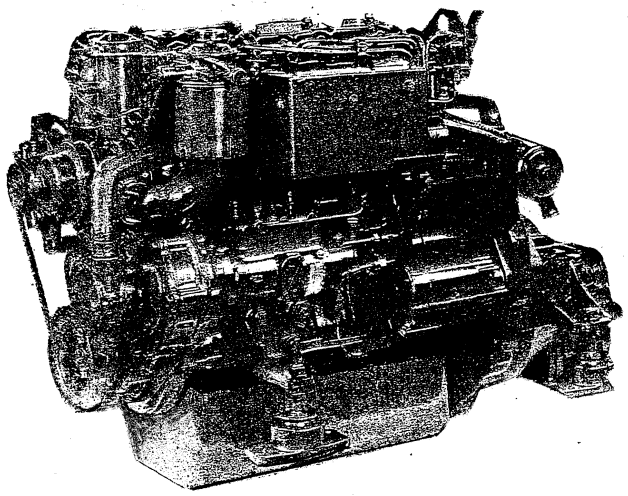
SERVICE MANUAL

W-46 MARINE DIESEL ENGINE

AND

15/12 BTD MARINE DIESEL GENERATOR

SINGLE AND THREE PHASE



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WESTERBEKE

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⚠ WARNING

Exhaust gasses contain Carbon Monoxide, an odorless and colorless gas. Carbon Monoxide is poisonous and can cause unconsciousness and death. Symptoms of Carbon Monoxide exposure can include:

- ***Dizziness***
- ***Nausea***
- ***Headache***
- ***Weakness and Sleepiness***
- ***Throbbing in Temples***
- ***Muscular Twitching***
- ***Vomiting***
- ***Inability to Think Coherently***

IF YOU OR ANYONE ELSE EXPERIENCE ANY OF THESE SYMPTOMS, GET OUT INTO THE FRESH AIR IMMEDIATELY. If symptoms persist, seek medical attention. Shut down the unit and do not restart until it has been inspected and repaired.

A WARNING DECAL is provided by WESTERBEKE and should be fixed to a bulkhead near your engine or generator.

WESTERBEKE also recommends installing CARBON MONOXIDE DETECTORS in the living/sleeping quarters of your vessel. They are inexpensive and easily obtainable at your local marine store.

CALIFORNIA PROPOSITION 65 WARNING

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

WESTERBEKE
Engines & Generators

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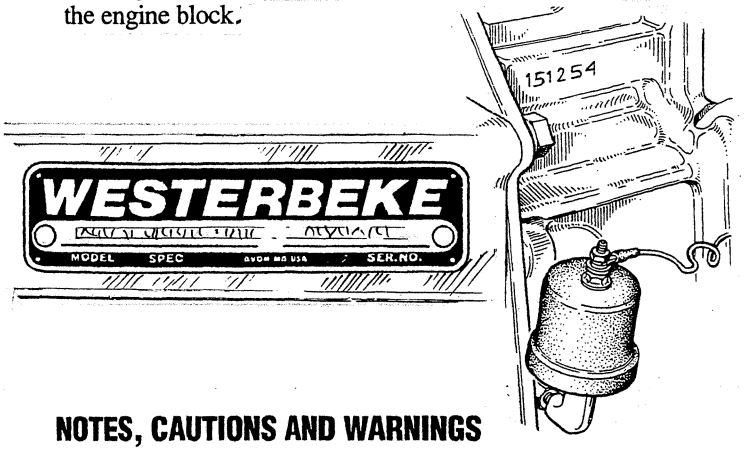
INTRODUCTION

SERIAL NUMBER LOCATION

The engine's model number and serial number are located on a nameplate mounted on the side of the engine's manifold. The engine's serial number can also be found stamped into the engine block.



NOTES, CAUTIONS AND WARNINGS

As this manual takes you through the disassembly, inspection and assembly procedure of your engine/generator, critical information will be highlighted by NOTES, CAUTIONS, and WARNINGS. An explanation follows:

NOTE: *An operating procedure essential to note.*

⚠ CAUTION: ***Procedures, which if not strictly observed, can result in the damage or destruction of your engine/generator.***

⚠ WARNING: ***Procedures, which if not properly followed, can result in personal injury or loss of life.***

ORDERING PARTS

Whenever replacement parts are needed, always provide the generator model number, engine serial number, and generator serial number as they appear on the silver and black name-plate located on the generator end. You must provide us with this information so we may properly identify your engine/generator. In addition, include a complete part description and part number for each part needed (see the separately furnished Parts List). Also insist upon WESTERBEKE packaged parts because *will fit* or generic parts are frequently not made to the same specifications as original equipment.

RAW WATER COOLING CIRCUIT

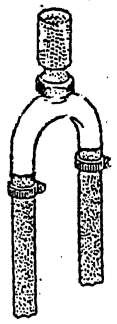
Siphon-Break

For installations where the water injected exhaust elbow is close to or will be below the vessels waterline, provisions **must** be made to install a siphon-break in the raw water supply hose to the water injected exhaust elbow. The siphon-break provides an air vent in the raw water cooling system to prevent raw water from filling the exhaust system and the engine's cylinders when the engine is shutdown.

If you have any doubt about the position of the water-injected exhaust elbow relative to the vessels waterline under the vessels various operating conditions, ***install a siphon-break.*** This precaution is necessary to protect your engine.

The siphon-break must be installed in the highest point of a hose that is looped a minimum of 20 inches (51cm) above the vessels waterline. This siphon-break **must always** be above the waterline during all angles of vessel operation to prevent siphoning.

NOTE: *A siphon-break requires periodic inspection and cleaning to ensure proper operation. Failure to properly maintain a siphon-break can result in catastrophic engine damage. Consult the siphon-break manufacturer for proper maintenance.*



SIPHON-BREAK WITH STAINLESS LOOP FOR 1" HOSE PART NO.044010

ENGINE OVERHAUL

The following sections contain detailed information relating to the proper operation characteristics of the major components and systems of the engine. Included are disassembly, inspection and reassembly instructions for the guidance of suitable equipped and staffed marine engine service and rebuilding facilities. The necessary procedures should be taken only by such facilities.

Additional detailed information and specifications are provided in other sections of this manual, covering the generator, alternator, starter motor, engine adjustments, cooling pumps, etc.

TESTING FOR OVERHAUL

HOW TO DETERMINE ENGINE OVERHAUL PERIOD

Cause of Low Compression

Generally, the time at which an engine should be overhauled is determined by various conditions such as lowered engine power output, decreased compression pressure, and increased fuel and oil consumption. The lowered engine power output is not necessarily due to trouble with the engine itself, but is sometimes caused by injector nozzle wear or injection pump wear. The decrease in compression pressure is caused by many factors. It is, therefore, necessary to determine a cause or causes on the basis of data produced by periodic inspection and maintenance. Oil analysis on a seasonal basis is a good means of monitoring engine internal wear. When caused by worn cylinders or piston rings, the following symptoms will occur:

1. **Low engine power output**
2. **Increased fuel consumption**
3. **Increased oil consumption**
4. **Hard engine starting**
5. **Noisy engine operation**

These symptoms often appear together. Symptoms 2 and 4 can result also from excessive fuel injection, improper injection timing, and wear of the injectors. They are caused also by defective electrical devices such as the battery, alternator, starter and glow plugs. Therefore it is desirable to judge the optimum engine overhaul time by the lowered compression pressure caused by worn cylinders and pistons plus increased oil consumption. Satisfactory combustion is obtained only under sufficient compression pressure. If an engine lacks compression pressure, incomplete combustion of fuel will take place even if other parts of the engine are operating properly. To determine the period of engine overhaul, it is important to measure the engine compression pressure regularly. At the same time, the engine speed at which the measurement of compression pressure is made should be checked because the compression pressure varies with engine rpm. The engine rpm can be measured at the front end of the crankshaft.

NOTE: *In case of severe vibrations and detonation noise, the cause may be fuel injector problems, see FUEL INJECTORS. Pool fuel quality, contaminates and loss of positive fuel pressure to the injection pump will result in injector faults.*

NOTE: *Make certain the engines valve clearances are properly adjusted. An incorrect valve clearance can cause symptons that might, incorrectly, suggest an engine overhaul (cylinder misfire, white smoke, noise, etc).*

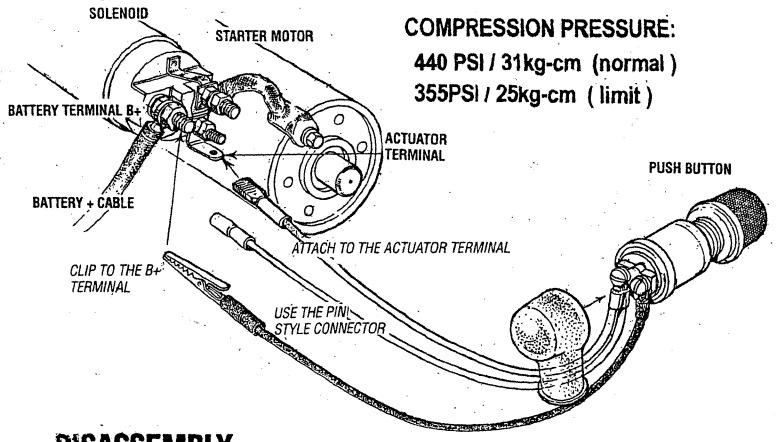
OVERHAUL CONDITIONS

Compression pressure tends to increase a little in a new engine until piston rings and valve seats have been broken in. Thereafter, it decreases gradually with the progress of wear of these parts.

When decrease of compression pressure reaches the repair limit, the engine must be overhauled.

COMPRESSION TEST

When testing compression the Control Panel (generators), or the Instrument Panel (propulsion engine) can be by-passed by connecting an electrical jumper directly to the starter as shown in the illustration below. A jumper can easily be fabricated using wires and a pushbutton.



COMPRESSION PRESSURE:
440 PSI / 31kg-cm (normal)
355PSI / 25kg-cm (limit)

DISASSEMBLY

NOTE: *Before disassembly and cleaning, carefully check for defects which cannot be found after disassembly and cleaning.*

- All disassembled parts should be carefully arranged in order of reassembly. Mark or label the parts as needed to insure proper mating and reassembly in the proper directions and positions.
- If the disassembly procedure is complex requiring many parts to be disassembled, the parts should be disassembled in a way that will allow them to be efficiently reassembled without any change in the engine's external appearance or its performance.
- Do not remove or disassemble the parts that require no disassembly.
- Carefully inspect each part after its removal for damage, deformation, and other problems.
- Carefully check gaskets, packings and oil seals, even if checking is not specified. Replace with new ones if defective.
- Be careful not to damage the disassembled parts. Keep the parts clean.
- Use proper tools. Apply oil when necessary. Take special care to keep the fuel system parts free from the intrusion of dust and dirt.

ASSEMBLY

1. Wash all parts, except for oil seals, O-rings, rubber sheets, etc., with cleaning solvent and dry them with pressure air.
2. Always use tools that are in good condition and be sure you understand how to use them before performing any job.
3. Use only good quality lubricants. Be sure to apply a coat of oil, grease or sealant to parts as specified..
4. Be sure to use a torque wrench to tighten parts for which torques are specified.

ENGINE TROUBLESHOOTING

The following troubleshooting chart describes certain problems relating to engine service, the probable causes of these problems, and the recommendations to overcome these problems.This chart may be of assistance in determining the need for an engine overhaul.

NOTE: *The engine's electrical system is protected by a 20-ampere manual reset circuit breaker. The preheat solenoid is mounted on the same bracket.*

PROBLEM	PROBABLE CAUSE	VERIFICATION/REMEDY
HARD STARTING	**LOW CRANKING SPEED**	
	1. Engine oil viscosity too high.	1. Replace engine oil with less viscous oil.
	2. Run-down battery.	2. Recharge battery.
	3. Worn battery.	3. Replace battery.
	4. Battery terminals loosely connected.	4. Clean terminals and correct cables.
	5. Defective starter.	5. Repair or replace starter.
	DEFECTIVE INJECTION SYSTEM	
	1. Air trapped in fuel passage.	1. Bleed air from fuel system.
	2. Clogged fuel filter.	2. Clean or replace filter.
	3. Low injection pressure.	3. Adjust injection pressure.
	4. Inadequate spray.	4. Clean or replace nozzle.
	5. Injection pump delivering insufficient fuel.	5. Repair or replace injection pump.
	6. Injection too early.	6. Adjust injection timing.
	MAIN ENGINE TROUBLES	
	1. Low compression.	
	a. Incorrect valve clearance.	a. Adjust valve clearance.
	b. Inadequate contact of valve seat.	b. Lap valve.
	c. Valve stem seized.	c. Replace valve and valve guide.
	d. Broken valve spring.	d. Replace valve spring.
	e. Compression leaks through cylinder head gasket.	e. Replace gasket.
	f. Piston ring seized.	f. Replace piston and piston ring.
	g. Worn piston ring and cylinder.	g. Overhaul engine.
	2. Burnt glow plug.	2. Replace glow plug.
	3. Faulty glow plug operation.	3. Check preheat circuit.
	4. Incorrect governor lever position.	4. Set lever to starting position.
	5. Governor spring out of POSITION	5. Correct spring
LOW OUTPUT	**LOW COMPRESSION**	**See *HARD STARTING***
	INJECTION SYSTEM OUT OF ADJUSTMENT	
	1. Incorrect injection timing.	1. Adjust injection timing.
	2. Insufficient injection.	2. Repair or replace injection pump.
	3. Low injection pressure.	3. Check injection nozzle and adjust pressure.
	INSUFFICIENT FUEL	
	1. Air trapped in fuel system.	1. Check and retighten connector.
	2. Clogged filter.	2. Clean or replace filter.
	3. Contaminated fuel tank.	3. Clean tank.
	INSUFFICIENT INTAKE AIR	
	1. Clogged air cleaner.	1. Clean or replace air cleaner.

(continued)

ENGINE TROUBLESHOOTING

PROBLEM	PROBABLE CAUSE	VERIFICATION/REMEDY
LOW OUTPUT *(cont..)*	**OVERHEATING**	
	1. Low coolant level.	**1.** Add coolant.
	2. Loose V-belt.	**2.** Adjust or replace V-belt.
	3. Incorrect injection timing.	**3.** Adjust injection timing.
	4. Low engine oil level.	**6.** Add engine oil.
EXCESSIVE OIL CONSUMPTION	**OIL LEAKAGE**	
	1. Defective oil seals.	**1.** Replace oil seals.
	2. Broken gear case gasket.	**2.** Replace gasket.
	3. Loose gear case attaching bolts.	**3.** Retighten bolts.
	4. Loose drain plug.	**4.** Retighten plug.
	5. Broken rocker cover gasket.	**5.** Replace gasket.
	6. Loose rocker cover attaching bolts.	**6.** Retighten attaching bolts.
	OIL LEVEL RISING	
	1. Leaking injection pump.	**1.** Repair pump plungers.
	2. Bent or twisted connecting rod.	**2.** Replace connecting rod.
	3. Worn piston ring.	**3.** Replace ring.
	4. Worn piston or cylinder.	**4.** Replace piston and rebore cylinder.
	OIL LEVEL FALLING	
	1. Defective stem seal.	**1.** Replace stem seal.
	2. Worn valve and valve guide.	**4.** Replace a valve and valve guide.
EXCESSIVE FUEL CONSUMPTION	**ENGINE BODY TROUBLES**	
	1. Noisy knocking.	**1.** See *KNOCKING.*
	2. Smoky exhaust.	**2.** See *SMOKY EXHAUST.*
	3. Moving parts nearly seized or excessively worn.	**3.** Repair or replace.
	4. Poor compression.	**4.** See *LOW COMPRESSION; HARD STARTING.*
	5. Improper valve timing.	**5.** Adjust.
	6. Improper valve clearance.	**6.** Adjust.
	INSUFFICIENT INTAKE AIR	
	1. Air intake obstructed.	**1.** Remove obstruction.
	NOZZLE TROUBLES	
	1. Seized nozzle.	**1.** Replace.
	2. Worn nozzle.	**2.** Replace.
	IMPROPER FUEL	Replace with proper fuel (Cetane #45 or better).
	FUEL LEAKS	Find fuel leaks.
SMOKY EXHAUST	**WHITISH OR PURPLISH**	
	1. Excessive engine oil.	**1.** Correct oil level.
	2. Excessive rise of oil into combustion chamber.	
	a. Poor piston contact.	**a.** Check.
	b. Seized piston ring.	**b.** Replace or clean.
	c. Excessive piston-to-cylinder clearance.	**c.** Replace or correct.

(continued)

ENGINE TROUBLESHOOTING

PROBLEM	PROBABLE CAUSE	VERIFICATION/REMEDY
SMOKY EXHAUST *(cont.*	**WHITISH OR PURPLISH *(cont.***	
	d. Worn valve stem and valve guide.	**d.** Replace.
	e. Low engine oil viscosity.	**e.** Replace.
	f. Excessive oil pressure.	**f.** Correct.
	3. Injection timing is too late.	**3.** Adjust.
	4. Insufficient compression.	**4.** See *LOW COMPRESSION; HARD STARTING.*
	BLACKISH OR DARK GRAYISH	
	1. Engine body troubles.	
	a. Poor compression.	**a.** See *LOW COMPRESSION; HARD STARTING.*
	b. Improper valve clearance.	**b.** Adjust.
	2. Insufficient intake air (air cleaner clogged).	**2.** Clean air cleaner.
	3. Improper fuel.	**3.** Replace with proper fuel.
ABNORMAL SOUND OR NOISE	**CRANKSHAFT AND MAIN BEARING**	
	1. Badly worn bearing.	**1.** Replace bearing and grind crankshaft.
	2. Badly worn crankshaft.	**2.** Grind crankshaft.
	3. Melted bearing.	**3.** Replace bearing and check lubrication system.
	CONNECTING ROD AND CONNECTING ROD BEARING	
	1. Worn connecting rod big end bearing.	**1.** Replace bearing.
	2. Worn crankpin.	**2.** Grind crankshaft.
	3. Bent connecting rod.	**3.** Correct bend or replace.
	PISTON, PISTON PIN, AND PISTON RING	
	1. Worn cylinder.	**1.** Rebore cylinder to oversize and replace piston.
	2. Worn piston pin.	**2.** Replace piston.
	3. Piston seized.	**3.** Replace piston and rebore cylinder.
	4. Piston seized and ring worn or damaged.	**4.** Replace piston and rings.
	VALVE MECHANISM	
	1. Worn camshaft.	**1.** Replace.
	2. Excessive valve clearance.	**2.** Adjust.
	3. Worn timing gear.	**3.** Replace.
	4. Worn fan pulley bearing.	**4.** Replace.
ROUGH OPERATION	**INJECTION PUMP SYSTEM**	
	1. Uneven injection.	**1.** Adjust injection or replace parts.
	2. Control rack malfunctioning.	**2.** Disassemble, check and correct injection pump.
	3. Worn delivery valve.	**3.** Replace.
	4. Inadequate injection nozzle spray.	**4.** Replace injection nozzle.
	GOVERNING SYSTEM	
	1. Governor lever malfunctioning.	**1.** Check governor shaft and correct operation.
	2. Fatigued governor spring.	**2.** Replace.

(continued)

ENGINE TROUBLESHOOTING

PROBLEM	PROBABLE CAUSE	VERIFICATION/REMEDY
KNOCKING	**ENGINE KNOCKS WITHOUT MUCH SMOKE**	
	1. Main engine troubles.	
	a. Overheated cylinder.	a. See *OVERHEATING; LOW OUTPUT.*
	b. Carbon deposits in cylinder.	b. Clean.
	2. Too early injection timing.	2. Correct.
	3. Too high injection pressure.	3. Correct.
	4. Improper fuel.	4. Replace with proper fuel.
	KNOCKING WITH DARK SMOKE	
	1. Poor compression.	1. See *LOW COMPRESSION; HARD STARTING.*
	2. Injection pump malfunctioning.	
	a. Worn plunger.	a. Replace.
	b. Pinion is not in mesh with control rack.	b. Correct.
	c. Broken delivery valve spring.	c. Replace.
	d. Worn delivery valve seat.	d. Replace.
	3. Improper nozzle.	
	a. Poor spray.	a. Clean or replace nozzle.
	b. Poor chattering.	b. Repair or replace nozzle.
	c. After-injection drip.	c. Repair or replace nozzle.
	d. Nozzle needle valve seized.	d. Replace.
INTERMITTENT EXHAUST SOUND	1. Fuel filter clogged.	1. Clean or replace.
	2. Fuel pipe sucks air.	2. Retighten pipe joints or replace pipe.
	3. Water mixed in fuel	3. Replace fuel.
OVERHEATING	1. V-belt slackening or slippery with oil.	1. Adjust, replace or clean.
	2. Damaged water pump.	2. Replace.
	3. Lack of coolant.	3. Add.
	4. Low oil level or poor oil quality.	4. Add or change.
	5. Knocking.	5. See *KNOCKING.*
	6. Moving parts seized or damaged.	6. Replace.
	7. Defective thermostat.	7. Replace.
LOW OIL PRESSURE	1. Worn Bearings.	1. Engine overhaul replace bearings.
	2. Relief valve malfunction.	2. Overhaul oil pump.
	3. Clogged oil cooler.	3. Repair.
	4. Diesel dilution of the oil.	4. Injection pump repair.

ENGINE DISASSEMBLY

DESCRIPTION

Switch off the batteries and disconnect the battery cables from the engine and tape over the terminals.

Drain or pump out all the engine oil and drain the coolant from the engine and engine hoses.

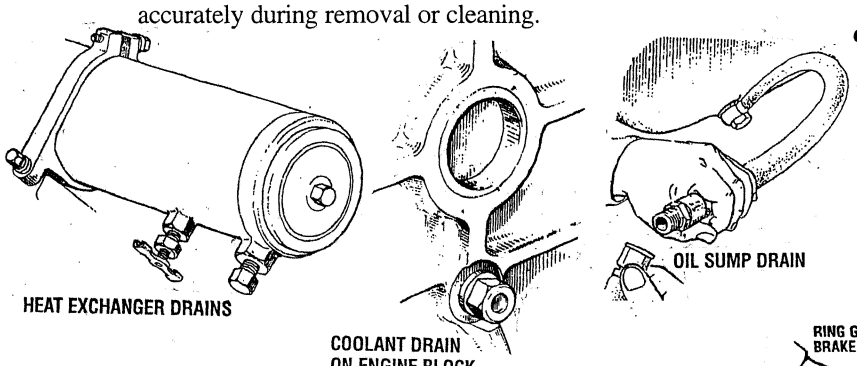
Unplug the instrumental panel wiring harness. Drain the transmission fluid and the transmission oil cooler hoses. Detach the oil cooler hoses and unbolt the transmission from the engine.

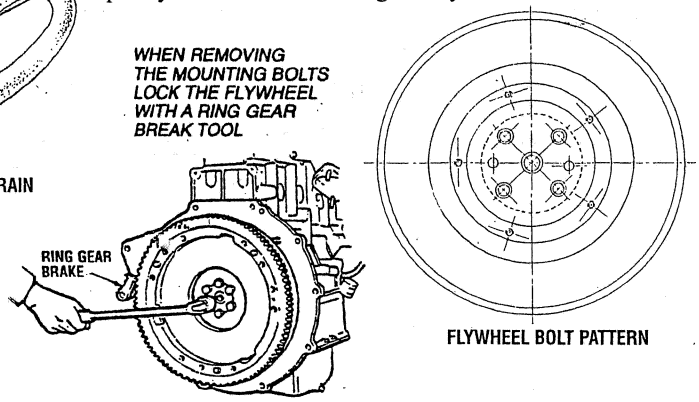
NOTE: *Label any lines, hoses or cables as you separate them.*

- Clean the exterior of the engine of any deposits of dirt and oil.
- Be careful not to damage the disassembled parts.
- Mount the engine on a suitable engine stand for disassembly.
- Pay attention to marks on assemblies, components and parts for their positions or directions. Put on marks, if necessary, to aid assembly.
- Carefully check each part or component for any sign of faulty condition during removal or cleaning. The part will tell you how it acted or what was abnormal about it more accurately during removal or cleaning.

DISASSEMBLY

1. **Remove the engine oil hose connections.**
2. **Remove the engine heat exchanger.** If possible, leave one end of each hose connected to the part being removed.
3. **Remove the engine back plate.**
4. **Remove the start motor, drive belt and the alternator.** Label the wires and cables.
5. **Remove the engine mounted raw water pump, adapter mounting plate, and drive from the front cover.** The drive is removed by turning in a counter clockwise direction. See *RAW WATER PUMP* for parts breakdown.
6. **Remove the coolant recirculating pump** See *COOLANT RECIRCULATING PUMP* for parts breakdown.
7. **Remove the air intake silencer and the intake manifold.**
   - **e.** Remove the alternator, drive belt, support brackets and adjusting strap.
   - **f.** Remove the engine mounted raw water pump and its connecting hoses. Refer to the raw water pump in this manual.
   - **e.** Remove the flywheel. Loosen the front crankshaft pulley nut before removing the flywheel.



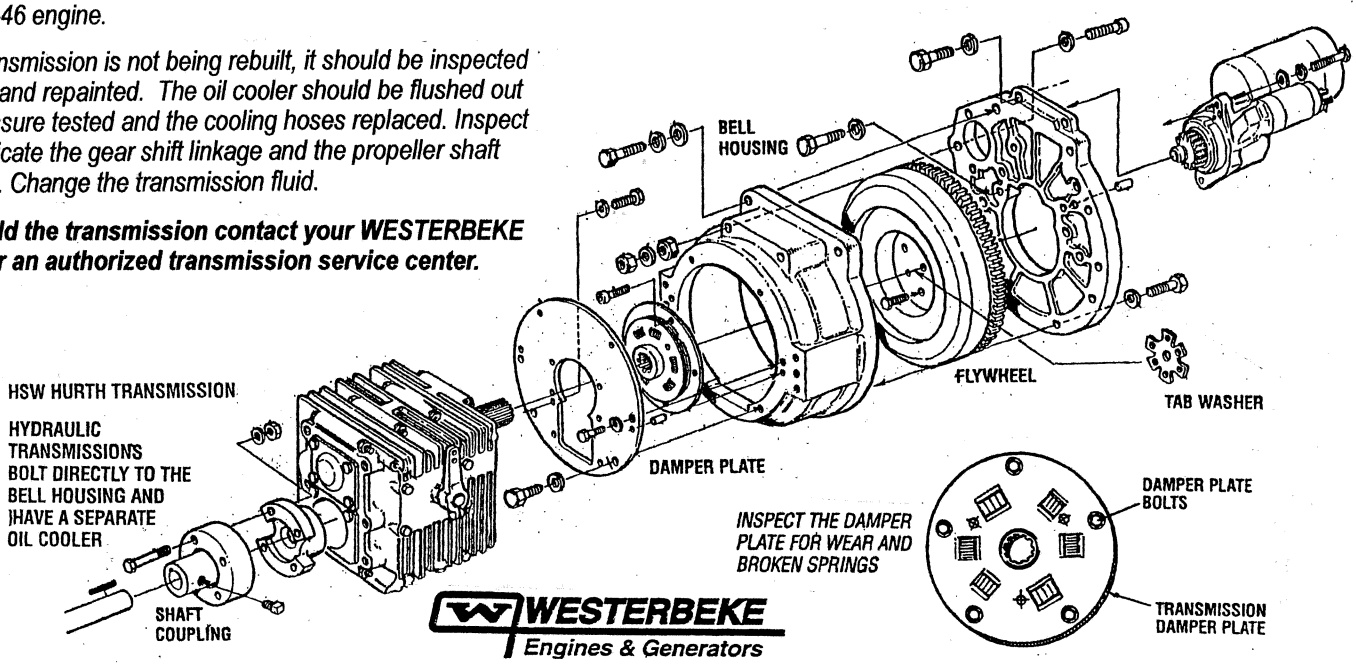


TRANSMISSIONS

The transmission section of this manual contains general information and specifications for the transmissions used in the W-46 engine.

If the transmission is not being rebuilt, it should be inspected cleaned and repainted. The oil cooler should be flushed out and pressure tested and the cooling hoses replaced. Inspect and lubricate the gear shift linkage and the propeller shaft coupling. Change the transmission fluid.

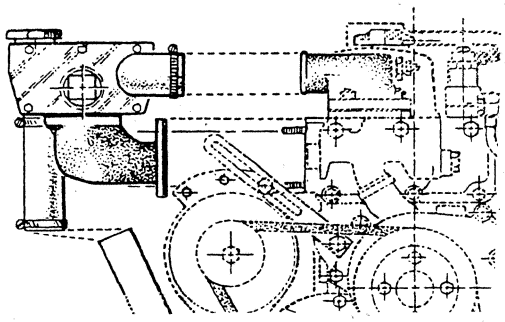
To rebuild the transmission contact your WESTERBEKE dealer or an authorized transmission service center.



8. **With the hoses disconnected, remove the thermostat housing and housing gasket**, leaving the temperature sender in place.
9. **Remove the coolant circulating pump.** Refer to *COOLANT PUMP ASSEMBLY.*
10. **Remove the air intake silencer and the intake manifold.**
11. **Remove the oil filter and the mounting bracket from the engine block.**
12. **Unbolt the elbows and remove the exhaust manifold in its entirety.**

    Remove the exhaust manifold/expansion tank in its entirety. Disassemble separately, clean all surfaces, install new gaskets when assembling. Use good quality gasket cement.

