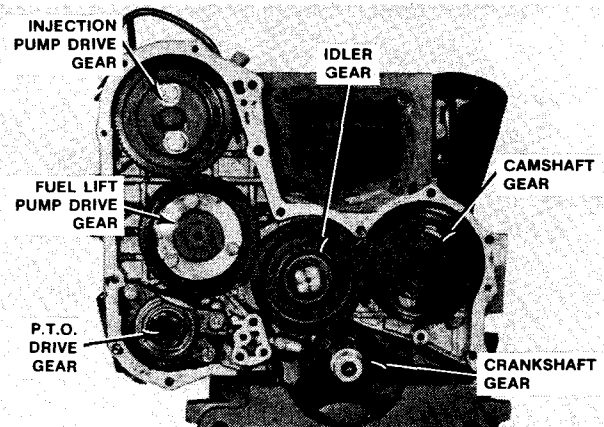


FIG. 37 Timing Gear Assembly - Cover Removed (SSD-327 and SSD-437)

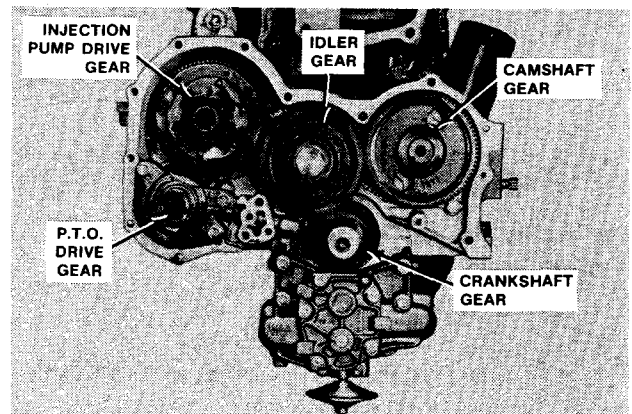


FIG. 38 Timing Gear Assembly - Cover Removed (SSD-655)

16. **SSD-327 and SSD-437 Engines** — Remove the snap ring retaining the fuel lift pump drive gear. Remove the drive gear and shaft (Fig. 37).
17. **SSD-655 Engine** — Remove the automatic advance variator from the injection pump drive coupling (Fig. 39). Remove the injection pump flange bolts. Remove the pump from the rear of the timing gear case.

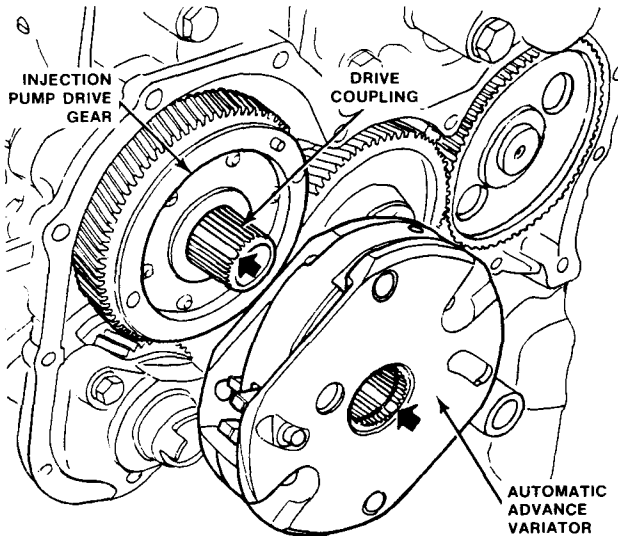


FIG. 39 Removing Automatic Advance Variator (SSD-655)

18. Invert the engine in its workstand to clear the mushroom type tappets from the cam lobes. Position the camshaft gear (Fig. 37 and 38) to permit access to the thrust plate retaining bolts. Remove the retaining bolts and pull the camshaft and gear assembly forward and out of the block.

**NOTE:** Use care when removing the camshaft. The camshaft lobes and/or bushings may become nicked or scratched through careless handling.

19. Identify and remove the tappets from the block bores.
20. Remove the timing gear case retaining bolts and lift the timing gear case from the front of the engine block.

**NOTE:** On the SSD-655 engine, the injection pump drive gear is removed with the timing gear case.

21. Position the engine vertically in its workstand and proceed to remove the connecting rod caps. Loosen the cap bolts a few turns and tap the caps with a soft hammer to release them from the rods. Then completely remove the bolts and remove the caps. Keep rod caps and bearing inserts together.
22. Push the piston and connecting rod assemblies out of the top of the block bores.

**NOTE:** It may be necessary to ream the cylinder bore upper ridge or to clean deposit buildup from this area to facilitate removal.

Remove rings from the pistons. Remove piston pin snap rings and discard. Push the piston pins out of the pistons and connecting rods. Keep component from piston and rod assemblies together.

23. Invert the engine in its workstand. Remove the holding tool from the flywheel. Remove the flywheel, flywheel housing and crankshaft rear oil seal.

24. Remove the main bearing caps. Lift the crankshaft from the block using a chain fall or floor crane.
25. Remove and identify camshaft bushings, rod bearing inserts, or main bearing inserts if they do not meet specifications or visual inspection. Refer to OVERHAUL, CLEANING, and INSPECTION procedures in this section.

### Cylinder Head Disassembly

The following procedures apply to a cylinder head which has been removed from the engine.

1. Compress the upper valve cup and valve spring with a valve spring compressor. Remove the two valve locks to release the valve. Remove the upper and lower valve cups and the valve spring.
2. Repeat this operation for each valve.
3. Turn the cylinder head on its side or invert it in the workstand and remove all valves. Keep the valves and valve components together and in proper order for cleaning, inspection, and possible reassembly.
4. If any injector sleeve must be removed from the cylinder head, tap the sleeve with an appropriate size tap, install a puller, and remove the sleeve from the top of the head (Fig. 40).

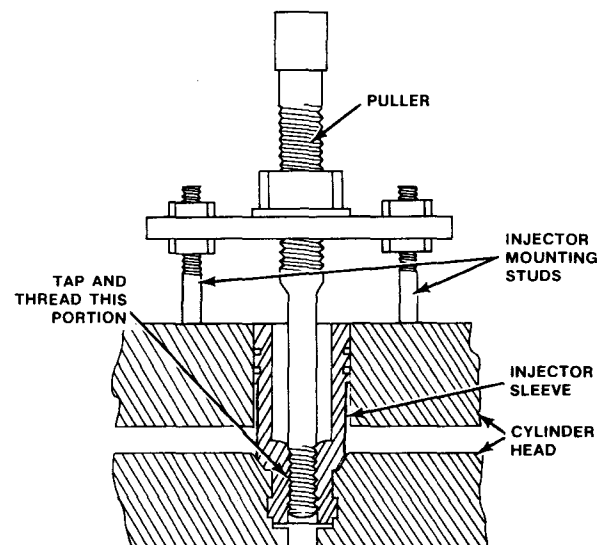


FIG. 40 Removing Injector Sleeve

### ENGINE ASSEMBLY

Before reassembling the engine, thoroughly clean and inspect the cylinder block and all components following the instructions detailed under CLEANING AND INSPECTION in this section of the manual.

Be sure to remove any piece of gasket material, dirt, or other foreign matter that enters a blind tapped hole during cleaning operations. If this is not done, a bolt may bottom-out on the resulting plug which will prevent an accurate torque reading.

Replace all parts found to be below service standards during inspection. If necessary, recondition the engine by overhauling the cylinder head, fitting new valve guides and/or grinding valve seats, refacing valves, and refinishing the head or block surfaces. If required, grind the crankshaft undersize, rebore the liners or install new ones, and install new camshaft bushings.

Check all oil passages and galleries to be sure that they are clear and unobstructed. When replacing pipe plugs, make sure that they are clean and apply a sealing compound to the threads to prevent the possibility of oil leaks or loosening while in service.

**NOTE:** In the following reassembly sequence, it is assumed that the highest standards of shop practice regarding cleanliness and parts lubrication will be followed and that all gaskets, seals, O-rings, lockwashers, and torque-retention bolts will be replaced.

Gaskets may be installed dry, however, silicone sealer must be applied to gasket mating segments and joints.

1. Install workstand mounting brackets to the engine block. Install the block in a rotary workstand and secure the mounting brackets.
2. If inspection shows that it is necessary to install camshaft bushings, install them using a driver. Ream the new bushings to specified clearance.
3. Install the timing gear case to the engine block using a new gasket and a new O-ring on the oil passage union. Torque the mounting bolts to specification.

**NOTE:** On the SSD-655 engine, the injection pump drive gear is installed with the timing gear case.

4. Invert the engine in its workstand and install the tappets in the block bores. Be sure that the tappets are able to move freely.
5. Lubricate the camshaft journals and guide the camshaft and gear assembly into position in its bushings. The mushroom type tappets must be clear of the cam lobes.

**NOTE:** Use care when installing the camshaft. The camshaft lobes and/or bushings may become nicked or scratched through careless handling.

Install the thrust plate bolts and torque to specification. Rotate the camshaft after installation to be sure it turns freely in its bushings.

6. Assemble main bearing inserts to the main caps and block bores.

**NOTE:** Inserts with oil holes are assembled to the block bores.

Wipe the insert locations clean and install so that the tangs engage in the locating grooves. If bearing inserts are being reused, be sure that they are installed in their original locations.

7. Lubricate the bearing inserts with engine oil and lower the crankshaft into place using a chain fall or floor crane. Position the thrust washer halves over the next to the last main bearing journal with the oil groove face against the crankshaft shoulder.

**NOTE:** The thrust washer half installed in the main bearing bore is not interchangeable with the half installed on the main bearing cap.

8. Install the main bearing caps. Install the main cap with the thrust washer so that the oil groove faces the crankshaft shoulder.
9. Check main bearing clearance with plastic gauging material as described in Main and Connecting Rod Bearing Overhaul in this section. If main bearing clearance is satisfactory, torque the main cap bolts to specification.

10. Lubricate the crankshaft rear oil seal with engine oil or light grease. Install the rear oil seal in the flywheel housing. Position a new O-ring on the flywheel housing and install the housing to the engine block. Torque attaching bolts to specification.
11. Check crankshaft end play as described under DIAGNOSIS AND TESTING in this section. If necessary, install oversize thrust washers to bring end play within specification.
12. Be sure that the flywheel mounting face and crankshaft flange is clean and free of burrs. Install the flywheel on the crankshaft flange and torque attaching bolts to specification.
13. Install bearing inserts to connecting rods and rod caps. If bearing inserts are being reused, be sure that they are installed in their original locations. Assemble pistons to the connecting rods. Install new piston pin snap rings. Install piston rings using a ring expander. Stagger the piston ring gaps 120°.

Rotate the engine vertically in its workstand. Apply engine oil to the rings, piston skirts, and cylinder liners. Slide the piston and rod assemblies into the cylinder bores from the top of the block with the rod identification numbers facing the side opposite the camshaft. Install the piston and rod assemblies into the cylinder bores using a ring compressor.

**NOTE:** Use care when installing the piston and rod assemblies to avoid nicking or scratching the crankshaft journals.

14. Apply engine oil to the crankshaft journals and install the rod caps. Be sure that the cap identification number is on the same side of the connecting rod as the rod identification number. Check connecting rod bearing clearance with plastic gauging material as described in Main and Connecting Rod Bearing Overhaul in this section. If rod bearing clearance is satisfactory, torque the cap bolts to specification. Check connecting rod side clearance and be sure that the crankshaft rotates freely.
15. Rotate the engine in its workstand so that it is upright. Install a dial indicator to the top of the block and check protrusion of each piston when in the top dead center position (Fig. 41). Piston protrusion should be within specification.

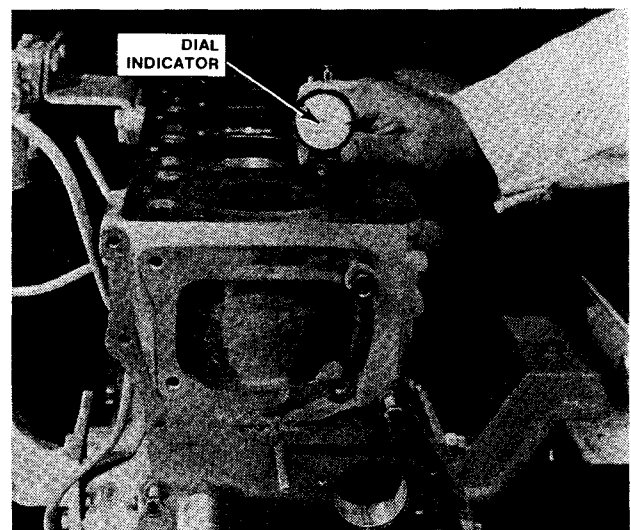


FIG. 41 Checking Piston Protrusion

16. Rotate the crankshaft until the number one piston is at top dead center on the compression stroke and the PMS1 mark on the flywheel lines up with the pointer on the flywheel housing.
17. Install a holding tool on the flywheel to prevent the crankshaft from rotating.
18. Proceed as follows to install and phase the timing gears:

• **SSD-327 and SSD-437 Engines**

- a. Install the injection pump to the flange on the rear of the timing gear case. Install the retaining nuts and washers and finger tighten only.
- b. Install the injection pump drive gear to the injection pump shaft and engage the key in the keyway. Tighten the pump shaft nut until the shaft is seated in the drive gear. Torque the two front flange retaining bolts to specification.
- c. Install the fuel lift pump drive gear and shaft. Match assembly number 4 on the lift pump drive gear with number 4 on the injection pump drive gear (Fig. 42). Install snap ring on the lift pump drive gear shaft.
- d. Install the fuel lift pump and support housing. Torque retaining bolts to specification.
- e. Install the P.T.O. drive gear in mesh with the lift pump drive gear and secure to the timing gear case (Fig. 42). Torque attaching bolts to specification.

**NOTE: The P.T.O. drive gear is not stamped with an assembly number. It may be installed in any position.**

- f. Install the thrust washers and idler gear on the idler gear shaft. Align number 3 on the idler gear with number 3 on the lift pump drive gear; number 2 on the idler gear with number 2 on the camshaft gear; and number 1 on the idler gear with number 1 on the crankshaft gear. With teeth in mesh, slide the idler gear fully onto its shaft and install the snap ring (Fig. 42).

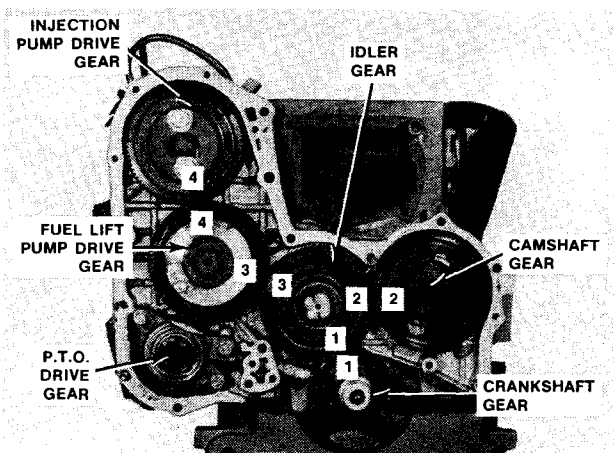


FIG. 42 Phasing Timing Gears (SSD-327 and SSD-437)

• **SSD-655 Engine**

- a. Install the thrust washers and idler gear on the idler gear shaft. Match assembly number 1 on the idler gear with number 1 on the crankshaft gear; number 2 on the idler gear with number 2 on the camshaft gear; and number 3 on the idler gear with number 3 on the injection pump drive gear.

With teeth in mesh, slide the idler gear fully onto its shaft and install the snap ring (Fig. 43).

- b. Install the P.T.O. drive gear in mesh with the injection pump drive gear and secure to the timing gear case (Fig. 43). Torque attaching bolts to specification.

**NOTE: The P.T.O. drive gear is not stamped with an assembly number. It may be installed in any position.**

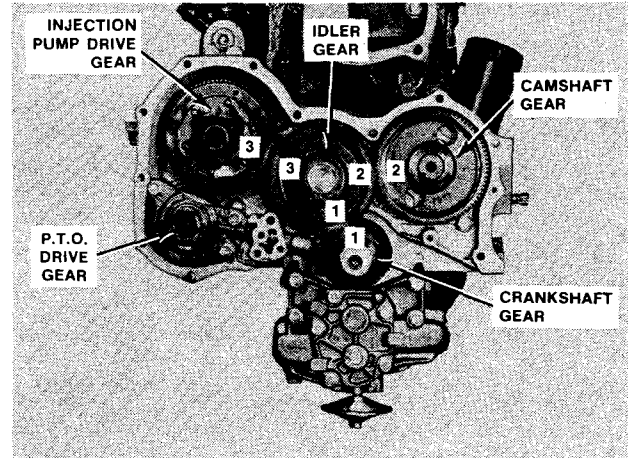


FIG. 43 Phasing Timing Gears (SSD-655)

- c. Install a new gasket on the injection pump mounting flange on the rear of the timing gear case. Engage the double groove in the pump splined shaft with the double tooth in the injection pump drive sleeve and slide the pump into place. Install the pump retaining bolts and finger tighten only. Install the automatic advance variator by pushing it firmly onto the injection pump drive sleeve and fasten it to the drive gear.
19. Install the timing gear case cover using new gaskets and seals. Torque attaching bolts to specification.
- **SSD-327 and SSD-437 Engines** — Install injection pump drive gear cover to the timing gear case cover using a new gasket. Torque attaching bolts to specification.
20. Align injection pump timing marks and torque the pump retaining nuts/bolts to specification. Refer to Injection Pump Installation in Section 3 for detailed pump timing procedures.
21. Invert the engine in its workstand and proceed as follows to install the oil sump:

- **SSD-327 Engine** — Install the oil pump to the engine block using a new gasket. Install the oil suction tube to the oil pump using a new gasket. Torque attaching bolts to specification. Install new oil sump gaskets to the engine block, timing gear cover, and flywheel housing. Apply silicone sealer to gasket mating segments and joints. Position the oil sump on the engine block and install attaching bolts.

Torque the sump attaching bolts to specification in the following order: first-bolts into flywheel housing; second-bolts into both sides of engine block and timing gear case.

- **SSD-437 Engine** — Install the oil pump to the engine block using a new gasket and torque the attaching bolts to specification. Install new oil sump gaskets to the engine block, timing gear cover, and flywheel

housing. Apply silicone sealer to gasket mating segments and joints. Lift the sump into position on the engine block using a chain fall or floor crane and install attaching bolts.

Torque the sump attaching bolts to specification in the following order: first-bolts into flywheel housing; second-bolts into both sides of engine block and timing gear case.

Install the dynamic balancer drive pinion and support flange. Engage with the teeth on the intermediate gear after lining up the timing marks (Fig. 44). Install attaching bolts and torque to specification. Install the drive pinion oil tube.

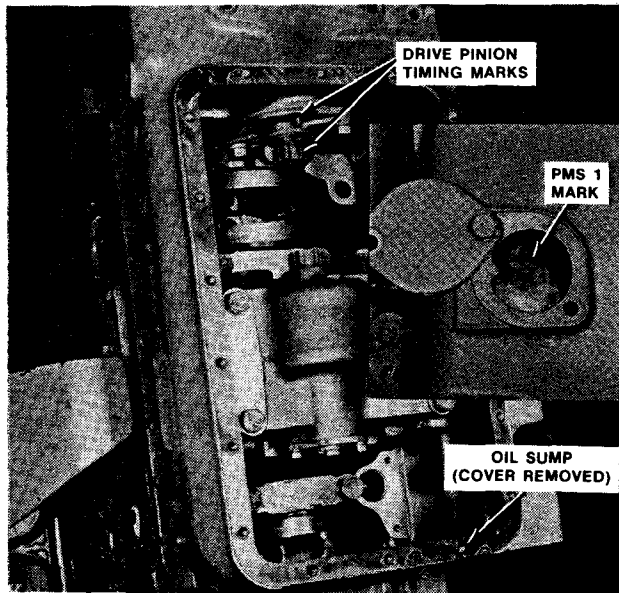


FIG. 44 Dynamic Balancer Drive Pinion Timing Marks (SSD-437)

Line up the flyweight timing marks with the timing marks on the balancer housing. Insert a pin or small drift in the housing to hold the flyweights in position (refer to Fig. 22). Install the balancer assembly and coupling sleeve into the sump. Mesh the double teeth on the sleeve spline with the double teeth on the drive pinion. Slide the balancer assembly forward and engage the coupling sleeve. Secure the balancer assembly to its supports and torque bolts to specification. Remove the pin or drift from the balancer housing.

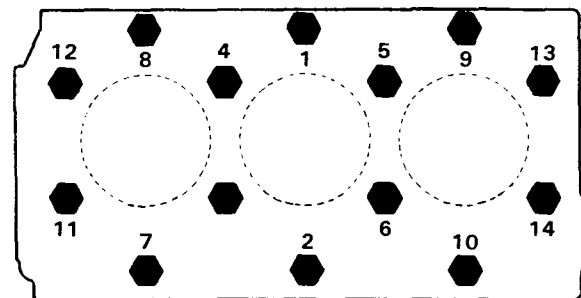
Install the oil suction tube to the oil pump using a new gasket. Install the oil sump cover using a new gasket. Torque attaching bolts to specification.

- **SSD-655 Engine** — Install the oil pump, oil pickup tube, and pressure tube to the engine block using new gaskets. Torque attaching bolts to specification. Install new oil sump gaskets to the engine block, timing gear cover, and flywheel housing. Apply silicone sealer to gasket mating segments and joints. Lift the sump into position on the engine block using a chain fall or floor crane and install attaching bolts.

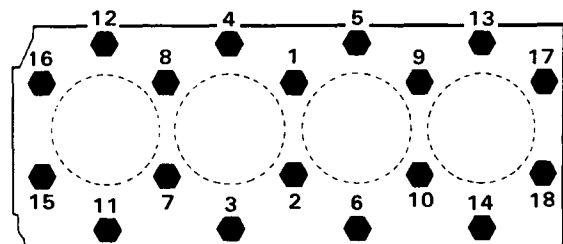
Torque the sump attaching bolts to specification in the following order: first-bolts into flywheel housing; second-bolts into both sides of engine block and timing gear case.

22. Remove the holding tool from the flywheel. Rotate the engine in its workstand so that it is in the upright position.

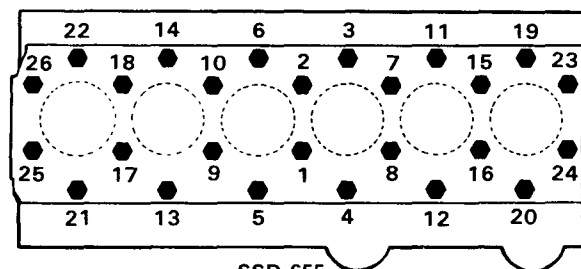
23. Assemble the valves and valve components to the cylinder head. If any valves or components are being reused, be sure to install them in their original location. Install new injector sleeves if necessary.
24. Install a new head gasket on the engine block. The letters ALTO on the gasket surface must be facing upward.
25. Install a lift cable and hook assembly to the lifting eyes on the cylinder head. Raise the cylinder head with a chain fall or floor crane and lower into position on the engine block. Remove the lift cable and hook assembly. Oil the head bolt threads lightly with engine oil and install the bolts in the cylinder head. Torque the head bolts to specification following the sequence shown in Fig. 45. Obtain the specified torque reading in three increments. First, torque the bolts in sequence to 1/3 of specification; then retorque in sequence to 2/3 of specification; finally, retorque in sequence to the full specified reading.



SSD-327



SSD-437



SSD-655

FIG. 45 Cylinder Head Bolt Tightening Sequence

26. Install the push rods and valve stem caps. Install the rocker arms and shaft assembly and torque the mounting bracket bolts to specification. If any of these components are being reused, be sure to install them in their original location.
27. Complete the following preliminary steps before proceeding to adjust valve clearance:

- **SSD-327 Engine**

- Rotate the crankshaft slowly in the operating direction until both valves of the cylinder to be adjusted are closed and the piston is in firing position.
- Adjust the valve clearance for that cylinder as directed in Step 28.
- Adjust the valve clearance for the remaining cylinders after positioning them as described in Step 27a.

- **SSD-437 Engine**

- Rotate the crankshaft slowly in the operating direction until both valves of the cylinder to be adjusted are closed. Check the valves of the symmetrical cylinder. They should be in a balanced condition. The symmetrical cylinders are number 1 and 4, and number 2 and 3. When the valves of one cylinder are in balance, the valves of the symmetrical cylinder will be closed and may be adjusted.
- Rotate the crankshaft until the valves of the number 4 cylinder are balanced, then adjust the valve clearance on the number 1 cylinder as directed in Step 28.
- Adjust the valve clearance for the remaining cylinders after positioning them as described in Step 27a.

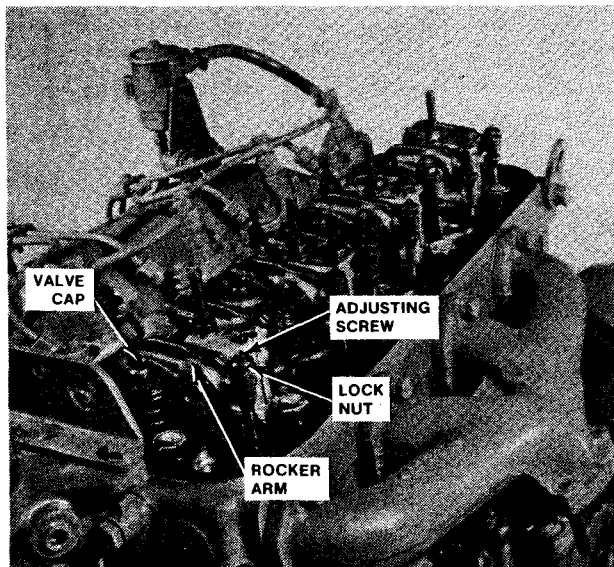
- **SSD-655 Engine**

- Rotate the crankshaft slowly in the operating direction until both valves of the cylinder to be adjusted are closed. Check the valves of the symmetrical cylinder. They should be in a balanced condition. The symmetrical cylinders are number 1 and 6, number 2 and 5, and number 3 and 4. When the valves of one cylinder are in balance, the valves of the symmetrical cylinder will be closed and may be adjusted.
- Rotate the crankshaft until the valves of the number 1 cylinder are balanced, then adjust the valve clearance on the number 6 cylinder as directed in Step 28.
- Adjust the valve clearance for the remaining cylinders after positioning them as described in Step 27a.