    NOTE: *Early versions were an assembly, later versions are a cast unit. (Cast units are only available today).*

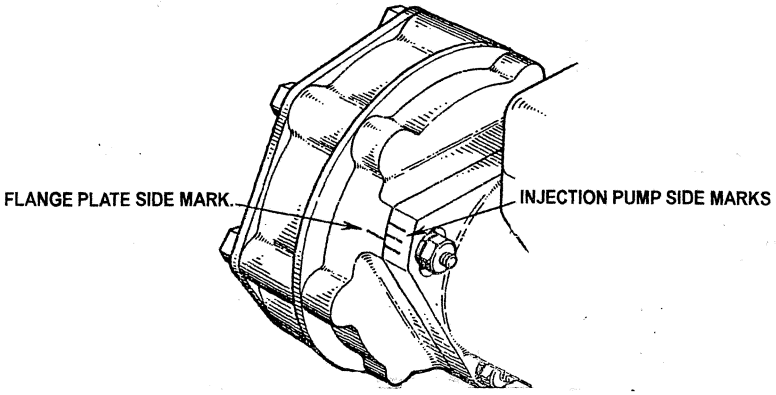


14. **Remove the engine mounted fuel filter with electric fuel lift pump and related lines.**

    NOTE: *The positions of the sealing washers that attach fuel lines to the fuel filter, the injection pump and the electric fuel pump.*
15. **Remove the fuel injection pump.**

    Disconnect the fuel injection pipes and fuel leak-off pipe from the fuel injection pump and nozzles.

    NOTE: *Put plugs or caps on the openings of the injection pump and nozzle connectors. Golf tees work well as plugs.*
16. **Remove the fuel injection nozzles.** Loosen the fuel injection nozzles with a wrench. Remove the nozzles and gaskets from the cylinder head.



Scribe mating marks on the pump body and the timing gear case before removing.

FUEL INJECTION PUMP REMOVAL

Early model injection pumps (DTAJ394-2F4-90) had tapered drive shafts, each with a woodruff key that fits into the injection pump drive gear and was held in place in the drive gear by a threaded tang used to drive the raw water pump.

1. **Remove drive tang locking plate and unscrew drive tang.**
2. **Manually rotate engine to position keyway in injection pump drive gear/shaft at 12:00.** This is important so that when the injection pump is removed, the woodruff key will not drop down into the front cover.
3. **Remove the fuel supply and return line from the injection pump.**
4. **Loosen the three bolts holding the injection pump to the front cover plate.**

   NOTE: *Inner hold-down bolt for injection pump is removed with a 10mm, flexible, 1/4 inch drive socket.*
5. **Place a soft metal drift punch against the threaded driveshaft end of the injection pump protruding through the drive gear.** With a hammer, give the drift punch a sharp blow. The should dislodge the pump from the drive gear.
6. **Remove the injection pump hold-down bolts and carefully so as not to drop the drive shaft woodruff key into the cover and withdraw the injection pump.**

   NOTE: *Although the drive gear will appear very loose in its position, it will not change mesh with its drive idle gear.*

Later Models DPAJ3942F580 OR 581

Later style injection pumps each have a splined drive shaft with a master spline. The drive gear has a dash mark on the front indicating which splines must engage the master spline on the drive shaft, ensuring the injection pump is in the correct timing sequence with the engine.

1. **Remove the three bolts that hold the injection pump onto the front cover plate and remove the pump from the engine.**

   NOTE: *When reinstalling the injection pump, the drive tang plate bolted to the front of the drive gear must be removed to expose the dash mark that indicates the splines which mate with the master spline on the injection pump drive shaft when reinstalling the shaft in the drive gear.*
2. **Removal of the fuel injectors.**
   a. Remove the fuel return line from the top of the injectors by removing the four 25mm attaching nuts.

   NOTE: *There are sealing washers between the injector return banjos and the injectors, these should be replace on reassembly.*

   b. With a 30mm deep socket unscrew the injectors from the cylinder head.

   c. Remove the copper injector sealing washers from the head once the injectors are removed.These sealing washers should be replaced upon reassembly.

   d. Put the injectors aside for cleaning and rebuilding in shop or by an authorized CAV/BOSH Injection Repair Shop.

ENGINE DISASSEMBLY

Disassemble in the following order:

1. Remove cylinder head rocker cover.

2. Remove the rocker shaft assembly as follows:

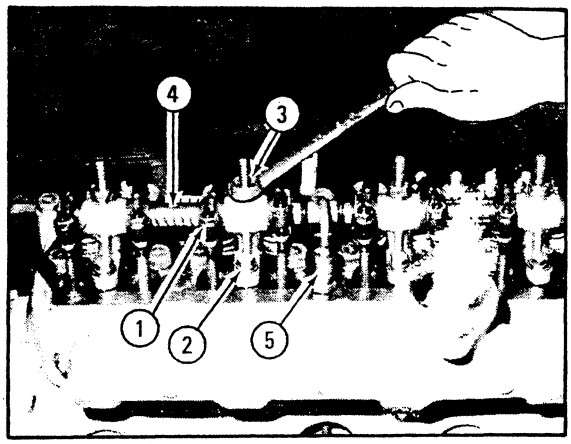
   a. Loosen and remove union nut. (1)

   b. Loosen and remove short bolts (2) and long bolts (3).

   c. Remove rocker shaft assembly (4).

   d. Remove oil pipe (5) and O-rings (2 pcs-to be replaced with new ones).

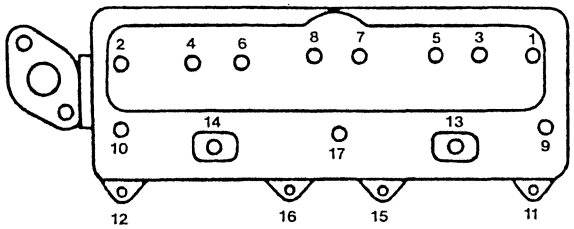
   e. Remove valve push rods and valve caps.



3. Remove the cylinder head assembly as follows:

   a. Loosen cylinder head bolts in reverse order of tightening and remove.

   b. Remove the cylinder head and gasket.

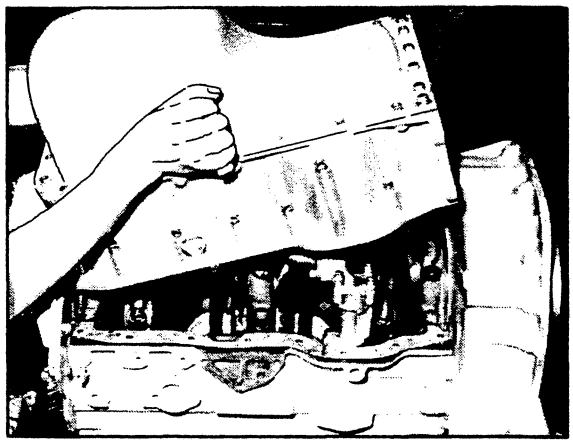


Cylinder Head Bolt Tightening Sequence

4. Remove the oil pan and oil pump assembly as follows:

   a. Loosen and remove attaching bolts and remove oil pan and gasket.

   b. Loosen and remove attaching bolts and remove oil pump assembly.



ENGINE DISASSEMBLY

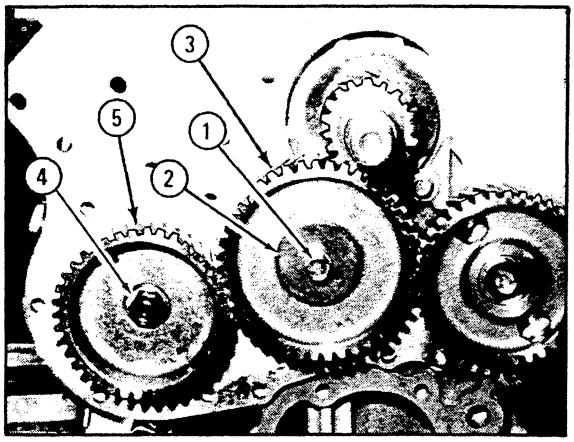
5. Removal of front gear train.

   a. Remove front crankshaft pulley retaining nut and pulley.

   b. Remove timing gear cover. (Early models: Remove injection pump drive gear with cover.)

   c. Remove idler gear retaining bolt (1),
   thrust plate (2),
   idle gear (3), and bushing.

   d. Remove camshaft retaining nut (4), thrust plate and gear (5).

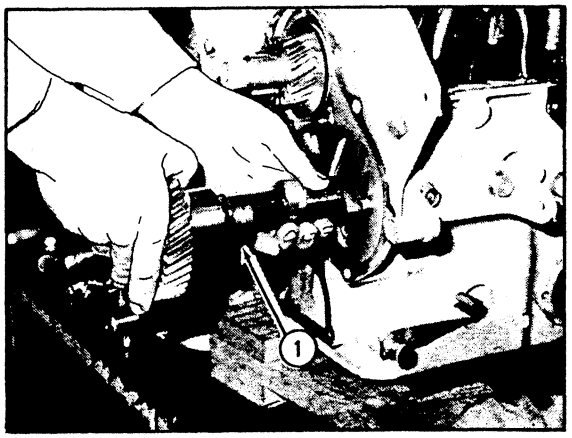


6. Remove the camshaft assembly as follows:

   a. Position engine block so that the cylinder head mounting surface is down.

   b. Carefully withdraw the camshaft (1) from the engine block.

   c. Remove all push rod solid lifters from engine block.

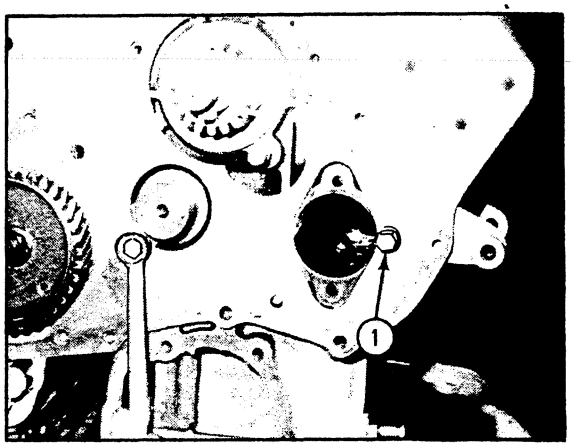


7. Remove the front plate and injection pump assembly as follows:

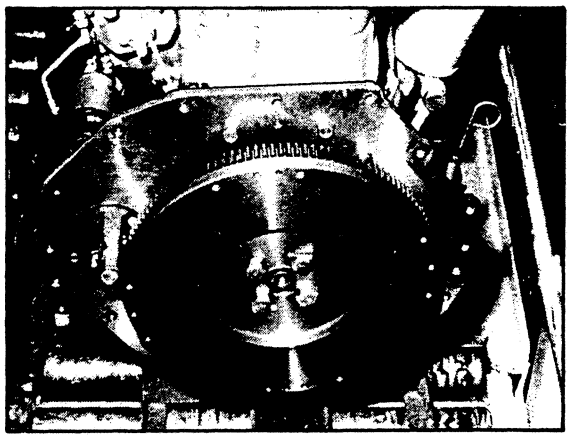
   a. Loosen attaching bolts (1).

   b. Remove front plate.

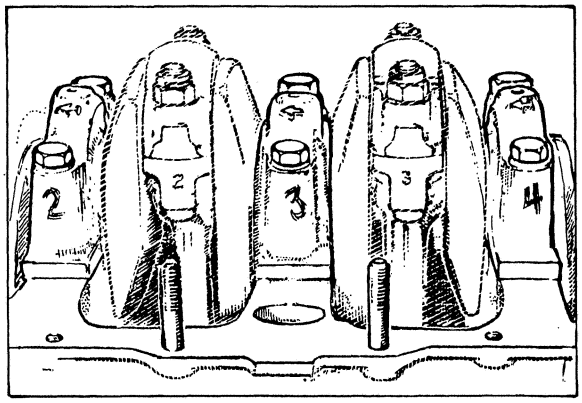
   c. Late models: injection pump drive gear is retained on bearing on front plate; use suitable puller to remove.



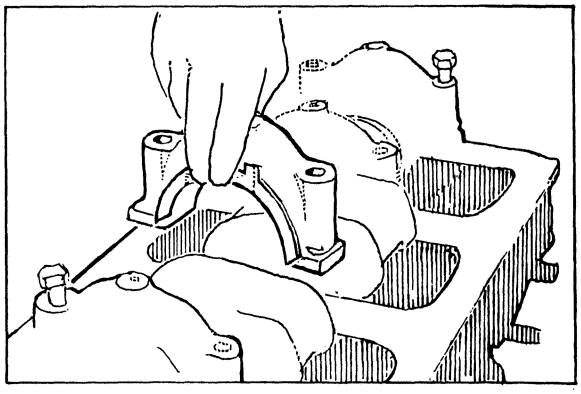
8. Remove the flywheel and back plate.



9. Remove the connecting rod bearing caps and bearings (lower shells) by loosening and removing the attaching bolts. Keep each cap and bearing with respective rod.



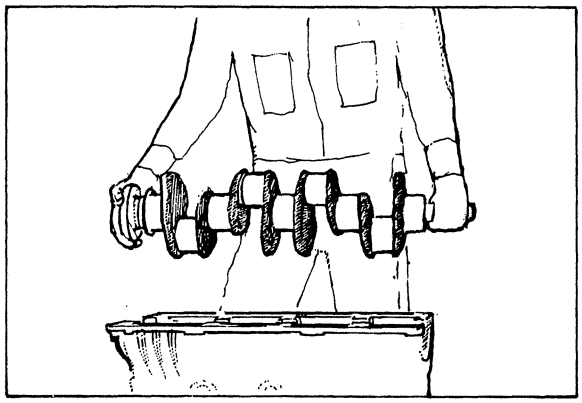
10. Remove the main bearing caps by loosening and removing the attaching bolts.



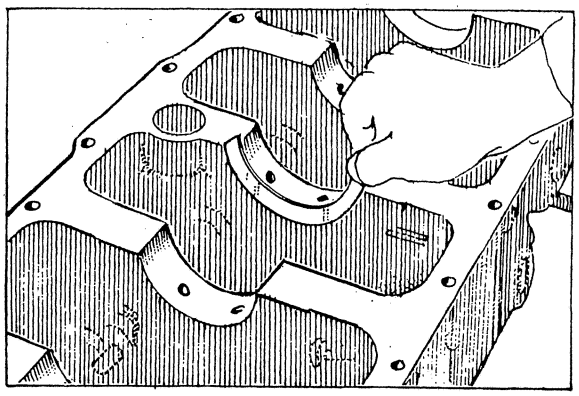
11. Remove the crankshaft.

a. Withdraw each rod and piston assembly from the bottom of the block.

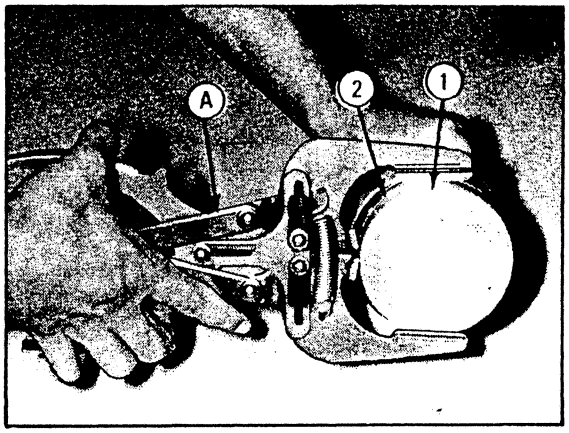
b. Loosely replace the bearing and rod caps. Make sure that each bearing and rod cap is replaced in the exact location from which it was originally removed. Also make sure that the caps are not turned 180° when replaced.



12. Remove the main bearing shells.

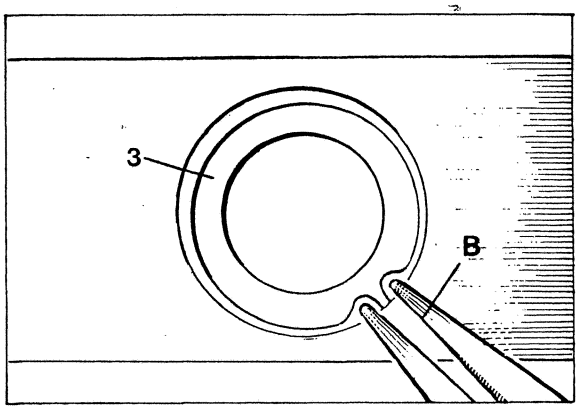


13. Disassembly piston and connecting rod as follows:

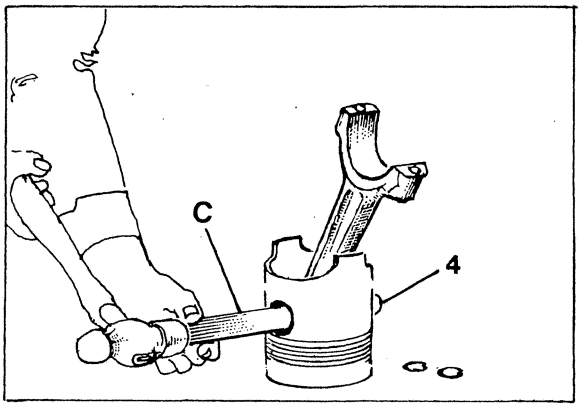


a. Remove compression rings (1) and oil ring by using piston ring tool (A).

b. Remove oil scraper expander spring. (2)



c. Remove snap ring (3) by using snap ring tool (B).



d. Remove piston pin (4) by using drift punch (C).

e. Remove piston pin bushing and connecting rod bearing (upper).

(NOTE: Heating the piston by resting the piston crown down on an electric hot plate will allow for easier removal of the piston pin.)

14. Disassemble the rocker shaft assembly as follows:

    a. Remove snap rings (1) on both ends of each rocker shaft.

    b. Remove rocker assembly.

    c. Remove rocker shaft bracket (2).

    d. Remove rocker assembly, (3)

    e. Remove rocker shaft spring (4),

15. Disassemble the cylinder head as follows:

    a. Remove glow plugs.

DOWN TO. F

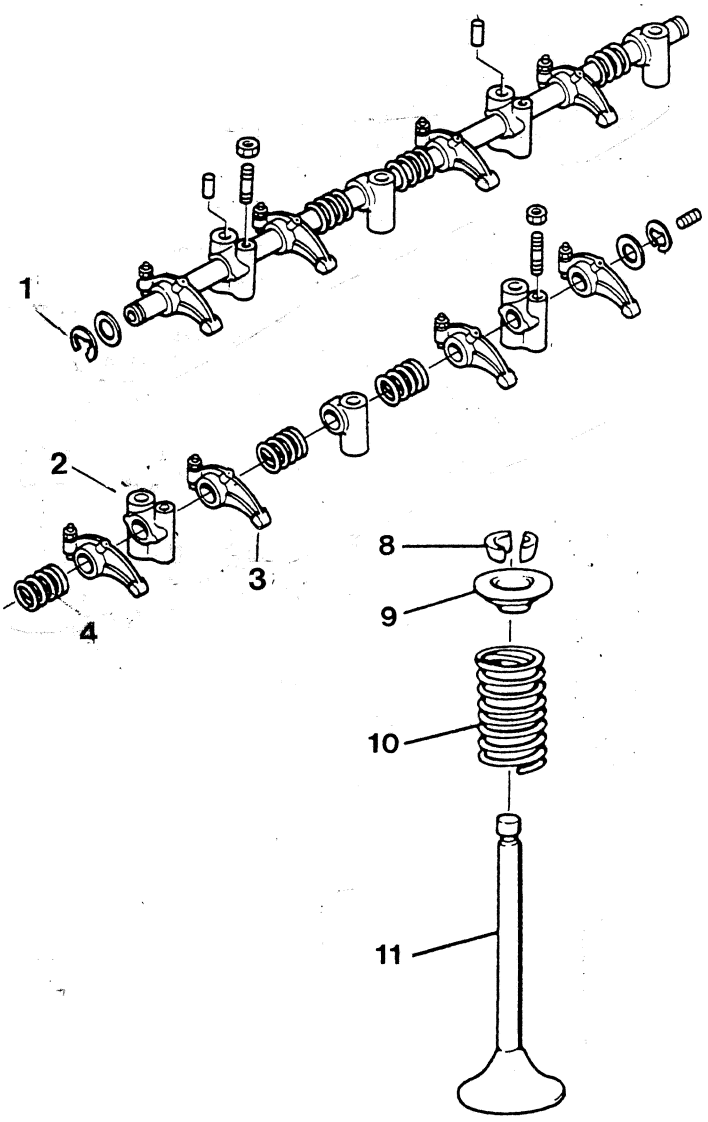
    f. Remove valve cotters (8). (depress valve spring by valve lifter.)

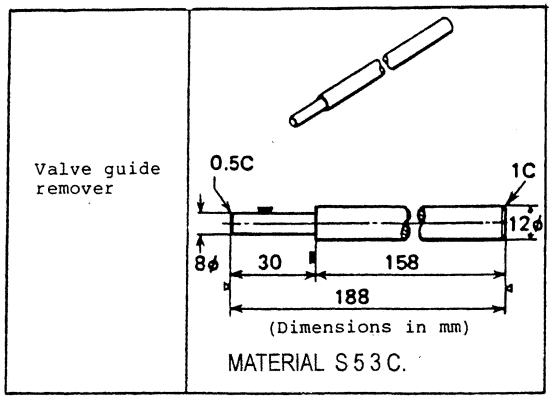
    g. Remove retainer (9).

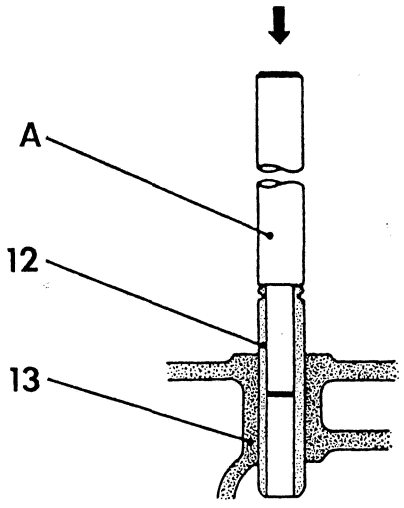
    h. Remove valve spring (10).

    i. Take out valve (11).

    j. Remove valve guide (12) from cylinder head (13) by using remover (A).







CYLINDER HEAD

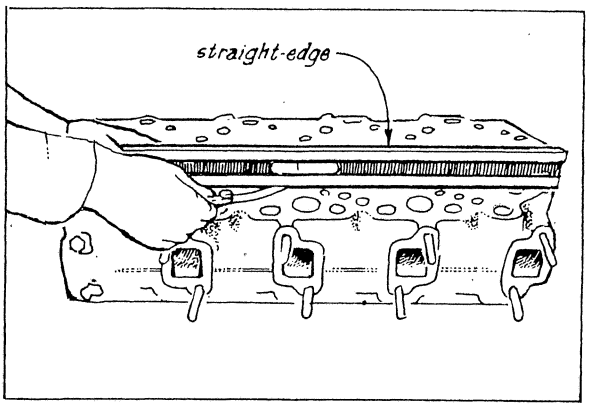
1. Inspection

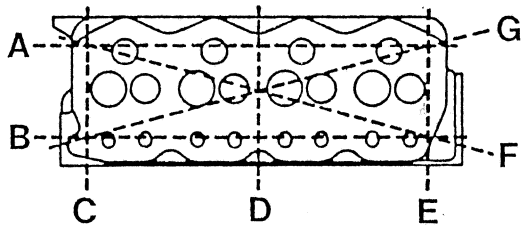
Check the gasketed surface of the cylinder head for flatness by using a straightedge and thickness gauge as in the case of checking the crankcase surfaces. Refer to Crankcase. This check is to be made with the precombustion chamber jets removed.

Use a surface grinder to reface the cylinder head, as necessary, to the specified flatness.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Warpage of gasketed surface of cylinder head	0.05, max (0.0020)	0.2 (0.008)

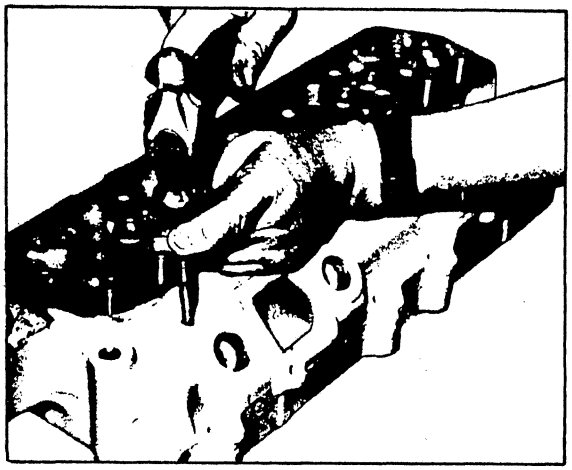




Checking cylinder head gasketed surface for flatness

2. Precombustion Chamber Jet Replacement

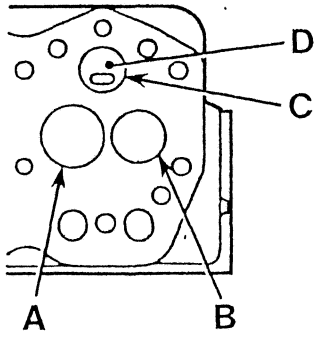
Do not remove the precombustion chamber jets unless their replacement is necessary. To remove the jet (if cracks are noted in it, or if head must be machined to specifications) ease it out by driving with a flat-faced drift pin inserted through the glow plug hole, as shown.



Removing precombustion chamber jet

Before installing the jet, wash the precombustion chamber cavity clean, and drive the jet into position, with its orifice pointing to the center of the cylinder. Calk one portion with a punch.

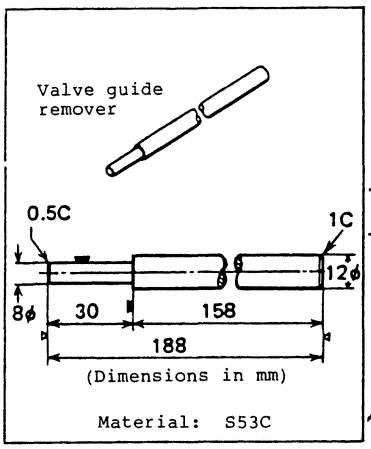
A-Intake port
B-Exhaust port
C-Jet
D-Caulking position



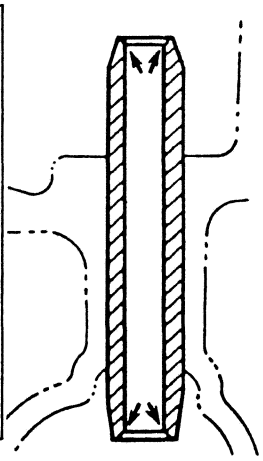
Valve Guides and Valve Seats

1. Check each valve for carboning, burning, wear or other defects on the head; also check cap end and stem for cracks. Replace the valve if damaged.

2. Check each valve guide for wear. Remember, the guide wears more rapidly at the ends. Measure the inside diameter of the guide at each end and at the middle from both directions. Measure the outside diameter of each valve stem. If the measurement exceeds the repair limit given in the table below, replace the valve guide.



Valve guide removal tool



Wear on valve guide

3. Valve face and valve seat.
Check valve face and valve seat for wear and contact. If the valve face is worn excessively, reface it by using a valve refacer. To reface the valve, proceed as follows:

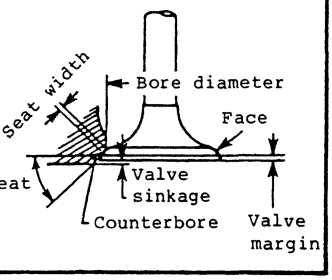
Specifications

Unit: mm (in.)

Item		Standard	Service limit
Clearance of valve stem in valve guide	Intake	0.055~0.085 (0.00217~0.00335)	0.15 (0.0059)
	Exhaust	0.070~0.100 (0.00276~0.00394)	0.20 (0.0079)
Valve guide length outside hole		18 ± 0.3 (0.709 ± 0.012)	
Valve stem diameter	Intake	$8^{-0.045}_{-0.060}$ ($0.315^{-0.00177}_{-0.00236}$)	−0.1 (−0.004)
	Exhaust	$8^{-0.060}_{-0.080}$ ($0.315^{-0.00236}_{-0.00315}$)	−0.15 (−0.0059)

Specifications

Unit: mm (in.)

Item		Nominal value	Standard	Repair limit	Service limit
Valve seat	Angle	30°			
	Sinkage	0.8 (0.031)	±0.2 (±0.008)	1.3 (0.051)	
	Width	1.4 (0.055)	±0.14 (±0.0055)	1.6 (0.063)	
Valve margin		1.7 (0.067)	±0.1 (±0.004)	Reface up to 1.2 (0.047)	

Valve Refacer

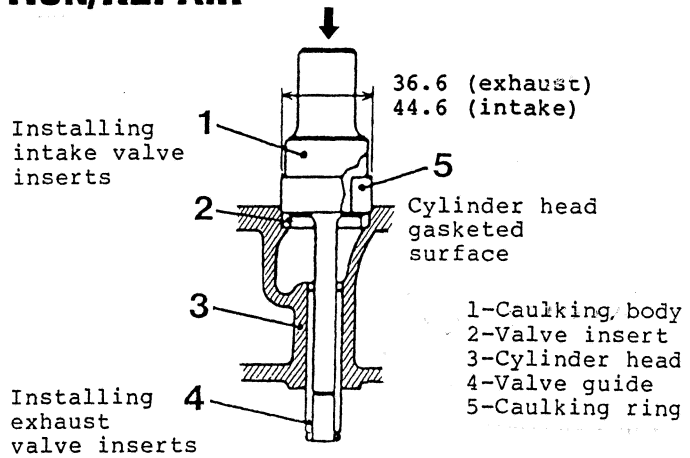
a. Set the valve refacer to an angle of 45 degrees.