- Adjust the valve clearance as follows:

- Insert the correct size feeler gauge between the rocker arm and valve cap (Fig. 46). Loosen the locknut and turn the adjusting screw until a slight drag is felt when moving the feeler gauge.
- When a slight drag is felt on the feeler gauge, hold the adjusting screw in position and tighten the locknut.
- Adjust the other valve for that cylinder in the same manner. Be sure to use the correct size feeler gauge. Intake valves and exhaust valves have different clearance adjustment specifications.
- Adjust the valve clearance for the remaining cylinders after positioning them as described in Step 27.

**NOTE:** When adjusting valve clearance on an engine which is in service, the valves must be adjusted with the engine cold.



**FIG. 46 Valve Clearance Adjustment Points**

- Position the crankshaft hub on the front of the crankshaft. Install the tabbed washer and hub nut. Draw the hub onto the crankshaft by torquing the hub nut to specification.

**NOTE:** The flywheel must be prevented from rotating while the hub nut is torqued.

Bend the tabs on the washer against the hub nut to prevent the nut from loosening. Install the crankshaft hub pulley and torque the attaching bolts to specification.

- Install the rocker arm cover using a new gasket. Torque the retaining nuts to specification.
- Install the injectors into their original position. Torque the retaining nuts to specification.
- Install the intake and exhaust manifolds using new gaskets. Torque attaching nuts and bolts to specification.
- Install the fuel lines, fuel filters, injector lines, and all thermostart components using new gaskets, seals, or O-rings. Torque all attaching nuts and bolts to specification.
- Install the water pump adapter housing, water pump, thermostat, and cylinder head coolant outlet using new gaskets. Torque all attaching nuts and bolts to specification.
- Install the fan hub and cooling fan to the water pump and torque attaching bolts to specification. Install the alternator and mounting bolts. Install new drive belt(s) and tighten to specification using a belt tension gauge. Torque the alternator pivot bolt and adjusting bolt to specification.
- Install the starter motor and torque attaching bolts to specification.
- Install new oil filter(s).

# PART 3 Fuel System

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## GENERAL INFORMATION

### SSD-327 AND SSD-437 ENGINES

The fuel system for the SSD-327 and SSD-437 engines consists of a gear driven fuel lift pump, dual fuel filters, gear driven rotary type injection pump, injectors (3 or 4), and a thermostart system (Fig. 1).

### SSD-655 ENGINE

The fuel system for the SSD-655 engine is similar; its components consist of a sediment filter, cam driven fuel lift pump, dual fuel filters, gear driven in-line type

injection pump, injectors (6), and a thermostart system (Fig. 2).

## DESCRIPTION

The fuel lift pump transfers fuel from the fuel tank, through the dual filters, to the injection pump. The sediment filter on the SSD-655 engine is located in the fuel line between the fuel tank and lift pump.

The injection pump is timed to permit fuel flow to the injector for each cylinder. Excess fuel from the injection pump is returned to the fuel tank by a return line. The return line also feeds the thermostart reservoir.

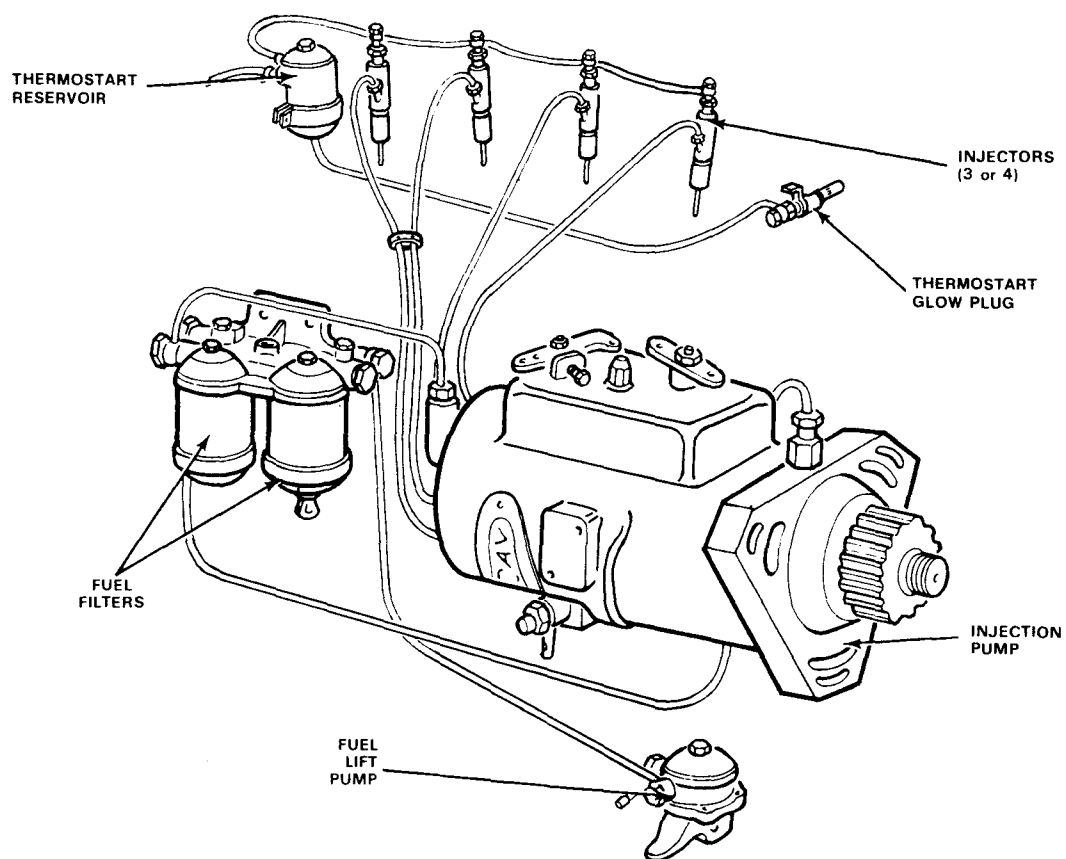


FIG. 1 SSD-327 and SSD-437 Fuel System

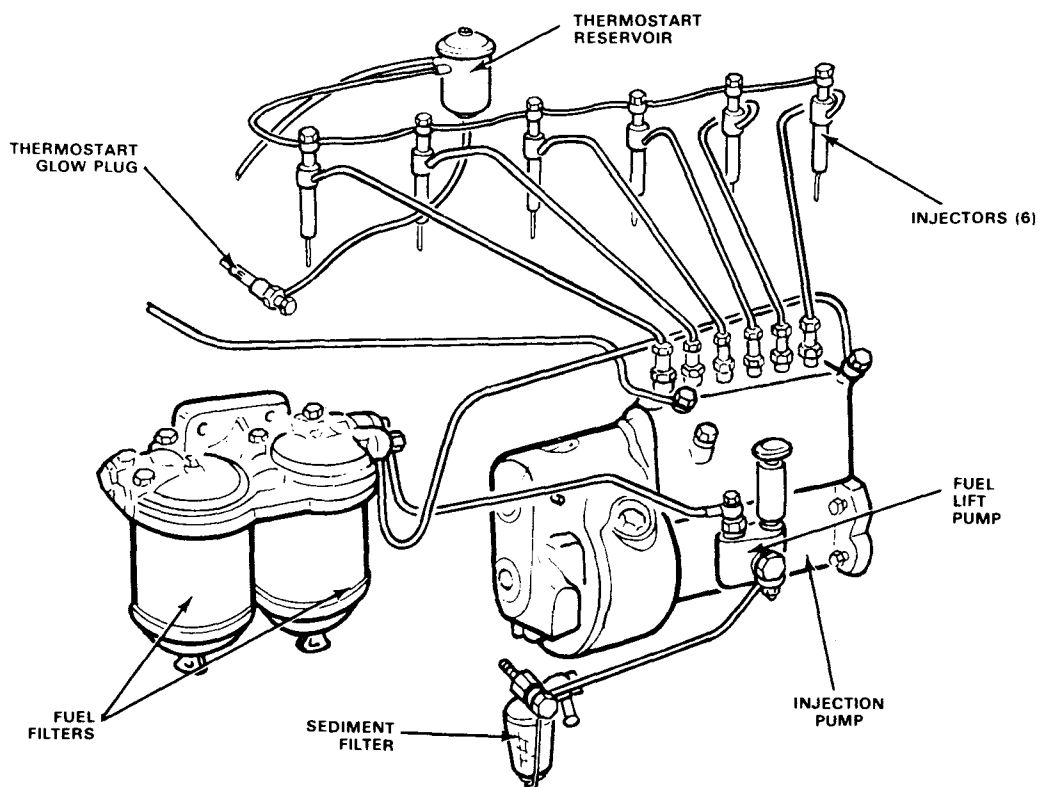


FIG. 2 SSD-655 Fuel System

## FUEL LIFT PUMP

### DESCRIPTION

#### SSD-327 and SSD-437

The fuel lift pump used on the SSD-327 and SSD-437 engines is a diaphragm type pump actuated by an eccentric cam and driven by a gear in the timing gear assembly. The lift pump is similar to the fuel pump used on automotive gasoline engines.

A lever is mounted on the fuel lift pump for use in manual priming of the injection pump and bleeding air from the fuel system (Fig. 3). A filter screen is located under the lift pump cover.

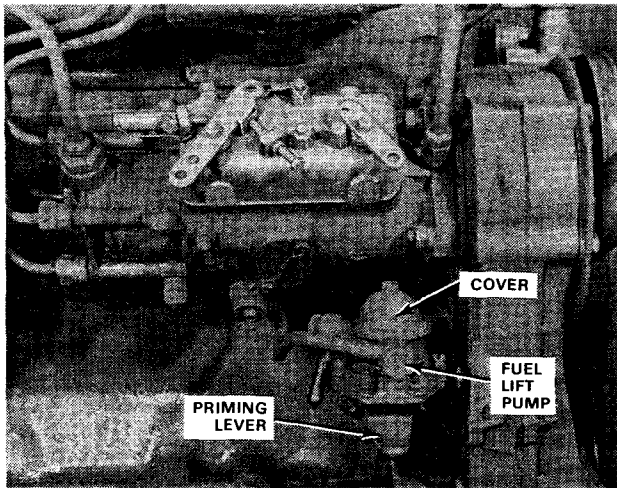


FIG. 3 SSD-327 and SSD-437 Fuel Lift Pump

#### SSD-655

The SSD-655 engine uses a reciprocating plunger type fuel lift pump which is mounted to the side of the injection pump. The lift pump is operated by a cam and cam follower on the the injection pump camshaft. This lift pump also has an external, manually operated priming pump for priming and bleeding the fuel system (Fig. 4).

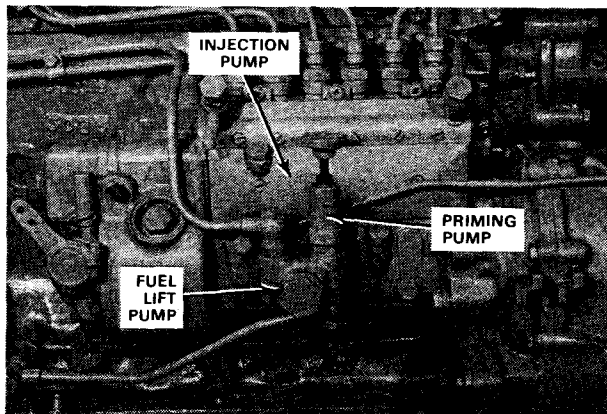


FIG. 4 SSD-655 Fuel Lift Pump

### TESTING

#### Pump Efficiency Test

Providing there are no air leaks or obstructions in the fuel system, a quick check on the pump efficiency can be made as follows:

1. Loosen the fuel filter air bleed screws two full turns (Fig. 5).

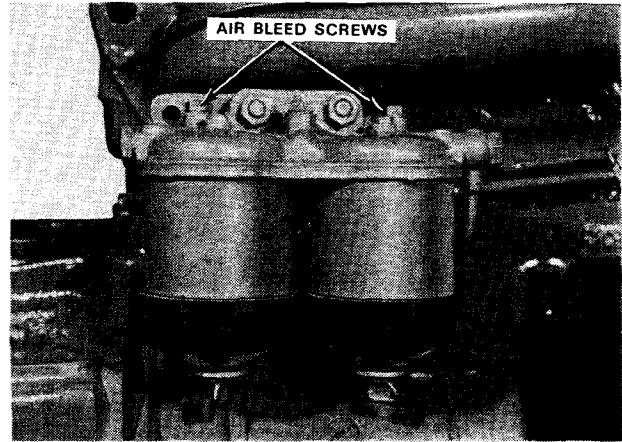


FIG. 5 Air Bleed Screws—Typical

2. Operate the manual priming lever. There should be a well-defined surge of fuel for each working stroke of the lever.

**NOTE:** SSD-327 and SSD-437 engines—If there is no resistance to the priming lever, it is likely that the pump diaphragm is held down due to the lever being on the high point of the eccentric. It will be necessary to rotate the engine approximately one turn.

If the lift pump does not operate correctly, use the following procedures to check the inlet vacuum and delivery pressure.

#### Inlet Vacuum Test

##### SSD-327 AND SSD-437

1. Operate the lift pump priming lever and fully prime the injection pump.
2. Disconnect the fuel inlet line from the lift pump and connect a vacuum gauge between the inlet line and the pump inlet fitting.
3. Start the engine and allow it to run at idle speed. The vacuum reading should be at least 15.98 in. of mercury (40.59 cm of Hg).
4. Remove the vacuum gauge and connect the inlet line to the lift pump.
5. Bleed the fuel system as outlined on page 3-12.

#### Delivery Pressure Test

1. Operate the lift pump priming lever and fully prime the injection pump.
2. Disconnect the fuel outlet line from the lift pump and connect a pressure gauge between the outlet line and the pump outlet fitting.
3. Start the engine and observe the pressure reading at idle speed. Increase the engine speed and check the pressure readings throughout the entire speed range. Pressure should be between 11.4-20 psi (0.8-1.4 Kg/cm<sup>2</sup>) for the SSD-327 and SSD-437; and 17-21.3 psi (1.2-1.5 Kg/cm<sup>2</sup>) for the SSD-655. A lift pump that does not meet specification should be replaced.

**NOTE:** Low fuel lift pump pressure may affect engine performance due to lack of fuel.

4. Remove the pressure gauge and connect the outlet line to the lift pump.
5. Bleed the fuel system as outlined on page 3-12.

## REMOVAL AND INSTALLATION

### Removal

1. Disconnect the fuel inlet and outlet lines.
2. Remove the nuts and washers securing the lift pump and remove the pump. Remove the pump mounting gasket.

## INJECTION PUMP

### DESCRIPTION

#### SSD-327 and SSD-437

The SSD-327 and SSD-437 engines are equipped with a C.A.V. distributor type (rotary) injection pump. The injection pump assembly combines a transfer pump, a high pressure pump, regulating valve, and a governor in the same housing. The injection pump is lubricated by the fuel and does not require a separate oil supply.

The injection pump is flange-mounted to the timing gear case and is gear driven by the timing geartrain (Fig. 6). Pump rotation is counterclockwise when viewed from the drive end. The injection pump and engine must be timed if the pump is removed from the engine or if a replacement pump is installed.

**NOTE:** Individual components of the injection pump are not serviced. The pump assembly should be serviced by an authorized diesel service center.

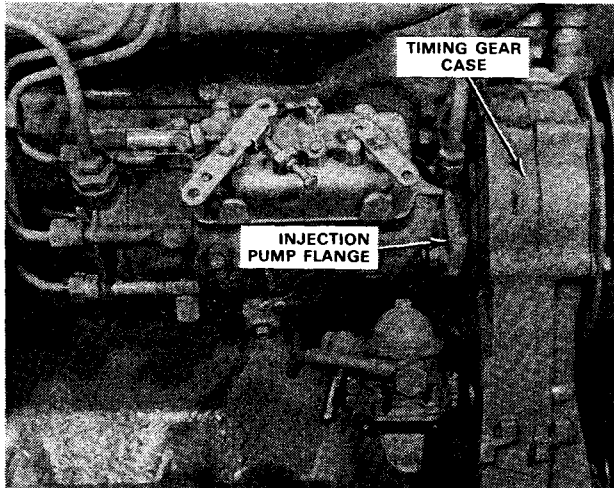


FIG. 6 SSD-327 and SSD-437 Distributor Type (Rotary) Injection Pump

#### SSD-655

The SSD-655 engine is equipped with an in-line injection pump (Fig. 7). This type of pump has one pumping plunger element for each injector. Plungers operate vertically through roller tappets actuated by the pump camshaft.

The injection pump is pressure lubricated by engine oil from the crankcase by way of an external line. Anytime the injection pump is removed for servicing, or if a new pump is being installed, an initial supply of oil **must** be added to the pump sump to prevent possible damage at start-up.

### Installation

1. Be sure that the pump mounting surfaces are clean. Install a new mounting gasket and secure the lift pump with the nuts and washers. Torque the nuts to specification.
2. Reconnect the fuel inlet and outlet lines.
3. Bleed the fuel system as outlined on page 3-12.

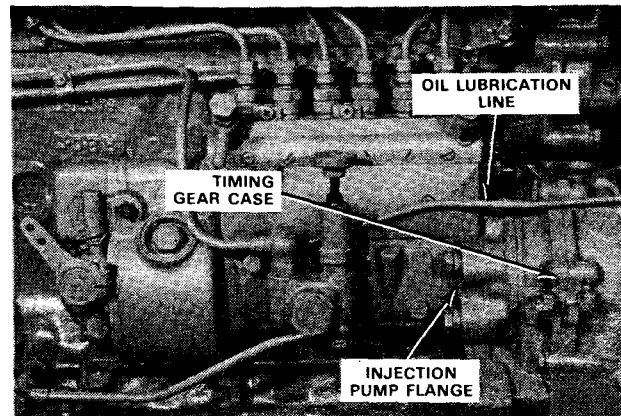


FIG. 7 SSD-655 In-Line Injection Pump

The injection pump is gear driven by the timing geartrain. Pump rotation is clockwise when viewed from the drive end.

An automatic advance variator is mounted to a drive coupling at the front of the pump drive (Fig. 8). At higher engine speeds, the variator causes the pump to inject fuel into the cylinders a few degrees early.

The injection pump and engine must be timed if the pump is removed from the engine or if a replacement pump is installed.

**NOTE:** Individual components of the injection pump are not serviced. The pump assembly should be serviced by an authorized diesel service center.

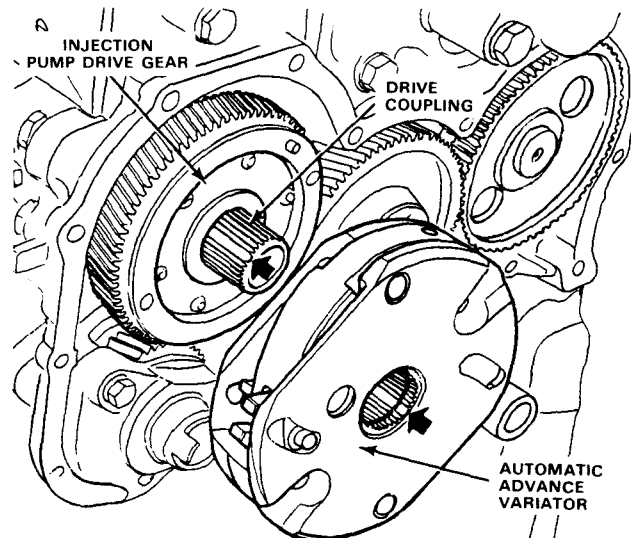


FIG. 8 SSD-655 Automatic Advance Variator

## REMOVAL AND INSTALLATION

### Removal

#### SSD-327 AND SSD-437

1. Crank the engine until the number one piston is at top dead center on the compression stroke and the PMS1 mark on the flywheel lines up with the pointer on the flywheel housing (Fig. 9).

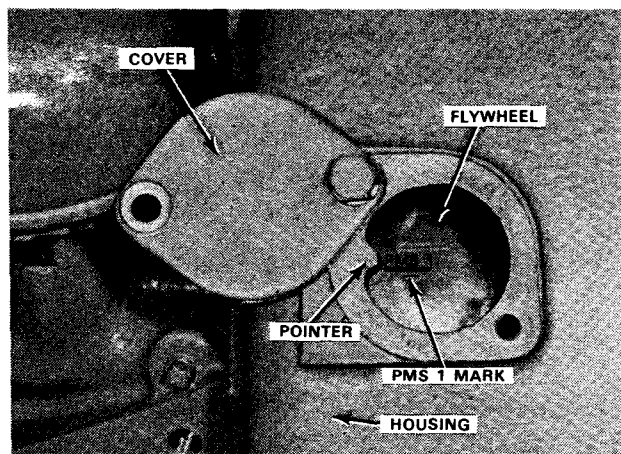


FIG. 9 Flywheel and Housing Timing Marks (SSD-327 and SSD-437)

2. Disconnect throttle control linkage from the levers. Disconnect the fuel lines and injector lines from the pump.
3. Remove the inspection cover and gasket from the front of the timing gear case. Remove the nuts and washers securing the pump flange from the rear of the timing gear case.
4. Loosen the two bolts retaining the flange to the front of the drive gear one or two turns. Loosen the pump shaft nut (which also serves as a puller) and withdraw the pump from its driving gear (Fig. 10).

**CAUTION:** The drive gear will now be loose and may fall out of place if forced.

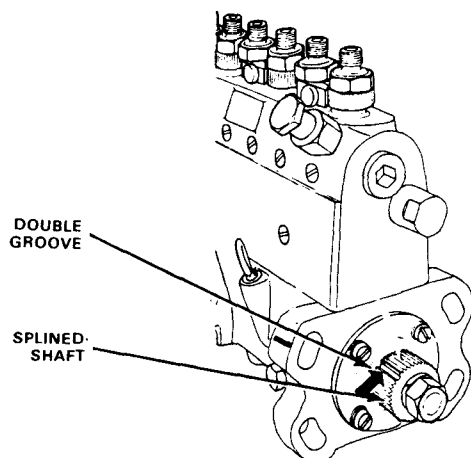


FIG. 12 Removing Injection Pump From Engine (SSD-655)

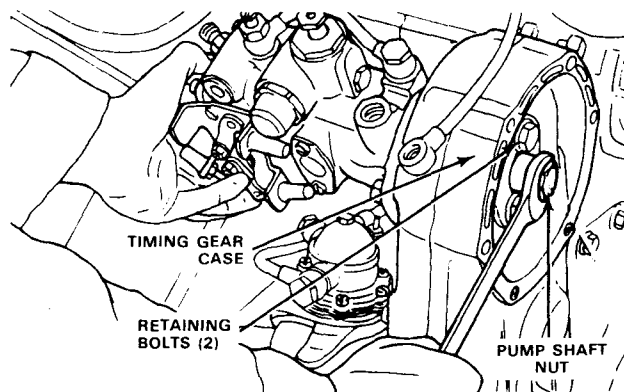


FIG. 10 Removing Injection Pump From Engine (SSD-327 and SSD-437)

#### SSD-655

1. Crank the engine until the number one piston is at top dead center on the compression stroke and the INIEZ mark on the flywheel lines up with the pointer on the flywheel housing (Fig. 11).

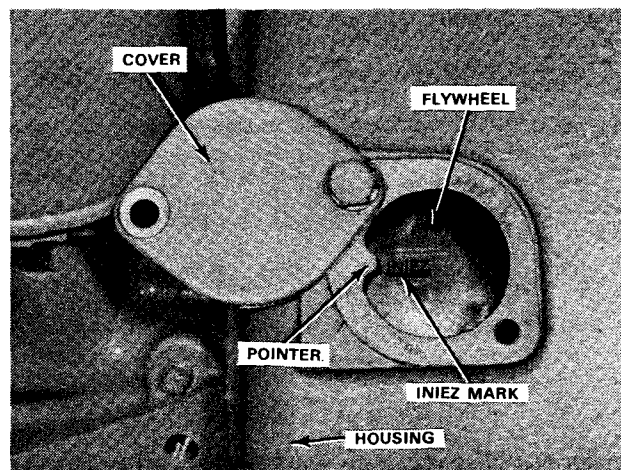
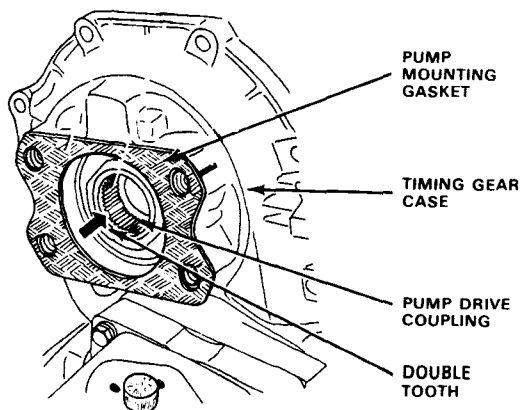


FIG. 11 Flywheel and Housing Timing Marks (SSD-655)

2. Disconnect the throttle control linkage from the lever. Disconnect the oil line, fuel lines, and injector lines from the pump.
3. Remove the bolts that secure the pump flange to the rear of the timing gear case.
4. Withdraw the pump from its driving gear. Remove the pump mounting gasket from the timing gear case (Fig. 12).



## Installation

### SSD-327 AND SSD-437

1. Be sure that the number one piston is at top dead center of the compression stroke and the PMS1 mark on the flywheel lines up with the pointer on the flywheel housing (Fig. 13).

**NOTE:** If the drive gear was removed or has fallen out of place, install with the timing mark (#4) aligned with the timing mark (#4) on the lift pump drive gear.

2. Slide the pump shaft into the pump drive gear and engage the key in the keyway. Position the elongated holes in the pump flange over the studs in the timing gear case. Install the washers and nuts on the studs and finger tighten only.
3. Tighten the pump shaft nut until the shaft is seated in the drive gear. Torque the two front flange retaining bolts to specification. Twist the injection pump housing until the assembly marks on the pump flange and the timing gear case are aligned (Fig. 13).
4. Install the inspection cover, using a new gasket and sealer, on the timing gear case.
5. Tighten all nuts and bolts to specifications.
6. Connect the fuel lines and injector lines to the pump. Connect the throttle control linkage to the levers.
7. Bleed the fuel system as outlined on page 3-12.
8. Adjust the idle speed and maximum speed screws to specification (see page 3-08).

### SSD-655

1. Be sure that the number one piston is at top dead center of the compression stroke and the INIEZ mark on the flywheel lines up with the pointer on the flywheel housing (Fig. 14).
2. Install a new gasket and sealer on the pump mounting flange. Engage the double groove in the pump splined shaft with the double tooth in the drive coupling and slide the pump into place (refer to Fig. 12).
3. Tighten the bolts that secure the pump mounting flange finger tight only. Twist the injection pump housing until the timing marks on the pump flange and timing gear case are aligned (Fig. 14). Tighten the mounting bolts to specification.
4. Add an initial supply of engine oil to the injection pump (refer to the Lubrication Section on page 3-07).

**NOTE:** The injection pump must be primed with engine oil before initial start-up to prevent possible damage to the pump.

5. Connect the oil line, fuel lines, and injector lines to the pump. Connect the throttle control linkage to the lever.
6. Bleed the fuel system as outlined on page 3-12.
7. Adjust the idle speed and maximum speed screws to specification (see page 3-08).

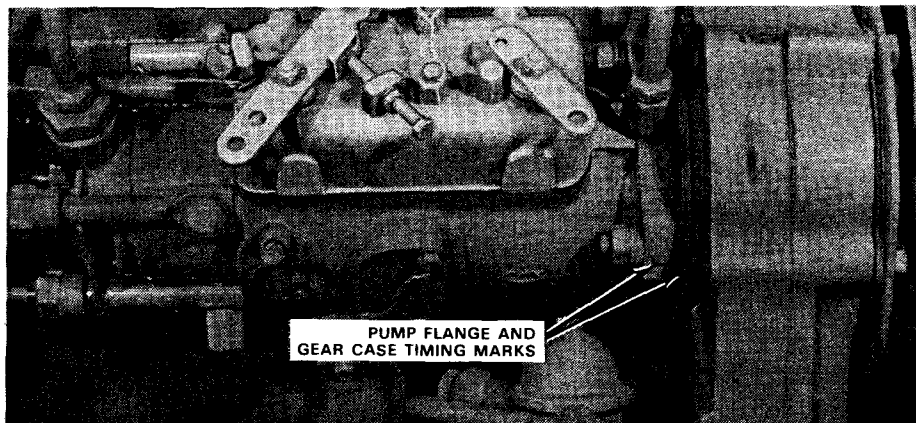
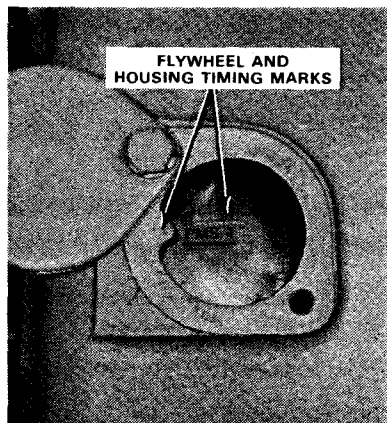


FIG. 13 Engine and Injection Pump Timing Marks (SSD-327 and SSD-437)

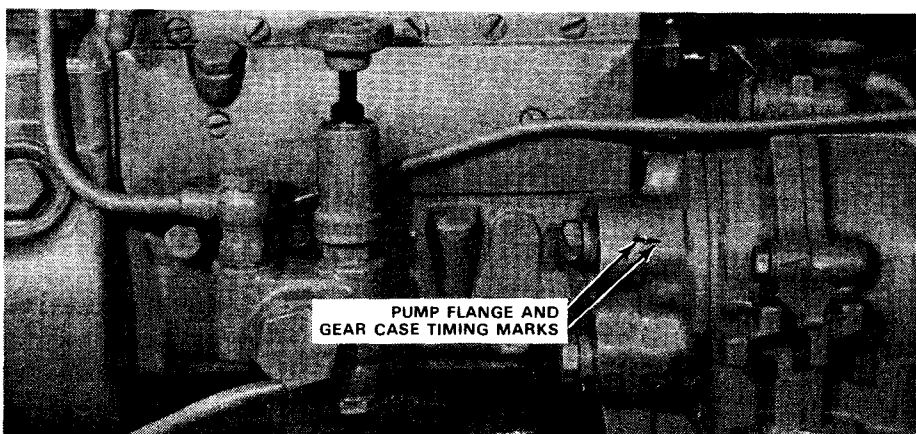
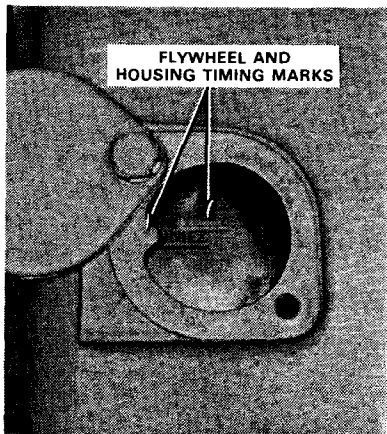


FIG. 14 Engine and Injection Pump Timing Marks (SSD-655)

## SSD-655 PUMP/ENGINE TIMING CHECK

If there is any doubt that the pump/engine timing is not correct, use the following "spill method" to verify:

1. Crank the engine until the number one piston is on the compression stroke and the INIEZ mark on the flywheel is coming up to the pointer on the flywheel housing (Fig. 15).
2. Disconnect the number one cylinder injector line at the pump and remove the pressure outlet. Lift out the delivery valve, spring, and reducer plug. Replace the pressure outlet.
3. Open the fuel valve, place the throttle control at maximum fuel, and fill the circuit with the priming pump (Fig. 15).
4. Remove the injection pump tappet cover to monitor plunger operation.
5. Rotate the crankshaft counterclockwise until the number one cylinder plunger is down at the start of the stroke.

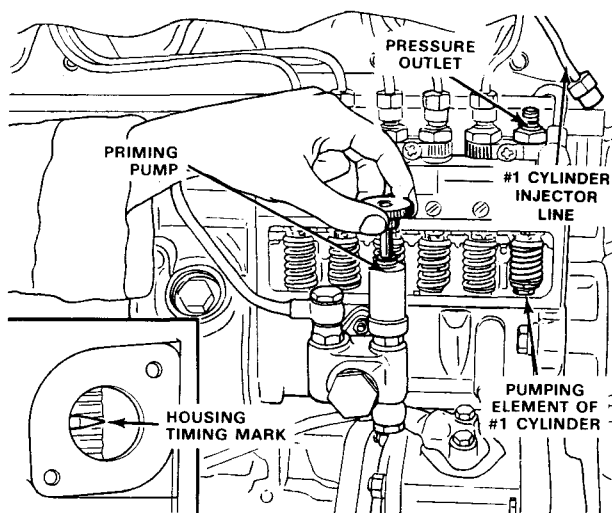


FIG. 15 Checking Pump/Engine Timing Using the "Spill Method" (SSD-655)

6. Operate the priming pump to be sure that fuel flows out of the pressure outlet. Turn the crankshaft slowly until fuel stops flowing and remains flush with the top of the pressure outlet.
7. This point marks the beginning of fuel delivery to the number one injector. The INIEZ mark on the flywheel should line up with the pointer on the flywheel housing (Fig. 16). If the INIEZ mark does not line up, turn the crankshaft until it does.

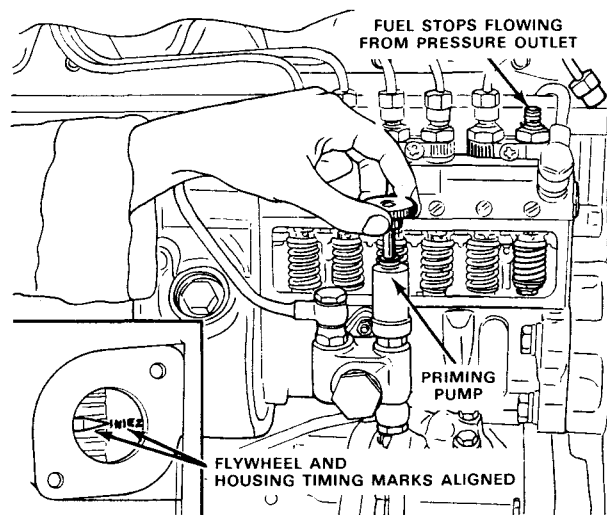


FIG. 16 Correct Pump/Engine Timing (SSD-655)

8. Loosen the injection pump mounting bolts and turn the pump toward the engine until fuel flows out of the pressure outlet again. Turn the pump away from the engine until fuel stops flowing. The timing is now correct. Tighten the mounting bolts to specification.
9. Install the reducer plug, spring, and delivery valve. Connect the number one injector line to the pump.
10. Bleed the fuel system as outlined on page 3-12.
11. Adjust the idle speed and maximum speed screws to specification (see page 3-08).

## LUBRICATION

### DESCRIPTION

#### SSD-327 and SSD-437

The C.A.V. rotary type injection pump used on the SSD-327 and SSD-437 engines is lubricated by the fuel and does not require a separate oil supply.

#### SSD-655

The in-line injection pump used on the SSD-655 engine is pressure lubricated by engine oil from the crankcase by way of an external line (Fig. 17). The oil is circulated through the pump and drains back to the engine crankcase.

#### ADDING OIL TO INJECTION PUMP SSD-655

Anytime the injection pump is removed for servicing, or if a new pump is being installed, an initial supply of engine oil **must** be added to the pump to prevent possible damage at start-up.

Remove the filler plug (Fig. 17) and add 8 oz. (237 mL) of engine oil to the injection pump. Replace the filler plug.

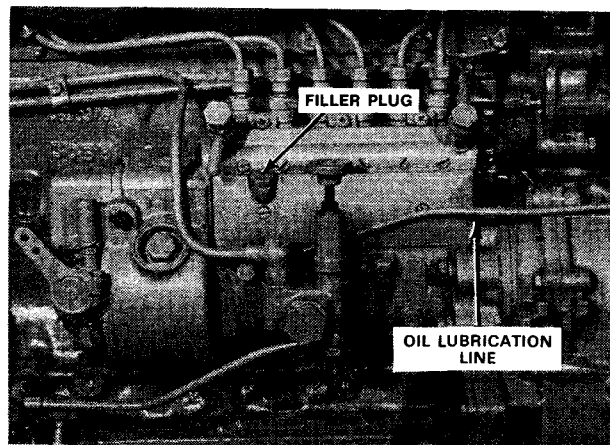


FIG. 17 Injection Pump Lubrication (SSD-655)

## IDLE SPEED AND MAXIMUM SPEED ADJUSTMENTS

### IDLE SPEED ADJUSTMENT

1. Start the engine and allow it to reach normal operating temperature.
2. With the engine idling, loosen the idle speed screw locknut (Fig. 18 and 19). Adjust the idle speed screw until the engine idles at the specified RPM. Turning the idle speed screw clockwise will increase the idle RPM; turning the screw counterclockwise will decrease the idle RPM. With the engine idling at the specified RPM, tighten the idle speed screw locknut.
3. Recheck the idle speed several times by increasing the engine speed and allowing it to return to idle. The engine should return to the previously set idle speed.

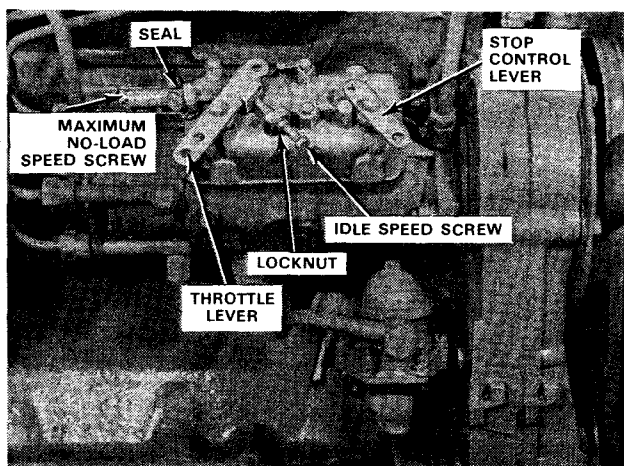


FIG. 18 SSD-327 and SSD-437 Speed Screw Locations

### MAXIMUM SPEED ADJUSTMENT

1. Start the engine and allow it to reach normal operating temperature.
2. Increase the engine RPM to maximum no-load speed. If necessary, adjust the maximum speed screw (Fig. 18 and 19) to obtain the no-load governed speed RPM specification.

**NOTE:** The maximum no-load speed screw is factory sealed for maximum no-load speed. If the seal is broken for adjustment purposes, be sure to reseal the screw before the engine is put into service.

3. SSD-327 and SSD-437 engines—Check operation of the stop control lever and linkage. Adjust if necessary.

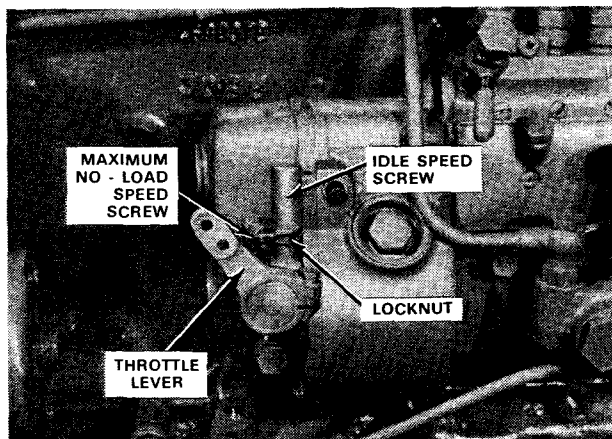


FIG. 19 SSD-655 Speed Screw Locations

## INJECTORS

### DESCRIPTION

Fuel injectors from four different manufacturers are used on the SSD-327, SSD-437 and SSD-655 engines. Although the four types of injectors operate and appear similar, they should not be inter-mixed on any one engine. Fig. 20 illustrates a typical injector.

### OPERATION

High pressure fuel from the injection pump enters the fuel inlet at timed intervals and flows down to the nozzle valve seat. When the preset injection pressure is reached, the nozzle valve is unseated and compresses the spring. Fuel is then forced through the holes in the nozzle body and is atomized in the combustion chamber. All SSD engine injector types operate at an injection pressure of 3200-3342 psi (225-235 Kg/cm<sup>2</sup>).

When injection pressure is cut off, the spring forces the nozzle valve back on its seat, preventing nozzle afterdrip. Excess fuel in the injector body leaks off through the fuel return line.

### MAINTENANCE

After every 400 hours of operation, the injectors should be removed from the cylinder head and cleaned. Remove carbon deposits from the injector tips with a wire brush. Check the nozzle spray holes to make sure they are not obstructed.

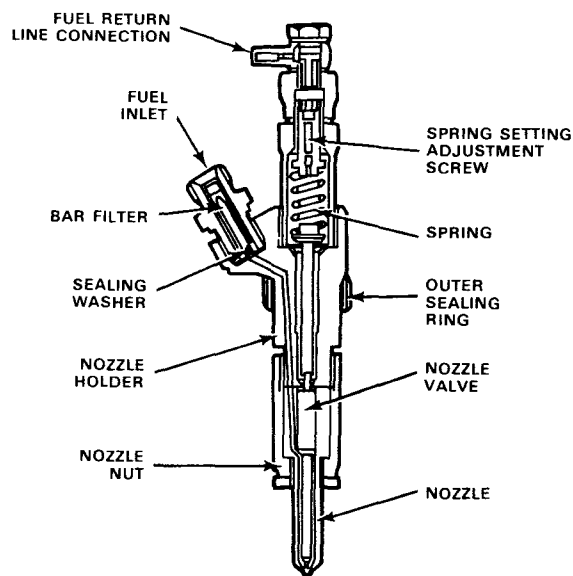


FIG. 20 Typical Fuel Injector

## REMOVAL AND INSTALLATION

### Removal

1. Clean the exterior of the injector and the adjacent surface of the cylinder head to remove any dirt accumulation.
2. Remove the bolt that secures the fuel return line to the injector.
3. Loosen the injector fuel line nut at the injection pump. Loosen the bracket securing the fuel lines together.
4. Remove the fuel line from the fuel inlet connection of the injector.
5. Remove the two nuts and washers from the studs securing the injector and remove the retaining collar (if so equipped). Pull the injector and outer sealing ring from the bore in the cylinder head.

### Installation

1. Inspect the injector bore in the cylinder head. It should be clean and free from any carbon deposits. If cleaning is necessary, use extreme care to prevent loose particles from entering the engine through the injector bore.
2. Install the outer sealing ring to the injector. Install the injector assembly into its bore so that it is fully seated.
3. Install the retaining collar (if so equipped). Install the two washers and nuts on the studs. Tighten the nuts alternately and evenly to specification.
4. Install the fuel line to the fuel inlet connection of the injector and tighten.
5. Tighten the injector fuel line nut at the injection pump. Tighten the bracket securing the fuel lines together.
6. Install the fuel return line to the injector and tighten attaching bolt.
7. Operate the engine for a short time and inspect the inlet connection, return line, and injector seal for fuel leaks.

## TESTING

The fuel injector must pass four tests to qualify for return to service: 1) nozzle opening pressure; 2) nozzle leak-back; 3) nozzle seat leakage; and 4) spray pattern.

**WARNING:** Use extreme care when testing injectors. The fuel spray must not contact any part of the body, as it will penetrate the skin due to the high pressure and atomization of the fuel. In case of accidental contact with the skin, consult a physician immediately.

The following test procedures apply to all four injector types:

### Nozzle Opening Pressure Test

Open the valve on the tester 1/2 turn to obtain an accurate reading of opening pressure. Connect the injector to the tester and operate the hand pump until fuel is released from the nozzle. Note the pressure (nozzle opening pressure) at which the fuel is released (Fig. 21). Opening pressure should be between 3200-3342 psi (225-235 Kg/cm<sup>2</sup>).

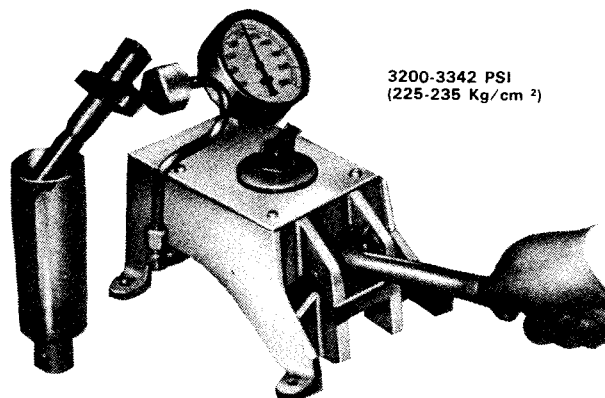


FIG. 21 Testing Nozzle Opening Pressure

If opening pressure does not meet specifications, rotate the spring setting adjustment screw clockwise to increase pressure; counterclockwise to decrease pressure (refer to Fig. 20). Recheck adjustment until opening pressure meets specification.

### Nozzle Leak-Back Test

Fully open the valve on the tester. Apply 2800 psi (196 Kg/cm<sup>2</sup>) test pressure to the injector. Check the amount of time it takes for the pressure to fall from 2800 psi to 2100 psi (196 Kg/cm<sup>2</sup> to 147 Kg/cm<sup>2</sup>). The time span should be between 10 and 40 seconds. If pressure drops in less than 10 seconds, it indicates a loose or dirty nozzle needle valve. Repair or replace the injector.

### Nozzle Seat Leakage Test

After the injector has been tested for nozzle leakback, use the following procedure to test for nozzle seat leakage. Wipe the nozzle tip dry with blotting paper. Operate the hand pump of the tester and apply between 3000-3142 psi (211-220 Kg/cm<sup>2</sup>) pressure to the injector. Maintain pressure for one minute. Then hold a piece of blotting paper to the nozzle tip. The fuel stain should not exceed 1/2 in. (13 mm) in diameter.

### Spray Pattern Test

SSD-327, SSD-437, and SSD-655 engines use fuel injectors which have 3-hole nozzles with a 140° spray pattern. The nozzle holes are irregularly spaced (Fig. 22).

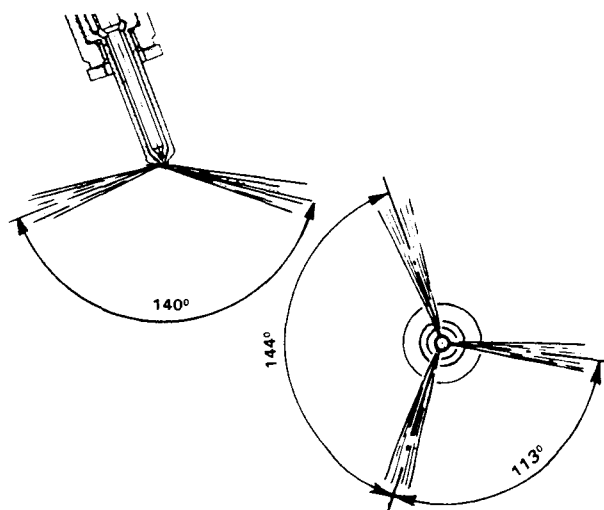


FIG. 22 Injector Spray Pattern

Close the valve on the tester and operate the hand pump until the specified pressure is reached. Observe the spray pattern in a container. The spray from each nozzle hole must be similar, with no visible streaks or distortion. Each spray should be fully atomized and form a cone about 3 in. (76 mm) before striking the side of the container.

**NOTE:** If the injector passes all of the four previous tests, it can be returned to service. If the injector fails any of the tests, it should be replaced or repaired. Injectors should be sent to an authorized diesel service center for overhaul and reconditioning.

## FUEL FILTERS

### DESCRIPTION

The presence of water and/or dirt in the fuel can cause corrosion and excessive wear to the fuel system components. Water and solid contaminants suspended in the fuel supply are eliminated by passing through two inline, replaceable cartridge-type fuel filters (Fig. 23).

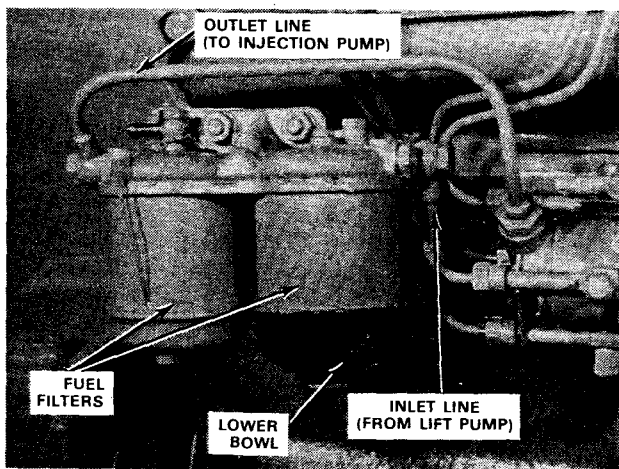


FIG. 23 Typical Dual In-Line Fuel Filters

### OPERATION

The first filter (inlet) separates the water and solid contaminants from the fuel. Water droplets are condensed into larger drops. These water drops are eliminated by sedimentation to the bottom of the filter where it is visible through the transparent lower bowl which is attached to the filter body. Solid particles are trapped by the filter element contained in the filter body.

After circulating through the first filter, the fuel flows through a second filter (outlet) which completes the filtration process. All SSD engines utilize the dual filter arrangement to ensure an uncontaminated fuel supply.

### Filter Screen

In addition to the dual in-line fuel filters, the SSD-327 and SSD-437 engines have a filter screen mounted in the fuel lift pump. The filter screen is located under the lift pump cover (refer to Fig. 3).

### Sediment Cup Filter

The lift pump on the SSD-655 engine is not equipped with a filter screen. Instead, a sediment cup-type filter is located in the fuel line between the fuel tank and the lift pump (refer to Fig. 2).

## MAINTENANCE

Efficient engine operation depends on timely performance of fuel filter maintenance.

### Cleaning

#### LIFT PUMP FILTER SCREEN (SSD-327 AND SSD-437)

After every 200 hours of engine operation, clean the lift pump filter screen as follows:

1. Turn off the fuel supply from the fuel tank.
2. Remove the bolt securing the cover to the lift pump and remove the cover.
3. Remove the filter screen from the lift pump (Fig. 24). Wash the filter screen in clean diesel fuel oil and remove all particles of dirt from the screen.
4. Inspect the screen and gasket surfaces for cracks or tears. Replace the filter if damaged.
5. Install the filter screen in the lift pump. Install the cover and tighten retaining bolt to specification.
6. Bleed the fuel system as outlined on page 3-12.

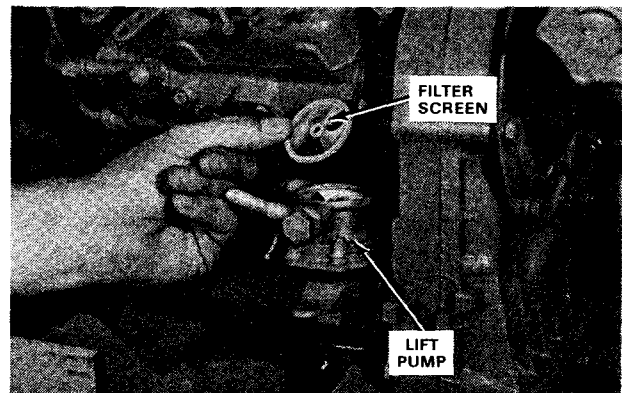


FIG. 24 Removing Lift Pump Filter Screen (SSD-327 and SSD-437)

#### SEDIMENT CUP FILTER (SSD-655)

After every 200 hours of engine operation, clean the sediment cup filter as follows:

1. Turn off the fuel supply from the fuel tank.
2. Loosen the thumbwheel on the filter cup retainer and swing the retainer away from the cup. Remove the cup from the filter housing (Fig. 25).
3. Remove the sediment filter and spring. Wash the filter in clean diesel fuel oil and remove all particles of dirt from the filter.
4. Inspect the filter for cracks or tears. Replace the filter if damaged.
5. Wash the filter cup in clean diesel fuel oil to remove all particles of dirt.
6. Assemble the spring to the filter. Fill the filter cup with clean diesel fuel oil and position the filter, spring, and cup to the filter housing.
7. Swing the cup retainer down and tighten the thumbwheel finger tight.
8. Bleed the fuel system as outlined on page 3-12.

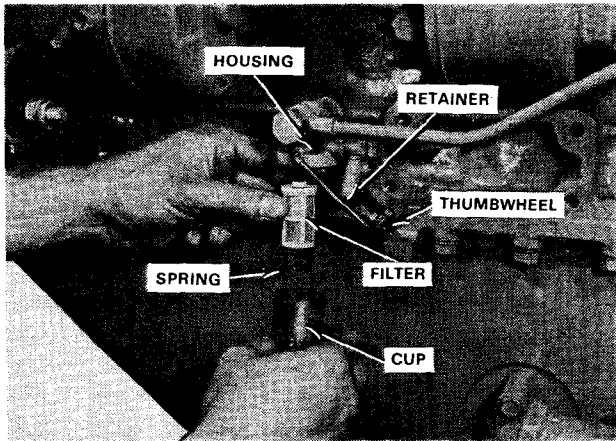


FIG. 25 Removing Sediment Cup Filter (SSD-655)

#### DUAL IN-LINE FILTERS (ALL SSD ENGINES)

The dual in-line fuel filters used on all SSD engines are the replaceable cartridge type. This type of filter cannot be disassembled for cleaning. The filters must be replaced at the recommended maintenance interval.