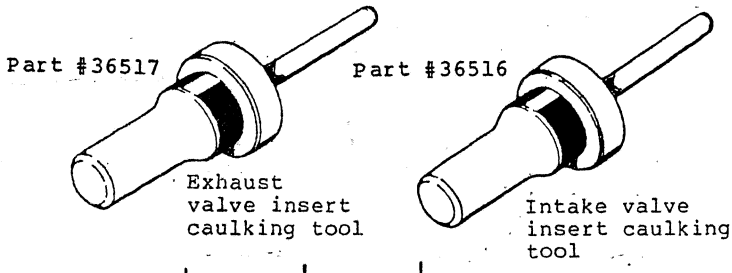
b. When grinding the valve, remove the least amount of material to properly reface the valve and, if the margin is less than 1.2 mm (0.047 in.), replace the valve.

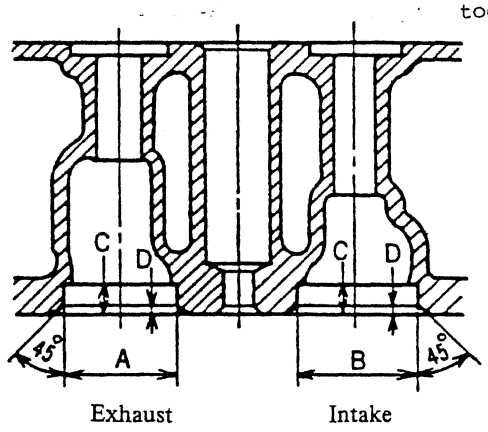
Valve seat cutter.
Repair an excessively worn valve seat by using a valve grinder or valve seat cutter.

c. When using a valve seat cutter, carefully apply a uniform pressure to the valve seat to prevent uneven cutting. After cutting, reface the seat by rotating the cutter with No.400 sandpaper placed between the cutter and seat.

d. If valve seat width is overcut, repair it using a 30 degree cutter. If valve seat width exceeds 1.6 mm (0.063 in.) due to wear, replace the seat. Also replace the seat when valve sinkage exceeds 1.3 mm (0.051 in.).







Valve Seat Installation

Heat cylinder head to a temperature of 80°C to 100°C (176°F to 212°F), and cool the valve seat sufficiently in ether or alcohol containing dry ice. Valve seat may be cooled in liquid nitrogen.

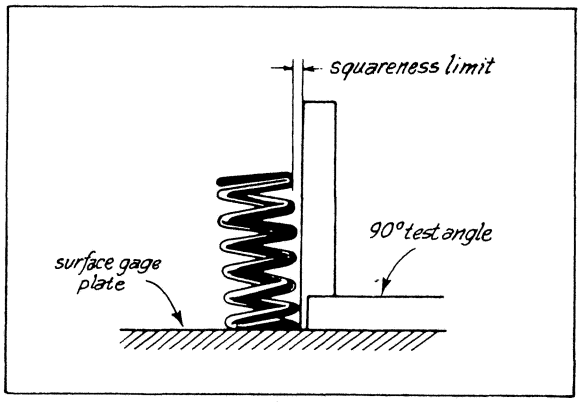
Press the valve seat into cylinder head and leave the head and seat until they cool down to room temperature.

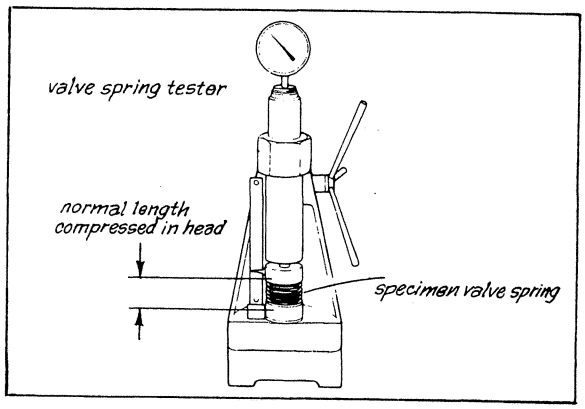
Specifications Unit: mm (in.)

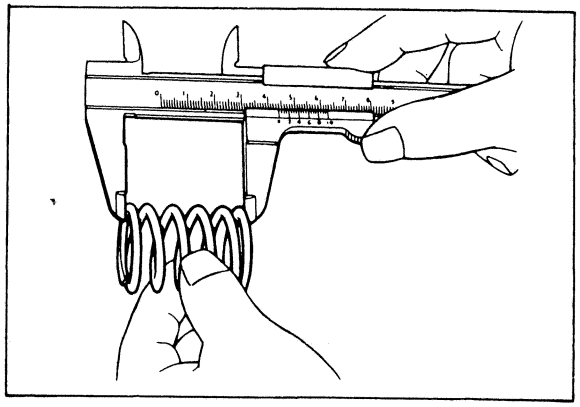
	A	B	C	D
Valve seat dimensions	$33^{+0.02}_{0}$ ($1.30^{+0.0008}_{0}$)	$41^{+0.025}_{0}$ ($1.61^{+0.00098}_{0}$)	7.8 ± 0.1 (0.307 ± 0.004)	2.8 ± 0.1 (0.11 ± 0.004)

Valve Springs

Inspect each spring for cracks, and check it for squareness, free length and as-installed length against these specifications.







SPECIFICATIONS

Unit: mm (in)

Item	Standard	Repair Limit
Valve Spring Free Length (outer)	48.85 (1.9232)	47.6 (1.874)
Valve Spring Free Length (inner)	40.90 (1.60)	39.65 (1.55)
Valve Spring Squareness	0.4/25 (0.016/0.98) max	
Load compress spring to initial working length 43 mm (1.69 in) kg(lb)	19 ± 1 (41.9 ± 2.21)	15 (33.08)

Cylinder Sleeves

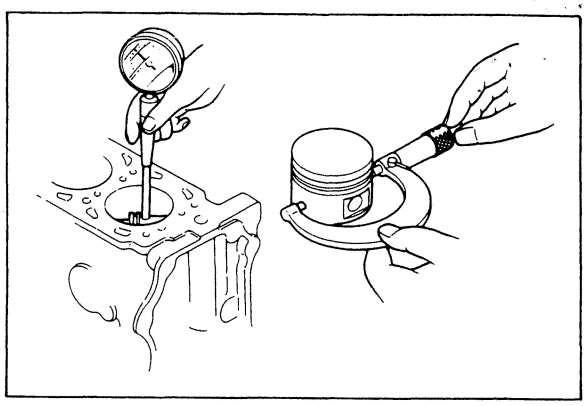
1. Using a cylinder gauge, take ID measurements in two directions (parallel and transverse to the crankshaft axis) on each cylinder sleeve at the three locations indicated below.

   If wear reaches the repair limit, rebore the sleeve to the next specified oversize.

Specifications

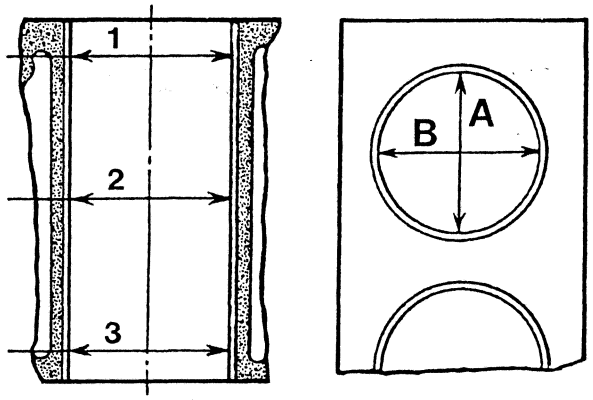
Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Cylinder sleeve ID	$84\,^{+0.035}_{0}$ ($3.307\,^{+0.00138}_{0}$)	+0.20 (+0.008)	0.7 (0.028)
Out of roundness	0.015 (0.00059), max		
Taper	0.05 (0.0020), max		



NOTE: Cylinder sleeve installed must be flush with, the block surface.

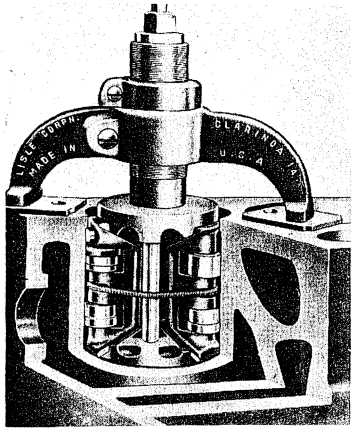
Crankcase gasketed surface



Positions for checking sleeve bore diameter

2. Two oversizes are provided for: +0.25 and +0.5 mm(0.00984 and 0.01969 in.). After reboring, be sure to hone the bore to the specified oversize accurately within plus 0.035mm (0.00138 in.) or minus 0 mm. Machining the bores of all four sleeves to the same oversize is recommended (Pistons and piston rings are available for the two oversizes).

3. If any sleeve bore is unevenly worn, determine the oversize which the sleeve is to be rebored on the basis of the maximum wear noted. This will ensure perfect roundness in the oversize bore.

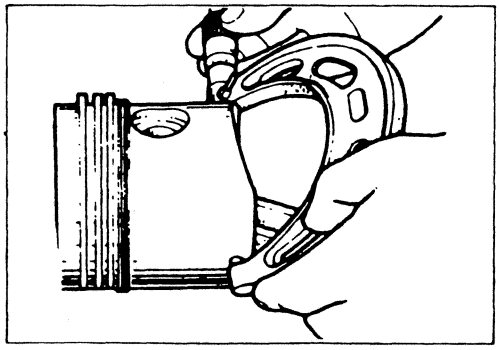


Removing ridge with ridge reamer

(NOTE: If the cylinder sleeves are found in good condition with the wear far less than the repair limit, it is permissible to rebuild the engine with replacement piston rings. In these cases, be sure to ream off the ridge and, as necessary, hone the bore to remove any glossy surface.)

Pistons and Piston Rings

1. Pistons
   Inspect each piston for any abnormal wear of its sliding surface; cracks at the crown and evidence of melting or fusion. Examine the ring grooves for stepped wear and sloped wear. Replace those pistons found in bad condition.

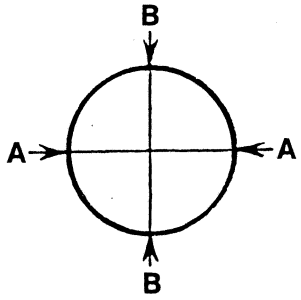


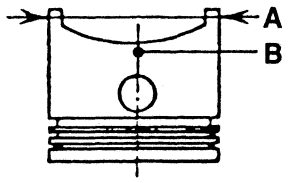
2. Piston clearance in the bore.
   Using a micrometer, measure each piston at the positions listed below and compute the radial clearance at each position by referring to the bore diameter of its sleeve determined in the previous text.

Specifications

Unit: mm (in.)

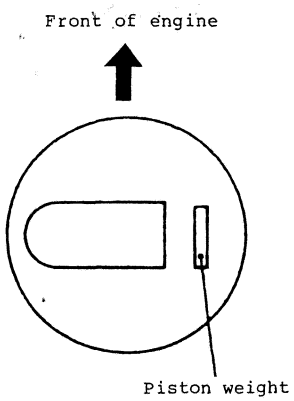
Item		Standard	Service limit
Diameter (at skirt A)	Standard	83.90 (3.3031)	−0.2 (−0.008)
	0.25 (0.0098) oversize	84.15 (3.3130)	
	0.50 (0.0197) oversize	84.40 (3.3228)	
Fit in cylinders	Top	0.545 ~ 0.610 (0.02146 ~ 0.02402)	
	Top of 2nd ring land	0.425 ~ 0.490 (0.01673 ~ 0.01929)	
	Bottom of 3rd ring land	0.245 ~ 0.310 (0.00965 ~ 0.01220)	
	Skirt	0.085 ~ 0.150 (0.00335 ~ 0.00591)	





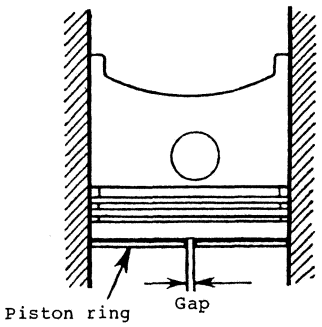
3. Replacing pistons.
Replace the piston with a new one if the measurement exceeds the service limit. When any pistons have to be replaced, the variance in weight among the pistons must not exceed the limit. It is recommended that the cylinder number be stamped on the piston selected for use in a particular cylinder for convenient identification.

When the cylinder sleeves are bored to the oversize, the pistons and piston rings of the same oversize dimension should be used. There are two oversizes for pistons and piston rings: +0.25 mm(0.00984in.) and + 0.50mm (0.01969 in.). The variance in weight among the pistons per engine should be ±3 grams (±0.1oz) max.



Piston weight marking

4. Piston ring gaps.
Always check piston ring gaps before assembling rings on piston. Insert rings into the cylinder squarely by using a piston. Check gaps with feeler gauge.



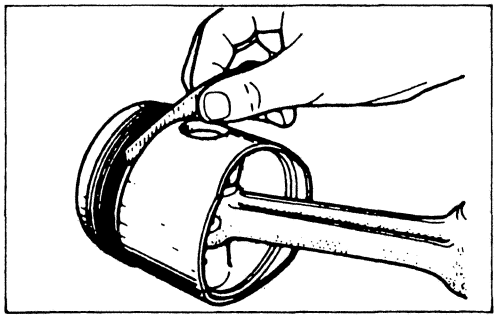
Checking piston ring gap

Specifications

Unit: mm (in.)

Item	Standard	Service limit
Piston ring gap	0.30 ~ 0.50 (0.0118 ~ 0.0197)	1.5 (0.059)

5. Piston ring grooves.
Insert the compression and oil rings of known thicknesses into the grooves; measure the side clearance with a feeler gauge (A).



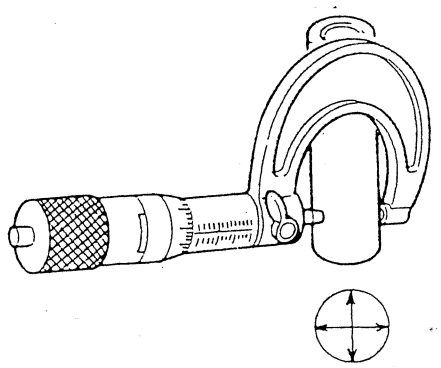
Specifications

Unit: mm (in.)

Item		Standard	Repair limit
Fit in ring grooves	No. 1 compression ring	0.050 ~ 0.080 (0.00197 ~ 0.00315)	0.20 (0.0079)
	No. 2 compression ring	0.025 ~ 0.060 (0.00098 ~ 0.00236)	0.15 (0.0059)
	Oil ring		

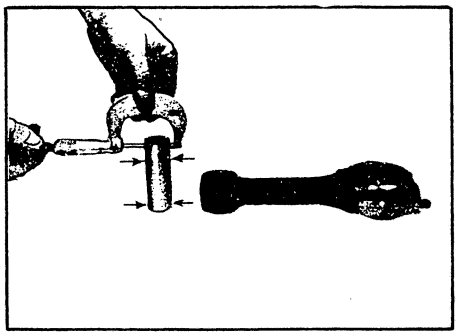
6. Replacing piston rings.
   If the rings are replaced, the gap width will exceed the standard value, but this is not important, provided that the service limit is not exceeded.

7. Piston pin bosses.
   Check the piston pin bosses by referring to the text which follows.



Piston Pins, Piston Pin Bosses and Piston Pin Bushings

1. Check the pin clearance in the pin boss of the piston by computing the difference between the two diameter readings, one taken on the pin and the other in the boss. If the computed difference (clearance) exceeds the repair limit, replace the piston pin with a new one.



Use a micrometer to measure piston pin bushing and piston pin

Specifications

Unit: mm (in.)

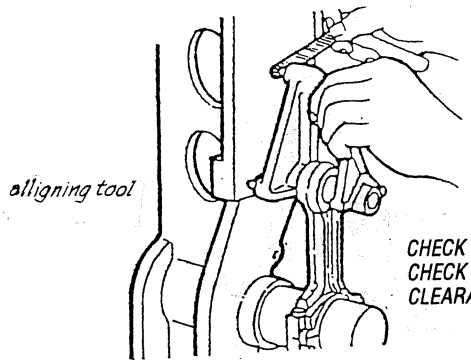
Item	Standard	Repair limit
Piston pin diameter	$25\ ^{0}_{-0.006}$ ($0.984\ ^{0}_{-0.00024}$)	

2. Check the clearance of the pin in the bushing fitted to the small end of the connecting rod by computing the difference between the two diameter readings. If the computed difference (clearance) exceeds the repair limit, replace the pin or the bushing, whichever is badly worn.

Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Piston pin boss ID	$25\ ^{+0.010}_{0}$ ($0.984\ ^{+0.00039}_{0}$)	
Piston pin clearance in piston pin boss	0 ~ 0.016 (0 ~ 0.00063)	0.05 (0.0020)
Piston pin bushing ID	$25\ ^{+0.045}_{-0.020}$ ($0.984\ ^{+0.00177}_{-0.00079}$)	
Piston pin clearance in piston pin bushing	0.020 ~ 0.051 (0.00079 ~ 0.00201)	0.08 (0.0031)



Checking connecting rod for bend

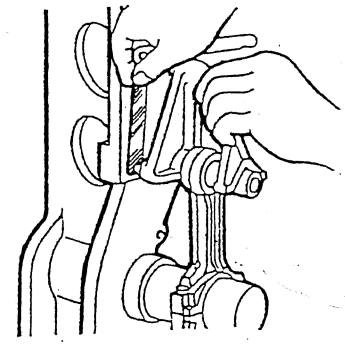
Connecting Rod Alignment and Bearings

1. Check the connecting rod for evidence of cracks, especially cracks in the fillets of its small and large ends. Replace the rod if any crack is noted in the fillets.

2. Mount each connecting rod in the connecting rod aligner and check for bend and twist, as shown in the illustrations. In a twisted connecting rod, the bearing is not trued to the small end bushing. Such a rod must be corrected with the use of a press.

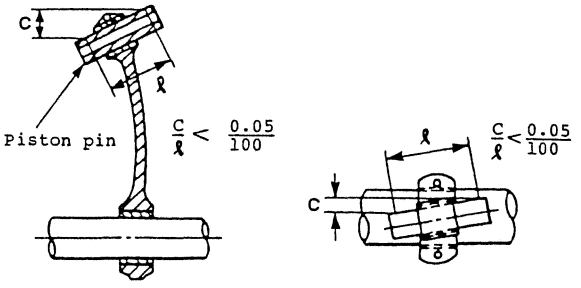
3. If a connecting rod aligner is not available, the rod may be checked as follows:

   a. To check the rod for bend, measure C and ℓ as shown in figure a above. If the measurement at C is greater than 0.05mm per 100mm (0.00197in. per 3.937 in.) of ℓ, straighten the rod with the use of a press.



Check the connecting rod bearings for peeling, burning, melting. Replace if faulty.

Checking connecting rod for twist



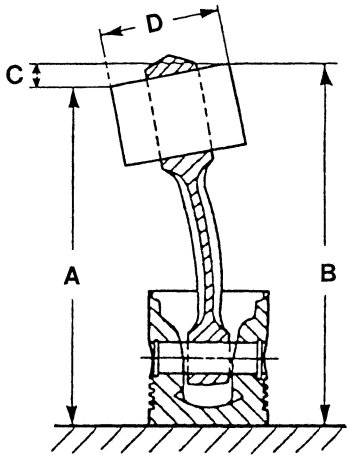
a. Checking the connecting rod for bend

b. Checking the connecting rod for twist

Checking connecting rod

b. To check the rod for twist, measure C as shown in figure b. If the measurement at C is greater than 0.05mm per 100mm (0.00197in. per 3.937in.) of ℓ, correct the rod.

4. To check the rod with a piston, place the rod on the surface plate as shown below, insert a round bar of the crankpin diameter into and through its large end bore and take measurements at A and B. The difference between the two measurements tells the straightness of the rod.



Checking connecting rod on surface plate

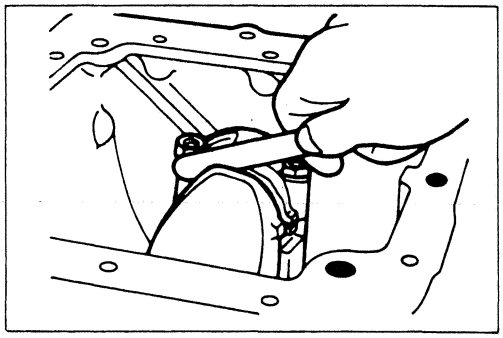
When one or more connecting rods are to be replaced, select new rods so that the variance in weight among the rods is within the value given in the specification.

Specification

Unit: gram (oz)

Variance in weight among connecting rods	±5 (±0.18)

5. Check the connecting rod end play as follows:
Tighten the capscrews to 5.5kg-m (39.8 lb-ft). Use a feeler. Gauge to measure the end play end play (the clearance between the large end and crank arm). If the clearance measured exceeds the service limit, replace the connecting rod or bearing.



Specifications

Unit: mm (in.)

Item	Standard	Service limit
Connecting rod end play	0.15 ~ 0.35 (0.0059 ~ 0.0138)	0.50 (0.0197)

6. Check the bearings as follows:

   a. Inspect each bearing for evidence of wiping or fatigue failure, scratches by imbedded dirt particles and improper seating on the bore. Determine by inspection whether the bearing should be repaired or replaced.

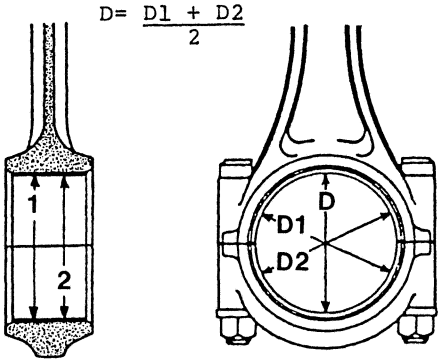
   b. Check the radial clearance between crankpin and bearing; if the repair limit specified below is exceeded by the checked clearance, replace the bearing. Where the crankpin is to be ground to the next undersize, use a replacement bearing of that undersize.

      The two bearing undersizes are 0.25mm (0.00984in.) and 0.50mm (0.01969in.).

Specifications

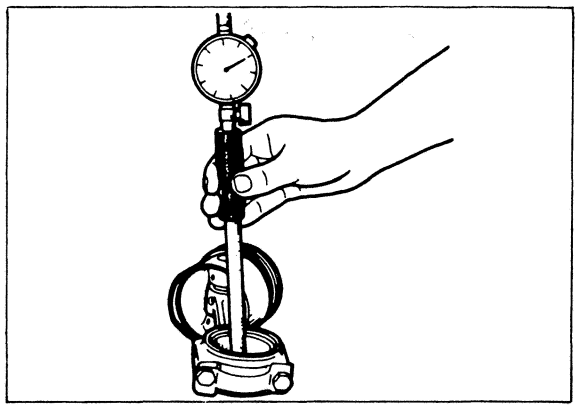
Unit: mm (in.)

Item	Standard	Repair limit
Crankpin diameter	$58\ ^{-0.035}_{-0.055}$ $(2.283\ ^{-0.00138}_{-0.00217})$	0.20 (0.008)
Radial clearance between bearing and crankpin	0.035 ~ 0.100 (0.00138 ~ 0.00394)	0.200 (0.00787)



Positions for measuring connecting rod bearing with a micrometer

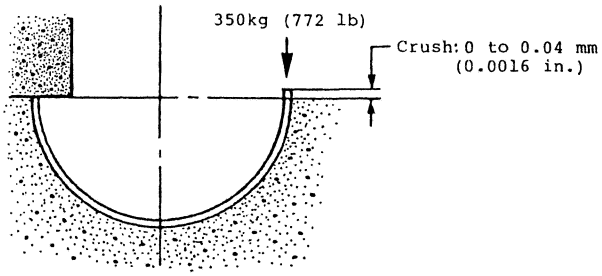
c. Check the contact pattern of the connecting-rod bearing on the crankpin by placing the large end into its operating position with the crankshaft laid out on a bench, and by applying a paste of red lead or Prussian blue to visualize the contact. Be sure to tighten the capscrews to the specified torque, 5.5kg-m (39.8lb-ft). The contact should occur over 75% of the entire surface; if not, replace the bearing.



(NOTE: The above job of checking the contact pattern may be eliminated where the crankpin is ground to the specified tolerance and the bearing has been replaced. This is because a replacement bearing is precision-finished to ensure the specified extent of contact).

d. Check each bearing shell for crush. Shells found to be loose in the bore or have an excessive crush must be replaced. A crush of up to 0.04mm (.0016in.), which will yield to a load of 350kg (772lb.), is prescribed. As in the case of the main bearing shells, some crush is needed for securing a proper fit, without which the bearing might roll or jump in place, resulting in localized overloading and consequent flaking, burning or fatigue failure.

Check to be sure that the crush disappears to allow the bearing cap to mate the large end positively when the capscrews are tightened to 5.5kg-m (39.8 lb-ft).

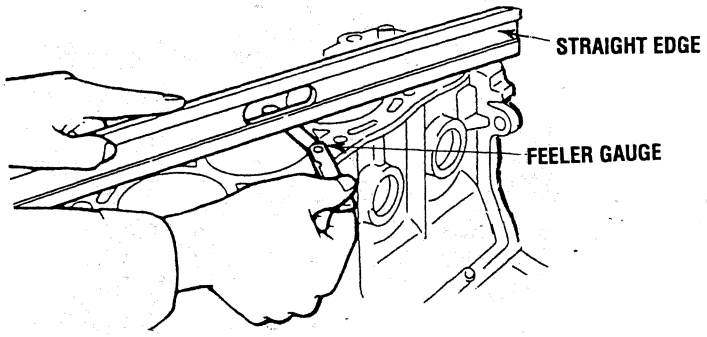


Connecting rod bearing crush

Crankcase

1. Inspect the outside and inside surfaces for evidence of cracking. Visually examine the cylinder bores for scuffing, rusting, erosion or any abnormal wear. Using a straightedge, check the top face (for mating with cylinder head), front face (for mating with front plate) and rear face (for mating with rear plate) for flatness.

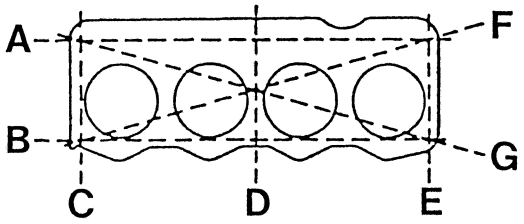
2. Make sure that the top face of the crankcase is flat within the standard specified below. If the standard is exceeded, reface the top by using a surface grinder to make it flat within the specified standard.



Checking crankcase top for flatness

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Warpage of crankcase gasketed surface	0.05, max. (0.0020)	0.2 mm (0.008)



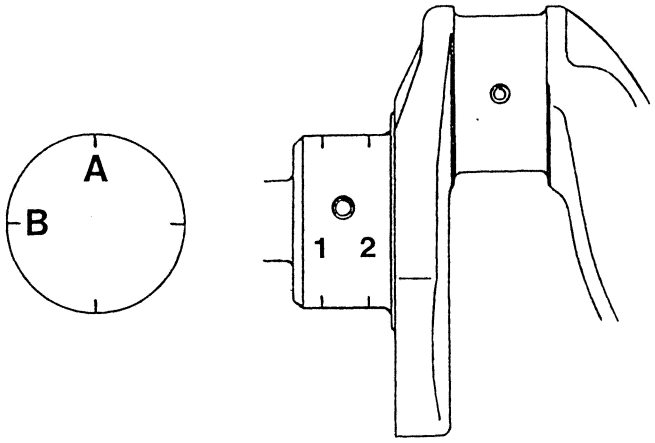
Checking crankcase top for flatness

Crankshaft

1. Journals

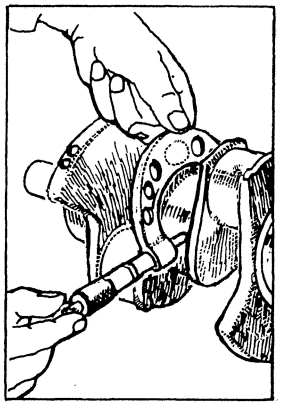
   a. Inspect each journal for surface flaws such as roughing, scratches, pitting and burns, and, as necessary, repair the journals by grinding to the next undersize or replace the crankshaft.

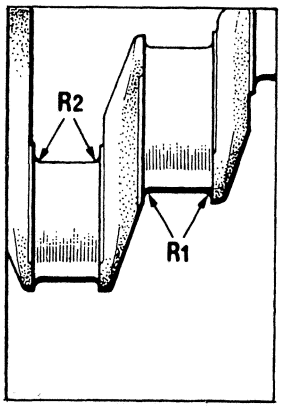
   b. Measure each journal with a micrometer (take a total of four readings) to determine the wear, out-of-round and taper (cylindricality). If any of the limits are exceeded, repair by grinding to the next undersize or replace the crankshaft.



Positions for measuring journal with a micrometer

(NOTE: If the fit or clearance of main bearings on journals is still in excess of 0.2mm (0.008in.) even if new bearings are used, or if the taper or out of roundness is not less than 0.03mm (0.0012in.), grind the journals to the next undersize).