#### Draining

The filter(s) must be drained at the recommended intervals to remove water and sediment accumulations. After every 100 hours of engine operation, drain the in-line filter(s) as follows:

##### SSD-327 AND SSD-437

1. Loosen the thumbscrew located at the bottom of the lower bowl of the first fuel filter (Fig. 26).
2. Operate the lift pump priming lever and drain the filter into a suitable container.
3. When all water and sediment is removed from the lower bowl, tighten the thumbscrew.

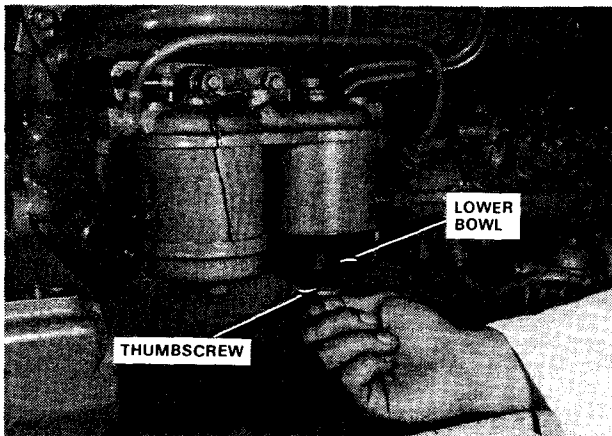


FIG. 26 Draining In-Line Fuel Filter (SSD-327 and SSD-437)

##### SSD-655

1. Loosen the thumbscrews located at the bottom of the lower bowls of both fuel filters (Fig. 27).

2. Operate the lift pump priming pump and drain the filters into a suitable container.
3. When all water and sediment is removed from the lower bowls, tighten the thumbscrews.

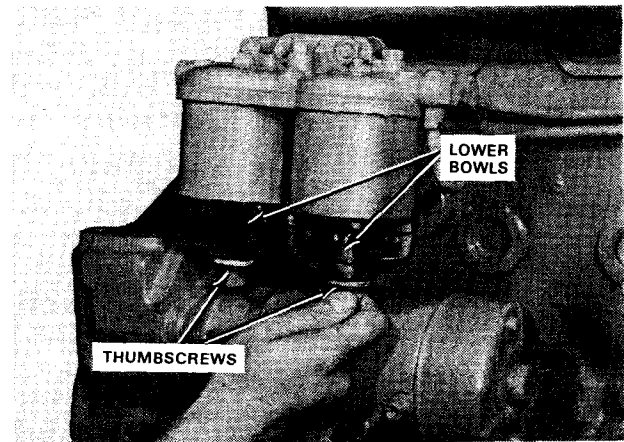


FIG. 27 Draining In-Line Fuel Filters (SSD-655)

#### Replacement

##### ALL SSD ENGINES

The filters must be replaced at the recommended intervals. After every 400 hours of engine operation, replace the in-line filters as follows:

1. Turn off the fuel supply from the fuel tank.
2. Loosen the center screws at the top of the housing and remove the fuel filters and lower bowls (Fig. 28). Remove the filter O-rings and gaskets.
3. Wash the lower bowls in clean diesel fuel oil and remove all particles of dirt from the bowls. Do not use a cloth to wipe the bowls dry.
4. Install the new filters, O-rings, and gaskets with the bowls to the filter housing. Install the center screws and tighten to specification.
5. Bleed the fuel system as outlined on page 3-12.

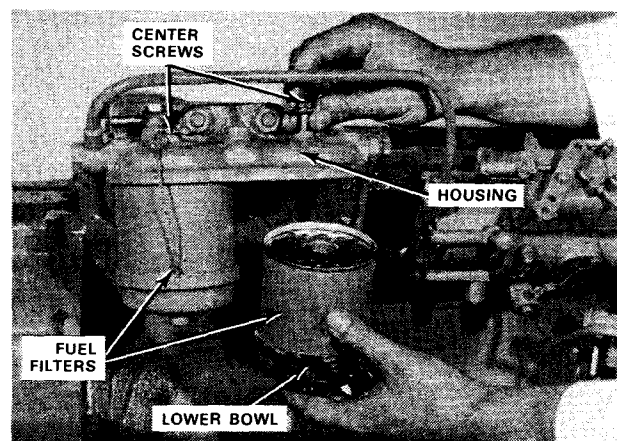


FIG. 28 Replacing In-Line Fuel Filters—Typical

## FUEL LINES

### MAINTENANCE

The fuel supply and return lines should be inspected periodically for cracks, kinks, and signs of leakage. Replace any fuel line that is damaged.

Check the fuel line fittings and retaining clips for tightness. The fitting nuts and bolts should not be overtorqued. Replace any fitting that is stripped or otherwise damaged. Bleed the fuel system after repairs to the fuel line or fittings have been made.

## INJECTOR LINES

### MAINTENANCE

The pre-formed steel injector lines should be inspected periodically for cracks, kinks, and signs of leakage. Replace any injector line that is damaged.

Check the injector line fittings and retaining clips for

tightness. The fitting nuts should not be overtorqued. Replace any fitting or fitting nut that is stripped or otherwise damaged. Bleed the fuel system if the injector lines have been removed or repaired.

When removing the injector lines, cap or plug the fitting nuts and the fittings on the injection pump and injectors to prevent the entrance of dirt.

## BLEEDING THE SYSTEM

### PROCEDURES

If **any** part of the fuel system has been disconnected, or if air has entered the system, it will be necessary to bleed the system. Remove air from the system and prime the injection pump by bleeding the fuel system as follows: **SSD-327 and SSD-437**

1. Loosen the air bleed screw at the top of the filter housing for the first fuel filter (inlet) two full turns (Fig. 29).
2. Operate the priming lever on the fuel lift pump. As soon as the fuel flowing from the bleed screw is free of air bubbles, tighten the bleed screw.
3. Loosen the air bleed screw on the second fuel filter (outlet) and the lower bleed screw on the injection pump.
4. Operate the lift pump priming lever until the fuel flowing from both bleed screws is free of air bubbles. Tighten the bleed screws.
5. Loosen the upper bleed screw on the injection pump and the inlet connections to the injectors.
6. Crank the engine using the starter motor. When the fuel flowing from the injector lines and the injection pump upper bleed screw is free of air bubbles, tighten the connections and bleed screw.
7. Start the engine and loosen both the upper and lower bleed screws on the injection pump. When the fuel flowing from both bleed screws is free of air bubbles, tighten the bleed screws.

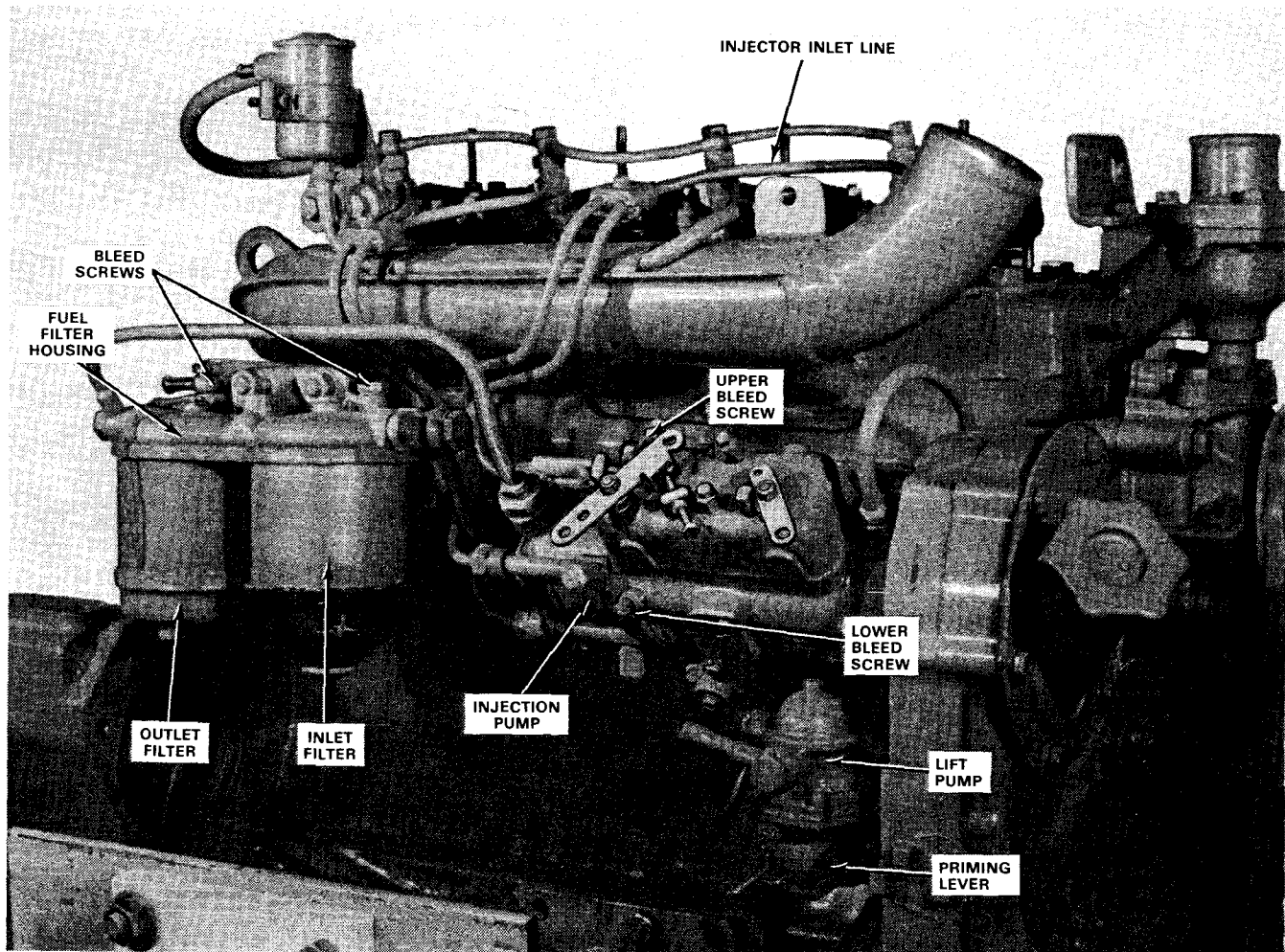


FIG. 29 SSD-327 and SSD-437 Fuel System Bleed Points

**SSD-655**

1. Loosen both air bleed screws at the top of the filter housing two full turns (Fig. 30).
2. Operate the lift pump priming pump. As soon as the fuel flowing from both bleed screws is free of air bubbles, tighten the bleed screws.

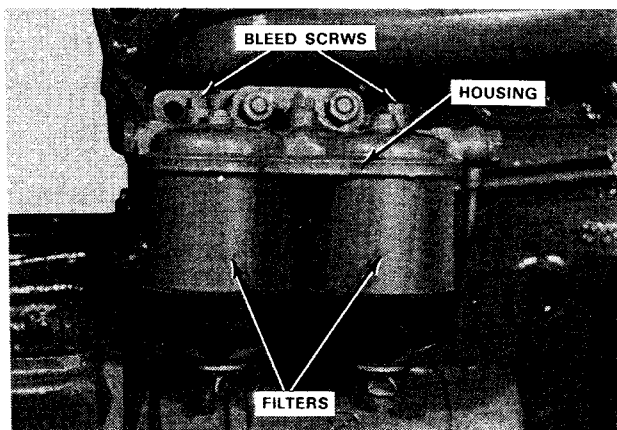
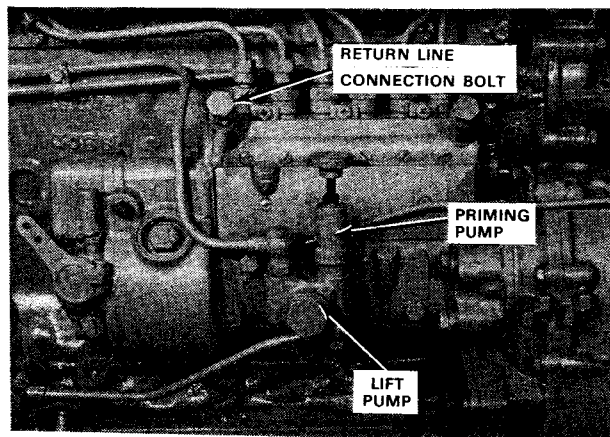


FIG. 30 SSD-655 Fuel System Bleed Points

3. Loosen the bolt securing the fuel return line connection to the injection pump two full turns.
4. Operate the priming pump until the fuel flowing from the return line connection is free of air bubbles. Tighten the return line connection bolt.

**COLD START ASSIST****DESCRIPTION**

As a cold starting aid, the injection pumps on all SSD engines are equipped with a device which supplies additional fuel during cold starting conditions.

**NOTE:** The cold start assist device is an integral part of the injection pump and is not serviced separately.

**LOCATION AND OPERATION****SSD-327 and SSD-437**

The rotary-type injection pump used on SSD-327 and SSD-437 engines has a cold start lever located at the bottom of the pump (Fig. 31).

Move the lever outward and hold for a cold start assist. The lever is spring-loaded and will return to the off position when released.

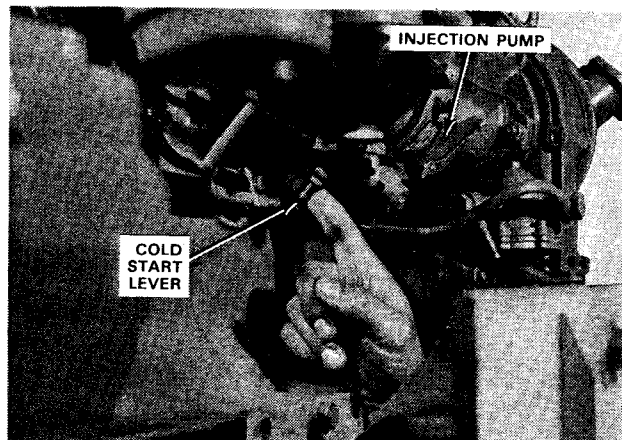


FIG. 31 SSD-327 and SSD-437 Cold Start Assist

**SSD-655**

The in-line injection pump used on the SSD-655 engine has an excess fuel control button located on the side of the pump governor housing (Fig. 32).

For a cold start assist, move the throttle control lever to the maximum speed position and hold. Depress the excess fuel control button and release the throttle control lever.

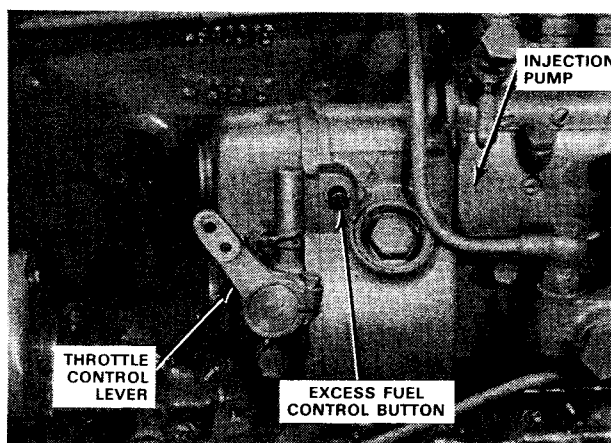


FIG. 32 SSD-655 Cold Start Assist

## THERMOSTART SYSTEM

### DESCRIPTION

All SSD engines are equipped with a thermostart system. The system consists of two major components; a glow plug and a fuel supply reservoir. The glow plug is mounted in the front of the air intake manifold (Fig. 33). The glow plug is fueled from the supply reservoir which is filled from the injector return line (refer to Fig. 1 and 2).

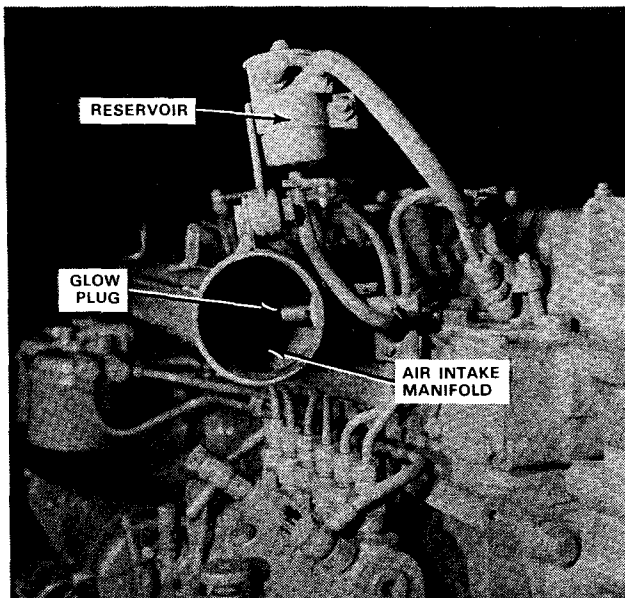


FIG. 33 Typical Thermostart System

**NOTE:** The thermostart glow plug and supply reservoir are serviced only as complete assemblies. Internal components are not available separately.

### OPERATION

The glow plug valve body contains a push rod and ball valve. When cold, the push rod holds the ball valve on its seat and fuel entry is prevented. A heating coil with an igniter for firing the fuel vapor surrounds the valve body (Figure 34).

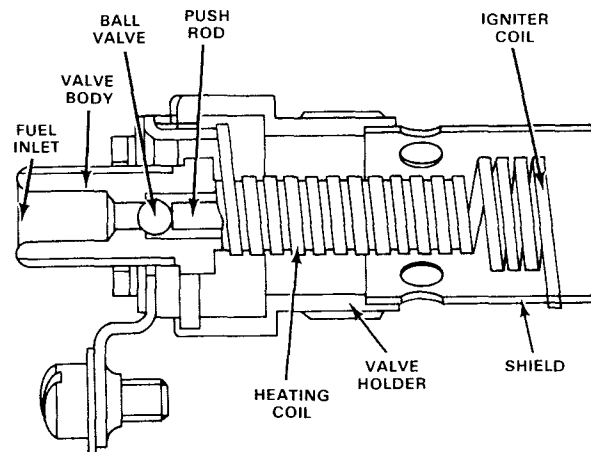


FIG. 34 Thermostart Glow Plug

Thermostart operation is controlled by a switch on the instrument panel. When the thermostart switch is turned on, electrical current is applied to the coil causing heat expansion. As the coil expands, it pulls the ball valve off its seat, allowing fuel to enter the valve body. Incoming fuel vaporizes on contact with the heating coil.

After approximately 15-20 seconds, the igniter becomes incandescent and fires the fuel vapor in the glow plug, thereby raising the temperature in the air intake manifold. When the starter cranks the engine, the heated air is drawn into the cylinder combustion chambers to improve cold weather starting. During extremely cold weather, the thermostart system may be left on for a few seconds after the engine starts to prevent stalling.

When the thermostart switch is turned off, the electrical circuit to the heating coil is opened. Air flow through the intake manifold quickly cools the valve body. The push rod then returns the ball valve to its seat which stops the flow of fuel through the valve body.

## DIAGNOSIS AND TESTING

### INTRODUCTION

Diagnosis and testing of diesel engines can be simple operations if performed in a logical manner.

To distinguish between a mechanical engine knock and a fuel knock, run the engine at maximum speed and pull the stop control. If the knock is no longer present, it is due to the fuel. If the knock is still audible, it is due to mechanical reasons. When the fuel supply to the engine is shut off, the mechanical knock will be reduced in volume, but will still be present.

Running problems will be due mainly to conditions arising in one or more of the following sections. By checking through the following procedures, the faulty component or area can be isolated.

### FUEL SYSTEM

1. Bleed all the air from the fuel system as outlined on page 3-12. If the air cannot be eliminated in this manner, check the fuel line between the lift pump and the fuel tank for air leaks.
2. Disconnect the injector lines at the injection pump and use the starter motor to crank the engine. Fuel delivery should be approximately equal from each injector line.
3. With the injector lines still disconnected from the injection pump, pull the stop control and operate the lift pump priming lever/pump. Any flow of fuel indicates a faulty delivery valve or a broken delivery valve spring.
4. Connect the injector lines to the injection pump and start the engine. As a preliminary indication of injector condition, run the engine just above idle speed and

loosen the lines one at a time. If the injectors are working properly, a definite drop-off in engine speed should be noticed as each injector is cut out in this manner.

### **TIMING**

1. Check the injection pump to engine timing as outlined in injection pump installation on page 3-06.
2. The injection pump to engine timing can also be checked by using the "spill method" on the SSD-655 engine. Refer to page 3-07 for procedures.

### **AIR SUPPLY**

1. Remove the air filter element from the air cleaner assembly. Inspect and clean the filter element. Replace the filter element if it is damaged or if it cannot be cleaned satisfactorily.

If an oil bath air cleaner is used, clean the filter tray and refill the oil bath tray to the correct level using the specified grade of oil.

Be sure that the air cleaner is properly installed and free of obstructions.

2. Examine the air ducts, hoses, and air intake manifold for obstructions. Correct as required.
3. Check the intake and exhaust valve clearances. Adjust the valves if necessary.
4. Check the engine compression. Each cylinder should have equal and similar compression.

### **GOVERNOR**

1. Check the engine idling and maximum no-load speeds. If incorrect, adjust the respective stop screws to obtain the correct speeds. Refer to the adjustment procedures on page 3-08.
2. If the engine surges at any point in its speed range, check the injection pump for proper lubrication. Operate the excess fuel device and stop control to check for tightness or binding in the control rod movement. Examine the throttle control linkage for tightness, binding, or excessive wear. Correct or replace as necessary.

# PART 4 Charging System

COMPONENT INDEX	PAGE	COMPONENT INDEX	PAGE
DESCRIPTION AND OPERATION .....	4-01	REMOVAL AND INSTALLATION	
DIAGNOSIS AND TESTING		Alternator Removal .....	4-08
Motorola Alternator .....	4-02	Alternator Installation .....	4-08
Ford Alternator .....	4-03	OVERHAUL	
DRIVE BELTS		Ford Alternator .....	4-08
Adjustments .....	4-08		

**NOTICE:** To obtain information and service procedures for Marelli alternators, please contact the IEO Parts and Service Office.

## DESCRIPTION AND OPERATION

### DESCRIPTION

The alternator charging system is a negative ground system, and consists of an alternator, a regulator, a charge indicator, a storage battery, and associated wiring.

The alternator is belt driven from the engine. Current is supplied from the alternator-regulator system to the rotating field of the alternator through two brushes to two slip rings.

### OPERATION

The alternator produces power in the form of alternating current. The alternating current is rectified to direct current by six diodes. The alternator regulator automatically adjusts the alternator field current to maintain the alternator output voltage with prescribed limits to correctly charge the battery.

If a charge indicator lamp is used in the charging system (Fig. 1), the system operation is as follows: When the ignition switch is turned ON, a small electrical current flows through the lamp filament (turning the lamp ON) and through the alternator regulator to the alternator

field. When the engine is started, the alternator field rotates and produces a voltage in the stator winding. When the voltage at the alternator stator terminal reaches about 3 volts, the regulator field relay closes. This puts the same voltage potential on both sides of the charge indicator lamp causing it to go out. When the field relay has closed, current passes through the regulator A terminal and is metered to the alternator field.

If an ammeter is used in the charging system (Fig. 2), the regulator I terminal and the alternator stator terminal are not used. When the ignition switch is turned ON, the field relay closes and electrical current passes through the regulator A terminal and is metered to the alternator field. When the engine is started, the alternator field rotates causing the alternator to operate. The ammeter indicates current flow into (charge) or out of (discharge) the battery.

**NOTE:** SSD engines use either a Ford alternator, a Motorola alternator, or a Marelli alternator. Most of this section applies to the Ford alternator since the Motorola unit is serviced by Motorola dealers. Contact the IEO Parts and Service Office for information regarding the Marelli alternator.

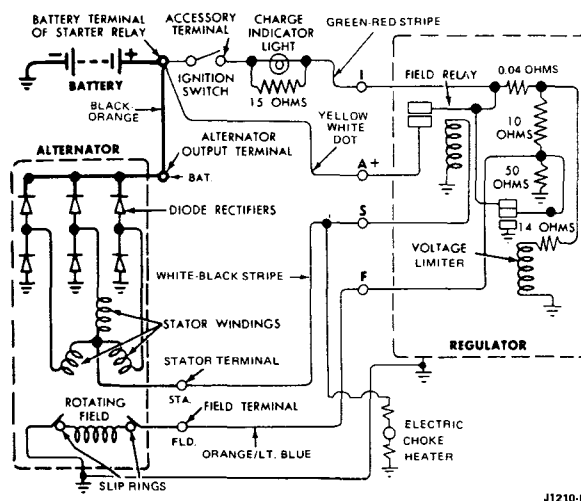


FIG. 1 Alternator Charging System — Indicator Lamp

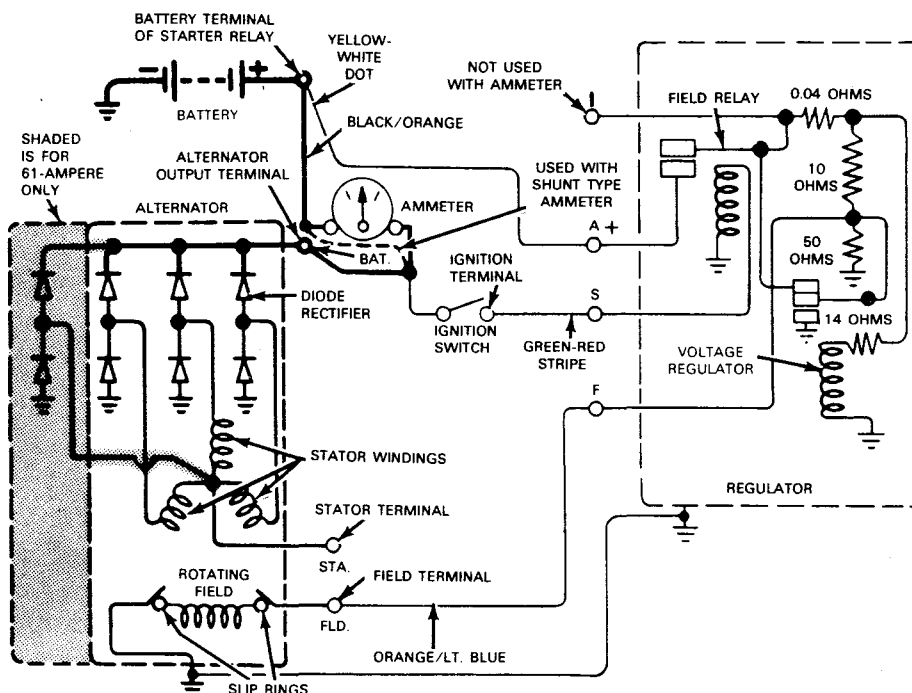


FIG. 2 Alternator Charging System — Ammeter

J1205-J

## DIAGNOSIS AND TESTING

### MOTOROLA ALTERNATOR

Before performing charging system tests on the engine, note the complaint such as: slow cranking, battery dead or using an excessive amount of water, top of battery wet, ammeter shows charge at all times, or indicator lamp does not go out. This information will aid in isolating the part of the system causing the problem. The battery must be in a proper state of charge (at least 1.200 specific gravity).

The following tests are made with the alternator on the engine with output and regulator connections maintained to the alternator except as noted in Steps 3 and 5. The field lead and voltage regulator are disconnected for these tests.

#### TEST PRECAUTIONS:

- DO NOT disconnect alternator output lead while the alternator is operating.
- DO NOT disconnect voltage regulator while the alternator is operating.
- DO NOT ground the field terminal.
- Check battery condition. Use a fully charged battery when testing the alternator.
- Disconnect the ground cable from the battery when removing and installing the alternator.

**NOTE:** All readings indicated are for correct operation.

#### ON ENGINE TESTING

##### Test 1 — Ignition On — Engine Not Running (Refer to Fig. 3)

Correct voltage at regulator terminal is approximately 1.5 to 2.5 volts. This test evaluates excitation circuit.

If voltage at regulator terminal is:

5.0 to 7.0 volts = open rotor (field circuit)

.75 to 1.1 volts = grounded rotor circuit  
8.5 to 10.0 volts = open in regulator's load circuit  
0 volts = open ignition switch or excitation resistor  
If test results are uncertain, make Test 2.

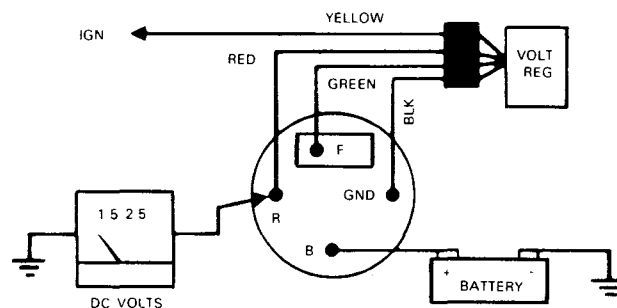


FIG. 3 Ignition On — Engine Not Running

##### Test 2 — Ignition On — Engine Not Running (Refer to Fig. 4)

The voltage regulator may be bypassed with a short jumper wire between the regulator and field terminals. If the jumper wire provides approximate correct voltage, the fault is in the regulator. No change from high voltage indicates that the fault is in the brush or rotor circuit.

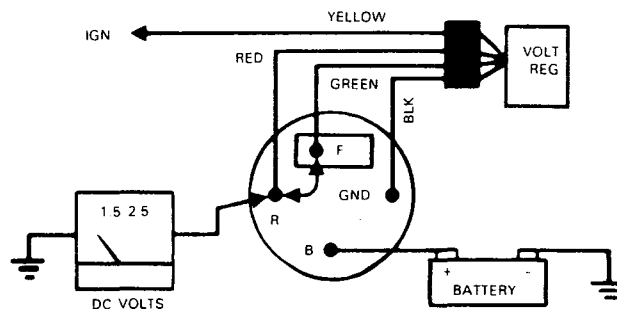


FIG. 4 Ignition On — Engine Not Running

### Test 3 — Field Draw Test — Ignition Off (Refer to Fig. 5)

This test evaluates the complete field circuit, independent of the voltage regulator. Circuit is through the brushes, slip rings, field coil to ground. Current should be 2 to 2.5 amps. If less than this, check the brushes and slip rings. It is desirable to use a field rheostat in series with the meter for protection of the meter. If the field is shorted, excessive current would flow through the meter and possible damage would result.

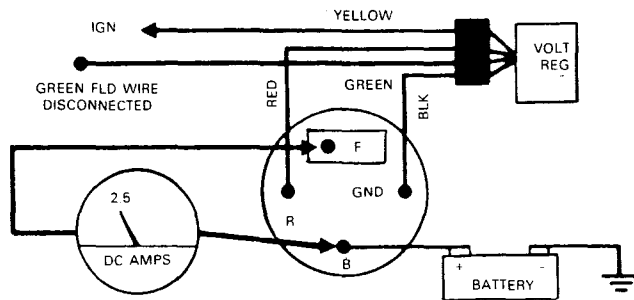


FIG. 5 Field Draw Test — Ignition Off

### Test 4 — Ignition On — Engine Running At Fast Idle (Refer to Fig. 6)

Voltage indicated is usually 13.9 to 14.7 volts, depending on regulator ambient temperature. High voltage may be due to a poor ground connection. If the ground connection is not faulty, the regulator will require replacement.

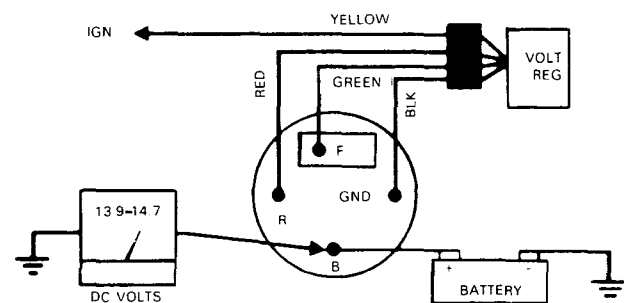


FIG. 6 Ignition On — Engine Running At Fast Idle

### Test 5 — Ignition On — Engine Running At Idle Speed (Refer to Fig. 7)

FIELD TERMINAL DISCONNECTED, VOLTAGE REGULATOR PLUG DISCONNECTED, AND BATTERY TERMINAL SHORTED TO FIELD TERMINAL

This test isolates the problem to either the alternator or regulator. If voltage at the auxiliary terminal rises to 15-16 volts now, when it did not in Test 4 with regulator connected, then the fault is in the regulator and it should be replaced. If voltage does not rise at the auxiliary terminal, the fault is in the alternator stator or rectifier diodes, if field circuit checked out properly.

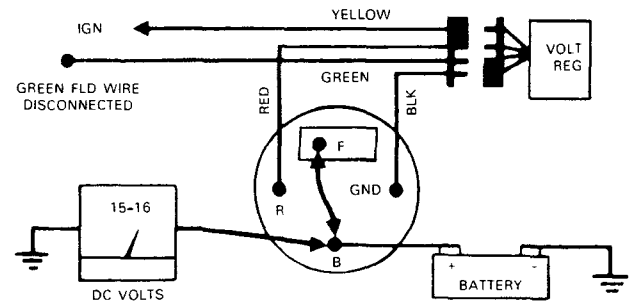


FIG. 7 Ignition On — Engine Running At Idle Speed

### FORD ALTERNATOR

Certain tests outlined are illustrated in schematic and in pictorial form. The schematics illustrate the connections of the Rotunda equipment so these connections can be duplicated when Rotunda equipment is not available. The various circuits involved in the tests can be selected by means of switches, without the necessity of changing connections when Rotunda equipment is used. This reduces the time required to test the units and circuits on the engine.

Where applicable, the tests are divided into On Engine and Bench Test procedures. Either procedure can be followed, depending on the equipment available for the tests.

Troubleshooting or diagnosis is required before actual repairs can be made on the electrical system. Even where an obvious fault makes the replacement of a unit necessary, it must be determined why the unit failed. When a trouble is diagnosed correctly, unnecessary repairs are prevented, the time the engine is out of service will be decreased, and the repairs that are made will be reliable.

### ON ENGINE TESTING

Before performing charging system tests on the engine, note the complaint such as: slow cranking, battery dead or using an excessive amount of water, top of battery wet, ammeter shows charge at all times or no charge, alternator indicator lamp does not come on or does not go out. This information will aid in isolating the part of the system causing the problem. The battery must be in a proper state of charge (at least 1.200 specific gravity).

### Visual Inspection

1. Check the battery posts and battery cable terminals for clean and tight connections. Remove the battery cables if corroded; clean and install them securely.
2. Check for clean and tight wiring connections at the alternator, regulator, and engine.
3. Check the alternator belt tension and tighten to specification if necessary.

### Indicator Lamp — Alternator Charging System

#### NORMAL CHARGE INDICATOR

- With ignition switch off . . . indicator lamp is off.
- With ignition switch on (engine not running) . . . indicator lamp is on.
- With ignition switch on (engine running) . . . indicator lamp is off.

1. If the charge indicator lamp does not come on with the ignition key in the ON position and the engine not running, check the I wiring circuit for an open circuit or burned out charge indicator lamp (ignition switch to regulator I terminal).
2. If the charge indicator lamp does not come on, disconnect the wiring plug connector at the regulator and connect a jumper wire from the I terminal of the regulator wiring plug to the negative battery post cable clamp.
3. The charge indicator lamp should go on with the ignition key turned to the ON position.
4. If the charge indicator lamp does not go on, check the bulb for continuity and replace if burned out.
5. If the bulb is not burned out, an open circuit exists between the ignition switch and the regulator.

A good indication of a problem in the I wiring circuit (ignition switch to regulator I terminal) will show when the charge indicator lamp goes out with high engine RPM. This is caused by an open circuit in the 15 ohm resistor wire (connected in parallel with the indicator lamp), generally at the terminal point (either end of the resistor wire).

### Ammeter — Alternator Charging System

#### NORMAL CHARGE INDICATOR

- With ignition switch off and no electrical load . . . ammeter should show 0 or center scale.
- With ignition switch on (engine running) . . . needle deflects towards charge and returns towards center scale in two steps (fully charged battery).
- With ignition switch off and lights on . . . ammeter should show between 0 and discharge scale.

### Tests Using a Voltmeter

When performing charging system tests with a voltmeter, turn off all lights and electrical components. Place the engine in neutral. The battery must be charged to at least 1.200 specific gravity before starting the test.

#### VOLTMETER TEST PROCEDURE

1. Connect the negative lead of the voltmeter to the negative battery cable clamp (not bolt or nut), and the positive lead of the voltmeter to the positive battery cable clamp (not bolt or nut) (Fig. 8).
2. Record the battery voltage reading shown on the voltmeter scale (Fig. 9).
3. Connect a tachometer to the engine.
4. Start the engine and operate at approximately 1500 RPM. With no other electrical load, the voltmeter reading should increase 1 volt and not exceed 2 volts above the first recorded battery voltage reading. The reading should be taken when the voltmeter needle stops moving.
5. With the engine running, turn on all the electrical equipment.
6. Increase the engine speed to 2000 RPM. The voltmeter should indicate a minimum of 0.5 volt above the first recorded battery voltage (Fig. 9).

If this test indicates proper voltage readings, the charging system is operating normally. Proceed to TEST RESULTS if a problem still exists.

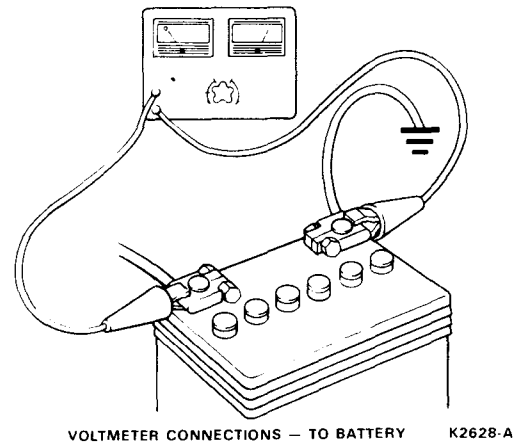


FIG. 8 Voltmeter-to-Battery Connections

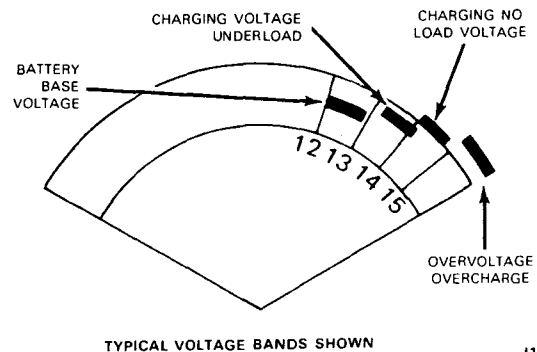


FIG. 9 Voltmeter Test Scale

#### TEST RESULTS

1. If the voltmeter reading indicates overvoltage (more than 2.0 volts above battery voltage), stop the engine and check the ground connections between the regulator and alternator and/or regulator to engine. Clean and tighten connections securely and repeat the Voltmeter Test Procedure.
2. If overvoltage condition still exists, disconnect the regulator wiring plug from the regulator and repeat the Voltmeter Test Procedure.
3. If overvoltage condition is corrected (voltmeter reads battery voltage), replace the voltage regulator and repeat the Voltmeter Test Procedure.
4. If overvoltage condition still exists with the regulator wiring plug disconnected, repair the short in the wiring harness between the alternator and regulator. Then, replace the regulator and connect the regulator wiring plug to the regulator and repeat the Voltmeter Test Procedure.
5. If the voltmeter reading does not increase (one volt), check for the presence of battery voltage at the alternator BAT terminal and the regulator A terminal. Repair the wiring if no voltage is present at these terminals and repeat the Voltmeter Test Procedure.
6. If the voltmeter reading does not increase one volt above battery voltage, proceed to the next step before performing other tests. The field circuit (regulator plug to alternator) must be checked for a grounding condition. If the field circuit is grounded and the jumper wire is used as a check at the regulator wiring

plug from the A to F terminals (Figure 10), excessive current will cause heat damage to the regulator wiring plug terminals and may burn the jumper wire (Fig.10). Also, if the field circuit was grounded, the connector wire inside the regulator will be burned open and an undervoltage condition will result.

7. The field circuit should be checked with the regulator wiring plug disconnected and an ohmmeter connected from the F terminal of the regulator wiring plug to the battery ground. The ohmmeter should indicate between 4 and 250 ohms (Fig. 11).

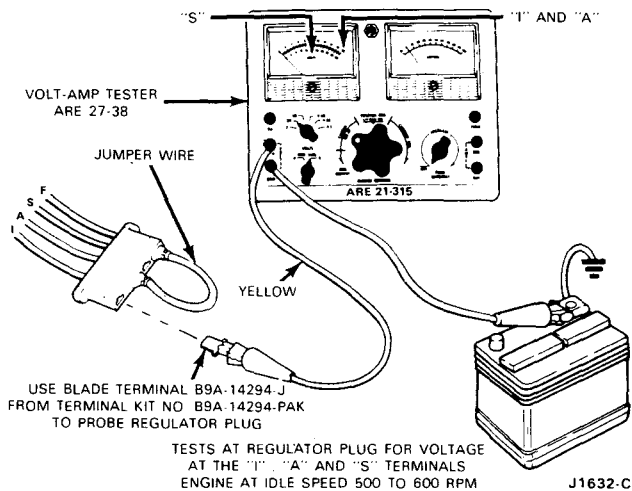


FIG. 10 Regulator Plug Voltage Tests

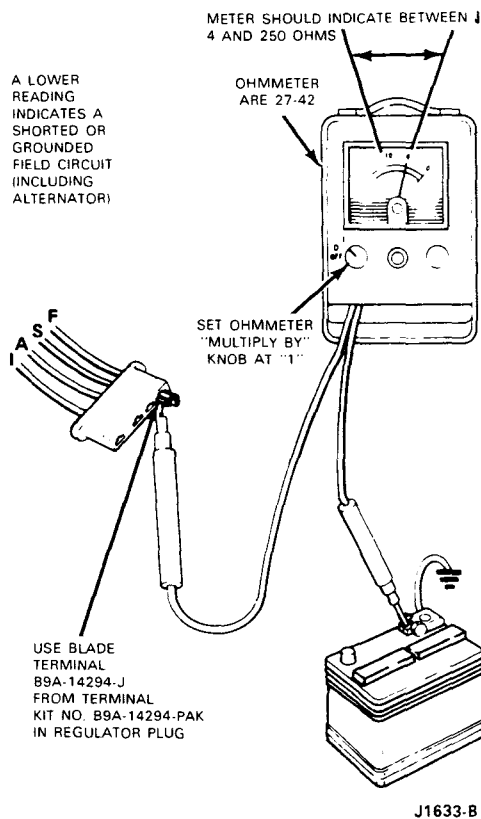


FIG. 11 Field Circuit Test

8. A check for the regulator burned open wire is made by connecting an ohmmeter from the I to F terminals of the regulator (Figure 12). The reading should indicate 0 (no resistance). If the reading indicates approximately 10 ohms, the connector wire inside the regulator is open.

**CAUTION:** The field circuit grounded condition must be located and repaired before installing a new regulator.

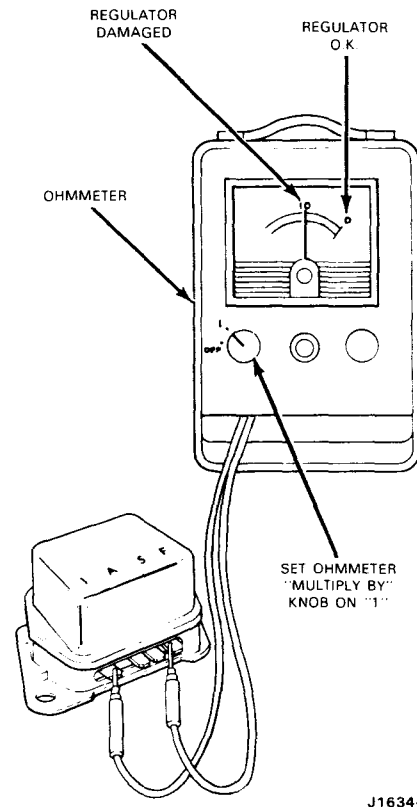


FIG. 12 Regulator Burned — Open Connector Wire Test

### Field Circuit and Alternator Tests

1. If the field circuit is satisfactory, disconnect the regulator wiring plug at the regulator and connect the jumper wire from the A to the F terminals on the regulator wiring plug (Fig. 10).
2. Repeat the Voltmeter Test Procedure.
3. If the Voltmeter Test Procedure still indicates a problem (undervoltage), remove the jumper wire from the regulator plug and leave the plug disconnected from the regulator. Then, connect a jumper wire to the FLD and BAT terminals on the alternator (Fig. 13).
4. Repeat the Voltmeter Test Procedure.
5. If the voltmeter test results are now satisfactory, repair the wiring harness from the alternator to the regulator. Then, remove the jumper wire at the alternator and connect the regulator wiring plug to the regulator.
6. Repeat the Voltmeter Test Procedure to be sure the charging system is operating normally.

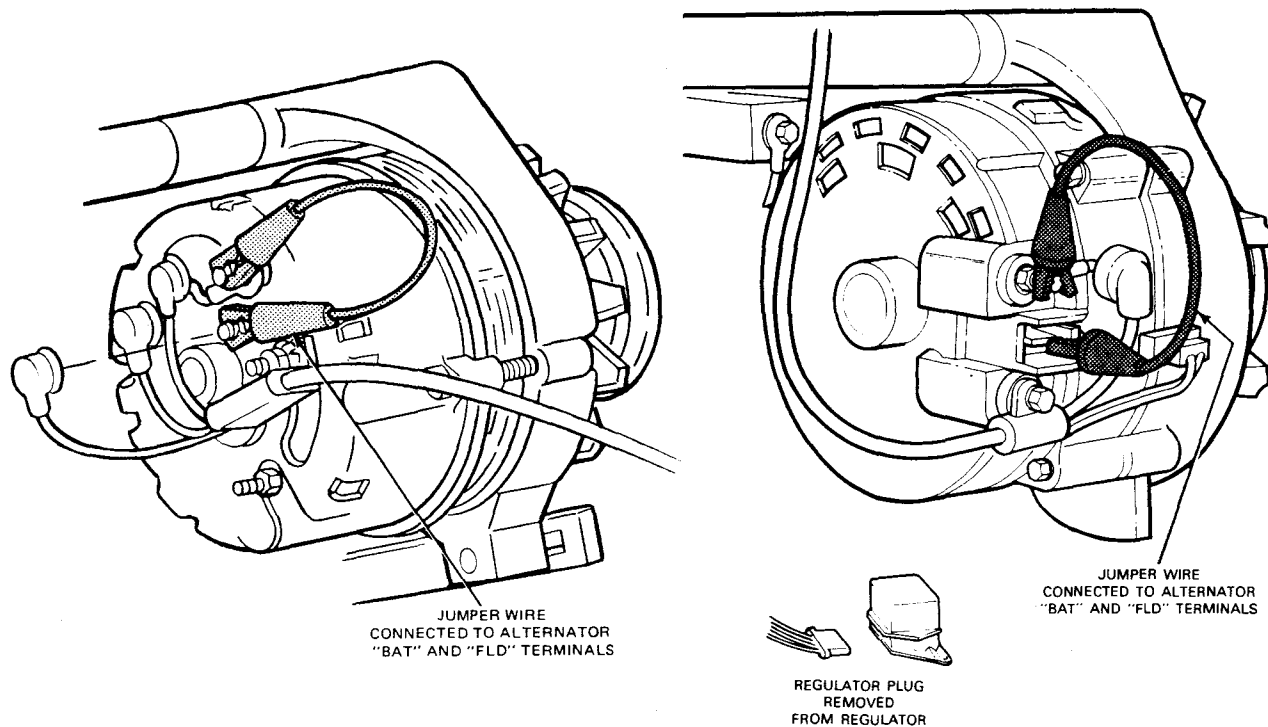


FIG. 13 Jumper Wire Connections

7. If the voltmeter test results still indicate undervoltage, repair or replace the alternator. With the jumper wire removed, connect the wiring to the alternator and regulator.
8. Repeat the Voltmeter Test Procedure.

### Regulator I and S Circuit Tests

#### S CIRCUIT — WITH AMMETER

1. Connect the positive lead of the voltmeter to the S terminal of the regulator wiring plug (Fig. 10). Then, turn the ignition switch to the ON position. Do not start the engine.
2. The voltmeter reading should indicate battery voltage.
3. If there is no voltage reading, disconnect the positive voltmeter lead from the positive battery clamp and repair the S wire lead from the ignition switch to the regulator wiring plug.
4. Connect the positive voltmeter lead to the positive battery cable terminal, connect regulator wiring plug to regulator and repeat the Voltmeter Test Procedure.

#### I AND S CIRCUIT — WITH INDICATOR LAMP

1. Disconnect the regulator wiring plug and install a jumper wire between the A and F terminal.
2. With the engine idling, connect the positive lead of the voltmeter to the S terminal and then to the I terminal of the regulator wiring plug (Fig. 10). The voltage of the S circuit should read approximately 1/2 of the I circuit.
3. If no voltage is present, repair the alternator or the wiring circuit at fault. Reconnect the positive voltmeter lead to the positive battery cable terminal.

4. If the circuit tests are satisfactory, install a new regulator.
5. Remove the jumper wire from the regulator wiring plug and connect the wiring plug to the regulator. Repeat the Voltmeter Test Procedure.

### Diode Test

1. Disconnect the regulator wiring plug.
2. Connect a jumper between the A and F terminal of the regulator wiring plug.
3. Connect a voltmeter to the battery cable clamps.
4. Start the engine — let the engine run at idle speed.
5. Read and record voltmeter reading.
6. Move positive voltmeter lead to the S terminal in the regulator wiring plug.
7. Note voltmeter reading.

#### TEST RESULTS

1. If voltmeter reads 1/2 of battery voltage, diode condition is satisfactory.
2. If voltmeter reads approximately 1.5 volts, the alternator has a shorted **negative** diode, or a grounded stator winding.
3. If voltmeter reads approximately 1.5 volts less than battery voltage, the alternator has a shorted **positive** diode.
4. If voltmeter reads approximately 1.0 to 1.5 volts less than 1/2 battery voltage, the alternator has an open **positive** diode.
5. If voltmeter reads approximately 1.0 to 1.5 volts more than 1/2 battery voltage, the alternator has an open **negative** diode.

## BENCH TESTING

### Rectifier Short or Grounded and Stator Grounded Test

These tests are performed with an ARE 27-42 ohmmeter. Set the Multiply By knob at 10 and calibrate the ohmmeter as directed inside the instrument cover.

Contact one ohmmeter probe to the alternator BAT terminal and the other probe to the STA terminal. Then, reverse the ohmmeter probes and repeat the test. A reading of about 60 ohms should be obtained in one direction and no needle movement with the probes reversed. A reading in both directions indicates a faulty positive diode, a grounded positive diode plate, or a grounded BAT terminal.

Infinite readings (no needle movement) in all four probe positions in the preceding test indicates an open STA terminal lead connection inside the alternator.

### Field Open or Short Circuit Test

This test is performed with an ARE 27-42 ohmmeter. Set the ohmmeter Multiply By knob at 1 and calibrate the ohmmeter as directed inside the instrument cover.

Contact the alternator field terminal with one probe and the ground terminal with the other probe. Then, spin the alternator pulley. The ohmmeter reading should be between 4 and 250 ohms, and should fluctuate while the pulley is turning. An infinite reading (no meter movement) indicates an open brush lead, worn or stuck brushes, or a faulty rotor assembly. An ohmmeter reading less than 4 ohms indicates a grounded brush assembly, a grounded field terminal, or a faulty rotor.

### Diode Test

Remove the rectifier assembly from the alternator as outlined under Disassembly. Set the ARE 27-42 ohmmeter Multiply By knob at 10 and calibrate the meter as directed inside the cover.

To test one set of diodes, contact one probe to the terminal bolt as shown in Fig. 14 and contact each of the three stator lead terminals with the other probe. Reverse the probes and repeat the test. All diodes should show a low reading of about 60 ohms in one direction and an infinite reading (no needle movement) with the probes reversed. Repeat the preceding test for the other set of diodes, except that the other terminal screw is used.

If the meter readings are not as specified, replace the rectifier assembly.

### Stator Coil Open or Grounded Test

These tests are performed to determine if the stator coil is operating properly. Disassemble the stator from the alternator as outlined under Disassembly.

Set the ARE 27-42 ohmmeter Multiply By knob at 1 and calibrate the meter as directed inside the cover.

Connect the ohmmeter probes between each pair of stator leads (3 different ways). The ohmmeter must show equal readings for each pair of stator leads. Replace the stator if the readings are not equal.