2. Crankpins

   a. Inspect each crankpin for surface flaws such as roughing, scratches, pitting and burrs; repair the crankpins, as necessary, by grinding to the next undersize or replace the crankshaft.

   b. Using a micrometer, measure each crankpin (take a total of four readings) to determine the wear, out-of-round and taper. If any of the limits is exceeded, repair by grinding to the next undersize or replace the crankshaft.

Specifications

Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Diameter of journal	$65^{-0.015}_{-0.035}$ ($2.559^{-0.00059}_{-0.00138}$)	−0.15 (−0.0059)	−0.9 (−0.035)
Out of roundness of crankpins and journals	0.01 (0.0004), max	0.03 (0.0012)	
Taper of crankpins and journals			
Diameter of crankpin	$58^{-0.035}_{-0.055}$ ($2.283^{-0.00138}_{-0.00217}$)	−0.20 (−0.008)	
Fit of journals in main bearings	0.03 ~ 0.089 (0.0012 ~ 0.00350)	0.2 (0.0079) Uneven wear: 0.03 (0.0012)	

c. Grinding the crankshaft.
The crankshaft journals and crankpins must be refinished to a dimension smaller by 0.100 to 0.120mm (0.00394 to 0.00472in.) than the undersize of bearings to be used.

Example: If 0.50mm (0.01969in.) undersize bearings are to be used:

The journals must be refinished to
65-0.5-(0.100 to 0.120)
[2.55905-0.01969-(0.00394 to 0.00472in.)

The crankpins must be refinished to
58-0.5-(0.100 to 0.120)
[2.28346-0.01969-(0.00394 to 0.00472in.)

When grinding the crankpins and journals, be sure to reproduce the same fillet radius (shoulder radius) as the original one. Too small a radius of fillet will result in fatigue/failure of crankshaft while too large a fillet radius will cause the bearing to ride on the radius and thereby result in a bearing failure.

CAUTION

Be extremely careful not to grind off the radius part beyond the desired dimension. An over-ground radius part can be corrected only by grinding off the shoulder face. If this occurs, it will present problems in obtaining a proper end clearance.

Also check the crankpin and journals for hardness. They should have a hardness of 620 or more according to the Vickers Hardness Number. If necessary, re-harden the crankpins and journals, and check them for cracks by conducting a magnaflux (magnetic particle) test.

Specifications Unit: mm (in.)

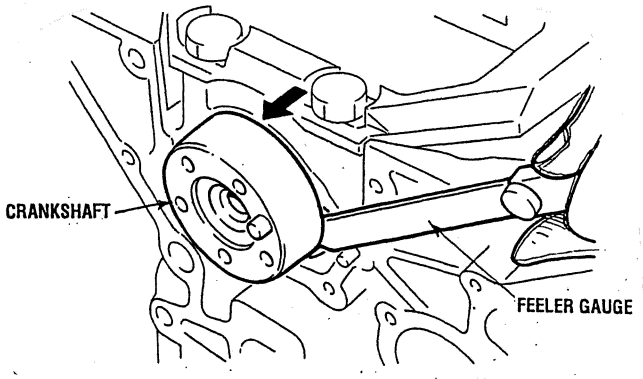
Undersize	Journals to be refinished to
0.25 (0.0098)	$64.75^{-0.015}_{-0.035}$ $(2.54921^{-0.00059}_{-0.00138})$
0.50 (0.0197)	$64.5^{-0.015}_{-0.035}$ $(2.53937^{-0.00059}_{-0.00138})$

3. End Play.

Check the crankshaft for end play, as shown, by using a thickness guage at the thrust bearing. If the limit is reached replace the thrust plate.

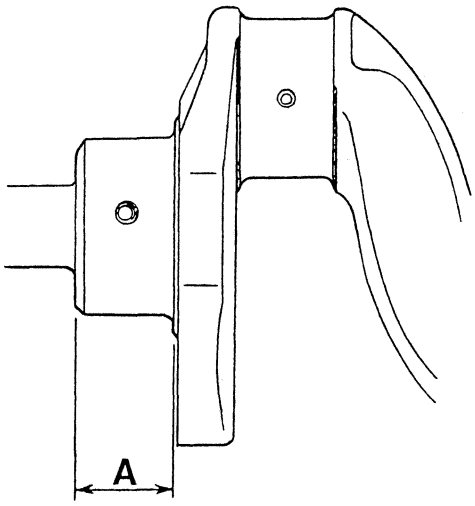
Specifications Unit: mm (in.)

Item	Standard	Repair limit
Journal width for thrust bearing	0.100~0.189 (0.00394~0.00744)	0.3 (0.012)



Checking crankshaft end play

The end play is due to the difference between the width of thrust bearing and the dimension (A) indicated below:



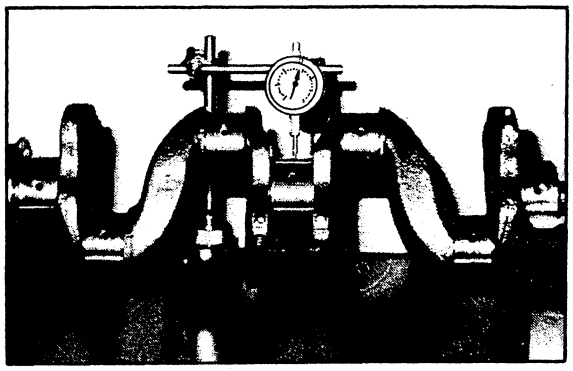
Journal width for thrust bearing

4. Runout
Support the crankshaft as shown and roll it to measure its deflection with a dial gauge. Distortion is one-half on the deflection (dial gauge reading;) if it exceeds the standard, reduce it by bending the crankshaft in a press.

Specifications

Unit: mm (in.)

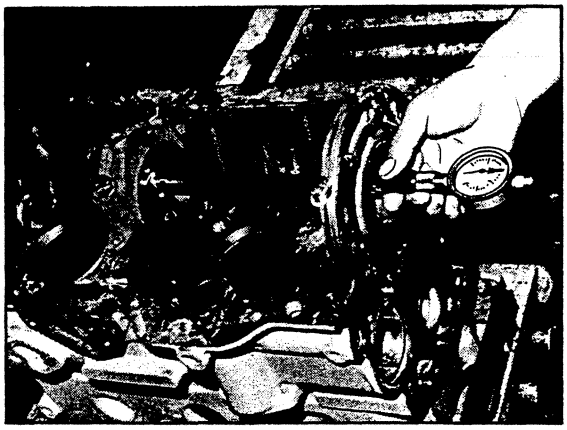
Item	Standard	Repair limit
Crankshaft runout	0.02 (0.0008)	0.5 (0.020)



Checking crankshaft for runout

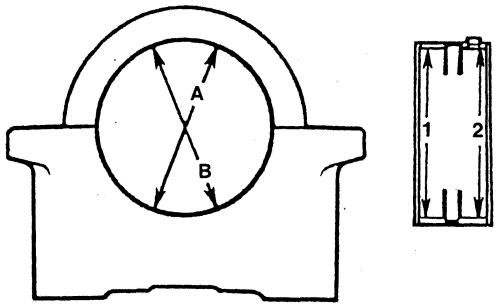
5. Main Bearing
Inspect each main bearing for evidence of wiping or fatigue failure, scratches from imbedded dirt particles and improper seating on the bore (bearing cap). Upon inspection, determine whether the bearing should be replaced or not.

Check each main bearing that will be installed during engine reassembly to determine the specified radial clearance. The checking procedure is as follows:



Measuring main bearing ID

Install the main bearings in the crankcase, without the crankshaft, securing each bearing cap by tightening the bolts to 8.5 kg-m (61.5 lb-ft) and measure the diameter from two positions, (A) and (B), as indicated in the illustration. Measure the journal with a micrometer. From these readings, compute the radial clearance.

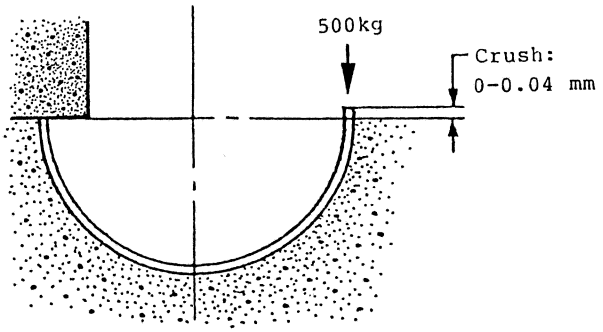


Positions for measuring main bearing

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Fit of main bearings on journals	0.03 ~ 0.089 (0.0012 ~ 0.0035)	0.2 (0.008)

Check each main-bearing shell for crush. Shells that are loose in the bore or have an excessive crush must be replaced. A crush of up to 0.04mm (0.0016in.), which will yield a load of 500kg (1103lb), is recommended.



Main bearing crush

Camshaft

1. Check the camshaft end play as outlined for the timing gears. Where the end play exceeds the repair limit, replace the thrust plate.

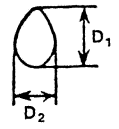
Specifications Unit: mm (in.)

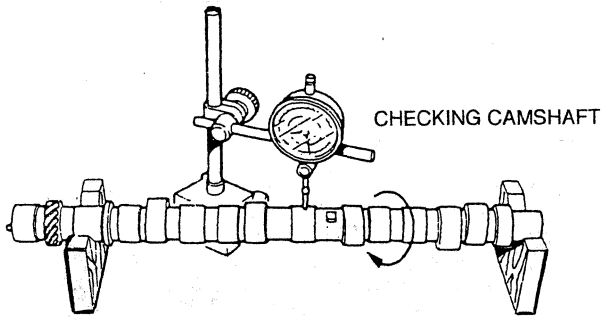
Item	Nominal value	Standard	Repair limit
Camshaft end play	5.0 (0.197)	0.05 ~ 0.112 (0.00197 ~ 0.00441)	0.3 (0.012)

2. Inspect the camshaft journals for abnormal wear and damage; the camshaft must be replaced if any of the three journals is found in disrepair.

3. Using a micrometer, measure each cam of the camshaft to read D1 (cam height) and D2 (diameter), then compute the difference between D1 and D2. If this difference is less than the service limit, replace the camshaft.

Specifications Unit: mm (in.)

Item		Standard	Repair limit
Intake cam profile	$(D_1 - D_2)$ 	D_1: $46.916^{+0.1}_{-0.3}$ ($1.84708^{+0.00394}_{-0.01181}$) $D_1 - D_2 = 6.684$ (0.26315)	$D_1 - D_2 = 6.184$ (0.24346)
Exhaust cam profile		D_1: $45.944^{+0.1}_{-0.3}$ ($1.80882^{+0.00394}_{-0.01181}$) $D_1 - D_2 = 7.344$ (0.28913)	$D_1 - D_2 = 6.844$ (0.26945)



CHECKING CAMSHAFT

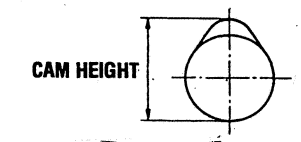
CHECKING CAMSHAFT RUNOUT.

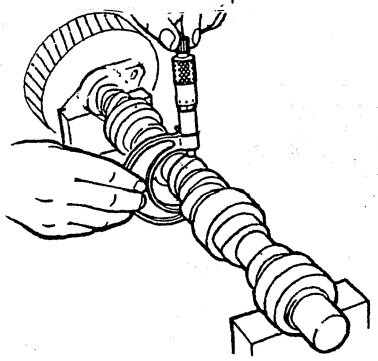
4. Check the camshaft for runout. Straighten the camshaft in a press or replace it, as necessary.

Specifications Unit: mm (in.)

Item	Standard	Service limit
Camshaft runout	0.02 (0.0008), max.	0.05 (0.0020)

INTAKE AND EXHAUST CAM





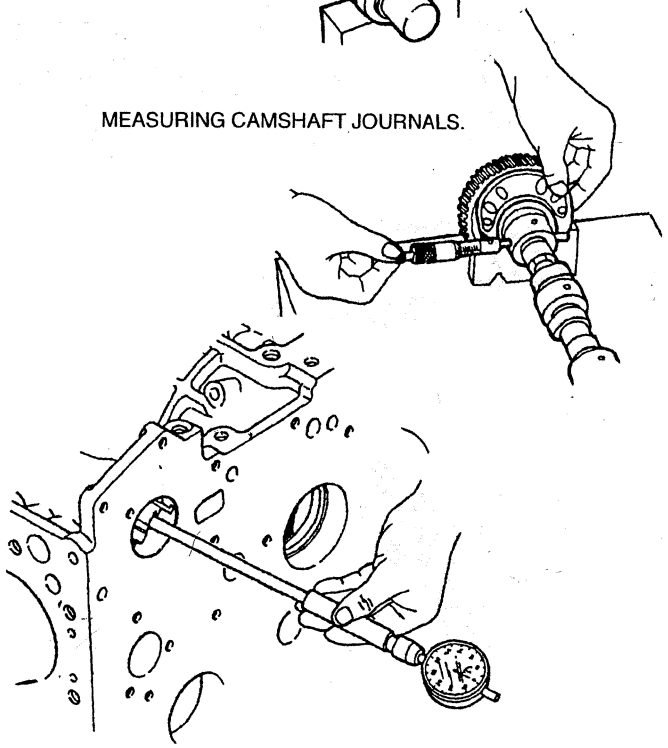
5. Measure the diameter of each journal in two directions to compute the fit or clearance in the camshaft hole.

MEASURING CAMSHAFT JOURNALS.

6. Use a micrometer to measure the ID of respective camshaft bosses and compute the fit on each journal. If the fit exceeds the repair limit, machine the holes and install bushings.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Fit of camshaft holes on journals	0.040 ~ 0.090 (0.00157 ~ 0.00354)	0.15 (0.0059)



COMPUTING THE CAMSHAFT FIT

Tappets and Tappet Holes.

1. Inspect the riding face of each tappet for wear, contact pattern and cracks. Replace defective tappets.

2. Check the fit of the tappet in the hole and confirm with the repair limit in the chart indicated below. If the limit is exceeded, replace the tappet. If the hole is worn, resulting in an excessive radial clearance, even with a new tappet, the crankcase must be replaced.

Specifications Unit: mm (in.)

Item	Standard	Repair limit	Service limit
Fit of holes on tappets	0.035 ~ 0.098 (0.00138 ~ 0.00386)	0.13 (0.0051)	+0.10 (hole) (+0.0039)
Tappet hole diameter	22 (0.87)		+0.10 (+0.0039)

Flywheel and Ring Gear

1. Check the flywheel for cracks and the crankshaft flywheel dowel pin for proper fit.

2. Check the threads of the flywheel retaining bolts for stretch and other defects. Replace the bolts as needed.

3. Check the ring gear for broken or excessively worn teeth. If the teeth are defective, remove the gear from the flywheel and replace it with a new one.

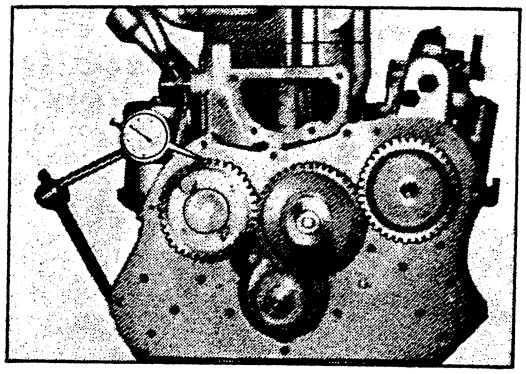
Timing Gear Case and Oil Seal.

1. Check the timing gear case for signs of cracks and inspect the condition of the dowel pin holes.

2. Check the oil seal for excessive wear and defects; replace it when stated conditions are present. Closely inspect the oil seal when excessive oil leaks from the crankshaft end.

Timing Gears.

1. It is important that the backlash in each mesh is within the repair limit. If the limit is exceeded, reduce the backlash by replacing the worn gear. To measure backlash, place a feeler gauge squarely between two gear teeth.



Specifications Unit: mm (in.)

Item	Standard	Repair limit
Backlash	0.12 ~ 0.24 (0.0047 ~ 0.0095)	0.3 (0.012)

2. Check the radial clearance between the idler bushing and shaft by measuring with a micrometer. Compute the clearance from the readings taken and, if the repair limit is exceeded, replace the bushing.

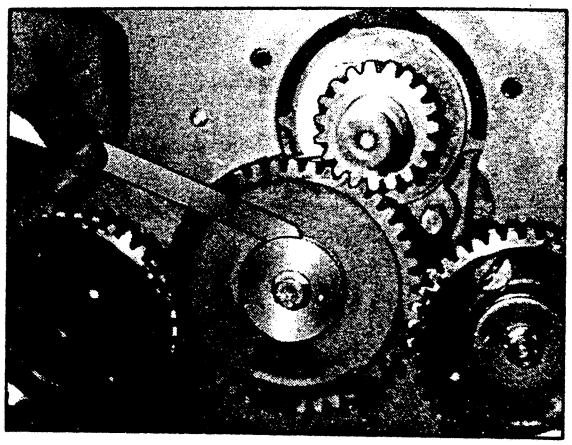
Specifications Unit: mm (in.)

Item	Nominal	Standard	Repair limit
Fit of shaft in idler bushing	36 (1.417)	0.025 ~ 0.075 (0.00098 ~ 0.00295)	0.1 (0.004)

3. Check the idler end play with a thickness gauge. Replace the thrust plate to reduce the play if the thickness gauge reading exceeds the repair limit.

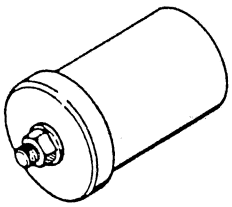
Specifications Unit: mm (in.)

Item	Standard	Repair limit
Idler end play	0 ~ 0.1 (0 ~ 0.004)	0.35 (0.0138)



Checking idler end play

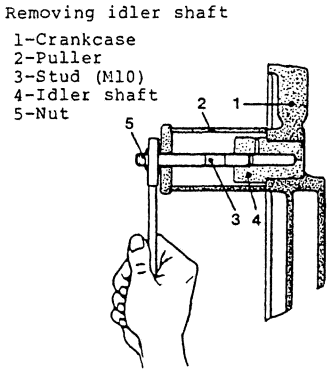
4. If the idler shaft must be replaced, use the idler shaft puller for removal, as illustrated. When installing the replacement shaft, the oil holes must be properly aligned.



Idler shaft puller
Part #36515

5. Inspect the timing gear as follows:

   a. Camshaft gear.
   Replace the gear if teeth show evidence of flaking or excessive wear, or if the keyway is galled, worn or disfigured. Make certain that the camshaft gear, when mounted on the camshaft, has no more end play than 0.4mm (0.0157in.) To check the end play, use a dial gauge. If the reading exceeds the repair limit, replace the thrust plate (Important: this gear is shrink-fitted to the camshaft).



Specifications

Unit: mm (in.)

Item	Standard	Repair limit
Camshaft end play	0.05 ~ 0.112 (0.00197 ~ 0.00441)	0.3 (0.012)

   b. Injection pump drive gear.
   Inspect the gear teeth for damage and condition of the mounting bolt holes. Replace the gear if observed to be damaged.

   c. Crankshaft gear.
   Replace the gear if teeth show signs of defective tooth contact, excessive wear or other defects.

   d. Idler gear.
   Inspect the idler gear teeth and, when necessary, replace the gear.

6. Inspect the gear case for cracks and for evidence of oil leakage at the part ahead of the crankshaft. A cracked case must be replaced. Inspect the crankshaft pulley. Examine condition of the surface in contact with the oil seal and check the keyway and key for wear. Replace the pulley if found defective.

ENGINE ASSEMBLY

GENERAL INFORMATION

- Be careful not to mix bolts and nuts. Metric and S.A.E. bolts are used on various engine assemblies.
- During assembly, recheck clearances and insure that parts are being assembled in their proper order and facing in the correct direction in relation to the engine block, such as, pistons, piston rings, bearings and bearing caps.
- Apply lubricating oil to moving parts during assembly. Insure that moving parts, when assembled on the engine, rotate or slide and are not subject to binding or excessive tension.
- If there are mating marks scribed during disassembly, reference them correctly for assembly.
- Use new gaskets, lockwashers, O-rings, packings and seals.
- Tighten the bolts and nuts on important parts of the engine to specified torques using a reliable torque wrench.
- When required, use liquid sealants when required on nuts, bolts and gaskets. Refrain from using tape sealants.
- Most gaskets and many bolt washers are asymmetrical, make certain they are positioned properly.

Torquing Hardware

Prevent mechanical damage by running fasteners down in three steps-1/2, 2/3, and 1/1 torque. Exceptions are torque-to-yield bolts and rocker arm shaft fasteners. The former are torqued as indicated. The latter-rocker shaft fasteners-should be brought down in very small increments, working from the center bolts out. Gaskets, especially head gaskets, might be damaged during assembly, they should be positioned with great care. See *TORQUE SPECIFICATIONS* thru out this manual.

Bolts and Fasteners

Lightly oil head bolts and other fasteners as you assemble them. Bolts and other plugs that penetrate the water jacket should be sealed with PERMATEX #2 or HIGH TACK.

When assembling the flywheel, coat the bolt threads with LOCTITE blue.

LITHIUM based grease is waterproof, ideal for water pump bearings and stuffing boxes.

Antiseize compounds and thread locking adhesives such as LOCTITE protect threaded components yet allow them to come apart when necessary. LOCTITE offers levels of locking according to the job.

Heavily oil all sliding and reciprocating components, always use clean engine oil.

Sealants and Lubricants

Oil based PERMATEX #2 and its HIGH TACK equivalent are excellent all purpose sealers. They are effective in just about any joint in contact with coolant, raw water, oil, or fuel. A light coating of oil or LIQUID TEFLON can be used on rubber gaskets and o-rings.

LOCTITE hydraulic red sealant should be used on oil adapter hoses and the oil filter assembly.

Coat both surfaces of the oil pan gasket with high temp RED SILICONE SEALER.

When installing gaskets that seal around water (coolant) passages, coat both sides with WHITE SILICONE GREASE.

Do not use sealant when installing a new gasket.

HIGH-COPPER ADHESIVE SPRAYS are useful for holding a gasket in position during assembly.

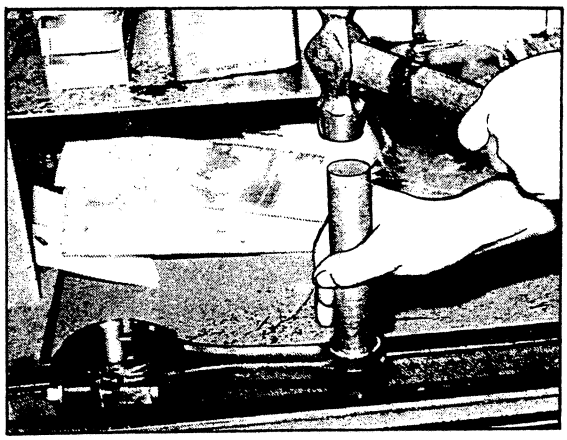
Specialized gasket sealers such as HYLOMAR work well in applications requiring non-hardening properties. HYLOMAR is particularly effective on copper cylinder-head gaskets and resists fuel, oil , and water.

NOTE: *TAPE SEALANTS should be used on pipe plugs and fitting that connect water coolant passages.*

ENGINE ASSEMBLY

1. Reassemble the connecting rod and piston as follows:

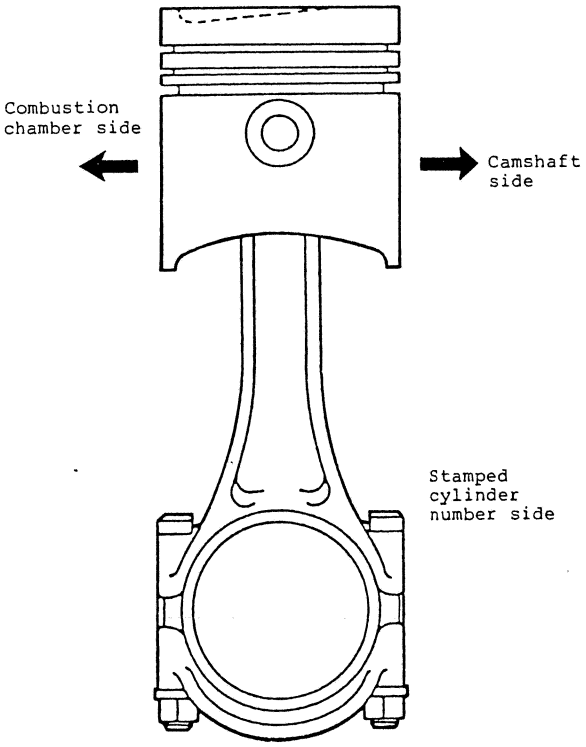
   a. Press bushing into small end of the connecting rod. Ensure that the oil holes in bushing and rod are aligned.



   b. Heat piston on a hot plate to between 100°C and 120°C (212°F and 248°F). Install small end of connecting rod into boss and connect piston and piston pin by slowly inserting piston pin into piston.

   (NOTE: Insert snap ring into one end in advance.)

   Install the connecting rod to the piston so that the cylinder number side will face the camshaft and the combustion chamber side of the piston will face away from the camshaft when the assembly is installed on the crankshaft.

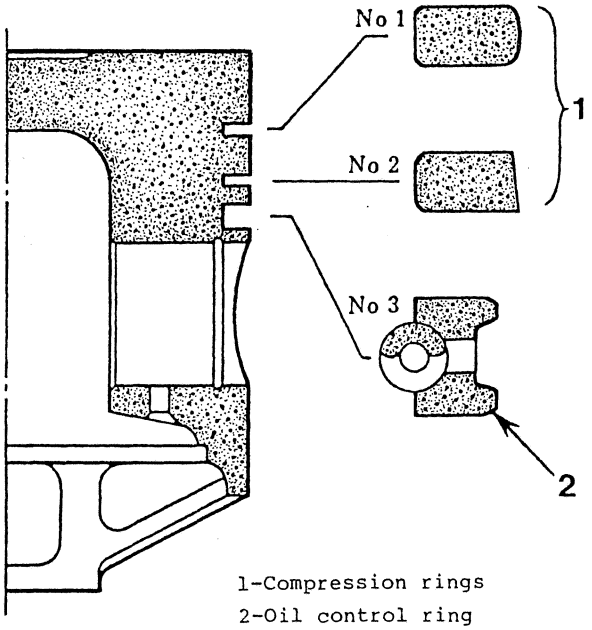


Piston and connecting rod assembly

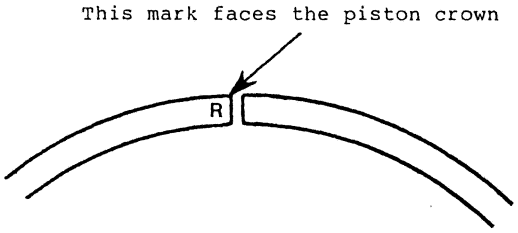
c. Install compression rings and oil control ring as shown in illustration at top right, using standard piston ring expanding tool.

(NOTE: No. 2 ring has an R marked on its top side. Be sure that this side faces the piston crown when installed in its groove, as shown in illustration at center right.)

d. Install No. 3 oil control ring and expander as shown in illustration at bottom right.



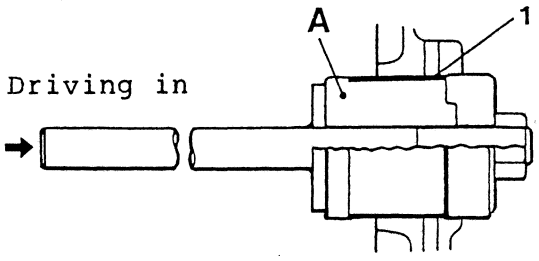
1-Compression rings
2-Oil control ring



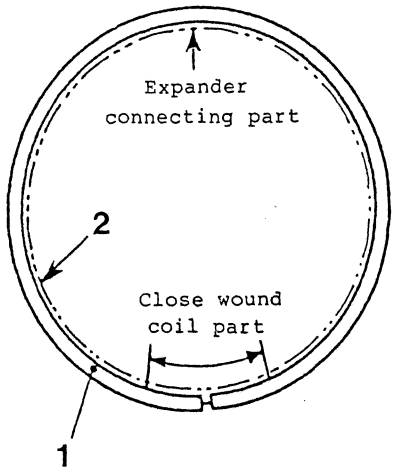
2. Reassemble the crankcase as follows:

a. Press three camshaft bushings (1) into camshaft holes in crankcase by using adapter (A). (If the fit exceeds the repair limit, machine the holes and install new bushings.)

Make certain the oil holes in the cam bushings align with the oil ports in the crankcase.

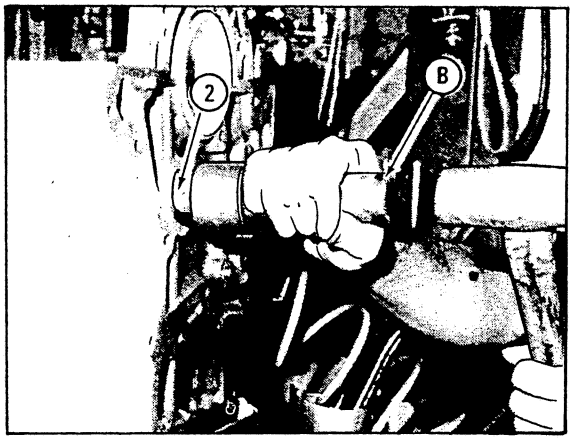


Driving in camshaft bushing

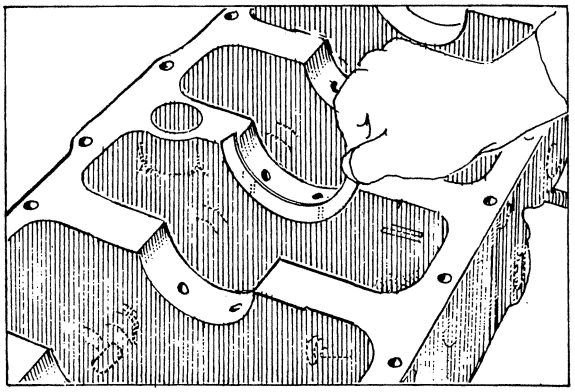


Oil control ring and expander installed

b. Drive idler shaft (2) into crankcase by using installer (B).



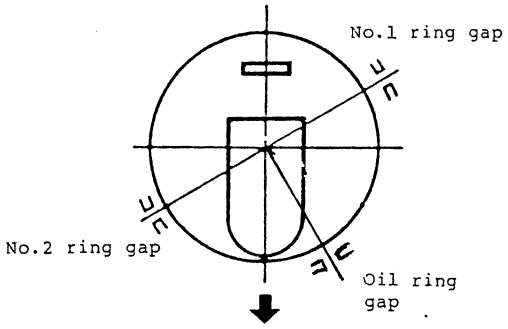
c. Lightly apply engine oil to the crankpins and install main bearings (upper). Securely engage the bearings with the crankpins.

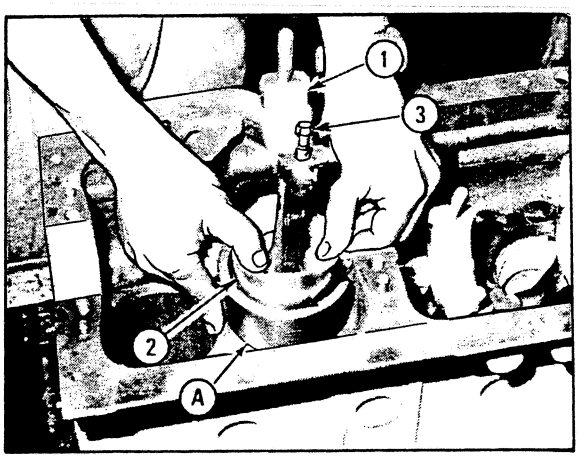


3. Install the piston assembly as follows:

Install upper connecting-rod bearing (1) into the large end of connecting rod. Apply engine oil to the internal surface of bearing and on the external periphery of piston. Position piston rings so that ring gaps are located 90° in relation to each other, as shown. Then insert piston assembly (2) into crankcase. Alignment marks on the connecting rod must face the camshaft side. Put attaching capscrews (3) into rod in advance. Insert piston assembly into its cylinder with the aid of a piston/ring installing tool.

(NOTE: Piston/rod assembly is installed from crankshaft side of engine block.)

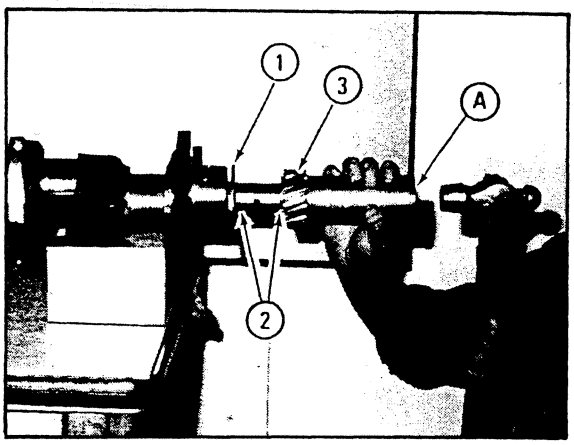




4. Install the crankshaft as follows:

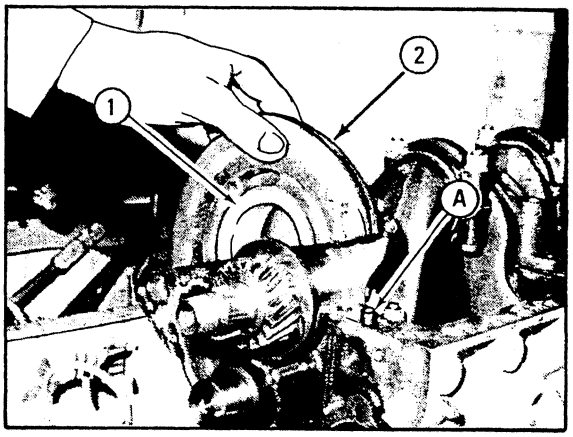
   a. Install thrust plate (1) and two woodruff keys (2) to the crankshaft and drive on crankshaft gear (3) by using suitable hollow drift (A).

   b. Install crankshaft to the crankcase.



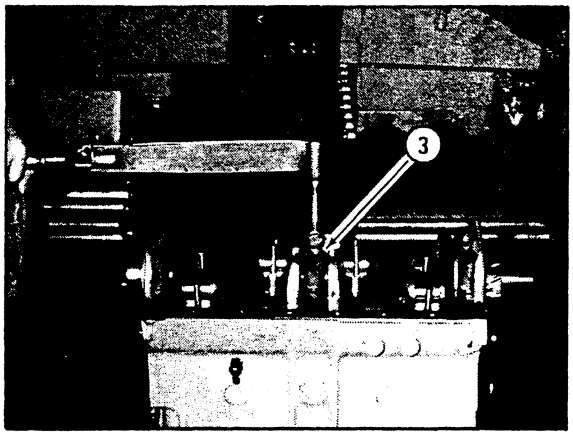
5. Install the main bearing caps as follows:

   a. Apply engine oil to the crankshaft journals and pins, and install the crankshaft into the crankcase securely. Attach lower main bearing (1) to main bearing cap (2) (front, center and rear) and install the cap in place by aligning it with dowel pin (A) on crankcase.



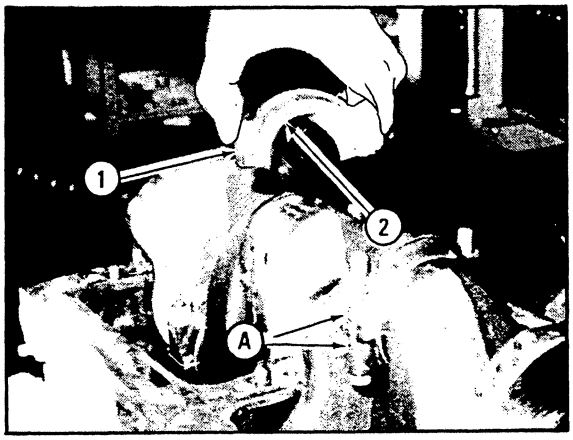
   b. Measure the crankshaft end play with a thickness gauge. Replace No.1 main bearing if the end play is out of specification. Tighten main bearing capscrews (3) to a torque of 8.5 kg-m (61.463 lb-ft)

   (NOTE: Rotate crankshaft to ensure no unusual binding or resistance occurs.)



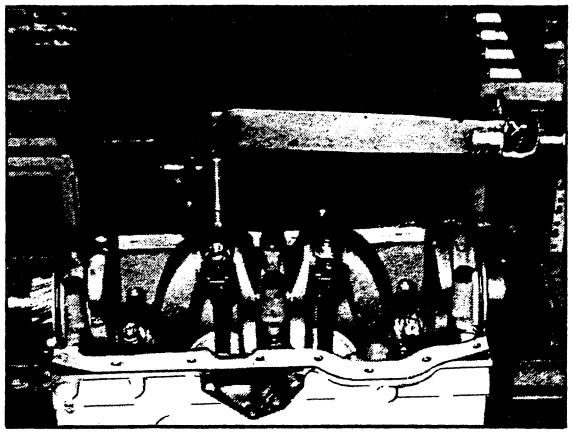
6. Install the connecting rod bearing caps as follows:

   a. Install lower connecting-rod bearing (2) into cap (1) and apply engine oil to the internal surface of the bearing. Then install the cap with the matching mark on the cap aligned with mark (A) on the rod.



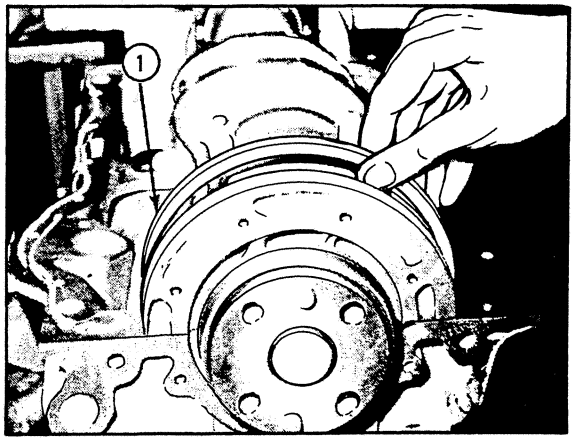
b. Tighten connecting rod clamping nuts to a torque of 5.5 kg-m (39.771 lb-ft)

(NOTE: Rotate the crankshaft.)

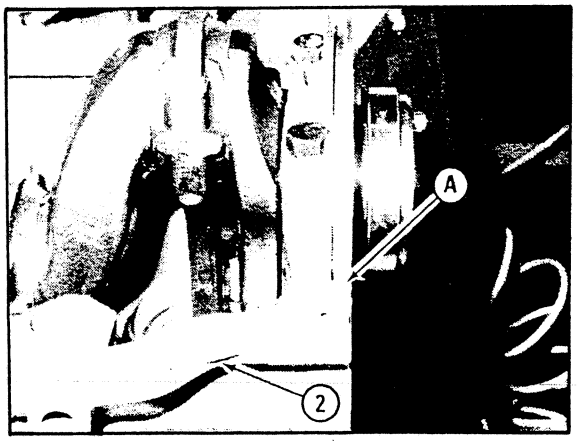


7. Install the retainers and gaskets as follows:

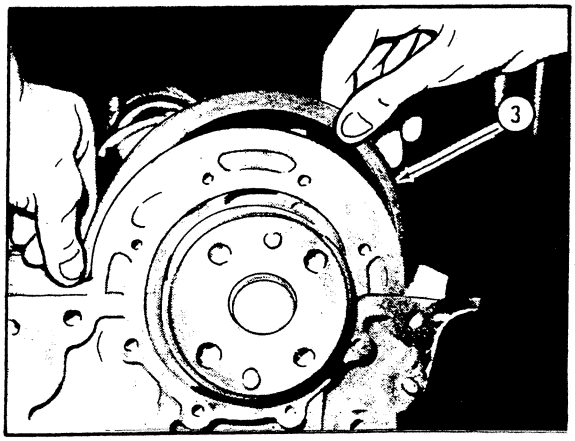
a. Install retainers (1) to the external peripheries of main bearing caps No.1 and No.3, with the flange facing the inside of the case.



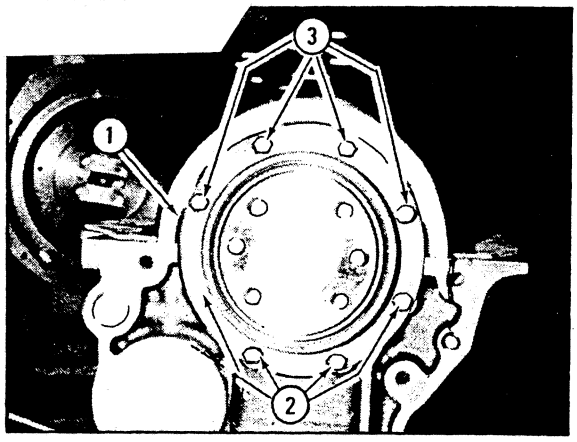
b. Apply good quality gasket cement on both sides of oil pan gasket (2) and attach it to crankcase. Make sure that the gasket is completely attached in the grooves (A) in the caps.



c. Apply gasket cement to both ends of rubber packing (3) and insert the packing into cap.



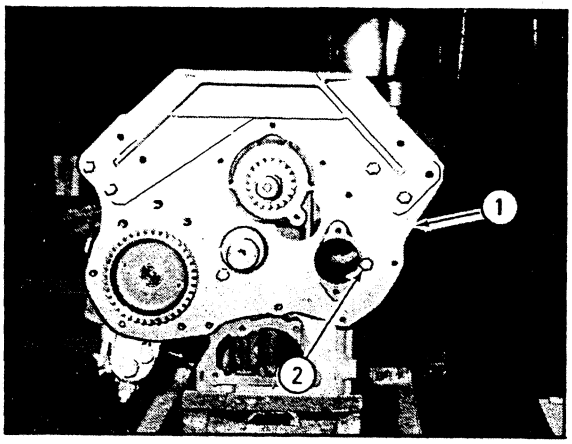
d. Install sleeve onto the rear end of crankshaft. Apply clean engine oil to the internal surface of oil seal (1) and secure it with bolts (2) by using an oil seal aligner.



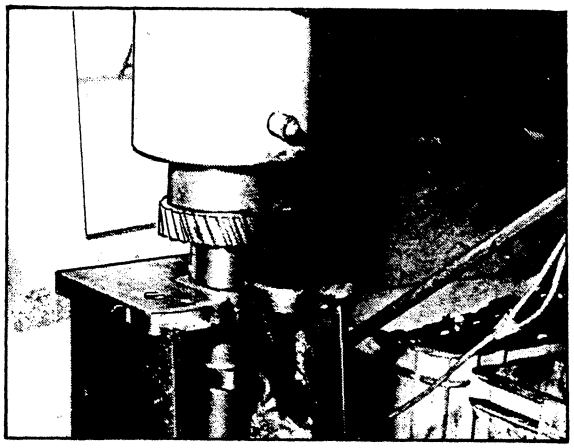
e. Apply gasket cement to the tip of bolts (3) as they fit into the four through-bolt holes in the bearing cap. Tighten the bolts to a torque of 0.4kg-m (2.9 lb-ft).

8. Install the front plate as follows:

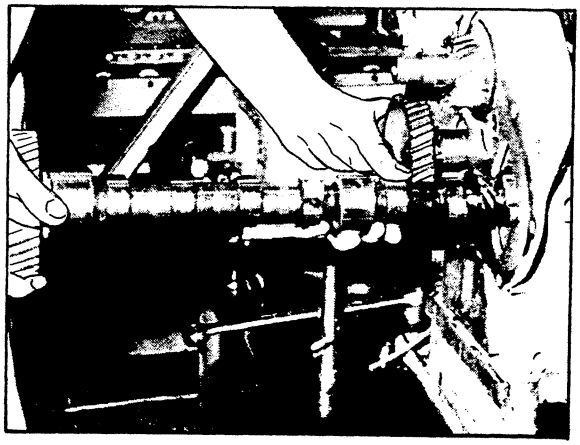
a. Apply gasket cement to both sides of the front plate packing and attach the packing to the front face of crankcase. Secure front plate (1) with injection pump fastened by two bolts (2). The tightening torque of the bolts is 2.1 kg-m (15.2 lb-ft).



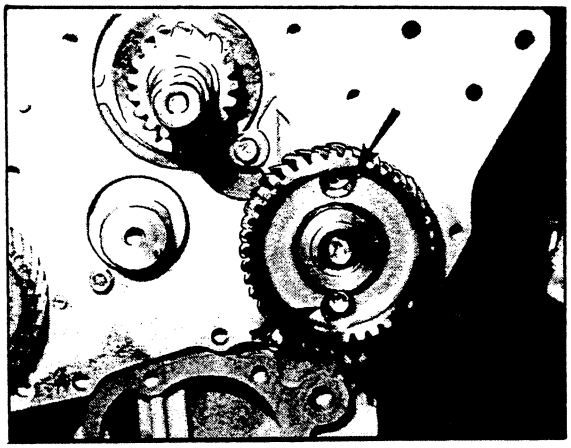
b. *Heat the camshaft gear on a hot plate to between 150 C and 180 C (342 F - 396 F) and fit gear to the shaft.*



c. Apply a light film of oil to the camshaft journals and bushings. Then carefully install the camshaft into engine block.

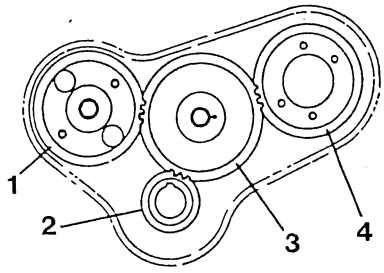


d. Tighten camshaft thrust plate to crankcase, gaining access to the thrust plate and securing bolts through machined holes in camshaft gear.



9. Install the idler gear as follows:

   a. Install idler gear by matching the timing mark on each gear.



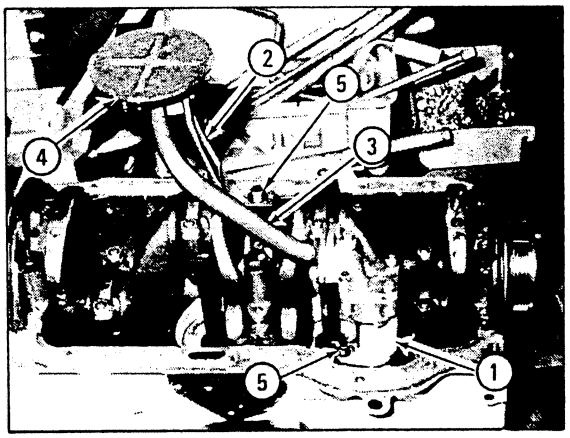
Timing gear match marks meeting each other

1-Camshaft gear
2-Crankshaft gear
3-Idler gear
4-Injection pump gear

10. Install the oil pump assembly as follows:

   a. Install oil pump (1) into the oil pump installation hole in the crankcase and mesh the pump drive gear with the camshaft pump drive gear.

   b. Install one end of the oil strainer stay (2) to No. 2 bearing cap with distance piece (3) inserted between both. Install the other end of the stay to oil strainer (4) by bolts (5).



11. Install the oil pan and torque pan bolts to 0.7 kg-m (5.1 lb-ft).

12. Install the backplate and flywheel as follows:

    a. Install dowel pins in crankshaft end and engine block.

    b. Position back plate to engine block fitting over dowel pins and bolt to block.

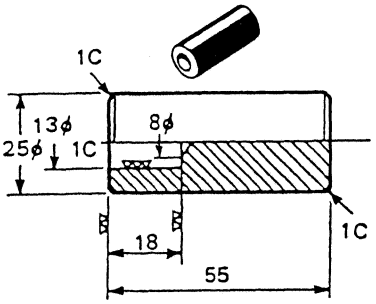
    c. Position flywheel on crankshaft using aligning dowel pin.

Unit: kg-m (lb-ft)

Flywheel bolt tightening torque	8.5 ± 0.5 (61.5 ± 3.6)

13. Reassemble the cylinder head as follows:

    a. Press valve guide (2) into cylinder head (1) as shown in illustration on right.

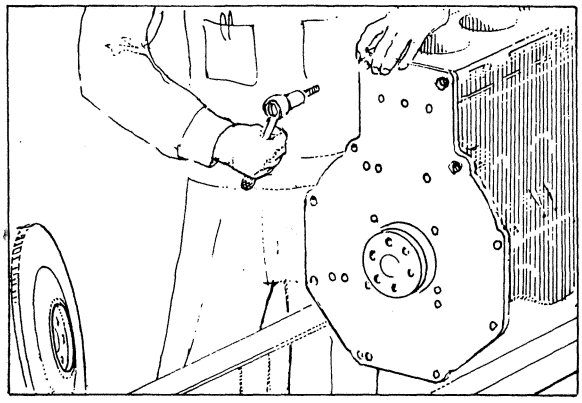


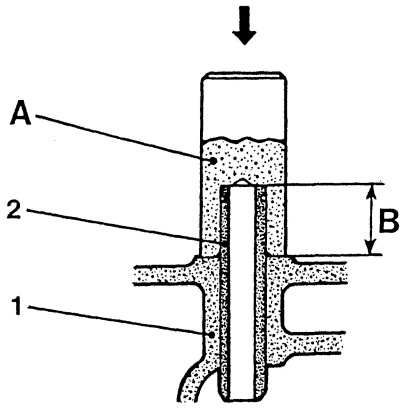
Valve guide installation tool

Install stem seal (3) to the valve guide. Completely fit the breast of the seal in the guide groove.

    b. Install valve (4), valve spring (5) and retainer (6) in this order. Compress the spring with a valve lifter to install valve cotter (7) securely. Install caps (8) when installing rocker shaft assembly.

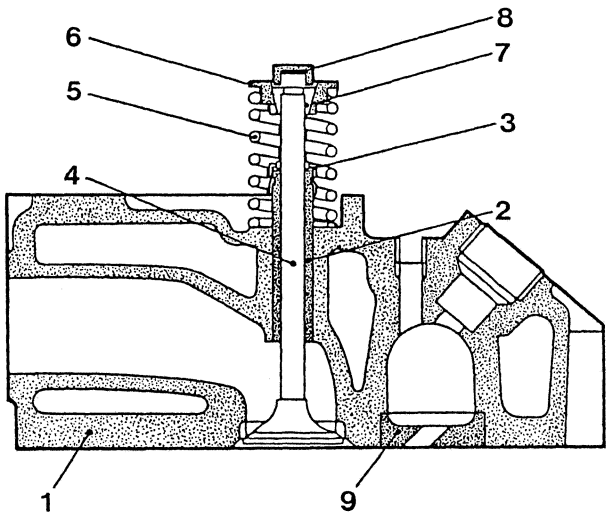
    c. Install thermostat, nozzle holders, glow plugs and exhaust manifold to the cylinder head.





1-Cylinder head
2-Valve guide

A-Valve guide installer
B-As installed length: 18 mm (0.709 in,)

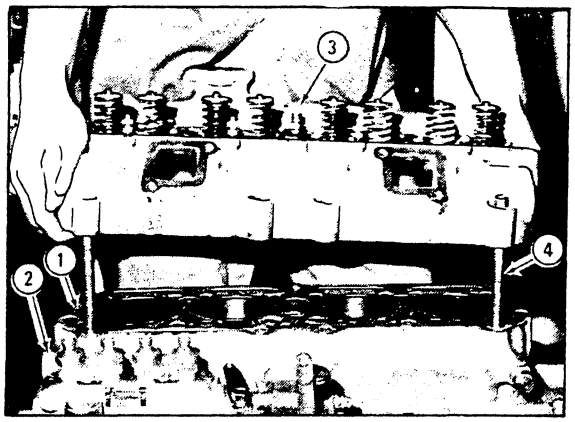


Cylinder head asembly

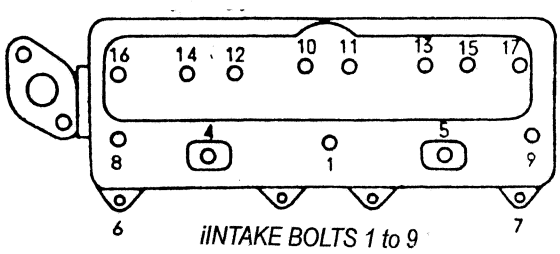
1-Cylinder head 2-valve guide 3-stem seal 4-valve 5-valve spring 6-Retainer 7-valve cotter 8-valve cap 9-combustion chamber jet

14. Install the cylinder head assembly as follows:

a. Lay the new cylinder head gasket (1) (no sealant required) onto the block (2) surface with the correctly marked side UP. Install the two guide studs (4) (12mm x 1.50 x 2 inches) to hold the gasket in position and place the cylinder head (3) onto the block.



b. Tighten the cylinder head bolts to a torque of 12 kg-m (86.8 lb-ft) at exhaust side and 10.5 kg-m (76 lb-ft) at intake side in the sequence shown in the cylinder head bolt tightening illustration.



CYLINDER HEAD BOLT TIGHTENING SEQUENCE

15. Install the push rods and rocker shafts as follows:

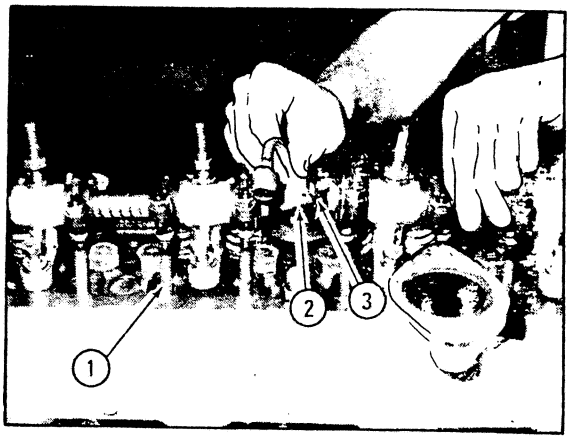
a. Insert the push rods (1) into the tappets.

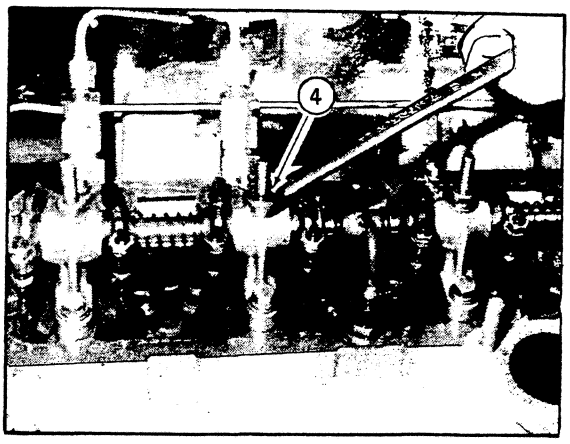
b. Install rocker shaft assembly as follows:

c. Insert O-rings (3) into oil pipe (2) and connect the oil pipe to the front and rear rocker shafts. Then temporarily install each bracket to the cylinder head.

d. Temporarily tighten two or three threads on the oil pipe union nut and connector.

e. Secure the preinstalled brackets by tightening four bolts at the front and rear sides uniformly to a torque of 1.5 kg-m (10.85 lb-ft) Tighten the long bolts (4) first.

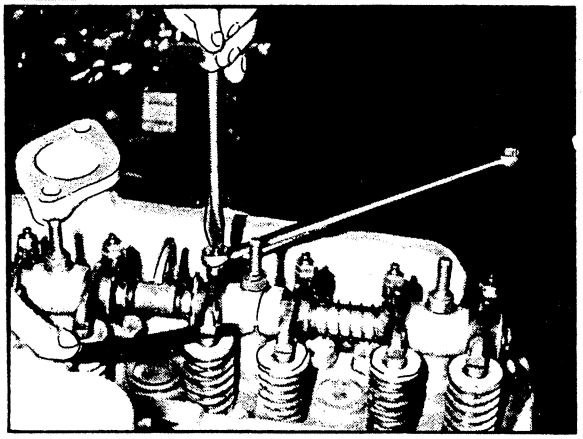




f. Connect oil pipe to connector securely. Then adjust the valve clearance to 0.25mm (0.01in.) for both intake and exhaust valves in cold setting.

16. Adjust valve clearance as follows:

The valve clearance specification for this engine is 0.25mm (0.0098in.) for both intake and exhaust valves. This value assumes that the engine is at normal temperature, there being no temperature difference throughout the body of the engine. The checking and adjusting procedure is as follows:



a. Rotate the crankshaft slowly to bring the piston in No. 1 cylinder to Top Dead Center (TDC). This can be accomplished by observing rocker arms of No.4 cylinder. As you turn the crankshaft, the exhaust-valve rocker arm of this cylinder rises: stop turning the crankshaft just when intake-valve rocker arm begins to go down after exhaust-valve rocker arm has come up all the way. Under this condition, adjust valve clearance in the usual manner on the intake and exhaust valves of No. 1 cylinder, intake valve of No. 2 cylinder, and exhaust valve of No. 3 cylinder.

b. Turn the crankshaft one complete rotation (360°) and hold it there. Adjust the clearance on intake and exhaust valves of No. 4 cylinder, exhaust valve of No. 2 cylinder, and intake valve of No. 3 cylinder.

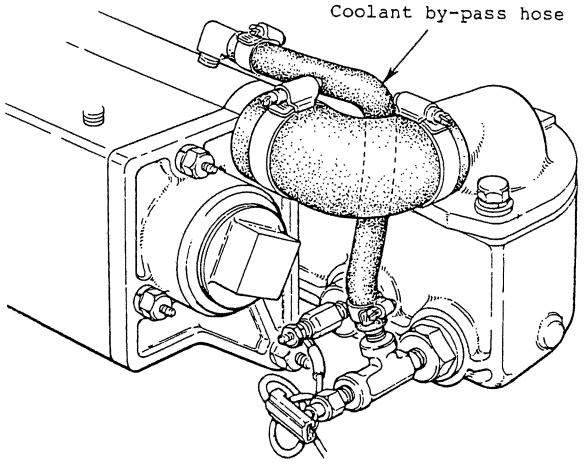
17. Install the rocker cover and gasket.

18. Install the fresh water pump assembly as follows:

a. Install water pump assembly.

b. Install the bypass hose between the manifold and tee below the thermostat.

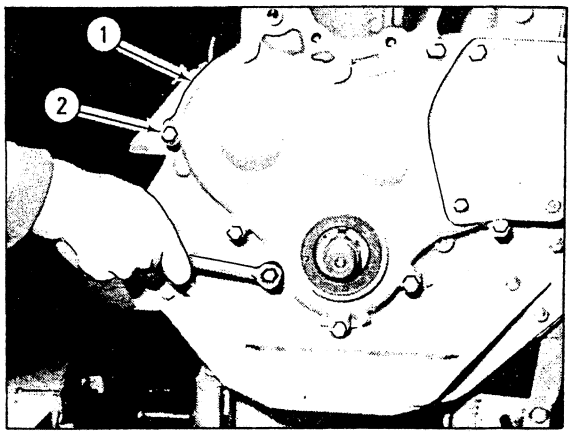
NOTE: *Early extruded / assembled manifolds only.*



19. Install the timing gear case (1) to the front plate properly. Use sealing washers behind the head of bolt (2) to prevent oil leaks.