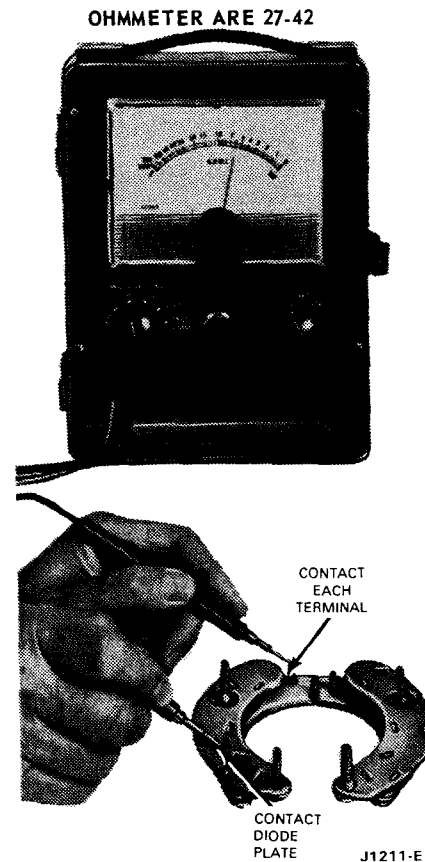


FIG. 14 Diode Test — Rear Terminal Alternator

Set the ARE 27-42 ohmmeter Multiply By knob at 1000 and calibrate the meter as directed inside the cover.

Connect the ohmmeter probes to one of the stator leads and to the stator laminated core. Be sure that the probe makes a good electrical connection with the stator core. The meter should show an infinite reading (no meter movement). If the meter does not indicate an infinite reading (no meter movement), the stator winding is shorted to the core and must be replaced. Repeat this test for each of the stator leads.

### Rotor Open or Short Circuit Test

Disassemble the front housing and rotor from the rear housing and stator as outlined under Disassembly. Set the ARE 27-42 ohmmeter Multiply By knob at 1 and calibrate the meter as directed inside the cover.

Contact each ohmmeter probe to a rotor slip ring. The meter reading should be 4 or 5 ohms. A higher reading indicates a damaged slip ring solder connection or a broken wire. A lower reading indicates a shorted wire or slip ring. Replace the rotor if it is damaged and cannot be repaired.

Contact one ohmmeter probe to a slip ring and the other probe to the rotor shaft. The meter reading should be infinite (no meter movement). A reading other than infinite indicates the rotor is shorted to the shaft. Inspect the slip ring soldered terminals to be sure they are not bent and touching the rotor shaft, or that excess solder is grounding the rotor coil connections to the shaft. Replace the rotor if it is shorted and cannot be repaired.

## DRIVE BELTS

### ADJUSTMENTS

A properly tensioned drive belt minimizes noise and also prolongs the service life of the belt. Therefore, it is recommended that a belt tension gauge be used to check and adjust the belt tension.

**NOTE:** Any belt that has been operated for a minimum of 10 minutes is considered a used belt, and when adjusted, it must be adjusted to the used belt tension shown in the specifications.

Belts must be replaced in matched sets on engines with dual belt drives.

### Belt Tension

Proceed as follows to check and adjust drive belt tension:

1. Install the belt tension gauge on the drive belt and check the tension.

**NOTE:** On dual belt arrangements, check tension on one belt only.

2. If the belt tension is not within specifications, loosen the alternator mounting bolts to a snug position and loosen the adjusting arm bolts.
3. Apply pressure on the alternator front housing only and tighten the adjusting arm-to-alternator bolt.
4. Check the belt tension using the tension gauge. Adjust the belt for specified tension.
5. Tighten all mounting bolts.

## REMOVAL AND INSTALLATION

### ALTERNATOR REMOVAL

1. Disconnect the battery ground cable.
2. Remove the electrical connectors from the alternator.
3. Loosen the alternator mounting bolts and remove the adjustment arm-to-alternator attaching bolt.
4. Disengage the alternator belt(s). Remove the alternator mounting bolts and remove the alternator.

### ALTERNATOR INSTALLATION

1. Position the alternator to the engine, install the spacer (if used), and the alternator mounting bolt. Tighten the bolt only finger tight.
2. Install the adjustment arm-to-alternator attaching bolt. Install the electrical connectors to the alternator.
3. Position the belt(s) on the pulley and adjust the belt tension using a belt tension gauge. Apply pressure on the alternator front housing only when tightening the belt. Tighten the adjusting arm bolt and the mounting bolts.
4. Connect the battery ground cable.

## OVERHAUL

### FORD ALTERNATOR

#### Disassembly

Fig. 15 shows a disassembled view of the alternator.

1. Mark both end housings and the stator with a scribe mark for assembly.
2. Remove the three housing through bolts.
3. Separate the front housing and rotor from the stator and rear housing.
4. Remove all the nuts and insulators from the rear housing and remove the rear housing from the stator and rectifier assembly.
5. Remove the brush holder mounting screws and remove the holder, brushes, brush springs, insulator, and terminal.
6. If replacement is necessary, press the bearing from the rear housing while supporting the housing on the inner boss.
7. If the rectifier assembly is being replaced, unsolder the stator leads from the rectifier terminals, separate the stator leads from rectifier terminals, and separate the stator from the rectifier assembly.

**NOTE:** Use a 100-watt soldering iron.

8. Original production alternators will have one of three types of rectifier assembly circuit boards (Fig. 16); one has the circuit board spaced away from the diode plates with the diodes exposed. Another type is a single circuit board with built-in diodes. The third

type circuit board has built-in diodes with an additional booster diode plate containing two diodes. This circuit board is used only in the 61-ampere alternator.

If the alternator rectifier has an exposed board, remove the screws from the rectifier by rotating the bolt heads 1/4 turn clockwise to unlock them and then remove the screws (Fig. 16). Push the stator terminal straight out on a rectifier with the diodes built into the circuit board (Fig. 16). Avoid turning the screw while removing to make certain that the straight knurl will engage the insulators when installing. Do not remove the grounded screw (Fig. 17).

9. Remove the drive pulley nut with the tool shown in Fig. 18; then, pull the lock washer, pulley, fan, fan spacer, rotor, and rotor stop from the rotor shaft.
10. Remove the three screws that hold the front end bearing retainer and remove the retainer. If the bearing is damaged or has lost its lubricant, support the housing close to the bearing boss and press out the old bearing from the housing.
11. Perform a diode test and a field open or short circuit test (Refer to DIAGNOSIS AND TESTING in this section).

#### Assembly

1. The rotor, stator, and bearings must not be cleaned with solvent. Wipe these parts off with a clean cloth.
2. Press the front bearing into the front housing bearing boss (apply pressure on the bearing outer race only) and install the bearing retainer (Fig. 15).

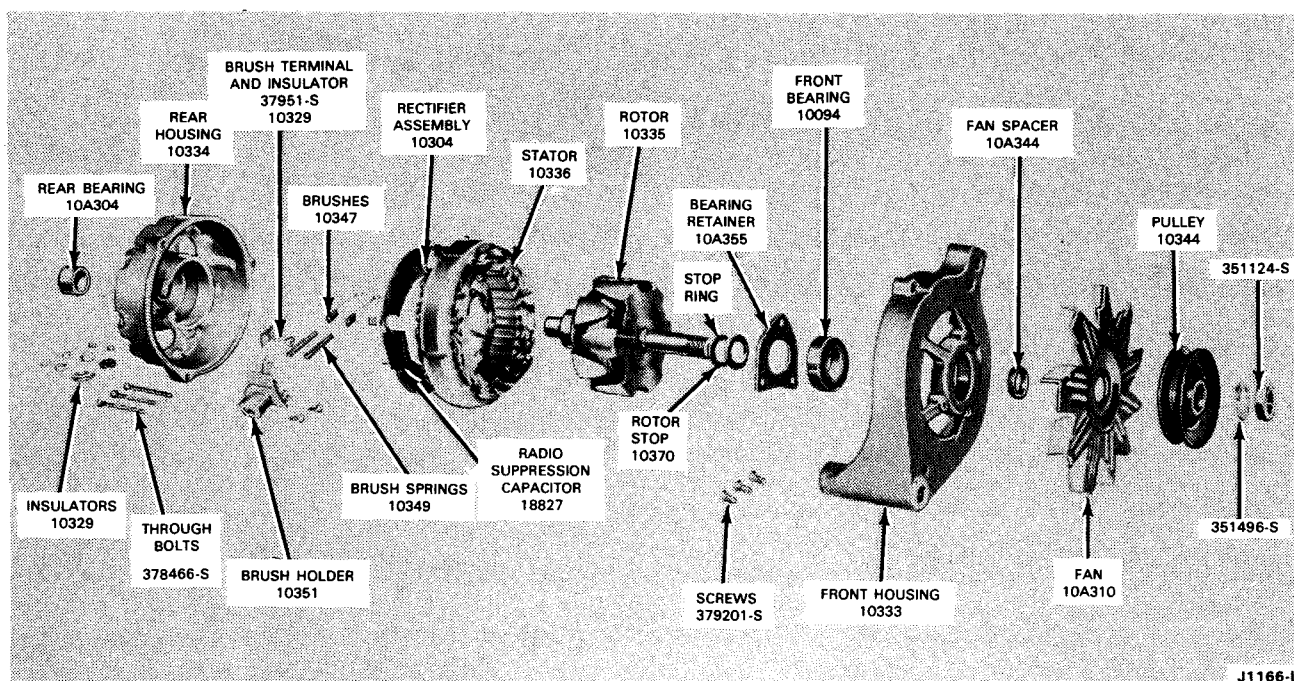


FIG. 15 Disassembled Alternator

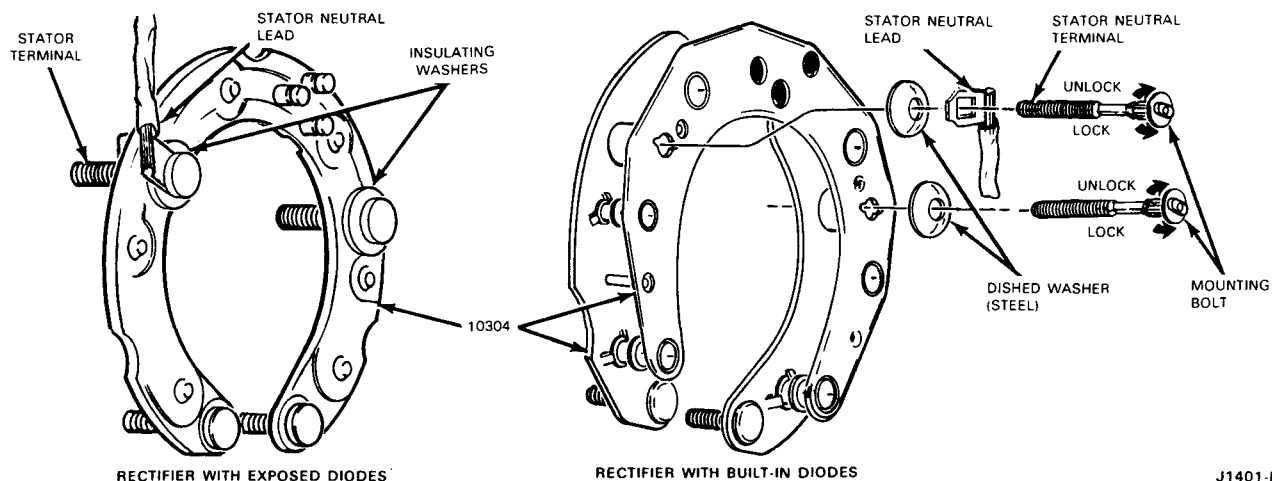


FIG. 16 Rectifier Assembly

3. If the stop ring on the rotor drive shaft is damaged, install a new stop ring. Push the new ring on the shaft and into the groove.

**NOTE:** Do not open the ring with snap ring pliers as permanent damage will result.

4. Position the rotor stop on the drive shaft with the recessed side against the stop ring.
5. Position the front housing, fan, spacer, fan, pulley, and lock washer on the drive shaft and install the retaining nut. Tighten the retaining nut to the specified torque with the tool shown in Fig. 18.
6. If the rear housing bearing was removed, support the housing on the inner boss and press in a new bearing flush with the outer end surface.

7. Place the brush springs, brushes, brush terminal, and terminal insulator in the brush holder and hold the brushes in position by inserting a piece of stiff wire in the brush holder as shown in Fig. 19.
8. Position the brush holder assembly in the rear housing and install the mounting screws. Position the brush leads in the brush holder as shown in Fig. 20.
9. Wrap the three stator winding leads around the rectifier terminals and solder them.

**NOTE:** Use a 100-watt soldering iron and rosin-core solder.

Position the stator neutral lead eyelet on the stator terminal screw and install the screw in the rectifier assembly (Fig. 21).

10. For a rectifier with the diodes exposed, insert the special screws through the wire lug, dished washers, and circuit board (Fig. 16). Turn them 1/4 turn counterclockwise to lock them. For single circuit boards with built-in diodes, insert the screws straight through the wire lug, insulating washer and rectifier into the insulator (Fig. 16).

The dished washers are to be used only on the circuit board with exposed diodes (Fig. 16). If they are used on the single circuit board, a short circuit will occur. A flat insulating washer is to be used between the stator terminal and the board when a single circuit board is used (Fig. 17).

11. Position the radio noise suppression capacitor on the rectifier terminals. On the circuit board with exposed diodes, install the STA and BAT terminal insulators (Fig. 21). On the single circuit board, position the square hole in the rectifier assembly (Fig. 22) on the BAT terminal.

Position the stator and rectifier assembly in the rear housing. Make certain that all terminal insulators are seated properly in their recesses. Position the STA (black), BAT (red), and FLD (orange) insulators on the terminal bolts and install the retaining nuts (Fig. 23).

12. Wipe the rear end bearing surface of the rotor shaft with a clean lint-free cloth.
13. Position the rear housing and stator assembly over the rotor and align the scribe marks made during disassembly. Seat the machined portion of the stator core into the step in both end housings. Install the housing through bolts. Remove the brush retracting wire and put a daub of weatherproof sealer over the hole to seal it.

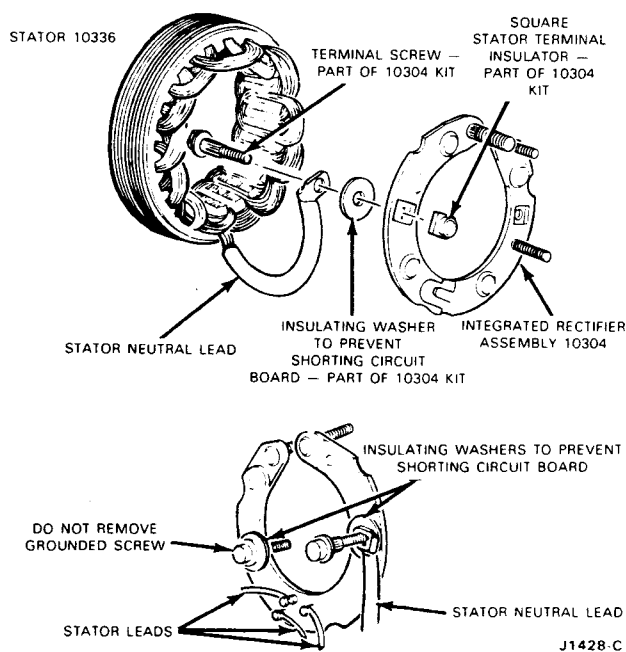


FIG. 17 Stator Terminal Installation — Integral Rectifier Circuit Board

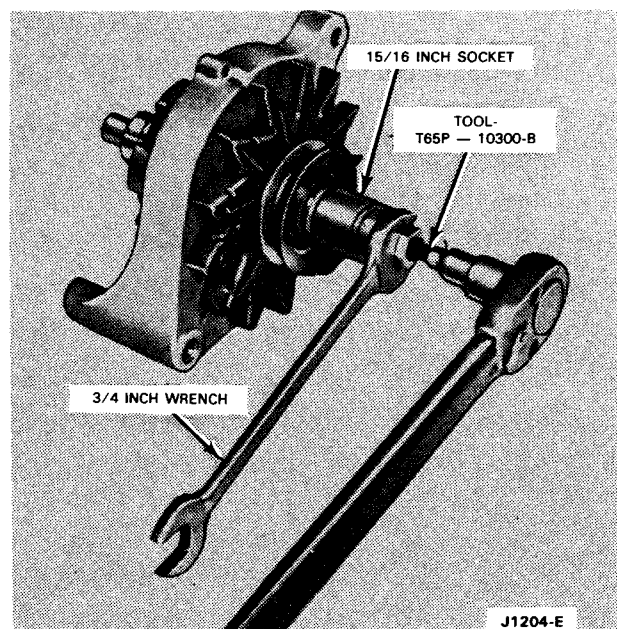


FIG. 18 Pulley Removal

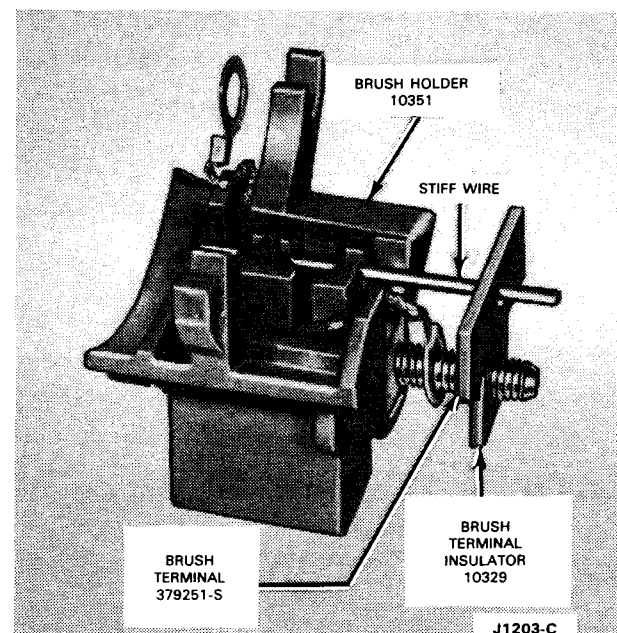


FIG. 19 Brush Holder Assembly

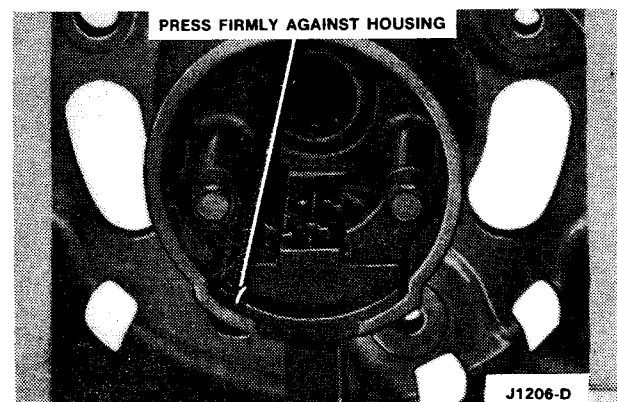


FIG. 20 Brush Lead Positions

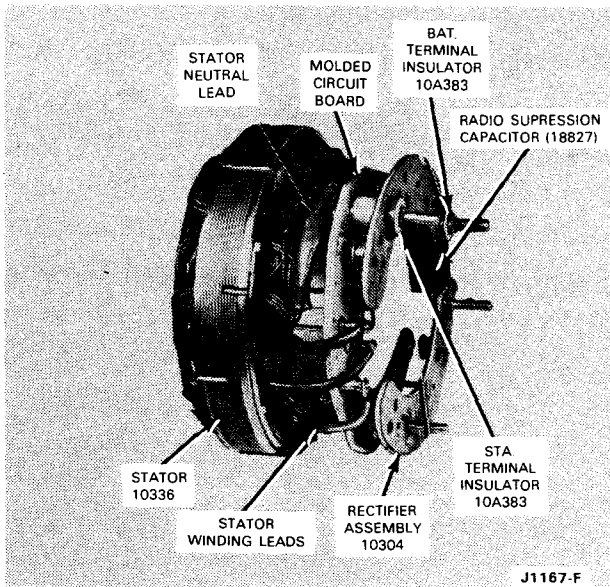


FIG. 21 Stator Lead Connections

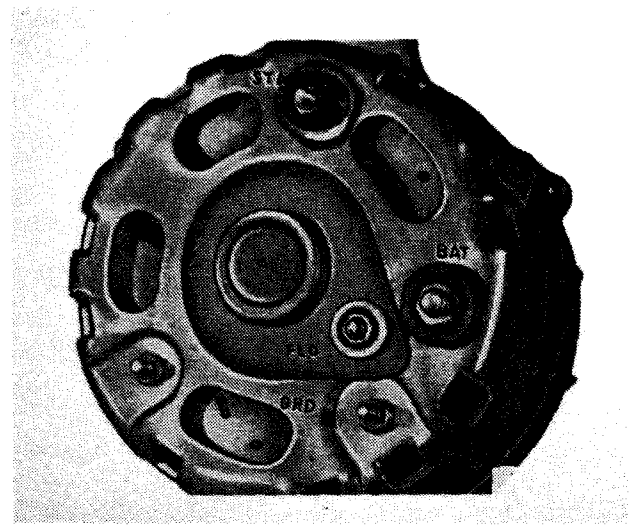


FIG. 23 Alternator Terminal Locations

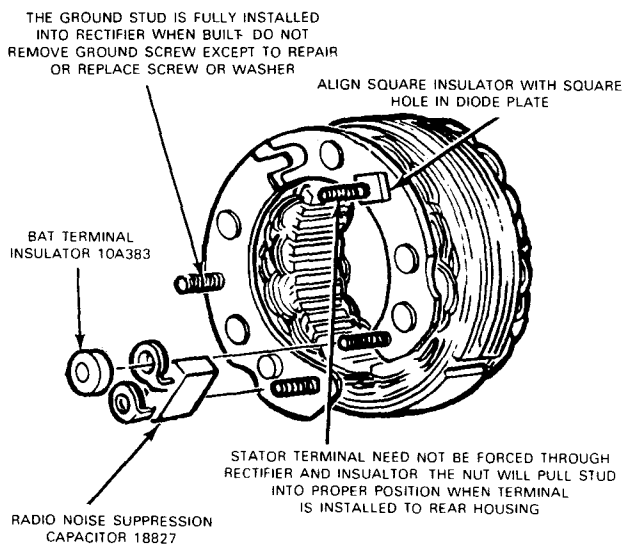


FIG. 22 Terminal Insulators — Fiber Glass Circuit Board

# PART 5 Starting System

COMPONENT INDEX	PAGE	COMPONENT INDEX	PAGE
DESCRIPTION .....	5-01	DIAGNOSIS AND TESTING	
SYSTEM COMPONENTS .....	5-01	Booster Battery .....	5-01
Bosch Starter .....	5-01	On Engine Testing .....	5-01
REMOVAL AND INSTALLATION		Bench Testing .....	5-02
Removal .....	5-01	CLEANING AND INSPECTION	
Installation .....	5-01	Cleaning .....	5-03
		Inspection .....	5-03

## DESCRIPTION

The function of the starting system is to crank the engine at a speed fast enough to permit the engine to start. Heavy duty cables, connectors, and switches are used in the starting system because of the high amount of current required by the starter while it is cranking the engine.

The amount of resistance in the starting circuit must be kept to an absolute minimum to provide maximum current flow for starter operation. Loose or corroded connections or partially broken cables will result in slower than normal cranking speeds, and may even prevent the starter from cranking the engine.

## SYSTEM COMPONENTS

The major components of the Bosch solenoid actuated starter used on SSD Industrial Engines are the frame and field coil, armature, brush plate, drive assembly, shift lever, drive housing, and starter solenoid assembly. If visual inspection, on engine testing, or bench testing show that the unit is damaged, or if performance does not meet specifications, the starter must be replaced.

### BOSCH STARTER

The Bosch starter has a solenoid operated roller clutch drive. The starter is mounted to the engine flywheel housing with three bolts (Fig. 1). When the starting switch is turned to the start position, the solenoid moves the drive pinion into engagement with the engine flywheel ring gear and full cranking torque is developed.

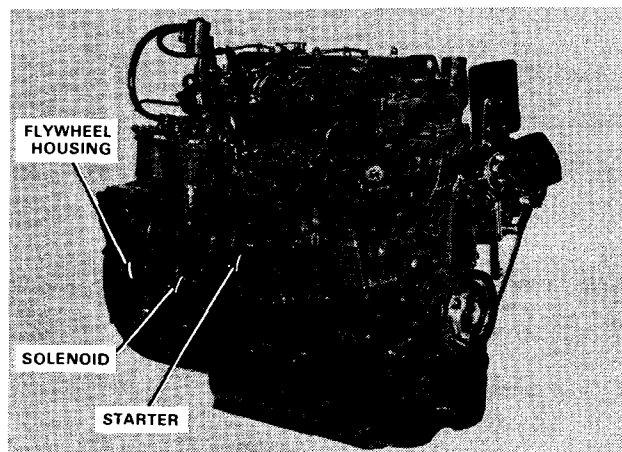


FIG. 1 Starter Mounting and Location—Typical

## REMOVAL AND INSTALLATION

### REMOVAL

Remove the negative battery cable from the battery post. Disconnect the starter switch lead and the positive cable from the solenoid terminals. Remove the three bolts securing the starter to the flywheel housing and remove the starter from the engine.

### INSTALLATION

Position the starter on the flywheel housing, install the three mounting bolts and finger tighten. Be sure that the starter mounting flange is seated squarely on the flywheel housing and torque mounting bolts to specification. Connect the starter lead and battery cables. Connections should be clean and tight.

## DIAGNOSIS AND TESTING

### BOOSTER BATTERY

A booster battery may be connected to the starting system in cases of a starter that will not crank the engine or a starter that cranks the engine very slowly.

**WARNING:** Be certain the correct battery polarity is observed when using a booster battery; positive-to-positive and negative-to-ground connection of the auxiliary cables.

If the starter does not crank the engine over with a booster battery attached, refer to the following tests. If any of the following tests indicate a malfunction or damage, replace the starter as an assembly.

### ON ENGINE TESTING

#### Starter Cranking Circuit Test

These tests will determine whether or not there is excessive resistance in the cranking circuit. Make each test connection as shown in Fig. 2. Connect a remote control starter switch to the solenoid between the battery terminal and the starter switch terminal. While cranking the engine, observe the voltage drop reading for each test.

The voltage drop in the circuit will be indicated by the voltmeter (0 to 2 volt range). Maximum allowable voltage drop should be:

1. 0.5 volt with the voltmeter negative lead connected to the starter terminal of the solenoid and the positive lead connected to the positive battery terminal (Fig. 2, connection 1).

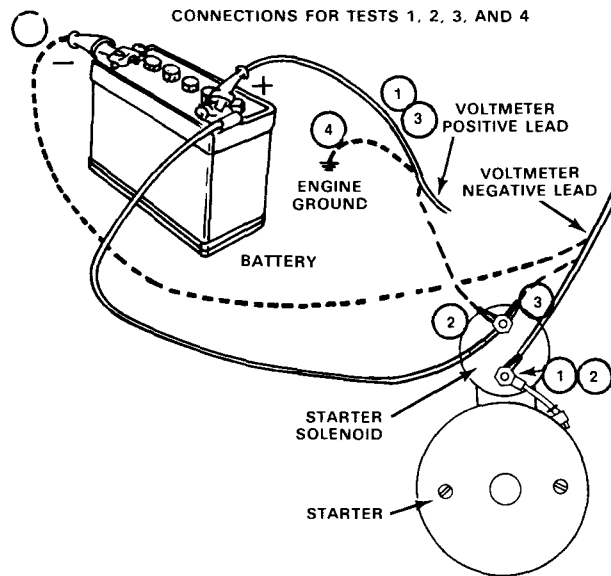


FIG. 2 Starter Cranking Circuit Test

2. 0.3 volt with the voltmeter negative lead connected to the starter terminal of the solenoid and the positive lead connected to the battery terminal of the solenoid (Fig. 2, connection 2).
3. 0.2 volt with the voltmeter negative lead connected to the battery terminal of the solenoid and the positive lead connected to the positive battery terminal (Fig. 2, connection 3).
4. 0.1 volt with the voltmeter negative lead connected to the negative battery terminal and the positive lead connected to the engine ground (Fig. 2, connection 4).

### Starter Load Test

Connect the test equipment as shown in Fig. 3. Be sure that no current is flowing through the ammeter or heavy duty carbon pile rheostat portion of the circuit (rheostat at maximum counterclockwise position).

Crank the engine with the stop control puller out and determine the exact reading on the voltmeter.

Stop cranking the engine and reduce the resistance of the carbon pile until the voltmeter indicates the same reading as that obtained while the starter cranked the engine. The ammeter will indicate the starter current draw under load.

### Starter Solenoid Test

If the solenoid does not pull in (starter load test), measure the voltage between the solenoid switch terminal and ground with the starter switch closed. If the reading is 10 volts or more, a worn or damaged solenoid is indicated. Remove the starter assembly for solenoid replacement.

## BENCH TESTING

### Starter No-Load Test

This test will determine conditions such as an open or shorted winding, rubbing armature, or bent armature.

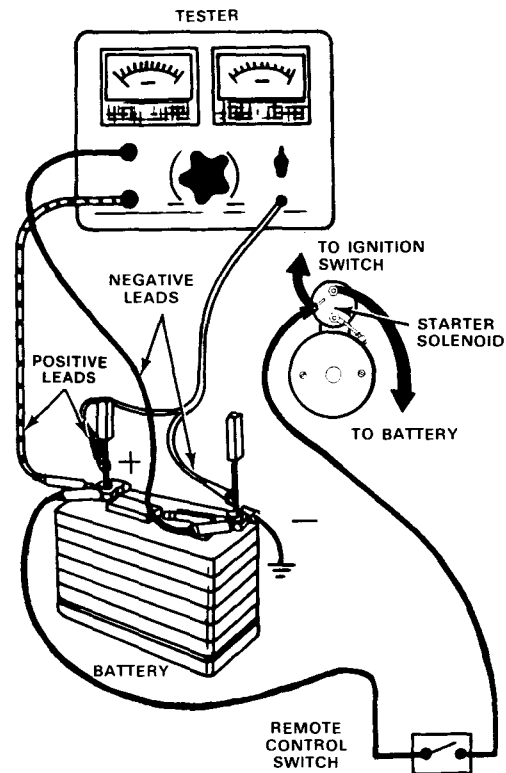


FIG. 3 Starter Load Test

Make the test connections as shown in Fig. 4. The starter will run at no-load. Be sure that no current is flowing through the ammeter (rheostat at maximum counterclockwise position). Determine the exact reading on the voltmeter.

Disconnect the starter from the battery and reduce the resistance of the rheostat until the voltmeter indicates the same reading as that obtained while the starter was running. The ammeter will indicate the starter no-load current draw.

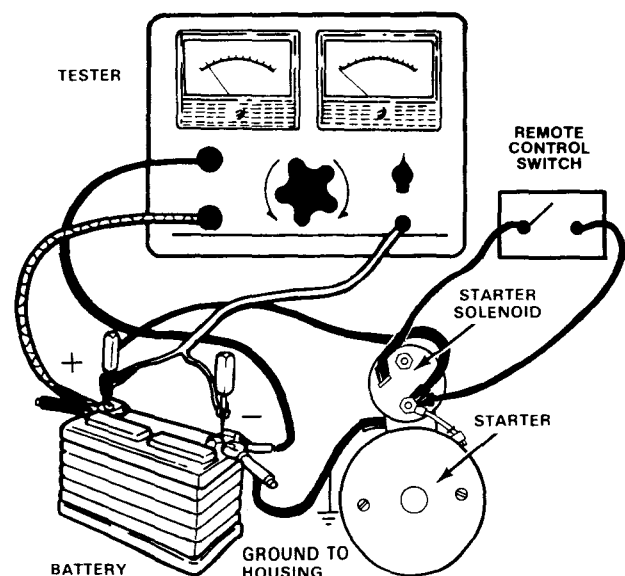


FIG. 4 Starter No-Load Bench Test

## CLEANING AND INSPECTION

### CLEANING

Carefully clean the outside of the starter and solenoid assembly with a brush using a suitable solvent. Do not disassemble the starter.

Do not wash the starter drive because the solvent will dilute the lubricant and cause the drive to slip. Use a brush or compressed air to clean the drive.

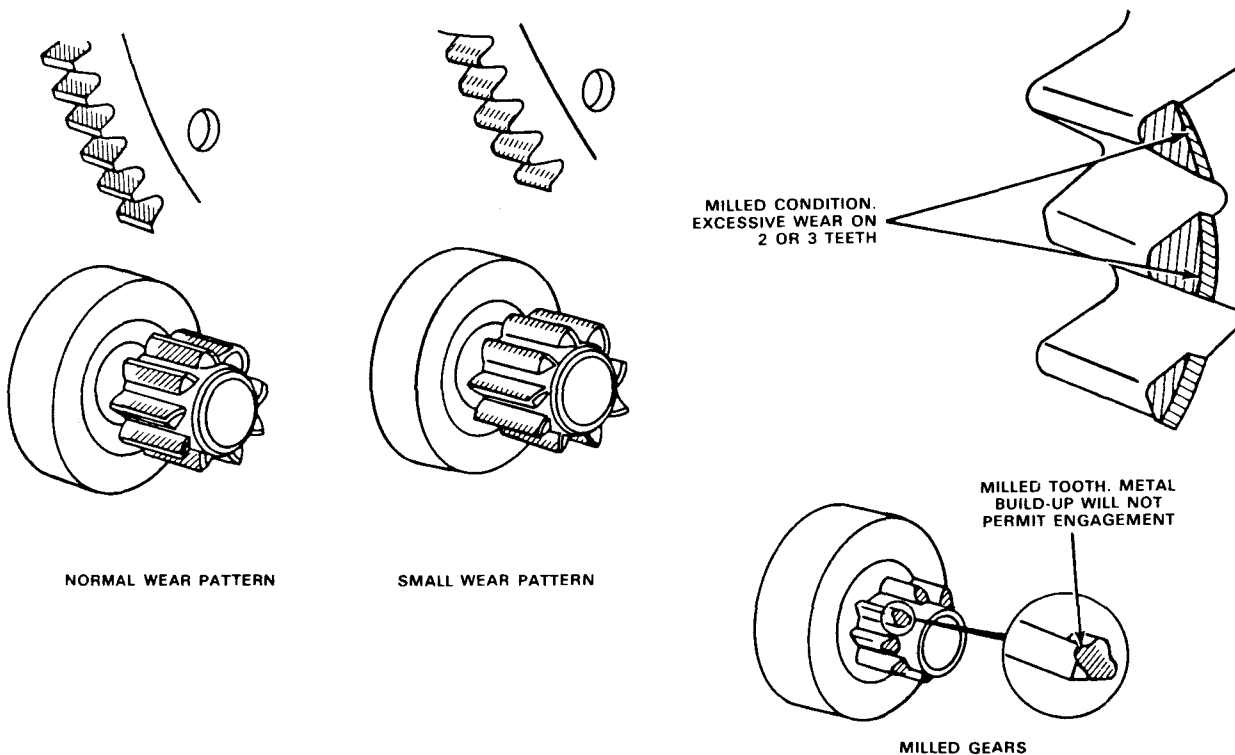
**CAUTION:** Do not immerse the starter assembly in cleaning solvent or allow the solvent to enter the inside of the starter.

### INSPECTION

Examine the wear pattern on the starter drive teeth. The pinion teeth must penetrate to a depth greater than  $1/2$  the ring gear tooth depth (Fig. 5) to prevent premature ring gear and starter drive failure.

Replace the starter if pinion teeth are milled, pitted, broken, or show evidence of inadequate engagement.

It may also be necessary to replace the flywheel ring gear. Refer to Flywheel and Ring Gear detailed in Section 1 under OVERHAUL for ring gear replacement procedures.



J1372-2A

FIG. 5 Pinion and Ring Gear Wear Patterns

# PART 7 Cooling System

COMPONENT INDEX	PAGE	COMPONENT INDEX	PAGE
DESCRIPTION AND OPERATION		DRIVE BELTS	
Description .....	7-01	Adjustments .....	7-03
Operation .....	7-01	CLEANING AND INSPECTION	
DIAGNOSIS AND TESTING		Cooling System .....	7-03
Recommended Equipment .....	7-02		

## DESCRIPTION AND OPERATION

### DESCRIPTION

The water pump (Fig. 1) is mounted on the front face of the cylinder block and is driven by the belt(s) from the crankshaft pulley. It is an impeller type centrifugal pump and assists the natural thermosiphon circulation of the coolant. Replacement water pumps are serviced as an assembly.

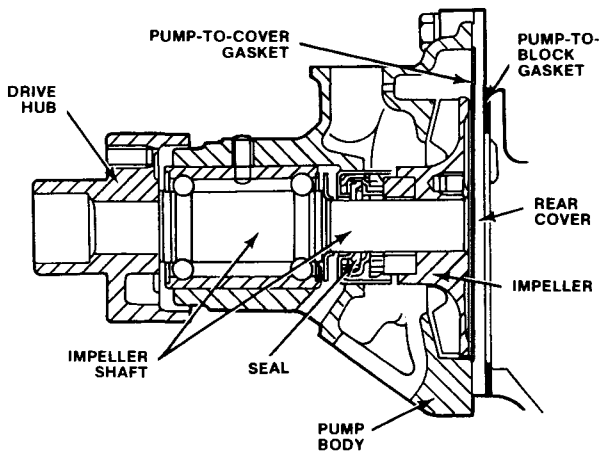


FIG. 1 SSD Engine Water Pump — Cross-Section

The thermostat is located inside the coolant outlet on the cylinder head. The thermostat maintains an engine operating temperature of approximately 178° - 185°F (81° - 85°C) by controlling coolant flow. The thermostat is sensitive to temperature changes, but is not affected by the pressure developed in the cooling system.

For protection against corrosion and coolant loss, as well as freezing, a fifty-fifty mixture of ethylene-glycol and water is recommended. Use Ford anti-freeze or an equivalent produced by a reputable manufacturer.

Use soft water whenever possible, since lime or alkali in the water will cause deposits to build up inside the block and head cooling passages. These deposits greatly reduce heat transfer, cause overheating, and eventually could result in a cracked block.

**NOTE:** The ethylene-glycol percentage may be below fifty, but never below the freezing protection level. Do not use more than fifty percent ethylene-glycol.

### OPERATION

#### SSD Industrial Engines

Coolant is drawn up from the bottom of the radiator by the water pump and delivered to the cylinder block (Fig. 2). The coolant flows around the cylinders, up through the head where deflectors direct flow around the valves and injectors, and past the thermostat (when open) into the top of the radiator. A bypass permits circulation when the thermostat is closed.

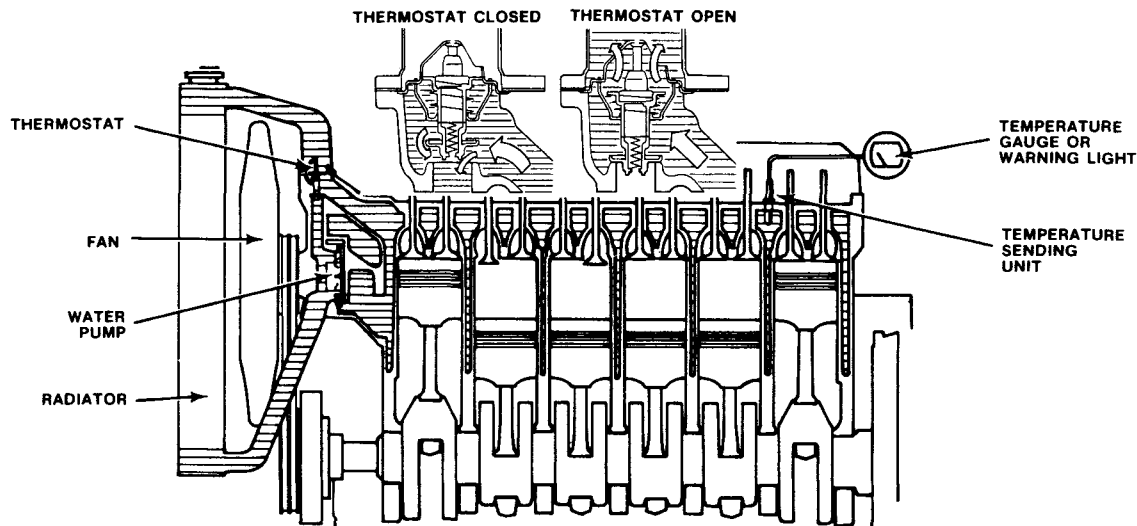


FIG. 2 SSD Industrial Engine Cooling System — Typical

### SSD Marine Engines

SSD engines adapted for marine applications are equipped with an expansion tank, water-cooled exhaust manifold, heat exchanger, oil cooler, raw water pump, and the conventional engine water pump (Fig. 3).

The engine water pump circulates the coolant through the block, head, and then through the exhaust manifold.

With the thermostat closed, coolant flows through a bypass to the engine oil cooler and then returns to the engine water pump for recirculation.

With the thermostat open, the bypass is closed and the coolant flows through the heat exchanger and into the engine oil cooler. The coolant then returns to the engine water pump for recirculation. An expansion tank, mounted on the front of the engine, is connected to the cooling system between the heat exchanger and the engine oil cooler.

The raw water pump is mounted on the right side of the engine and is driven by the P.T.O drive. It draws water from outside the hull and circulates the water through the heat exchanger, transmission oil cooler, and then back overboard.

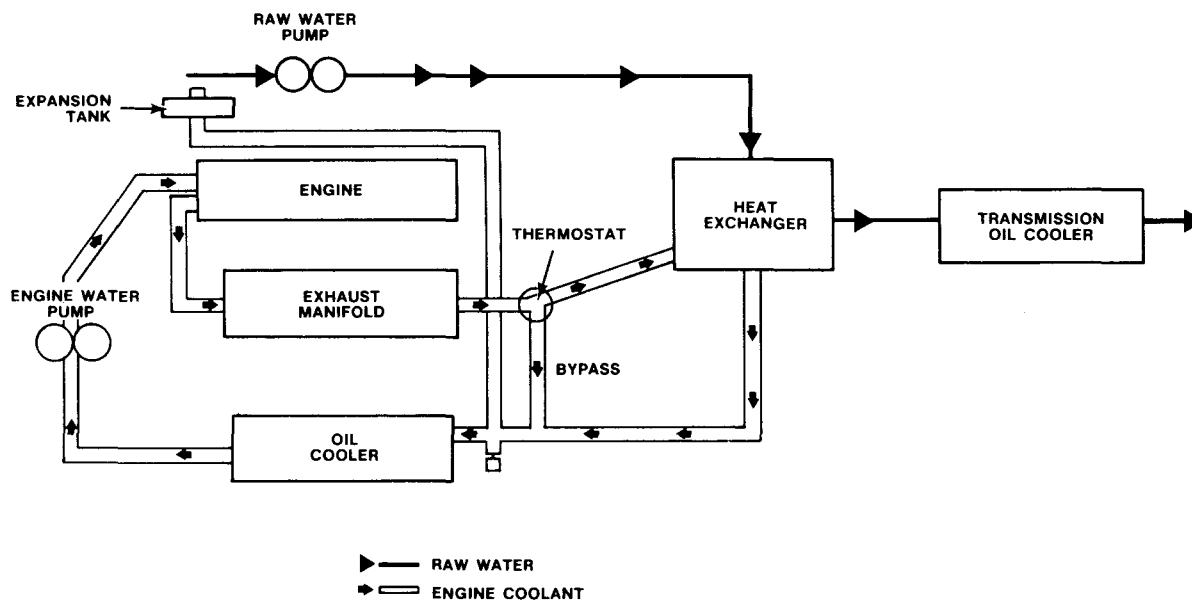


FIG. 3 SSD Marine Engine Cooling System — Typical

## DIAGNOSIS AND TESTING

### RECOMMENDED EQUIPMENT

Use of the Rotunda Cooling System Analyzer (Fig. 4) is recommended for all cooling system diagnosis and testing.

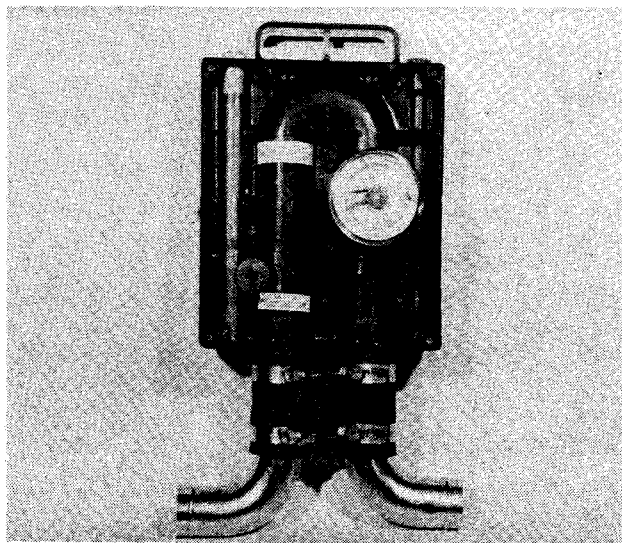


FIG. 4 Rotunda Cooling System Analyzer

The Rotunda Analyzer connects directly into the coolant circulation system and may be used to test each of the following:

- Coolant Condition and Operating Temperature
- Anti-Freeze Protection Level
- Thermostat
  - Condition
  - Opening Temperature
  - Operating Temperature
- Radiator Cap Condition
- Radiator Condition
- Water Pump Efficiency and Condition
- Cracked Block or Cylinder Head
- Leaky Cylinder Head Gasket
- Temperature Gauge Accuracy

Follow the manufacturer's instructions for connection and testing procedures.

**NOTE:** If a new thermostat or water pump is installed, test the cooling system with the analyzer before returning the engine to service.

## DRIVE BELTS

### ADJUSTMENTS

The fan drive belt(s) should be properly adjusted at all times. A loose drive belt can cause improper alternator, fan, and water pump operation. A belt that is too tight places a severe strain on the water pump and alternator bearings.

A properly tensioned drive belt minimizes noise and also prolongs the service life of the belt. Therefore, it is recommended that a belt tension gauge be used to check and adjust the belt tension.

**NOTE:** Any belt that has been operated for a minimum of 10 minutes is considered a used belt, and when adjusted, it must be adjusted to the used belt tension shown in the specifications.

Belts must be replaced in matched sets on engines with dual belt drives.

#### Belt Tension

Proceed as follows to check and adjust drive belt tension:

1. Install the belt tension gauge on the drive belt and check the tension (Fig. 5).

**NOTE:** On dual belt arrangements, check tension on one belt only.

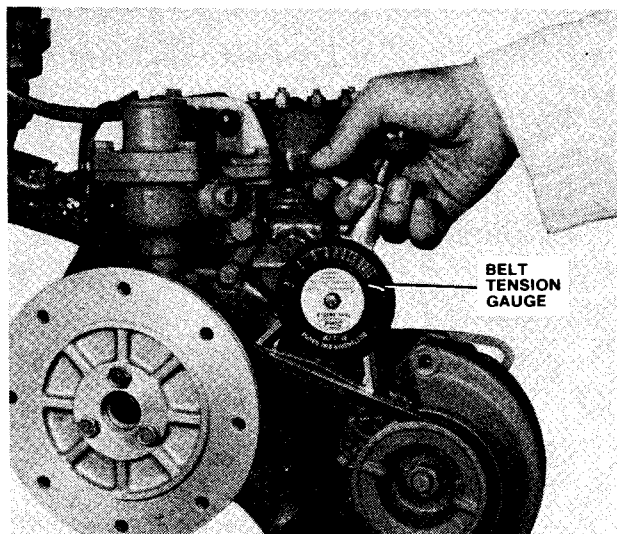


FIG. 5 Checking Drive Belt Tension

2. If adjustment is necessary, loosen the alternator mounting bolts and adjusting arm bolts. Move the alternator toward or away from the engine until the correct tension is obtained. Remove the tension gauge.
3. Tighten the alternator adjusting arm bolts and the mounting bolts. Install the tension gauge and recheck the belt tension.

## CLEANING AND INSPECTION

### COOLING SYSTEM

To remove rust, sludge, and other foreign material from the cooling system, use either Ford Cooling System Cleaner or in severe cases use Heavy Duty Cleaner. Follow directions on manufacturer's container. Removal of such material restores cooling efficiency and avoids overheating.

In severe cases where cleaning solvents will not properly clean the cooling system for efficient operation, it will be necessary to use the pressure flushing method.

**CAUTION:** Always remove the thermostat prior to pressure flushing.

Various types of flushing equipment are available. Follow the equipment manufacturer's instructions for flushing procedures.

**NOTE:** A pulsating or reversed direction flushing water flow will loosen sediment more rapidly than a steady flow in the normal direction of coolant travel.

# PART 8 Specifications

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Valve Mechanism .....	8-02	Lift Pump .....	8-07
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Valve Timing and Clearances .....	8-03	STARTING SYSTEM	
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Dynamic Balancer (SSD-437) .....	8-07		

## ENGINE

### GENERAL SPECIFICATIONS

SSD-327 (3 Cylinder) .....	2.7 Litre (168 CID)
SSD-437 (4 Cylinder) .....	3.7 Litre (224 CID)
SSD-655 (6 Cylinder) .....	5.5 Litre (335 CID)
Bore and Stroke	
SSD-327, SSD-437, and SSD-655 .....	4.05 x 4.33 in. (103 x 110 mm.)
Firing Order	
SSD-327 .....	1-2-3
SSD-437 .....	1-3-4-2
SSD-655 .....	1-5-3-6-2-4
Idle Speed (RPM)	
SSD-327 and SSD-437 .....	650 RPM
SSD-655 .....	600-650 RPM
Maximum No-Load RPM	
Industrial .....	2750 RPM
Marine .....	3520 RPM

### CYLINDER HEAD

Gasket Surface Flatness (Head and Block in Same Area) .....	0.0039 in. (0.1 mm) Max.
Injector Protrusion .....	0.04 to 0.06 in. (1.0 to 1.5 mm.)
Valve Guide Assembly Clearance Between Valve Stems and Guides .....	0.0009 to 0.0021 in. (0.023 to 0.053 mm.)
Valve Guide Bore Dia. ....	0.549 to 0.550 in. (13.966 to 13.983 mm.)
Valve Guide I.D. ....	0.3158 to 0.3160 in. (8.023 to 8.028 mm.)
Valve Guide O.D.	
Standard .....	0.5507 to 0.5518 in. (13.988 to 14.016 mm.)
Oversize	
0.008 in. (0.2 mm.) .....	0.5586 to 0.5596 in. (14.188 to 14.216 mm.)
Valve Guide Interference Fit in Cylinder Head .....	0.0002 to 0.002 in. (0.005 to 0.050 mm.)
Valve Recess in Cylinder Head .....	0.035 ± 0.008 in. (0.9 ± 0.2 mm.)
Valve Seat Angle .....	45° ± 5'
Valve Seat Width .....	1/16 to 3/32 in. (1.59 to 2.38 mm.)
Valve Seat Runout	
Intake .....	0.0012 in. (0.03 mm.)
Exhaust .....	0.0016 in. (0.04 mm.)

**VALVE MECHANISM**

Valve Stem Dia. ....	0.314 to 0.315 in. (7.985 to 8.000 mm.)
Valve Head Dia.	
Intake .....	1.7224 to 1.7323 in. (43.750 to 44.000 mm.)
Exhaust .....	1.4469 to 1.4567 in. (36.750 to 37.000 mm.)
Valve Face Angle .....	45° 23' to 45° 37'
Stem-to-Guide Clearance .....	0.0009 to 0.0021 in. (0.023 to 0.053 mm.)
Valve Clearance (Engine Cold)	
Intake .....	0.010 in. (0.25 mm.)
Exhaust .....	0.014 in. (0.35 mm.)
Intake and Exhaust (Timing Check) .....	0.018 in. (0.45 mm.)
Valve Spring Free Length (Nominal)	
Industrial .....	2.62 in. (66.5 mm.)
Marine	
Inner .....	2.008 in. (51 mm.)
Outer .....	2.48 in. (63 mm.)
Valve Spring Pressure (Lbs. @ Specified Length)	
Industrial	
Valve Closed .....	66.3 to 74.7 Lbs. @ 1.59 to 1.63 in. (30.1 to 33.9 Kg. @ 40.5 to 41.5 mm.)
Valve Open .....	106.0 to 114.8 Lbs. @ 1.17 to 1.25 in. (48.1 to 52.1 Kg. @ 29.8 to 31.8 mm.)
Marine	
Inner	
Valve Closed .....	14.4 to 16.6 Lbs. @ 1.476 to 1.516 in. (6.55 to 7.55 Kg. @ 37.5 to 38.5 mm.)
Valve Open .....	34.0 to 36.8 Lbs. @ 1.055 to 1.134 in. (15.4 to 16.7 Kg. @ 2.68 to 28.8 mm.)
Outer	
Valve Closed .....	42.5 to 47.8 Lbs. @ 1.59 to 1.63 in. (10.3 to 21.7 Kg. @ 40.50 to 41.45 mm.)
Valve Open .....	80.2 to 86.8 Lbs. @ 1.17 to 1.25 in. (36.4 to 39.4 Kg. @ 29.8 to 31.8 mm.)
Valve Spring Out-of-Square .....	5/64 in. (1.984 mm.)
Tappet Intermediate O.D. (Max.)	
Standard .....	0.5492 to 0.5500 in. (13.950 to 13.970 mm.)
Oversize	
0.004 in. (0.10 mm.) .....	0.5531 to 0.5539 in. (14.050 to 14.070 mm.)
0.008 in. (0.20 mm.) .....	0.5570 to 0.5578 in. (14.150 to 14.170 mm.)
0.012 in. (0.30 mm.) .....	0.5610 to 0.5618 in. (14.250 to 14.270 mm.)
Tappet-to-Tappet Bore Clearance .....	0.0012 to 0.0027 in. (0.030 to 0.068 mm.)