20. Install front crankshaft pulley. Take care not to damage front crankshaft seal when slipping pulley onto crankshaft and through the front seal.

    Torque: 295-292 lb-ft (39.5-40.5 Kg-m)



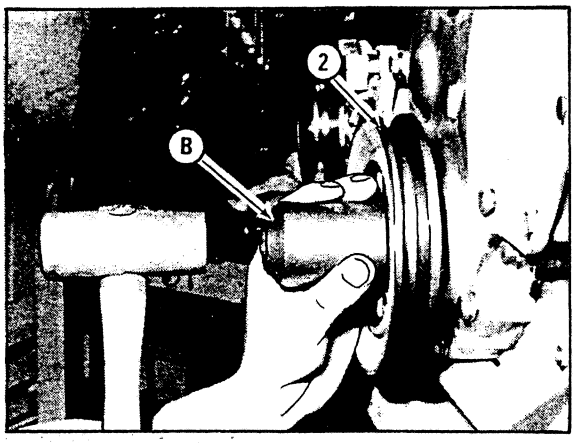
21. Install the DC charging alternator mounting bracket and mount the alternator.

22. Install alternator drive belt as follows:

    a. Attach fan belt to the pulley.

    b. Adjust the fan belt tension to a slack of 12mm (1/2in.)

23. Install the starting motor.



24. Install the oil filter mounting adaptor, filter, oil lines and lube oil cooler with all related hoses.

25. Install transmission drive damper to the flywheel.

26. Propulsion: Install the bell housing along with transmission and related items in reverse order of removal.

27. Generator: Install the generator components in the reverse order of removal.

28. Install heat exchanger with new cooling hoses as needed.

29. Install rear lifting eye with attached components.

30. Install new senders and switches as needed.

31. Reconnect the propulsion harness to all components. Reconnect generator harness to all engine components and secure control box to AC generator end.

NOTE: *Use di-electric grease on all push on electrical connections to provide sealing and corrosion protection.*

32. Propulsion: Install mounting brackets and new isolators.

    Generator: Install new isolators on the mounting rails and attach rails to generator and engine mounting brackets.

    Install all new fluids and filters on the drive engine. New fluid in the propulsion engine transmission. Bleed fuel system as needed to test run prior to reinstalling in vessel.

ENGINE ASSEMBLY

FUEL INJECTION PUMP

Two styles of injection pumps were used with this engine.

Early - DPA #J3942F490 (PN#034378)
This type had a tapered/keyed drive shaft.

Later - DPA #J3942F580 (PN#036169)
This type had a splined drive shaft with a master spline.

The injection pump is mounted to the engine front plate. It is secured to the front plate by three studs with 11-mm hex nuts and washers.

Installing Early Model Injection Pump (PN#034378)

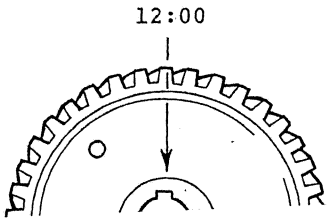
a. Rotate engine so as to position keyway in pump drive gear at 12:00 o'clock.

b. Rotate injection pump drive shaft to position keyway at 12:00 o'clock. Insert woodruff key in keyway.

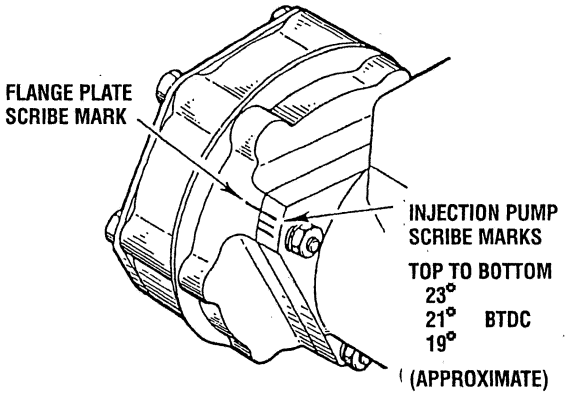
c. Carefully slide pump onto the engine mounting flange and guide the tapered drive shaft with woodruff key into the drive gear.

d When drive shaft is positioned in the drive gear, secure in drive gear by threading raw water pump drive tang onto the pump drive shaft protruding from the drive gear.

e. Snug the injection pump up to the front plate with the three securing nuts and washers. Position the 23° scribe mark on the pump flange in line with the scribe on the front cover. Tighten the three securing nuts.



MOVE FLANGE PLATE SCRIBE MARK DOWN AS SHOWN ON THE ATTACHED ILLUSTRATION.



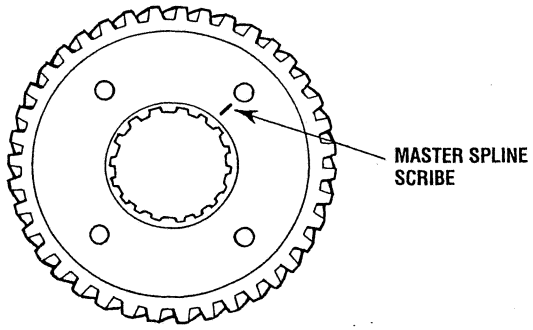
Installing Late Model Injection Pump (PN#036169)

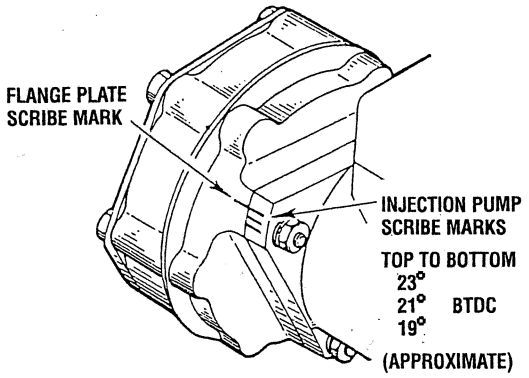
a. Remove drive tang plate from front of injection pump drive gear and locate scribe mark on face of gear that designates mating splines for master spline on injection pump drive shaft.

b. Locate master spline on injection pump drive shaft and position to correspond to scribe mark on drive gear by rotating injection pump drive shaft.

c. Carefully slide the injection pump onto the engine mounting flange, centering the master spline with the scribe mark on the drive gear, and engage the two.

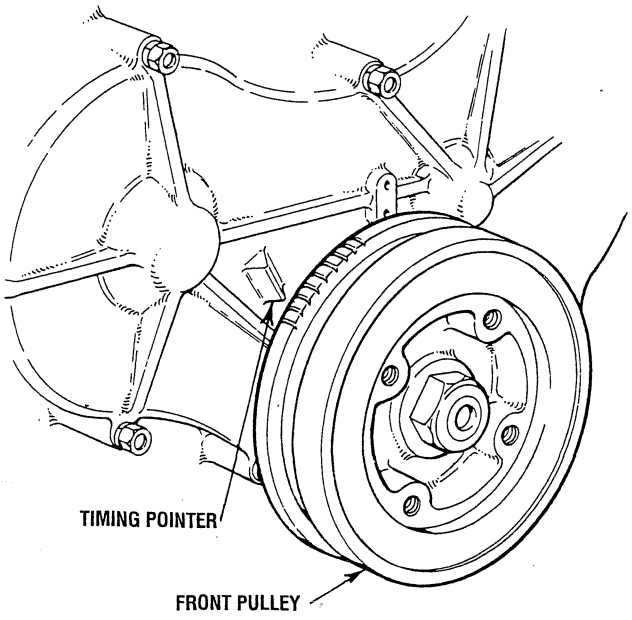
d. Snug up on the injection pump's three securing nuts and rotate the injection pump so as to align the 23° scribe on the injection pump flange with the timing scribe on the front cover. Tighten the 3 securing nuts.





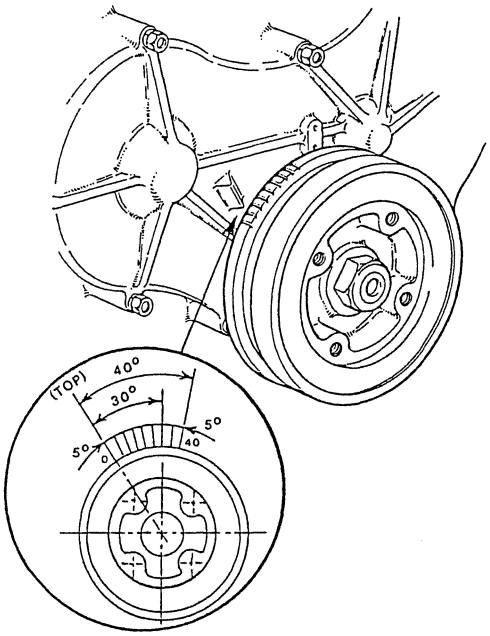
Verifying Injection Pump Timing

a. Locate timing pointer on front gear cover. This pointer is located at about the 10:00-o'clock position when viewing the front crank shaft pulley.



b. The front crankshaft pulley has timing marks embossed on its circumference from 0° top dead center (TDC) to 40° before top dead center (BTD) in five-degree increments. Locate the 20° and 25° marks and place a visible mark halfway between the two points to represent.....23°.

c. Rotate the engine by hand to position the number one piston on its compression stroke. Continue rotating the engine to align the ..... 23° mark on the crankshaft pulley with the timing pointer and stop.



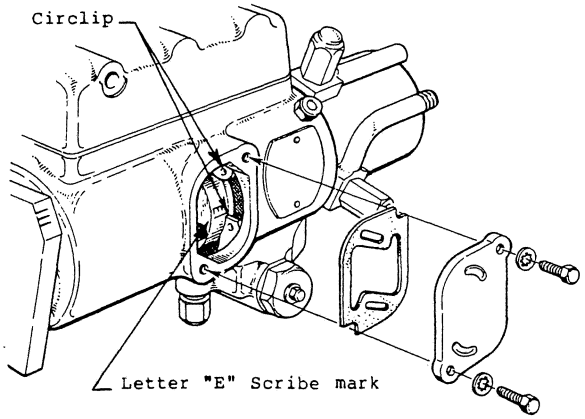
d. On the side of the injection pump body is an oval cover plate, mounted to the pump body by two screws that are wired together. Cut the connecting lock wire, remove the screws and cover plate, including the gasket.

(NOTE: Some fuel will be lost from inside the pump when this cover is removed. Be prepared to catch it in a container.)

e. Inside the opening in the injection pump is a circlip and the rotor body of the pump. The rotor body has a scribe mark on it with the Letter E stamped above it. The scribe mark should align with the top flat surface of the circlip. If the mark does not align, loosen the injection pump securing nuts and gently rotate the injection pump body up or down to align the scribe mark with the circlip flat. The pump is now statically timed to the engine. Secure the pump to its mounting flange, replace the pump side cover and gasket and lock wire the side cover attaching bolts.

(NOTE: Do not over-tighten the side cover attaching bolts.)

Reattach fuel supply and return lines to and from injection pump. Connect high-pressure injector lines between the injection pump and injectors. Do not cross or mix up these lines.



LUBRICATION SYSTEM

1. Lube Oil Circulation

A trochoid rotary pump draws oil from the oil pan through the oil strainer and delivers it under pressure to a full-flow oil filter, then the cleaned oil is forwarded into the oil gallery inside the crankcase. From the gallery, the oil is distributed to the various parts of the engine. The pump is driven from the camshaft. The oil filter is a replacable cartridge-type element, through which the oil is forced.

2. Oil Pump

The pump is located inside the right-hand rear portion of the crankcase. Its main shaft is driven from the skew gear formed to the camshaft.

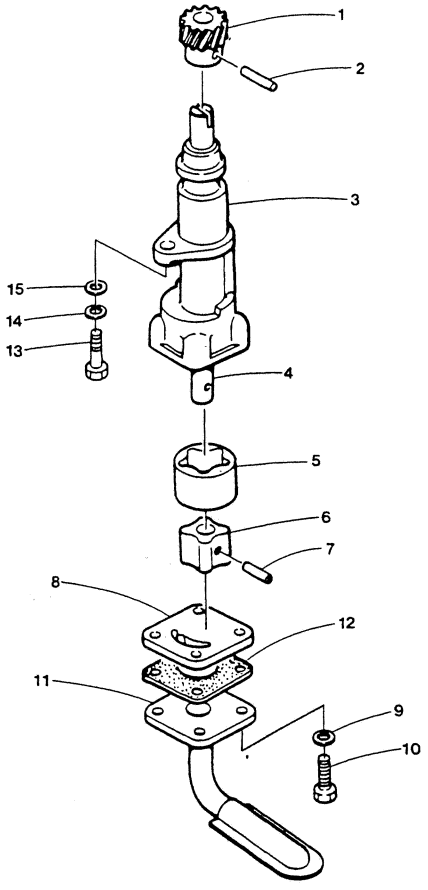
2.1 Disassembly

a. Loosen and remove the four capscrews and washers (9,10) securing oil strainer (11), gasket (12), and oil pump cover (8) to the oil pump (3), and separate the strainer, gasket, and cover from oil pump case.

b. To facilitate removal of outer rotor (5), turn the oil pump case upside down.

c. Drive out the oil pump drive gear taper pin (2) and remove drive gear (1) from main shaft (4). Pull out the main shaft from pump case.

d. Drive out inner rotor pin (7) and separate inner rotor (6) and outer rotor (5) from



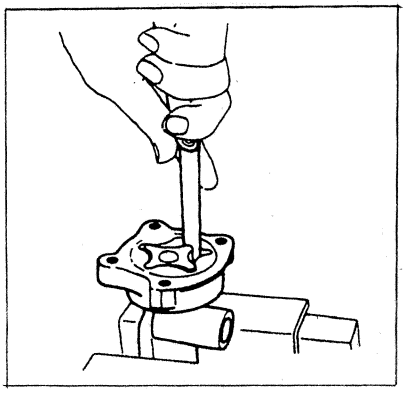
2.2 Inspection

a. Running clearance between outer rotor and inner rotor.

Using a feeler gauge, check the clearance at various positions. If the reading exceeds the service limit, replace both rotors.

Specifications Unit: mm (in.)

Item	Standard	Service limit
Clearance between inner rotor and outer rotor	0.013~0.15 (0.00051~0.0059)	0.25 (0.0098)



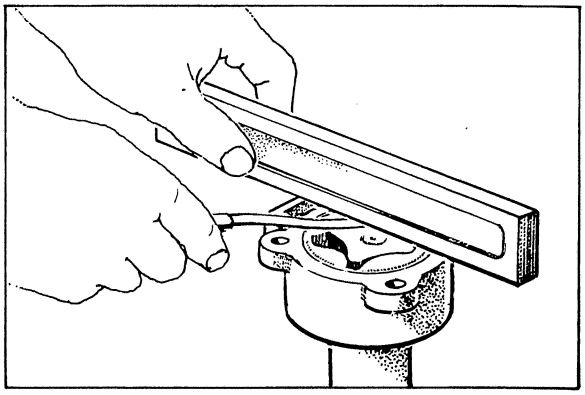
Checking rotor-to-rotor clearance

b. Sliding clearance between rotors and cover.

This clearance is required not to be greater than 0.15mm (0.00591in.) If this limit is exceeded grind off the mating face of the body to reduce the clearance.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Clearance between rotors and cover	0.04~0.09 (0.0016~0.0035)	0.15 (0.0059)



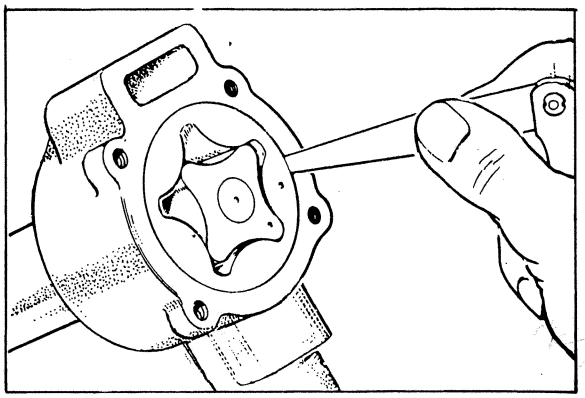
Checking rotor-to cover clearance

c. Radial clearance between outer rotor and pump body.

Insert a feeler gauge between the outer rotor and the body. If the clearance checked is greater than the limit, replace the worn part.

Specifications Unit: mm (in.)

Item	Standard	Repair limit
Clearance of outer rotor in body	0.2~0.28 (0.0079~0.0110)	0.5 (0.020)



Checking rotor-to-body clearance

d. Rotor Shaft Diameter.

Inspect the shaft for damage, and check it for wear by measuring with a micrometer. Determine the available clearance of the shaft in the pump body from the micrometer readings; if the service limit in terms of clearance value is exceeded or if the shaft is in badly-damaged condition, replacement is necessary.

Specifications Unit: mm (in.)

Item	Standard	Service limit
Rotor shaft diameter	$12.6^{+0.06}_{+0.04}$ ($0.496^{+0.0024}_{+0.0016}$)	
Shaft to body clearance	0.040~0.085 (0.00157~0.00335)	

2.3 Reassembly

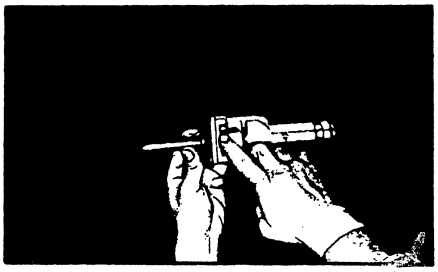
a. Install inner rotor to pump shaft with pin.

b. Place pump shaft in pump case. Install pump drive gear to the shaft with pin.

c. Place outer rotor in pump case, and install pump case cover complete with gasket and oil strainer.

(NOTE: If pump shaft or drive gear has been replaced, a new pin hole must be made by drilling through the gear mounted on the shaft.)

d. After replacing the cover, check to be certain that the match marks are correctly indexed. If the cover is in the wrong position relative to the case, the pump will not draw in oil. Tighten the bolts after checking to be sure that the marks are correctly matched.



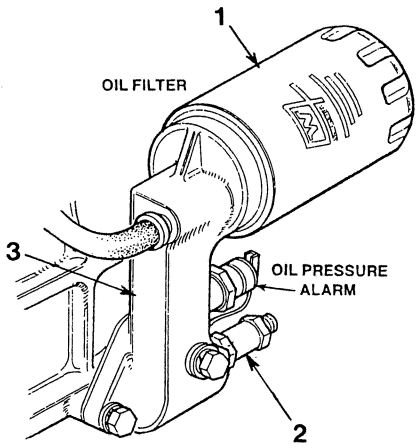
Fitting cover-to-case by matching marks

e. After reassembling the pump complete with its strainer, immerse the strainer in a pool of oil and run the drive gear by hand to make certain that the pump is capable of sucking oil in.

3. Oil Filter

The filter is mounted on the right-hand side of the crankcase at its center part. The oil bypass valve for letting the oil bypass the filter is actually a relief valve located in the center portion of the element. This valve is set to open when the differential pressure across the filter rises to 1.0±0.2kg/cm2 (14.2±2.8psi); when the valve opens, the oil flows directly from the inlet side to the outlet side. The filter must be serviced regularly or before the filter becomes so dirty that it actuates the bypass valve.

The oil filter has a built-in relief valve operating in response to the oil pump discharge pressure. This valve starts relieving when the pressure rises to 3±0.3kg/cm2 (43±4.3psi), thereby bleeding the excess oil to the oil pan and limiting the pressure of oil reaching the engine oil gallery to a constant level.



3.1 Disassembly

1. Remove filter (1) and relief valve (2) from filter bracket (3).

3.2 Inspection

The engine oil and oil filter must be replaced after the first 50 hours of engine break-in. Then replace the oil and filter every 100 hours of engine operation.

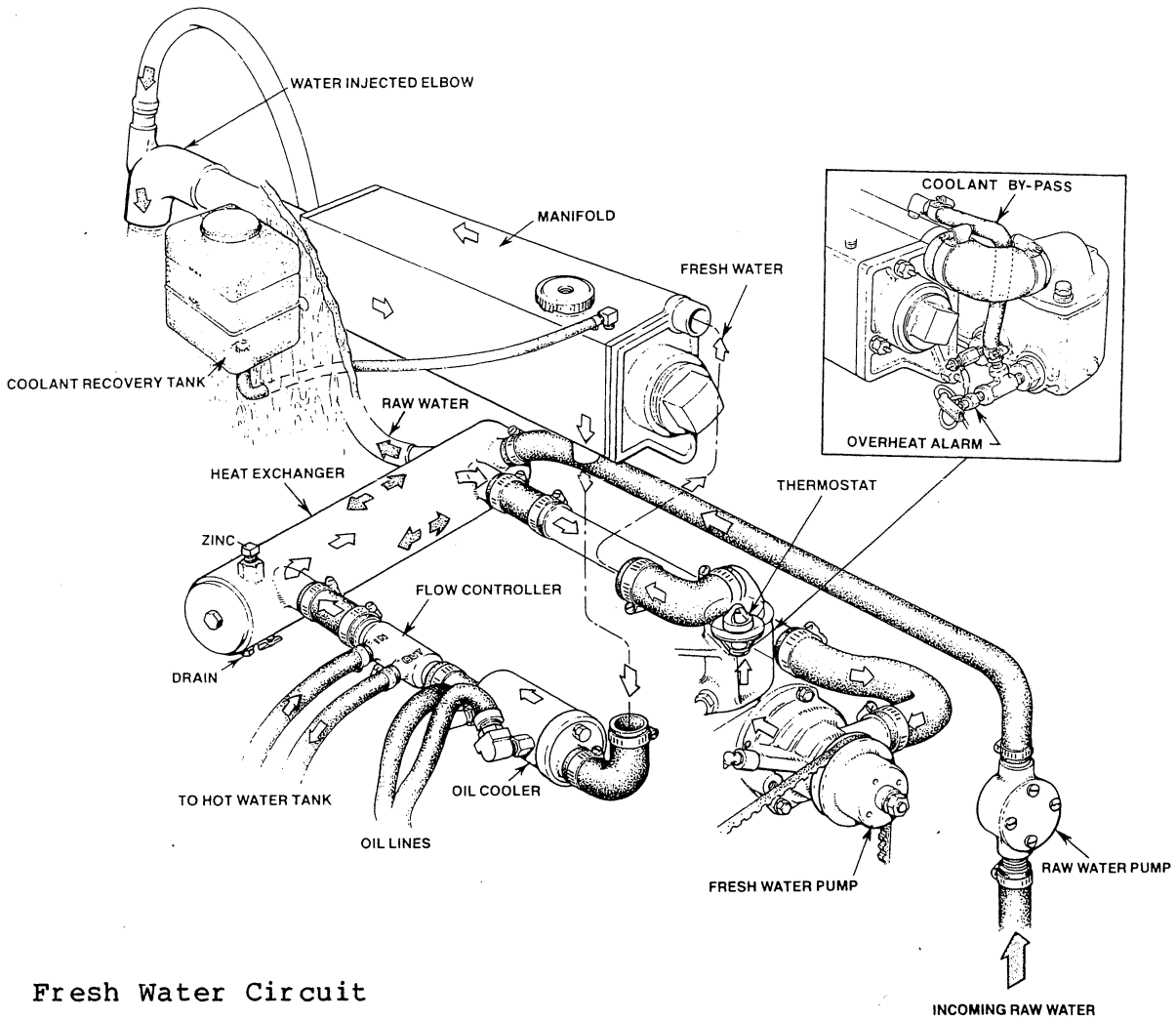
Being conscious about regular oil and filter changes should have a beneficial affect on the engine in reducing internal engine wear.

A good preventative maintenance step to follow every third of fourth oil change is to take a sample of the engine oil being removed (6-8 ounces) and have a spectrographic analysis performed on the oil. This will show what type of internal wear is taking place as the engine accumulates operating hours.

Service Facility: Sample kits are available from them.
Analysts, Inc
2450 Hassell Road
Hoffman Estates, IL 60169
800-222-0071

COOLING SYSTEM

(FRESH AND RAW WATER)



1. Fresh Water Circuit

Refer to the illustration above. Fresh water coolant is circulated through the circuit by the belt-driven fresh water pump mounted on the front of the engine block.

The circulating pump draws coolant from the discharge side of the heat exchanger and moves it through the engine block/head. The thermostat, located in a housing at the top forward part of the cylinder head, controls the operating temperature of the engine by opening and closing to regulate coolant flow through the engine block/head.

The coolant passes through the opened thermostat and the exhaust manifold to the lower discharge of the manifold through the lube oil cooler. The coolant then passes through the domestic water heater flow controller and into the engine's heat exchanger, where it is finally cooled by the raw water circuit.

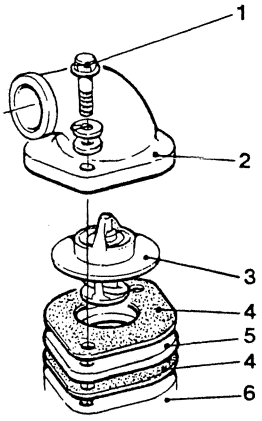
2. Raw Water Circuit

Raw water is drawn into the raw water pump (positive displacement-neoprene impeller type) by the suction action of the impeller in the pump. This raw water is pumped to the raw water inlet of the heat exchanger where it passes through the tubes inside the exchanger and removes heat from the fresh water coolant flowing around the outside of the tubes. (Refer to the cooling system illustration.)

The raw water is then discharged from the exchanger and then may be directed to the transmission oil cooler. It then passes into the exhaust injection elbow to be mixed with the exhaust gases, cooling them as this mix falls into the exhaust muffler and is pushed overboard by exhaust gas pressure.

3. Thermostat #024688

The thermostat is a wax type, designed to maintain engine operating temperature between 170°-190°F. (77°-88°C).



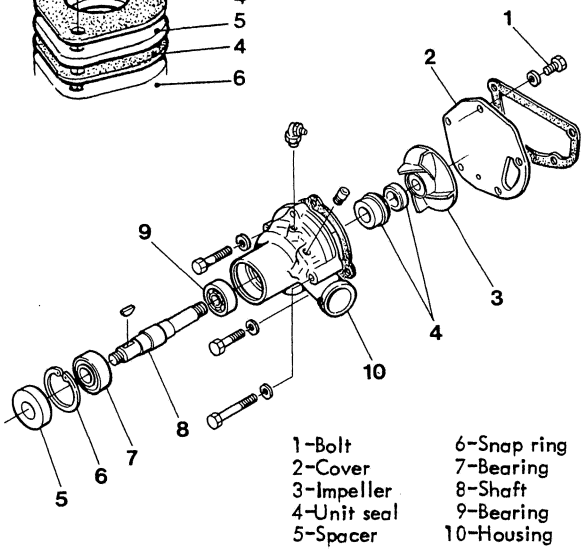
3.1 Disassembly

a. Remove thermostat cover (2) by loosening and removing bolts (1) and washer.

b. Remove thermostat (3), gaskets (4) and spacer (5) from engine block (6).

4. Fresh Water Pump #034370

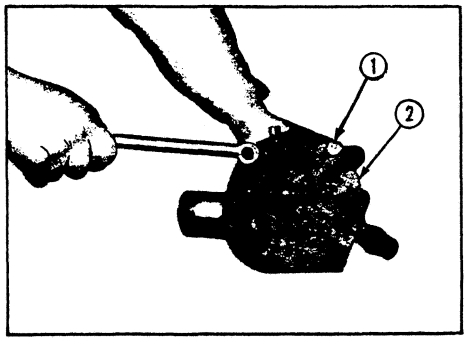
The water pump is the centrifugal type. Its bearings are lubricated by water pump bearing grease applied thru the zerk fitting on the side of the pump.



4.1 Disassembly

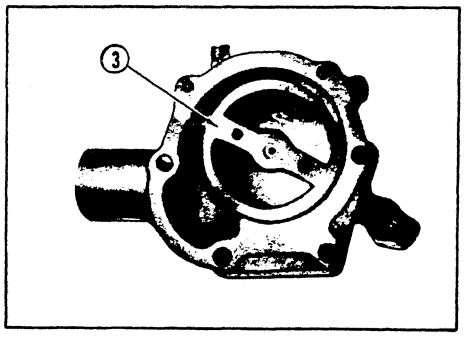
a. Loosen and remove water pump shaft nut and lock washer; remove water pump pulley and woodruff key.

Remove pump cover (2) by loosening and removing cover attaching bolts (1).

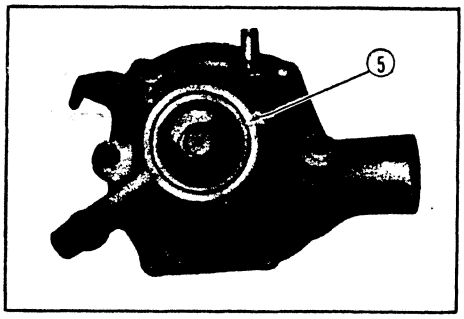


c. To remove impeller (3), support the shaft with a stand and unscrew impeller.

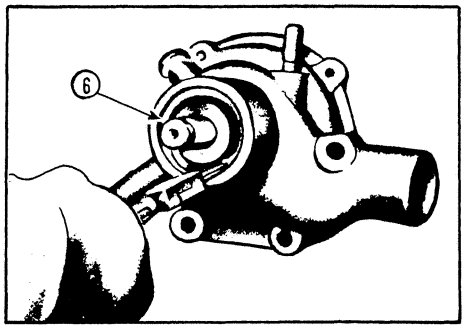
(NOTE: The impeller is thread-mounted on the shaft. The thread is right-handed.)



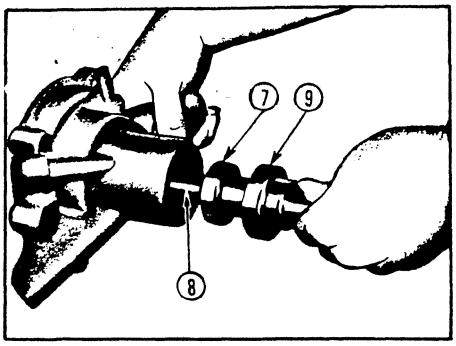
d. Remove spacer (5) from the shaft at the pulley side of the pump case.



e. Remove snap ring (6) from the pulley side of the pump case.



f. Pull shaft (8) off the pulley side of the pump case and remove bearings (7) and (9) from the shaft.



4.2 Inspection

a. Examine the pump operation by slowly rotating it. If the pump is erratic in rotation, replace bearings. bearings.

b. Visually check the impeller for corrosion or breakage. Replace a defective impeller. Also check for signs of rubbing. If such rubbing is evident, check the cause. The impeller and case or cover, if found damaged due to rubbing, must be replaced with new ones.

c. Check the condition of the unit seal. Replace the seal if it is badly worn or damaged.

d. Check the pump shaft bearing journals for wear. Replace the shaft if the journals are excessively worn.

e. Check the surfaces of the pump case where the bearings are fitted for excessive wear or damage. Replace the case (or the pump assembly) if those surfaces on the case are found in bad condition.

(NOTE: Upon assembling the water pump, turn it by means of the pulley, making certain that the pump rotation is smooth without any signs of binding.)

4.3 Reassembly

a. Install bearings (2) on pump shaft (1) and install the shaft in pump case (4).

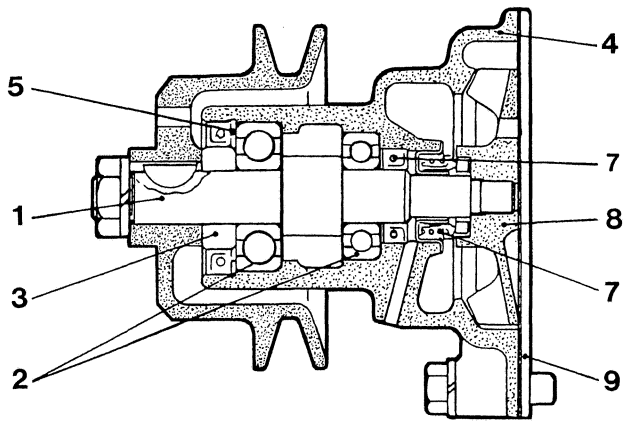
b. Install snap ring (5) in pump case on pulley side.

c. Install larger half of unit seal (7) in the pump case and smaller half of seal in the impeller (8); screw the impeller onto the shaft.

d. Install cover (9)

e. Install spacer (3) onto the pulley side of the shaft, position the woodruff key in the shaft keyway, and install the pulley onto the shaft; fasten the pulley to the shaft with the lock-washer and water pump shaft nut.

f. Rotate the shaft to check that the impeller does not interfere with cover.

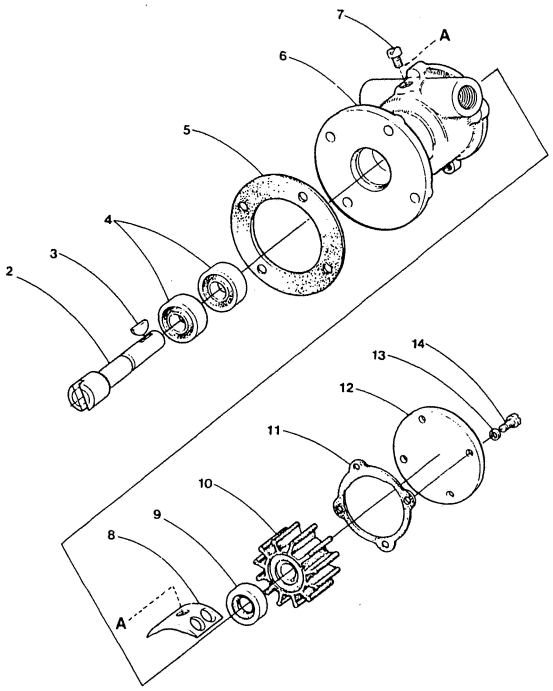


g. Apply water pump grease thru the Zerk fitting. Capacity-20cc (1.2 cubic inches). Do not overfill.

5. Raw Water Pump (PN: 016423)

The pump is a positive replacement type pump, engine driven, with a replaceable neoprene impeller.

5.1 Disassembly



a. Remove front cover screws and washers (13) & (14) and front cover (12) with gasket (11.)

b. With a pair of screw drivers positioned 180° apart on the impeller (10), carefully pry the impeller from the shaft and out of the pump body.

c. Remove screw (7) and take cam (8) out of the pump.

d. Remove key (3) from the impeller shaft (2).

e. Support the pump base in an arbor press or similar press and push the impeller shaft (2) and bearings (4) out of the pump housing (6).

f. Properly support bearings (4) and remove from shaft (2). In some disassembly, bearings may remain in pump housing. In those cases, support the housing and push bearings out.

g. Push seal (9) from inner housing.

(Note placement of seal in housing (seal lip) to reinstall correctly).

5.2 Inspection

a. Visually examine impeller (10). Look for any cracked or worn impeller blades. Material should be flexible. Replace if suspected.

b. Visually examine cover (12) inner surface. Replace if there is any indication of wear or grooving from the impeller turning on the inner surface.

c. Check cam (8) for wear. Replace as needed.

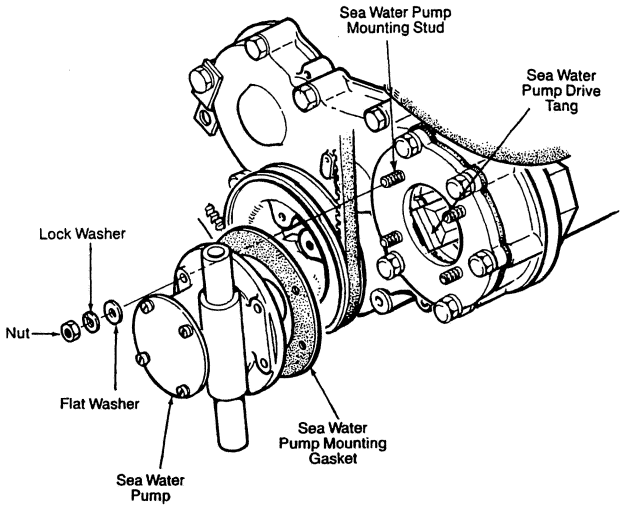
d. Check bearings (4) and rotate. Look for binding and any indications of damage.

e. Visually examine shaft (2) for wear in the areas of the bearing journals and the area of seal (9) contact. Replace if badly worn or damaged.

f. Visually examine pump housing (8) for any wear or damage in the areas of the shaft bearing outer journals and housing area where the impeller turns in.

6. Raw Water Pump Engine Mounting

a. Care must be taken when mounting the raw water pump to the mounting flange. The slotted drive in the shaft of the sea water pump should fit onto the drive tang from the engine. The slotted drive and the tang should not be forced against each other when the raw water pump is secured. This would cause undue stress on the pump bearings and the drive tang gear.



b. Alignment is just as critical as the drive clearance. The raw water pump intentionally has no pilot because the location of the timing cover and the mounting flange vary when bolted to the engine. To assure that the pump shaft is axial (centered) with the driving tang, install the pump with its gasket(s) just snuggly. With the fuel lever on the injection pump in the OFF position, crank the engine for a few seconds, so the raw water pump will align with the drive tang. Visually verify movement of the pump, as it aligns during cranking. Secure the pump by tightening up on its four hold-down nuts.

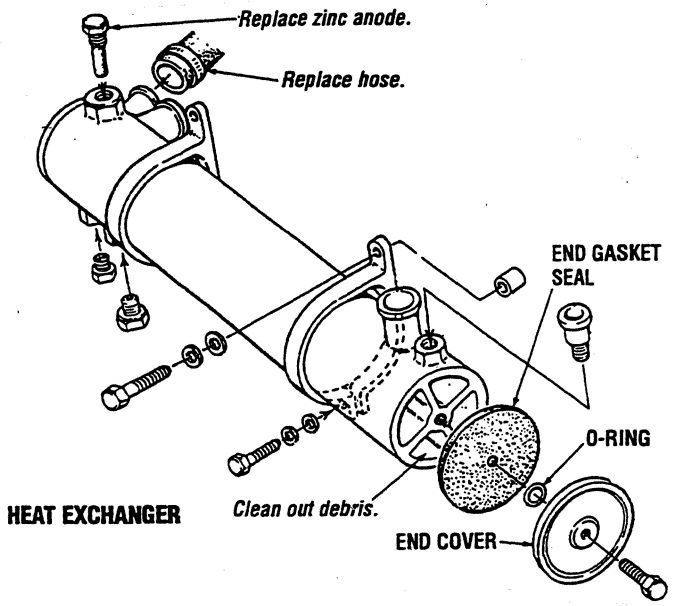
(NOTE: This procedure must be followed any time the raw water pump is removed or loosened for any reason.)

NOTE: *Inspect the drive tang that fits into the sea water pump each season or when removing the pump. Replace if worn.*

HEAT EXCHANGER

The heat exchanger should be inspected and serviced during an engine overhaul.

1. Disconnect the hoses and remove the hose fittings, petcock, drain plugs and zinc anode. Also, remove the end fittings and gaskets.
2. Inspect the tube (casing) for wear and dents, if at all suspect replace the heat exchanger.
3. Have the exchanger professionally cleaned and pressure tested by a radiator shop.
4. When reassembling always use new end cover gaskets and "O" rings.
5. Install a new zinc anode. **Do Not** use any sealant on its threads.

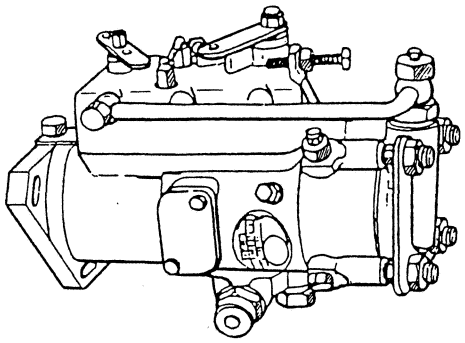


NOTE: *All of the above can be accomplished by sending the heat exchanger to a radiator shop. They will also service transmission and engine oil coolers.*

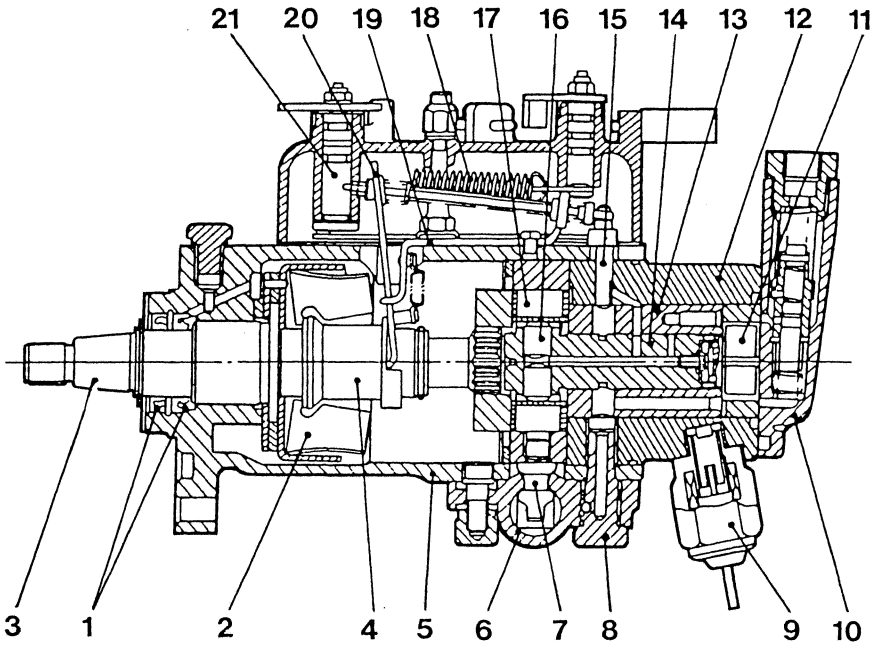
1. Fuel Injection Pump (DPA).

Description

The DPA injection pump is a distributor type pump consisting of a transfer pump, fuel pumping plunger, distributing device, automatic advance, mechanical governor and control linkage, which are built into a compact, lightweight pump housing. Functionally, this pump features a pair of pumping plungers for metering and delivering fuel.



DPA Fuel Injection Pump



1-Drive hub seal	8-Head locating stud	15-Metering valve
2-Governor weight	9-Shut-off solenoid valve	16-Plunger
3-Drive shaft	10-End plate (regulating valve)	17-Cam roller
4-Thrust sleeve	11-Transfer pump	18-Governor spring
5-Pump housing	12-Head & rotor assembly	19-Governor arm bracket
6-Automatic advance	13-Hydraulic head	20-Governor arm
7-Cam advance screw	14-Rotor	21-Shut-off shaft

DPA Fuel Injection Pump - Sectional View

(NOTE: Ref #3 Drive Shaft - earlier pumps had a keyed drive shaft; later pumps had a splined drive shaft with master spline.)

2. Fuel Filter #024363

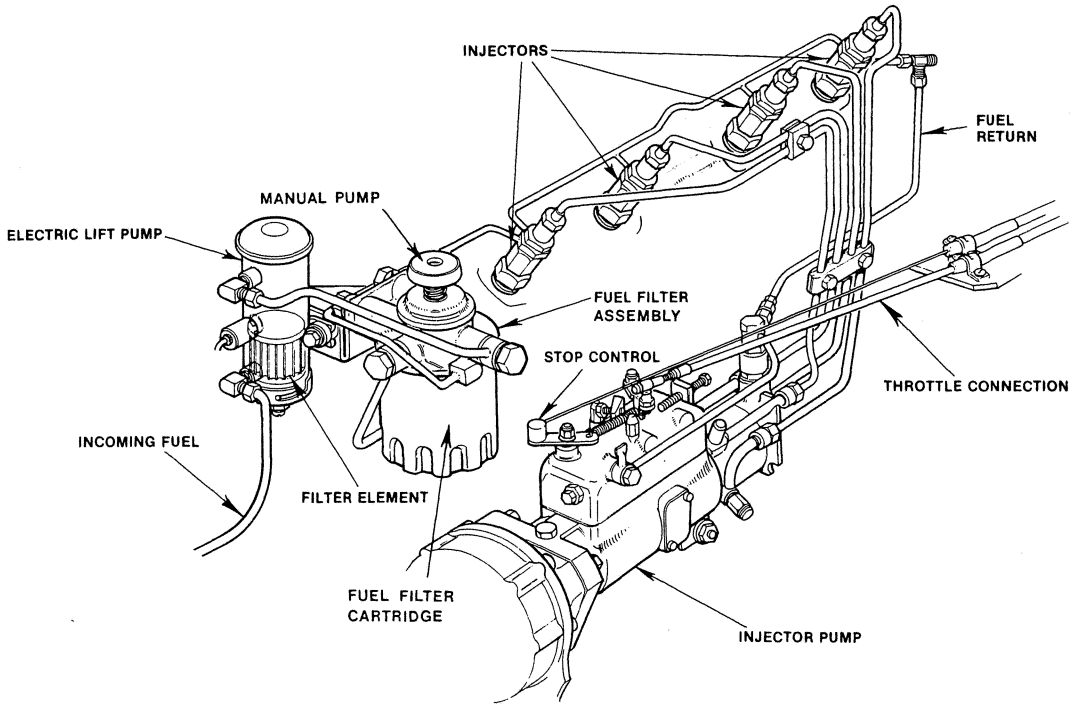
The fuel filter is a spin-on type. Its mounting housing has a manual priming pump.

a. Servicing

Remove the filter element by unscrewing it from the filter housing with the aid of a small filter wrench. Care should be taken to catch any fuel that may be spilled while removing the filter.

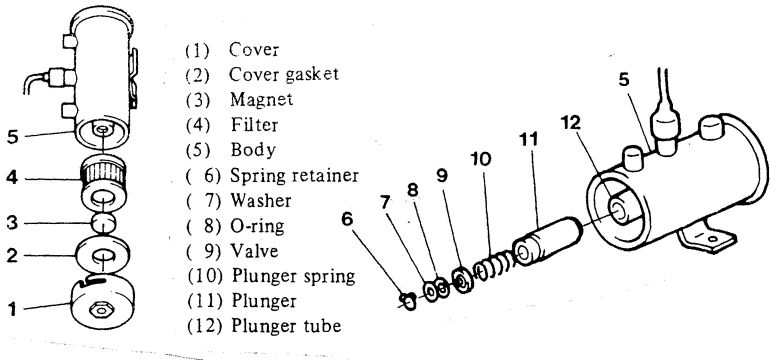
(NOTE: In installations with fuel tanks located above engine height, to prevent fuel syphoning when the filter is removed, shut the fuel OFF at the tank shut-off during this servicing. Turn the fuel back ON, once a new filter has been installed. Install the new filter simply by applying some fuel to the sealing gasket of the filter and screwing it carefully onto the filter housing. Tighten approximately 3/4 of a turn once the sealing gasket contacts the housing. Turn the ignition key ON to activate the fuel pump. This will prime the filter and vent any air from it.)

(NOTE: The manual priming pump on the filter housing may be used to accomplish this same function without having to turn the ignition key ON. (It takes approximately 20 pumps to prime the filter.)



3. Fuel Pump #301385

This is a solenoid-operated (transistor type) 12-Volt DC fuel pump. The reciprocating motion of the pump plunger is controlled by a transistorized circuit.



Disassembly and Reassembly of the Electric Fuel Pump for Cleaning

Because this transistorized fuel pump is totally enclosed, only the cover, filter and plunger assembly require cleaning.

Using a 17-mm wrench, remove the cover (1). (See illustration) Then, the cover gasket (2), magnet (3) and filter (4) can be removed from the pump body (5). Replace the filter as needed.

Check the cover gasket, and if damaged, replace it. Clean the magnet and cover thoroughly.

To remove the plunger, first remove the spring retainer (6) from the plunger tube (12). Then remove the washer (7), O-ring seal (8), valve (9), plunger spring (10) and plunger (11) from inside the tube. Wash these parts in clean diesel oil and remove the oil and other contaminants using compressed air.

CAUTION The plunger tube (12) has very small wall thickness. Be careful not to deform the tube during removal of the plunger parts. Carefully handle the plunger to prevent it from being dented or otherwise damaged.

(1) To assemble, install the plunger, plunger spring, valve, O-ring and washer, in that order, and secure assembled parts with the retainer.

(2) Install the filter element, and then the magnet and gasket in the cover and tighten the cover with a 17-mm wrench to the ends of the slotted stop.

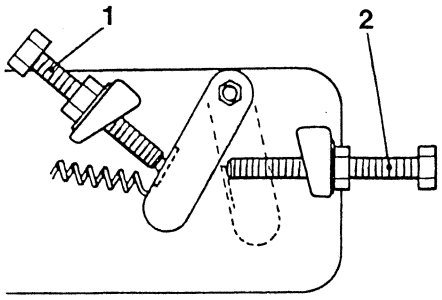
Checking the Electric Fuel Pump

Turn on the ignition switch (for a generator, use PREHEAT). The pump should produce a clicking sound. If the pump does not produce any operating sound, check with a DC voltmeter to determine that 12 Volts is being supplied to the pump. If 12 Volts is being supplied to the pump and the pump still does not make any operating sound, replace the fuel pump assembly. If 12 Volts is not present at the pump, check the unit circuit breaker, electrical connections and switch. Fuel delivery (free flow) is 225cc (.48 pints) every 15 seconds. The electrical fuel pump should maintain a positive fuel inlet pressure to the injection pump during engine operation.

1. Idling and Maximum No-Load Speed Adjustments

These adjustments are initially made at the factory during engine testing. To adjust idle speed, loosen the 8-mm locknut and adjust the stop screw (1) clockwise to increase idle speed, or counterclockwise to lower idle speed; normal idle speed is between out, to lower (8 mm stop screw) normal idle speed is between 700-850 RPM.

This may vary with installations and reduction gears used. No-load speed is adjusted and sealed at the factory with 8-mm stop screw (2). RPM full open throttle in neutral is 3220 RPM. Do not tamper with this adjustment.



(NOTE: Propeller load should hold engine speed between 2900-3000 RPM, full open throttle, underway, and in forward gear.

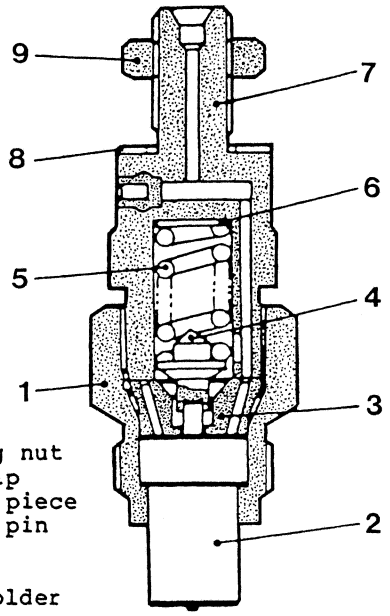
Any time RPM is questionable, ensure that tachometer calibration is correct with engine speed before attempting other adjustments.

2. Fuel Injection Nozzles

a. Description

The injection nozzle provides a means of spraying fuel, delivered under pressure from the injection pump, into the precombustion chamber. The nozzle sprays oil in a conical pattern of finely-atomized droplets. The mating surfaces of the nozzle holder body, distance piece and nozzle are precision-finished to be oil tight.

The injection pressure is adjusted by an adjusting washer. Increasing the thickness of the washer will increase the spring tension and, hence, the injection pressure, and vice versa.



1-Retaining nut
2-Nozzle tip
3-Distance piece
4-Pressure pin
5-Spring
6-Washer
7-Nozzle holder
8-Gasket
9-Nut

Inspection Nozzle - Sectional View

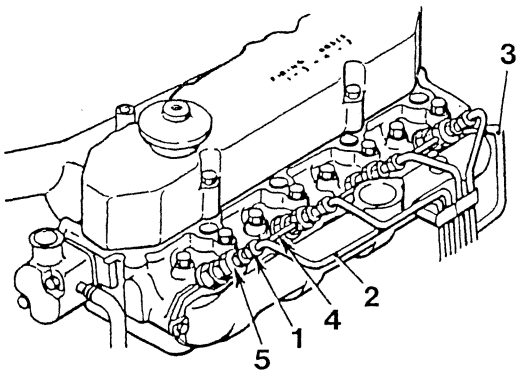
b. Removal and Installation

1. Removal Sequence

a. Connectors (1) (4 Pcs)
b. Fuel Feed pipes (2)
c. Fuel return pipe (3)
d. Fuel leak-off pipe (4) (nuts (5) 4 pcs)
e. Fuel injection nozzle assemblies

2. Installation Sequence

Follow the reverse of removal sequence.



Unit: kg-m (lb-ft)

Fuel injection nozzle tightening torque	5 ± 0.5 (36.2 ± 3.6)

CAUTION

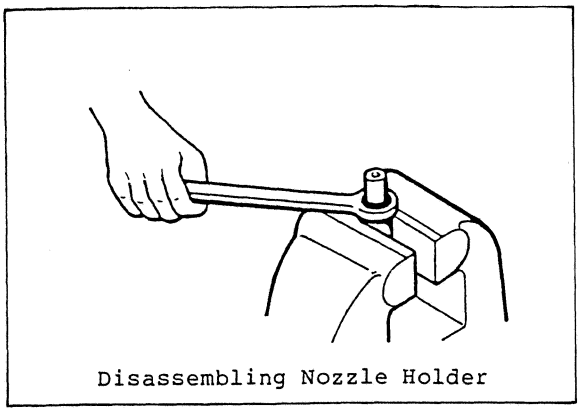
After removing injection nozzles, be certain to cover disconnected ends of injection pipes and nozzle holes in cylinder head to prevent entry of dirt.

c. Disassembly and Reassembly

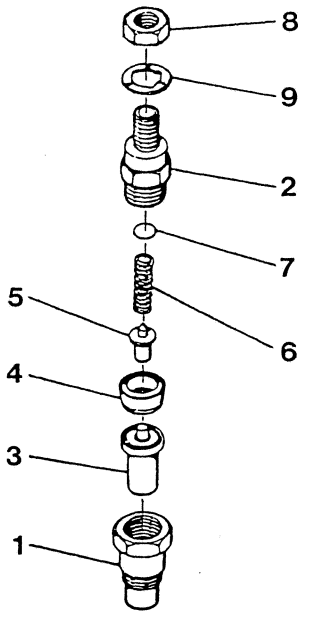
(NOTE: Before disassembly, collect data on the nozzle by testing it for injection pressure (beginning of injection), spray pattern and internal oil-tightness, all in the manner already described. Throughout the disassembly, cleaning, and reassembly work, handle each nozzle assembly with care to protect, in particular, the nozzle tip.)

1. Disassembly Sequence

a. Retaining nut (1) (hold it in a vise).
b. Nozzle holder (2)
c. Nozzle tip (3)
d. Distance piece (4)
e. Pressure pin (5)
f. Spring (6)
g. Washer (7)



Disassembling Nozzle Holder



1-Retaining nut
2-Nozzle holder
3-Nozzle tip
4-Distance piece
5-Pressure pin
6-Spring
7-Washer
8-Nut
9-Gasket

Injection Nozzle Assembly - Disassembled View

2. Reassembly Sequence

Follow the reverse of disassembly sequence.

(NOTE: If the needle valve and nozzle proper have to be replaced, be sure to wash the replacement parts in a pool of kerosene after removing their protective films of plastic: wash off the rust preventive oil from the nozzle proper by stroking the needle valve back and forth in the needle valve stem bore.)

d. Inspection

Needle valve and nozzle body

1. Immerse needle valve and nozzle body in a pool of clean kerosene, insert the valve into the body, and move the valve back and forth to be sure that the sliding contact is smooth without evidencing any excessive clearance. The entire injection nozzle must be replaced if the fit is found defective.

2. Visually examine the nozzle body with a magnifying glass having a power of 4 or 5.

3. Inspect the needle valve for distortion or damage at its seating part and for wear of its end face in contact with the pressure pin.

4. Poor seating contact may be corrected, if the defective condition has not advanced too far, by lapping the valve against the seat with a coat of clean lube oil applied to the seating faces. If this does not help, the injection nozzle must be replaced.

Nozzle holder and distance piece.

Check the fit between nozzle holder and distance piece. Determine the quality of the fit from contact patterns obtained with the use of red lead paste: defective fit will be obvious by an abnormally high rate of return oil (leak-off) flow.

Pressure spring and pressure pin.

1. Replace any pressure spring that is broken, cracked or otherwise defective, and out of square. Inspect each spring carefully for these defects.

2. Inspect each pressure pin for wear at its end faces, one for pressure spring and the other for needle valve.

Leak-off pipe packing

If the packing is found to be in a deteriorated condition, replace it.

3. Testing and Adjustment

Injection Pressure

The pressure at which the needle valve unseats itself against the force of the pressure spring is referred to as valve opening pressure or beginning-of-injection pressure, however, it will be referred to as injection pressure in this manual. The value of this pressure is specified; it is checked and adjusted as follows:

a. Install the injection nozzle in the nozzle tester, and operate the manual pumping handle of the tester several times to prime the nozzle.

b. Move the lever in an up-and-down cycle of one per second to pressurize the injection nozzle, while observing the indication of the test pressure gauge. As the nozzle begins to spray, the deflected gauge needle will indicate the injection pressure.

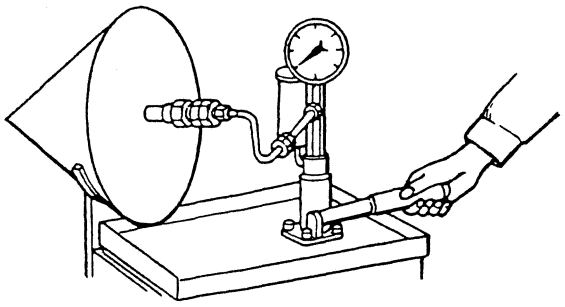
Specifications Unit: kg/cm² (psi)

Item	Standard	Repair limit
Injection pressure	120^{+10}_{0} ($1706.4^{+142.2}_{0}$)	110 (1564.2), max

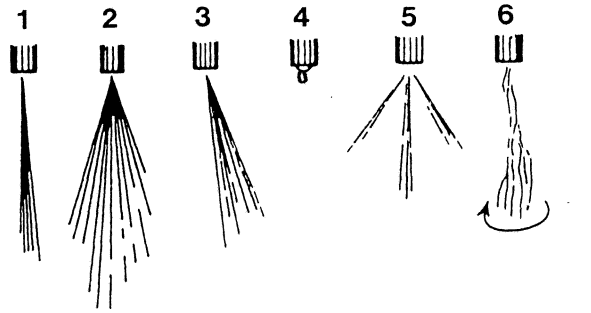
c. If the indicator reading is below the limit, increase the thickness of the washer used on the pressure spring. Increasing the washer thickness by 1mm (0.04in.) increases the injection pressure by about 10kg/cm2 (142psi). Washer stock for adjustment purposes is available in 20 sizes, ranging from 1.0mm (0.0394in.) up to 1.95mm (0.0768in.), in increments of 0.05mm (0.0020in.) each.