**CAMSHAFT AND TIMING GEARS**

Camshaft Journal Dia.	
SSD-327 and SSD-437	
Front .....	2.006 to 2.007 in. (50.970 to 51.000 mm.)
Intermediate .....	1.987 to 1.988 in. (50.470 to 50.500 mm.)
Rear .....	1.967 to 1.968 in. (49.970 to 50.000 mm.)
SSD-655	
Front .....	2.026 to 2.027 in. (51.470 to 51.500 mm.)
Front Intermediate .....	2.006 to 2.007 in. (50.970 to 51.000 mm.)
Rear Intermediate .....	1.987 to 1.988 in. (50.470 to 50.500 mm.)
Rear .....	1.967 to 1.968 in. (49.970 to 50.000 mm.)
Camshaft Journal Runout .....	0.004 to 0.006 in. (0.10 to 0.15 mm.)
Camshaft Bushing I.D.	
SSD-327 and SSD-437	
Front .....	2.011 to 2.012 in. (51.180 to 51.130 mm.)
Intermediate .....	1.991 to 1.993 in. (50.580 to 50.630 mm.)
Rear .....	1.971 to 1.973 in. (50.080 to 50.130 mm.)
SSD-655	
Front .....	2.031 to 2.033 in. (51.580 to 51.630 mm.)
Front Intermediate .....	2.011 to 2.012 in. (51.080 to 51.130 mm.)
Rear Intermediate .....	1.991 to 1.993 in. (50.580 to 50.630 mm.)
Rear .....	1.971 to 1.973 in. (50.080 to 50.130 mm.)

**CAMSHAFT AND TIMING GEARS (Cont'd)**

Camshaft Bushing O.D.	
SSD-327 and SSD-437	
Front .....	2.160 to 2.163 in. (54.875 to 54.930 mm.)
Intermediate .....	2.140 to 2.142 in. (54.375 to 54.430 mm.)
Rear .....	2.121 to 2.123 in. (53.875 to 53.930 mm.)
SSD-655	
Front .....	2.180 to 2.182 in. (55.375 to 55.430 mm.)
Front Intermediate .....	2.160 to 2.163 in. (54.875 to 54.930 mm.)
Rear Intermediate .....	2.140 to 2.142 in. (54.375 to 54.430 mm.)
Rear .....	2.121 to 2.123 in. (53.875 to 53.930 mm.)
Camshaft End Play .....	0.002 to 0.023 in. (0.051 to 0.584 mm.)
Camshaft Journal-to-Bushing Running Clearance .....	0.0032 to 0.0063 in. (0.080 to 0.160 mm.)
Camshaft Bushing-to-Bore Interference Fit .....	0.0027 to 0.0059 in. (0.070 to 0.150 mm.)
Camshaft Gear-to-Idler Gear Backlash .....	0.004 to 0.006 in. (0.10 to 0.15 mm.)
Camshaft Lobe Lift	
Intake .....	0.366 in. (9.3 mm.)
Exhaust .....	0.420 in. (10.2 mm.)
Idler Gear Shaft Dia. ....	1.2588 to 1.2598 in. (31.975 to 32.000 mm.)
Idler Gear Bushing Bore Dia. ....	1.2617 to 1.2627 in. (32.050 to 32.075 mm.)
Idler Shaft and Bushing Assembly Clearance .....	0.0020 to 0.040 in. (0.050 to 0.100 mm.)
Idler Gear Thrust Washer Thickness .....	0.057 to 0.059 in. (1.450 to 1.500 mm.)
Idler Bushing Interference Fit in Gear .....	0.0025 to 0.0055 in. (0.063 to 0.140 mm.)

**VALVE TIMING AND CLEARANCES**

Valve Clearance (Engine Cold)	
Intake .....	0.010 in. (0.25 mm.)
Exhaust .....	0.014 in. (0.35 mm.)
Intake and Exhaust (Timing Check) .....	0.018 in. (0.45 mm.)
Timing	
Intake Opens .....	3° before T.D.C.
Intake Closes .....	23° after B.D.C.
Exhaust Opens .....	48° 30' before B.D.C.
Exhaust Closes .....	6° after T.D.C.
Valve Lift .....	0.394 in. (10 mm.)
Rocker Arm Bushing O.D. ....	0.8279 to 0.8291 in. (21.031 to 21.060 mm.)
Rocker Arm Bushing Bore Dia. ....	0.8244 to 0.8257 in. (20.939 to 20.972 mm.)
Rocker Arm Bore and Bushing Interference Fit .....	0.0023 to 0.0048 in. (0.058 to 0.121 mm.)
Rocker Arm Bushing I.D. (Installed) .....	0.7003 to 0.7100 in. (18.016 to 18.034 mm.)
Rocker Arm Shaft and Bushing Assembly Clearance .....	0.0006 to 0.0020 in. (0.016 to 0.052 mm.)
Rocker Arm Side Clearance .....	0.0025 in. (0.061 mm.) Max.

**FLYWHEEL**

Clutch Face Runout .....	0.0020 in. (0.050 mm.)
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**CRANKSHAFT**

Main Bearing Journal Dia.	
Standard .....	2.9994 to 3.0000 in. (76.187 to 76.200 mm.)
Undersize	
0.010 in. (0.254 mm.) .....	2.9895 to 2.9900 in. (75.933 to 75.946 mm.)
0.020 in. (0.508 mm.) .....	2.9795 to 2.9800 in. (75.679 to 75.692 mm.)
0.030 in. (0.762 mm.) .....	2.9695 to 2.9700 in. (75.425 to 75.438 mm.)
0.040 in. (1.016 mm.) .....	2.9595 to 2.9600 in. (75.171 to 75.184 mm.)
Main Bearing Thickness	
Standard .....	0.0853 to 0.0855 in. (2.165 to 2.172 mm.)
Undersize	
0.010 in. (0.254 mm.) .....	0.0902 to 0.0905 in. (2.292 to 2.299 mm.)
0.020 in. (0.508 mm.) .....	0.0952 to 0.0955 in. (2.419 to 2.426 mm.)
0.030 in. (0.762 mm.) .....	0.1002 to 0.1005 in. (2.546 to 2.553 mm.)
0.040 in. (1.016 mm.) .....	0.1053 to 0.1055 in. (2.673 to 2.680 mm.)
Main Bearing Journal Operating Clearance .....	0.0016 to 0.0035 in. (0.043 to 0.090 mm.)
Main Bearing Journal Runout .....	0.002 in. (0.05 mm.)

**CRANKSHAFT (Cont'd)**

Connecting Rod Journal Dia.	
Standard	2.3121 to 2.3126 in. (58.730 to 58.743 mm.)
Undersize	
0.010 in. (0.254 mm.)	2.3021 to 2.3026 in. (58.446 to 58.489 mm.)
0.020 in. (0.508 mm.)	2.2920 to 2.2926 in. (58.222 to 58.235 mm.)
0.030 in. (0.762 mm.)	2.2822 to 2.2827 in. (57.968 to 57.981 mm.)
0.040 in. (1.016 mm.)	2.2721 to 2.2726 in. (57.714 to 57.727 mm.)
Connecting Rod Bearing Thickness	
Standard	0.0715 to 0.0717 in. (1.816 to 1.822 mm.)
Undersize	
0.010 in. (0.254 mm.)	0.0765 to 0.0767 in. (1.943 to 1.949 mm.)
0.020 in. (0.508 mm.)	0.0814 to 0.0817 in. (2.070 to 2.076 mm.)
0.030 in. (0.762 mm.)	0.0865 to 0.0867 in. (2.197 to 2.203 mm.)
0.040 in. (1.016 mm.)	0.0915 to 0.0918 in. (2.324 to 2.330 mm.)
Connecting Rod Operating Clearance	0.008 to 0.0023 in. (0.021 to 0.058 mm.)
Thrust Washer Thickness	
Standard	0.133 to 0.135 in. (3.378 to 3.429 mm.)
Oversize	
0.005 in. (0.127 mm.)	0.138 to 0.140 in. (3.505 to 3.556 mm.)
Main Bearing Width (Next to Rear Bearing)	1.2598 to 1.2638 in. (32.000 to 32.100 mm.)
Crankshaft End Play	0.003 to 0.013 in. (0.082 to 0.334 mm.)
Main and Connecting Rod Journal Out-of-Round	0.0003 in. (0.008 mm.)
Main and Connecting Rod Journal Taper	0.0004 in. (0.012 mm.)
Crankshaft Flange Face Runout on Periphery (TIR)	0.001 in. (0.025 mm.)

**CONNECTING RODS**

Piston Pin Dia.	
Standard	1.3379 to 1.3381 in. (33.983 to 33.990 mm.)
Oversize	
0.005 in. (0.127 mm.)	1.3429 to 1.3431 in. (34.110 to 34.117 mm.)
Piston Pin Bushing I.D.	
Standard	1.3387 to 1.3390 in. (34.005 to 34.012 mm.)
Oversize	
0.005 in. (0.127 mm.)	1.3438 to 1.3441 in. (34.132 to 34.139 mm.)
Piston Pin-to-Bushing Assembly Clearance	0.0006 to 0.0011 in. (0.015 to 0.029 mm.)
Piston Pin Bushing O.D.	1.4952 to 1.4967 in. (37.979 to 38.017 mm.)
Piston Pin Bushing Bore Dia.	1.490 to 1.4915 in. (37.846 to 37.884 mm.)
Bushing-to-Bore Interference Fit	0.0037 to 0.0067 in. (0.095 to 0.171 mm.)
Connecting Rod Axial Misalignment—	
Measured at a Point 4.9212 in. (125 mm.) From Vertical Axis	0.0028 in. (0.07 mm.)
Connecting Rod-to-Crankshaft Side Clearance	0.008 to 0.0023 in. (0.021 to 0.058 mm.)

**PISTONS**

Piston Ring Groove Width	
Compression (Top)	0.1016 to 0.1024 in. (2.58 to 2.60 mm.)
Oil Scraper (Intermediate)	0.1000 to 0.1008 in. (2.54 to 2.56 mm.)
Oil Control (Bottom)	0.1587 to 0.1594 in. (4.030 to 4.050 mm.)
Piston Ring Side Clearance	
Compression (Top)	0.0035 to 0.0048 in. (0.090 to 0.122 mm.)
Oil Scraper (Intermediate)	0.0020 to 0.0032 in. (0.050 to 0.082 mm.)
Oil Control (Bottom)	0.0016 to 0.0028 in. (0.040 to 0.072 mm.)
Piston Dia.—Measured at a Point 1.968 in. (50 mm.) Above Base of Piston Skirt, Normal to Pin Axis	
Standard	4.0477 to 4.0482 in. (102.813 to 102.825 mm.)
Oversize	
0.008 in. (0.2 mm.)	4.0556 to 4.0561 in. (103.013 to 103.025 mm.)
0.016 in. (0.4 mm.)	4.0635 to 4.0639 in. (103.213 to 103.225 mm.)
0.020 in. (0.6 mm.)	4.0713 to 4.0718 in. (103.413 to 103.425 mm.)
0.032 in. (0.8 mm.)	4.0792 to 4.0797 in. (103.613 to 103.625 mm.)

**PISTONS (Cont'd)**

Piston-to-Liner Clearance — Measured at a Point 1.968 in. (50 mm.)

Above Base of Piston Skirt, Normal to Pin Axis .....	0.0068 to 0.0080 in. (0.175 to 0.205 mm.)
Piston Protrusion .....	0.018 to 0.030 in. (0.46 to 0.78 mm.)
Piston Pin Dia.	
Standard .....	1.3379 to 1.3381 in. (33.983 to 33.990 mm.)
Oversize	
0.008 in. (0.20 mm.) .....	1.3457 to 1.3460 in. (34.183 to 34.190 mm.)
Piston Pin Bore Dia.	
Standard .....	1.3383 to 1.3385 in. (33.993 to 34.000 mm.)
Oversize	
0.008 in. (0.20 mm.) .....	1.3461 to 1.3464 in. (34.193 to 34.200 mm.)
Piston Pin Clearance in Piston .....	0.0001 to 0.0006 in. (0.003 to 0.017 mm.)
Piston Weight Variation (Max.) .....	± 0.36 oz. (10 gr.)
Piston Ring End Gap (Installed in Liner)	
Compression (Top) .....	0.014 to 0.022 in. (0.350 to 0.550 mm.)
Oil Scraper (Intermediate) .....	0.012 to 0.020 in. (0.300 to 0.500 mm.)
Oil Control (Bottom) .....	0.012 to 0.018 in. (0.300 to 0.450 mm.)
Piston Ring End Gap Stagger (On Piston Before Assembly into Block) .....	120°

**CYLINDER BLOCK**

Cylinder Liner O.D.	
Standard .....	4.2133 to 4.2145 in. (107.020 to 107.050 mm.)
Oversize	
0.008 in. (0.2 mm.) .....	4.2212 to 4.2224 in. (107.220 to 107.250 mm.)
Block Bore	
Standard .....	4.2082 to 4.2102 in. (106.890 to 106.940 mm.)
Oversize	
0.008 in. (0.2 mm.) .....	4.2161 to 4.2181 in. (107.090 to 107.140 mm.)
Liner Interference Fit in Bores .....	0.0031 to 0.0063 in. (0.080 to 0.160 mm.)
Cylinder Liner Press-Fitted I.D. ....	4.0551 to 4.0558 in. (103.000 to 103.018 mm.)
Block Main Bearing Bore Dia. ....	3.1727 to 3.1735 in. (80.587 to 80.607 mm.)
Block Camshaft Bushing Bore	
SSD-327 and SSD-437	
Front .....	2.1567 to 2.1577 in. (54.780 to 54.805 mm.)
Intermediate .....	2.1370 to 2.1380 in. (54.280 to 54.305 mm.)
Rear .....	2.1173 to 2.1183 in. (53.780 to 53.805 mm.)
SSD-655	
Front .....	2.1764 to 2.1774 in. (55.280 to 55.305 mm.)
Front Intermediate .....	2.1567 to 2.1577 in. (54.780 to 54.805 mm.)
Rear Intermediate .....	2.1370 to 2.1380 in. (54.280 to 54.305 mm.)
Rear .....	2.1173 to 2.1183 in. (53.780 to 53.805 mm.)
Tappet Block Bore Dia.	
Standard .....	0.5512 to 0.5519 in. (14.000 to 14.018 mm.)
Oversize	
0.004 in. (0.10 mm.) .....	0.5551 to 0.5558 in. (14.100 to 14.118 mm.)
0.008 in. (0.20 mm.) .....	0.5590 to 0.5598 in. (14.200 to 14.218 mm.)
0.012 in. (0.30 mm.) .....	0.5630 to 0.5637 in. (14.300 to 14.318 mm.)

**TAPPETS, ROCKER ARMS AND SHAFT**

Tappet O.D.	
Standard	
Top and Bottom .....	0.5807 to 0.5818 in. (14.750 to 14.780 mm.)
Intermediate .....	0.5885 to 0.5893 in. (14.950 to 14.970 mm.)
Oversize	
0.004 in. (0.10 mm.)	
Top and Bottom .....	0.5846 to 0.5858 in. (14.850 to 14.880 mm.)
Intermediate .....	0.5925 to 0.5933 in. (15.050 to 15.070 mm.)
0.008 in. (0.20 mm.)	
Top and Bottom .....	0.5885 to 0.5897 in. (14.950 to 14.980 mm.)
Intermediate .....	0.5964 to 0.5972 in. (15.150 to 15.170 mm.)
0.012 in. (0.30 mm.)	
Top and Bottom .....	0.5925 to 0.5937 in. (15.050 to 15.080 mm.)
Intermediate .....	0.6003 to 0.6011 in. (15.250 to 15.270 mm.)

**TAPPETS, ROCKER ARMS AND SHAFT (Cont'd)**

Rocker Arm Shaft Bracket Bore Dia. ....	0.7087 to 0.7103 in. (18.000 to 18.043 mm.)
Rocker Arm Shaft Dia. ....	0.7079 to 0.7087 in. (17.982 to 18.000 mm.)
Rocker Arm Shaft Clearance in Bracket .....	0 to 0.0024 in. (0 to 0.061 mm.)
Rocker Arm Bushing O.D. ....	0.8270 to 0.8280 in. (21.006 to 21.031 mm.)
Rocker Arm Bushing Interference Fit in Rocker Arm .....	0.0013 to 0.0036 in. (0.034 to 0.092 mm.)
Rocker Arm Bushing I.D. (Installed).....	0.7092 to 0.7100 in. (18.016 to 18.034 mm.)
Rocker Arm Shaft Clearance in Bushing.....	0.0006 to 0.002 in. (0.016 to 0.052 mm.)
Rocker Arm Bushing Bore Dia. ....	0.8243 to 0.8256 in. (20.939 to 20.972 mm.)

**LUBRICATION****SSD-327 and SSD-437**

Type .....	Force-Fed
Oil Pump .....	Gear Type
Pump Drive .....	Camshaft Driven
Drive Ratio .....	1 to 2
Pump Drive Shaft-to-Bushing Clearance .....	0.0006 to 0.0021 in. (0.016 to 0.055 mm.)
Pump Driven Shaft-to-Gear Clearance.....	0.0007 to 0.0022 in. (0.017 to 0.057 mm.)
Oil Pump Gear Tooth Backlash .....	0.004 in. (0.100 mm.)
Gear-to-Body Clearance .....	0.001 to 0.005 in. (0.025 to 0.126 mm.)
Drive and Driven Gear End Play .....	0.001 to 0.005 in. (0.025 to 0.126 mm.)
Drive and Driven Gear Diametral Clearance .....	0.0024 to 0.0067 in. (0.060 to 0.170 mm.)
Oil Filters .....	Screen Filter on Suction Line Spin-on Replaceable Type Filter on Pressure Line
Oil Pressure (Engine Warm)	
At Idle .....	10 psi. (0.7 Kg/cm <sup>2</sup> )
At Max. Governed Speed .....	43 to 56 psi. (3 to 4 Kg/cm <sup>2</sup> )
Pressure Relief Valve Opening Pressure .....	51.2 psi. (3.6 Kg/cm <sup>2</sup> )
Pressure Relief Valve Spring	
Free Length .....	1.77 in. (45 mm.)
Length at 10.1 to 11 Lb. (4.6 to 5 Kg.) Test Load .....	1.48 in. (37.5 mm.)
Length at 20 to 21 Lb. (9 to 9.6 Kg.) Test Load .....	1.20 in. (30.5 mm.)
Oil Capacity With Filter (Industrial)	
SSD 327 .....	8 qts. (U.S.) (7.5 L.)
SSD 437 .....	12 qts. (U.S.) (11.4 L.)

**SSD-655**

Type .....	Force-Fed
Oil Pump .....	Gear Type
Pump Drive .....	Through Gear on Front Hub of Crankshaft
Drive Ratio .....	1.264 to 1
Driving Shaft Dia. ....	0.7082 to 0.7086 in. (17.989 to 18.00 mm.)
Driving Shaft Bushing I.D. ....	0.7092 to 0.7109 in. (18.016 to 18.059 mm.)
Driving Shaft Running Clearance .....	0.0006 to 0.0027 in. (0.016 to 0.070 mm.)
Driving Shaft Bushing Interference Fit.....	0.0013 to 0.0036 in. (0.034 to 0.092 mm.)
Driven Gear Shaft Interference Fit in Housing .....	0.0004 to 0.0019 in. (0.012 to 0.050 mm.)
Driven Gear Shaft Dia. ....	0.5901 to 0.5905 in. (14.989 to 15.000 mm.)
Driven Gear Shaft Bushing I.D. ....	0.5911 to 0.5922 in. (15.016 to 15.043 mm.)
Driven Gear Shaft Running Clearance.....	0.0006 to 0.0021 in. (0.016 to 0.054 mm.)
Driven Gear Shaft-to-Bushing Interference Fit .....	0.0020 to 0.0029 in. (0.051 to 0.073 mm.)
Pump Gear Tooth Backlash.....	0.004 in. (0.10 mm.)
Radial Gear Clearance in Pump Body .....	0.0012 to 0.0053 in. (0.030 to 0.134 mm.)
Gear End Play .....	0.0006 to 0.0042 in. (0.016 to 0.107 mm.)
Oil Filters .....	Screen Filter on Suction Line Two Spin-on Replaceable Type Filters on Pressure Line
Oil Pressure (Engine Warm)	
At Idle .....	10 psi. (0.7 Kg/cm <sup>2</sup> )
At Max. Governed Speed .....	42.7 to 56.9 psi. (3 to 4 Kg/cm <sup>2</sup> )
Pressure Relief Valve Opening Pressure .....	51.2 psi. 3.6 Kg/cm <sup>2</sup> )
Pressure Relief Valve Spring	
Free Length .....	1.77 in. (45 mm.)
Length at 10.1 to 11 Lb. (4.6 to 5 Kg) Test Load .....	1.48 in. (37.5 mm.)
Length at 20 to 21 Lb. (9 to 9.6 Kg) Test Load .....	1.20 in. (30.5 mm.)
Oil Capacity With Filter (Industrial) .....	16 qts. (U.S.) (15.1 L.)

**DYNAMIC BALANCER (SSD-437)**

Idler Shaft in Bore Interference Fit .....	0.0004 to 0.0029 in. (0.009 to 0.073 mm.)
Idler and Drive Gear Bushing Interference Fit .....	0.0025 to 0.0055 in. (0.063 to 0.140 mm.)
Idler and Drive Gear Shaft-to-Bushing Clearance .....	0.0020 to 0.0039 in. (0.050 to 0.100 mm.)
Drive Shaft-to-Splined Sleeve Clearance .....	0.0011 to 0.0041 in. (0.028 to 0.106 mm.)
Drive Gear Bushing-to-Balancer Housing Interference Fit .....	0.0025 to 0.0055 in. (0.063 to 0.140 mm.)
Drive Gear Bushing-to-End Support Interference Fit .....	0.0015 to 0.0039 in. (0.037 to 0.101 mm.)
Balancer Weight Drive Gear Bushing-to-Hub Clearance .....	0.0020 to 0.0039 in. (0.050 to 0.100 mm.)
Bushing-to-Balancer Weight Interference Fit .....	0.0016 to 0.0039 in. (0.040 to 0.100 mm.)
Balancer Weight Bushing I.D. ....	0.9851 to 0.9867 in. (25.020 to 25.060 mm.)
Balancer Weight Shaft-to-Bushing Clearance .....	0.0008 to 0.0029 in. (0.020 to 0.073 mm.)
Weight Drive Idler Gear Shaft-to-Housing Bore Interference Fit .....	0.0003 to 0.0024 in. (0.007 to 0.061 mm.)
Bushing-to-Weight Drive Idler Gear Interference Fit .....	0.0015 to 0.0039 in. (0.037 to 0.101 mm.)
Weight Drive Idler Gear Bushing I.D. ....	0.9848 to 0.9859 in. (25.013 to 25.040 mm.)
Idler Gear Shaft-to-Bushing Clearance .....	0.0005 to 0.0024 in. (0.013 to 0.061 mm.)
Gear Tooth Backlash .....	0.0031 in. (0.080 mm.)

**FUEL SYSTEM****INJECTION PUMP**

Type	
SSD-327 and SSD-437 .....	Distributor (Rotary) Type
SSD-655 .....	In-line
Pump Rotation (From Drive End)	
SSD-327 and SSD-437 .....	Counterclockwise
SSD-655 .....	Clockwise

**INJECTORS**

Type .....	Three Hole Nozzle
Pressure Setting .....	3200 to 3342 psi. (225 to 235 Kg/cm <sup>2</sup> )

**LIFT PUMP**

Min. Pump Output @ RPM	
SSD-327 and SSD-437 .....	22 gal./hr. (100 L./hr.) @ 1600 RPM
Delivery Pressure	
SSD-655 .....	21.3 psi. (1.5 Kg/cm <sup>2</sup> ) @ 600 RPM

**AUTOMATIC ADVANCE VARIATOR (SSD-655)**

Type .....	Flyweight Type
Max. Angular Variation at Max. Governed Speed .....	6° to Pump Shaft

**STARTING SYSTEM****STARTER**

Type .....	Solenoid Actuated Drive Pinion
Engine Cranking Speed @ 70°F (20°C) .....	155 RPM
Pinion and Gear Ratio .....	12.125 to 1
Current Draw	
Under Normal Load .....	550 amps ± 50 amps
No Load .....	70 amps ± 10 amps

**DRIVE BELTS****BELT TENSION**

New .....	120 to 150 Lbs. (533 to 667 N.)
Used (In Operation 10 Minutes or More) .....	90 to 120 Lbs. (400 to 533 N.)

**TORQUE DATA****SPECIAL APPLICATIONS**

Description	Thread Size	Torque Ft.-lb.	Torque N·m
Balancer Retaining Bolts	M-12 x 1.25	110	150
Connecting Rod Cap Bolts	M-12 x 1.25	81	110
Crankshaft Pulley Bolts	—	36	50
Crankshaft Pulley Hub Nut	M-30 x 1.5	220	300
Cylinder Head Bolts (Cold Only)	M-12 x 1.25	110	150
Fan Hub Bolts	—	17	23
Flywheel Bolts	M-12 x 1.25	88	120
Injector Retaining Nuts	M-8	17	23
Main Bearing Cap Bolts	M-14 x 1.5	110	150
Oil Pressure Valve Body	M-24 x 1.5	51	70
Oil Pump Body Bolts	M-8	17	23
Oil Pump Cover Bolts	M-8	17	23
Rocker Arm Shaft Bracket Bolts	M-8	17	23
Rocker Arm Shaft Bracket Stud Nuts	M-8	17	23
Timing Gear Case and Cover Bolts	M-8	17	23

**GENERAL APPLICATIONS**

Metric Thread Size	Torque Ft.-lb.	Torque N·m
M-6	6-9	8-12
M-8	14-21	19-28
M-10	28-40	38-54
M-12	50-71	68-96
M-14	80-114	108-155

U.S. Thread Size	Torque Ft.-lb.	Torque N·m
1/4-20	6-9	8-12
5/16-18	12-18	16-24
5/16-24	14-20	19-27
3/8-16	22-32	30-43
3/8-24	27-38	37-52
7/16-14	40-55	55-75
7/16-20	40-60	55-81
1/2-13	55-80	75-108

Pipe Thread Size	Torque Ft.-lb.	Torque N·m
1/8	5-8	7-11
1/4	12-18	16-24
3/8	22-33	30-45
1/2	25-35	34-47