Spray Pattern

The injection nozzles used in the present engine are the throttle type. Some throttling action takes place when the needle valve begins to unseat, limiting the amount of sprayed fuel during the initial stage of each fuel injection. Thus, each slug of sprayed fuel may be regarded as comprised of two portions; initial throttled spray and terminating main spray.



Checking injection pressure on nozzle tester



1-Good
2-Spray cone too large
3-Off center spray
4-After-dribble
5-fissured spray
6-Whirling spray

Possible patterns of spray

When tested on the nozzle tester, the injection nozzle can reproduce these two spray types for visual inspection. Initial throttled spray occurs when the tester lever is operated at a rate of 60 cycles-per-minute (up and down in one second); terminating main spray occurs when the lever is operated rapidly at a rate of 4 to 6 cycles-per-second.

a. Initial Throttle Spray

When the nozzle is producing this spray only, the atomization is generally poor and the pattern is straight then conical. Evidence of after-dribble, fuel dribbling after injection, is also present. All these are due to the injected fuel being throttled by the pintle protruding from the valve.

While the nozzle is producing this spray, check the needle valve for chattering in synchronism with the cyclic motion of the lever; if so, then the needle valve is free from any sticking or hitching tendency. If not, the nozzle and needle valve must be cleaned by washing and then re-tested.

Evidence of off-center spray or directionally-erratic spray, indicates that the injection nozzle needs thorough cleaning.

b. Terminating Main Spray

With the tester lever operated at a rate of 4 to 6 cycles-per-second, the initial throttle spray is minimally visible. The spray under this condition may be regarded as main spray. The main spray should be a good straight cone, consisting of finely-atomized fuel particles without any large droplets, finely-atomized fuel particles without any large droplets, and should terminate with no dribble or dripping fuel at the tip.

Seating Tightness

An injection nozzle, tested and adjusted as above, and found to produce a good spray pattern, may be re-used in the engine, provided that it passes this final test: seating tightness test.

With the injection nozzle mounted on the nozzle tester, raise the pressure slowly to 100 or 110kg/cm2 (1422 or 1564psi), without exceeding the set pressure of 120kg/cm2 (1706psi), so that the needle valve will not unseat. Hold the pressure and observe the nozzle tip; there should be no evidence of fuel oozing out to form a dribble. If such evidence is noted, the contacting faces of the needle valve and seat must be repaired by lapping in the manner previously suggested or the entire injection nozzle must be replaced.

(NOTE: Check injection nozzle for spray pattern every 1200 hours and remove carbon deposits around nozzle tip. Overhaul or replace as needed.)

TIGHTENING TORQUE SPECIFICATIONS

Important bolts and nuts

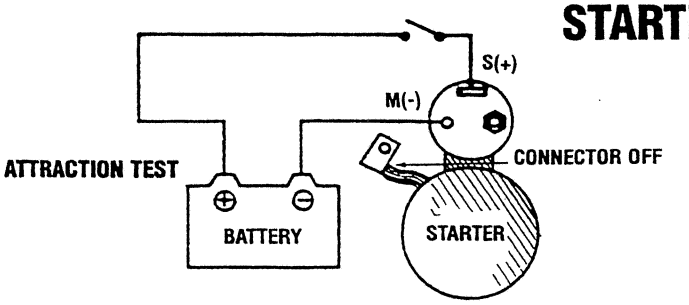
kg-m (lb-ft)

Secured part or component	Threads	Tightening torque
	Diameter – Pitch	
Cylinder head	12 – 1.75	12 (86)
Main bearing cap	12 – 1.75	8.5 (61)
Connecting rod bearing cap	10 – 1.0	5.5 (40)
Flywheel	12 – 1.25	8.5 (61)
Camshaft thrust plate	8 – 1.25	1.8 (13)
Front plate	8 – 1.25	1.0 (7)
Timing gear case	8 – 1.25	1.0 (7)
Crankshaft pulley	24 – 1.5	40 (288)
Rear plate	10 – 1.25	3.5 (25)
Idler thrust plate	10 – 1.25	3.5 (25)
Rear oil seal	6 – 1.0	0.4 (3)
Oil pan	8 – 1.25	0.7 (5)
Oil pan drain plug	18 – 1.5	10.0 (72)
Rocker shaft bracket	8 – 1.25	1.5 (11)
Injection pump delivery valve holders		3.0 (22)
Nozzle holder retaining nuts		5.0 (36)

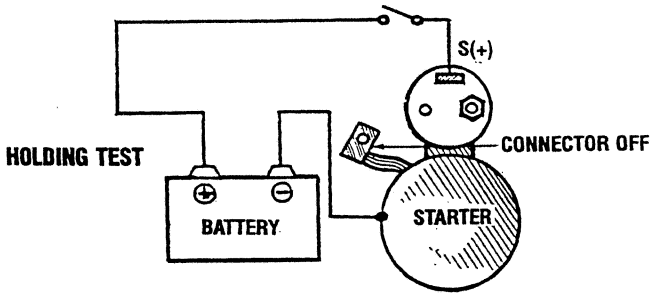
General bolts and nuts

Screw thread		Tightening torque			
		With spring washer		Without spring washer	
dia.	pitch	kg-m	lb-ft	kg-m	lb-ft
8	1.0	1.8	13	2.2	16
	1.25	1.8	13	2.1	15
10	1.25	3.6	26	4.2	30
	1.5	3.4	25	4.0	29
12	1.25	6.5	47	7.6	55
	1.75	6.0	43	7.1	51
14	1.5	10.4	75	12.2	88
	2.0	9.8	71	11.5	83
16	1.5	15.8	114	18.6	135
	2.0	15.0	108	17.6	127
18	1.5	22.9	166	26.9	195
	2.5	20.7	150	24.4	176

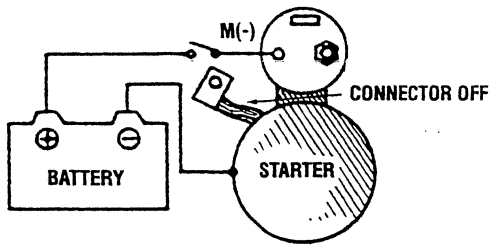
STARTER MOTOR



3. *Holding test.* With a battery connected to the solenoid terminal S (+) and to the starter body, manually pull out the pinion fully. The pinion must remain at that position even when released from holding with your hand.



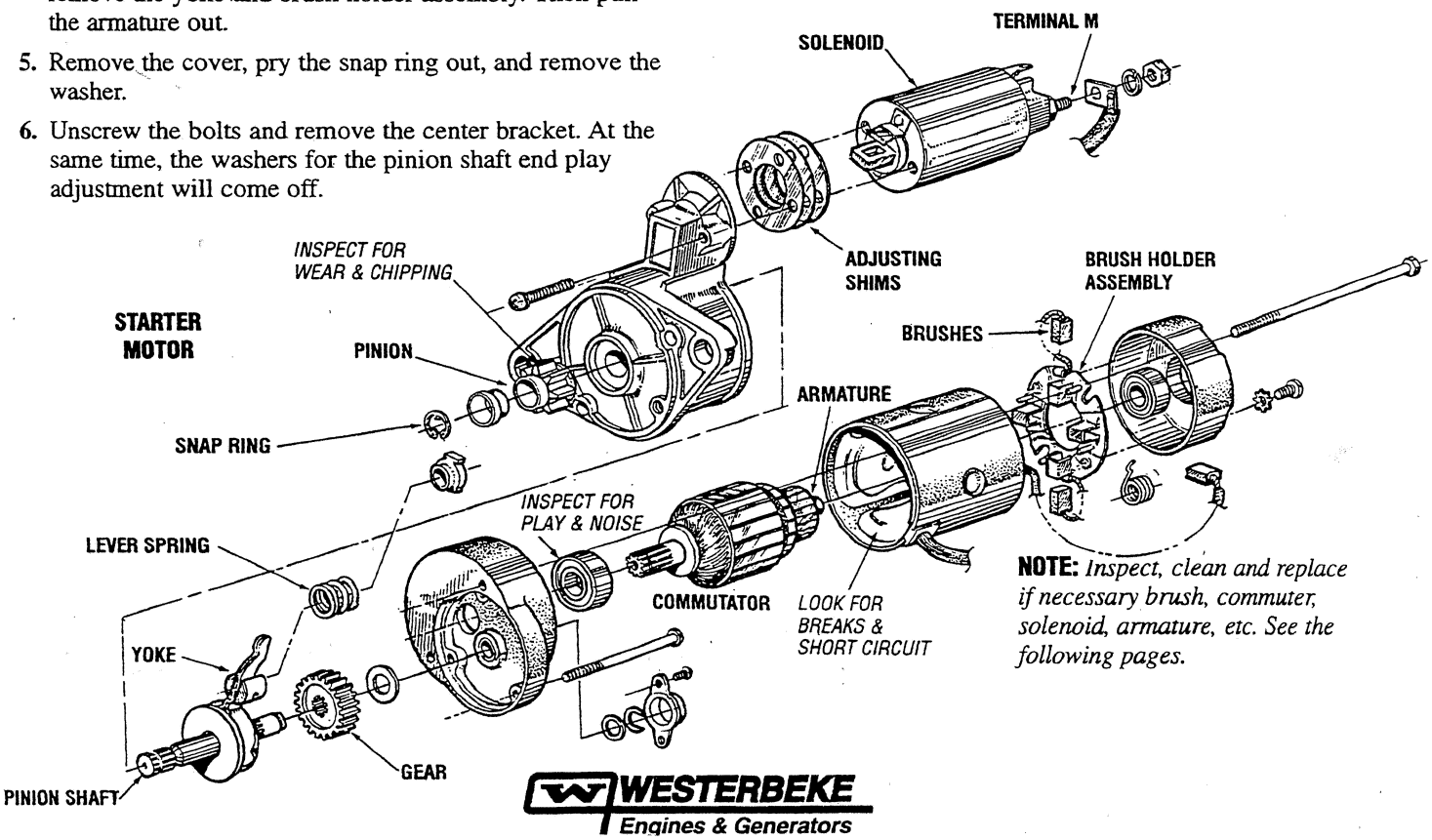
4. *Return test:*. With a battery connected to the solenoid terminal M (-) and to the starter body, manually pull out the pinion fully. The pinion must return to its original position when released from holding by hand.



RETURN TEST

STARTER DISASSEMBLY

1. Disconnect the wire from the solenoid terminal M (-).
2. Loosen the two screws fastening the solenoid. Remove the solenoid assembly.
3. Remove the two long through bolts and two screws fastening the brush holder. Remove the rear bracket.
4. With the brushes pulled away from the armature, remove the yoke and brush holder assembly. Then pull the armature out.
5. Remove the cover, pry the snap ring out, and remove the washer.
6. Unscrew the bolts and remove the center bracket. At the same time, the washers for the pinion shaft end play adjustment will come off.
7. Pull out the reduction gear lever and lever spring from the front bracket.
8. On the pinion side, pry the snap ring out, and pull out the pinion and pinion shaft.
9. At each end of the armature, remove the ball bearing with a bearing puller. It is impossible to replace the ball bearing press-fitted in the front bracket. If that bearing has worn off, replace the front bracket assembly.

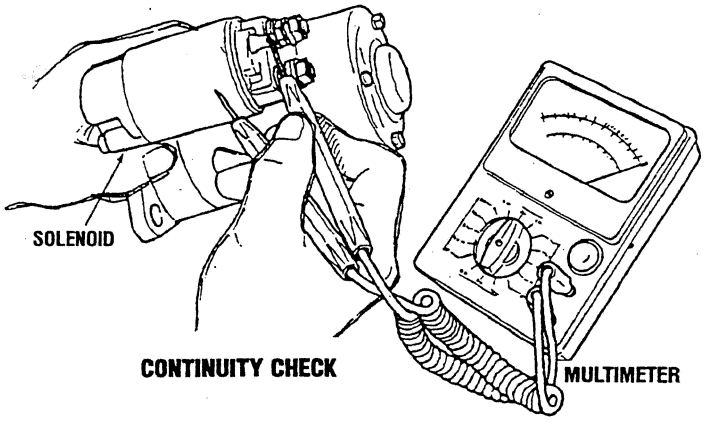


NOTE: *Inspect, clean and replace if necessary brush, commuter, solenoid, armature, etc. See the following pages.*

STARTER INSPECTION

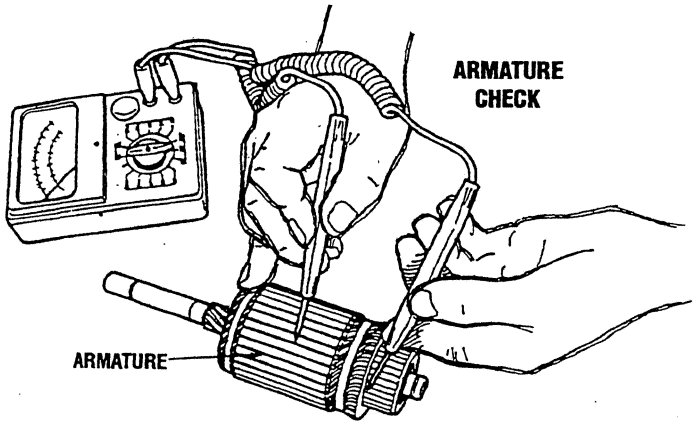
Solenoid

Inspect the solenoid for continuity between terminals S and M and between terminals S and body. No continuity should be found between S and M. Continuity should be found between S and the body and M and the body.

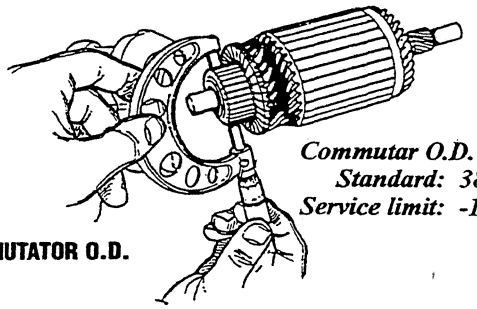


Inspecting The Armature

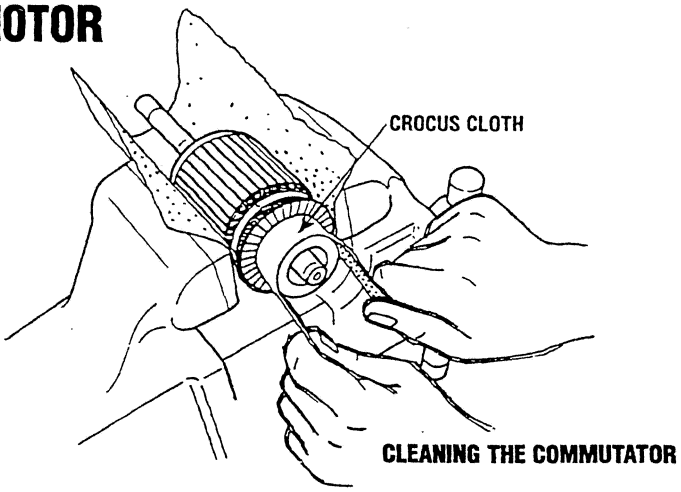
1. Check the armature with a growler tester. If it's short circuited, replace the armature. Also check for insulation between the communicator and its shaft. If poorly insulated, replace the armature.



2. Measure the commutator O.D. and the depth of undercut. Repair or replace it if the service limit is exceeded. Also check the commutator outside surface for dirtiness and roughness. If rough, polish the commutator with fine crocus cloth.



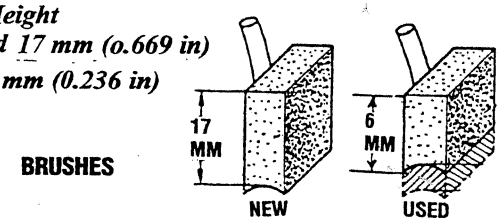
Commutar O.D. Standard
Standard: 38.7 mm (1.523 in)
Service limit: -1.0 mm (-0.039 in)



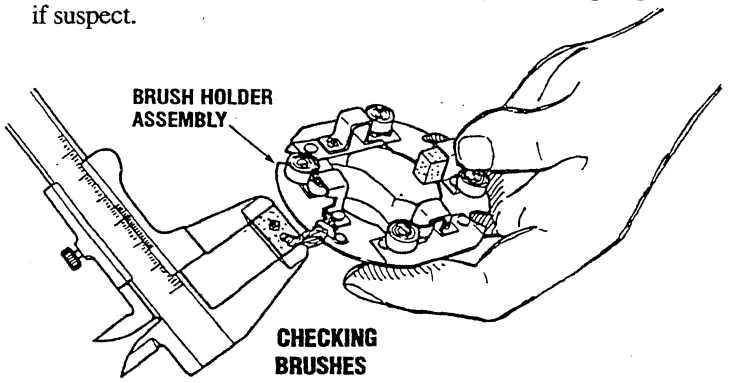
Brush and Brush Holder Inspection

1. Check the brushes. If worn out beyond the service limit, replace the brushes.

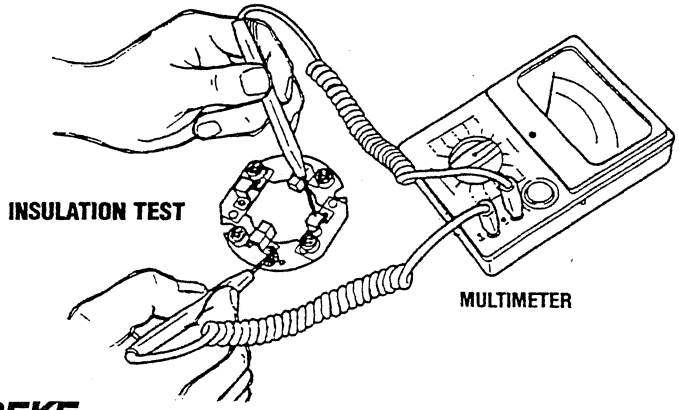
Brush Height
Standard 17 mm (o.669 in)
Limit 6 mm (0.236 in)



2. Check the brush spring tension. A weak or defective spring will cause excessive brush wear; replace the springs if suspect.

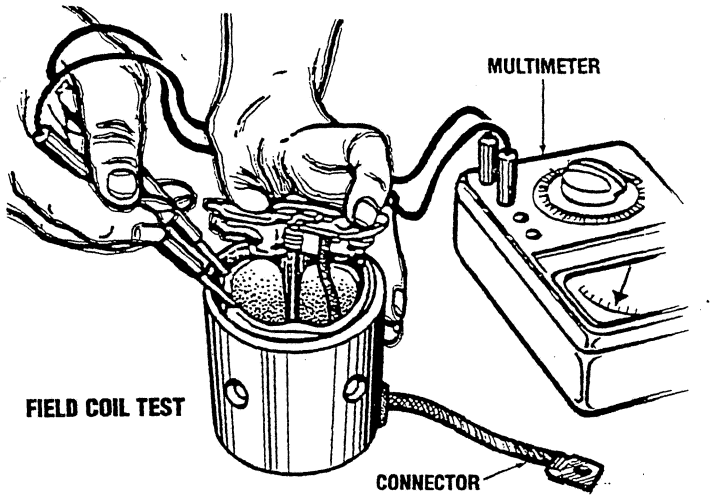


3. Check for insulation between the positive brush holder and holder base. If poorly insulated, replace the holder assembly. Also check the brush holders for proper staking.



Field Coil Inspection

1. Check for insulation between one end (brush) of the coil and yoke.
2. Check for continuity between both ends (brushes) of the coil
3. Check the poles and coil for tightness.



STARTER ADJUSTMENT AND REASSEMBLY

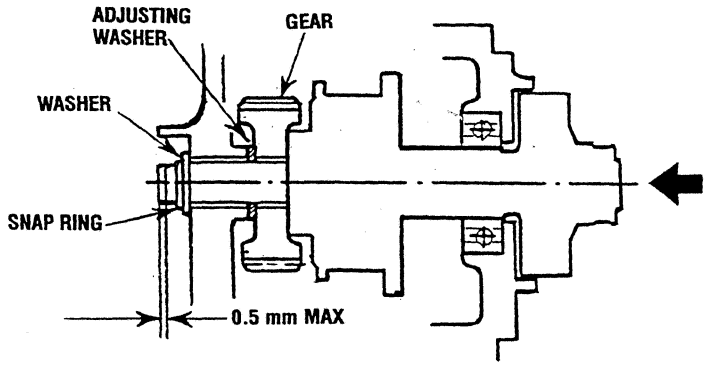
> ⚠ **CAUTION:** ***Before installing, thoroughly clean the starter flange and mounting surfaces, remove all oil, old paint, and rust. Starter performance largely depends on the quality of the wiring. Use wire of sufficient size and grade between the battery and starter and fully tighten to the terminal.***

Reassemble the starter assembly in the reverse order of disassembly, making sure of the following:

1. *Pinion shaft end play adjustment.* Set the end play (thrust gap) to between 0.5 to 2 mm by inserting an adjusting washer between the center bracket and the reduction gear.
   a. Fit the pinion shaft, reduction gear washer and snap ring to the center bracket.
   b. Measure end play by moving the pinion shaft in the axial direction. If the end play exceeds 0.5 mm, increase the number of adjusting washers inserted.
2. *Greasing.* Whenever the starter has been overhauled, apply grease to the following parts:
   a. Armature shaft gear and reduction gear.
   b. All bearings.
   c. Bearing shaft washers and snap rings.
   d. Bearing sleeves.
   e. Pinion.
   f. Sliding portion of lever.

> ⚠ **CAUTION:** ***Never smear the starter fitting surface, terminals, brushes, or commutator with grease.***

3. After reassembly, check by conducting a no-load test again.



PINION SHAFT END PLAY

ALTERNATOR/REGULATOR SERVICE

DESCRIPTION

The alternator serves to keep the battery constantly charged. It is driven from the pulley at the end of the crankshaft by a V-belt. The type of alternator used is ideal for high speed engines having a wide range of engine speeds. It contains diodes that convert AC to DC, and an IC regulator that keeps the generated voltage constant even when the engine speed changes.

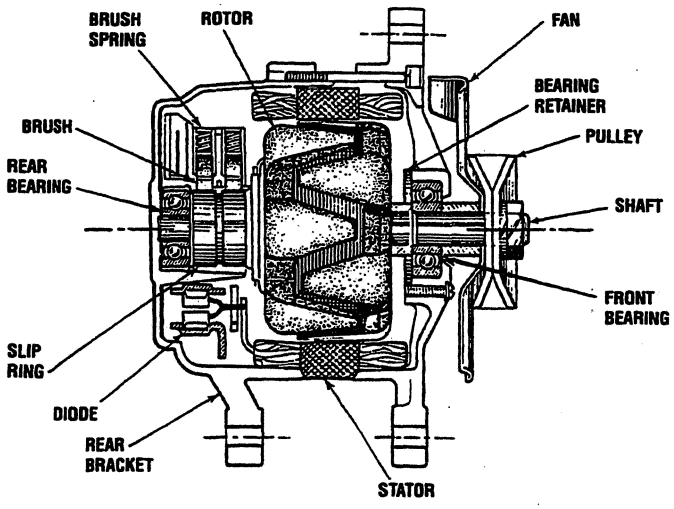
⚠ CAUTION: ***Do not use any high-voltage tester such as a megger. Otherwise, damage to diodes will result.***

During high-speed running of the engine, do not disconnect the positive or negative terminal of the battery from terminal B of the alternator. If this is done, diode failure will result.

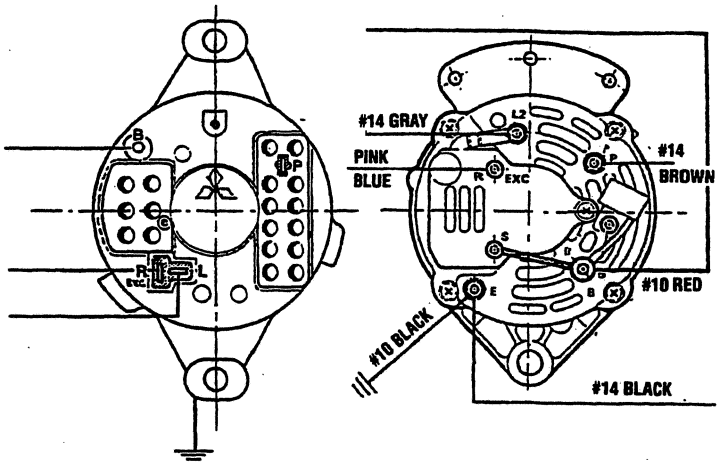
With alternators having IC regulators, absolutely avoid a short circuit between terminals B and L. This would allow current to flow in the "diode trio" and damage it.

Do not start the engine with the lead disconnected from terminal B of the alternator. Otherwise, damage to the voltage regulator will result.

When charging the battery with a quick charger, be sure to disconnect the battery terminals to prevent damage to diodes.



NOTE: *The alternator connections and color coding described on the following illustrations may vary from earlier WESTERBEKE engines. Always refer to the wiring diagrams in this manual and also make a quick sketch of your alternator wiring before disconnecting for service.*



ALTERNATOR TROUBLESHOOTING

If you suspect that the alternator is not producing enough voltage to charge the engine's battery, check the following:

- ☐ Make certain your alternator is securely mounted.
- ☐ Check the drive belts for proper tension.
- ☐ Inspect for loose or disconnected wires at the alternator

⚠ WARNING: ***A failed alternator can become very hot. Do not touch until the alternator has cooled down.***

Testing The Charging Voltage

If you suspect the alternator has failed, perform the following tests.

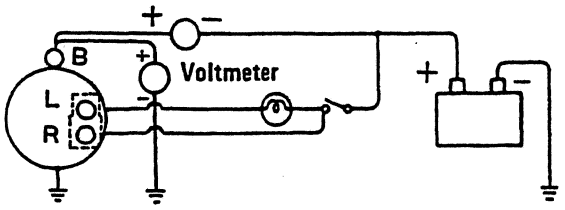
1. Using a voltmeter, connect the voltmeter red wire clip to the output terminal B.
2. Connect the other voltmeter wire to any ground on the engine.
3. Start the engine and record the voltmeter's readings.

⚠ CAUTION: ***To avoid damage to the battery charging circuit, never shut off the engine battery switch when the engine is running!***

ALTERNATOR/REGULATOR SERVICE

The voltage reading for a properly operating alternator should be between 13.5 and 14.5 volts. If your alternator is over- or undercharging, have it repaired at a reliable service shop, or continue with the following tests.

NOTE: *Before removing the alternator for repair, use your voltmeter to ensure that 12 volts DC excitation is present at the R (EXC) terminal if the previous test showed only battery voltage at the B output terminal.*

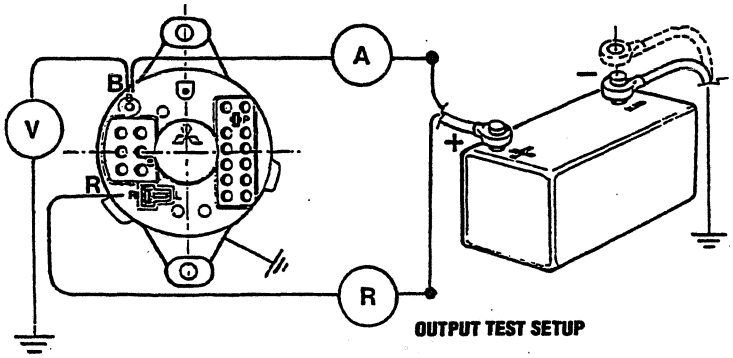


Output Test

1. Disconnect the battery ground cable.
2. Disconnect the wire from terminal B on the alternator and connect an ammeter between B and this wire.
3. Connect a voltmeter between terminal B (+) and ground (–).
4. Connect to the P terminal.
5. Reconnect the battery ground cable to the (–) terminal. *The voltmeter should indicate the battery voltage.*
6. Connect B+ to the R terminal (regulator).
7. Start the engine.
8. Turn on 12 volt accessories equaling the amperage output of the alternator, accelerate the engine to the specified speed (2000 to 3000 rpm) and measure the output current. The output current should be close to the alternator's maximum ouput.

Output Current	1300 rpm	2500 rpm	5000 rpm
Hot	16 amp	41 amp	48 amp
Cold	24 amp	50 amp	–

NOTE: *rpm is that of the alternator. The pulley ratio (alternator vs crank pulley) is 1.78 to 1; all readings are at 13.5 volts.*



OUTPUT TEST SETUP

DISASSEMBLY

1. After removing the three assembly through-bolts, insert a screwdriver between the front bracket and stator. While prying it, remove the front bracket and rotor.

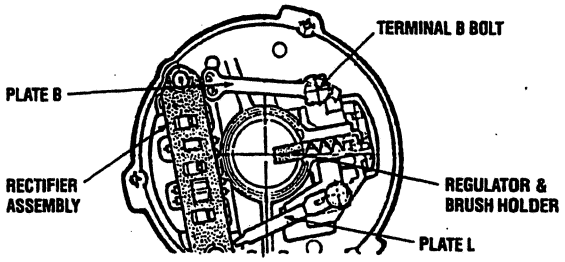
NOTE: *If the screwdriver is inserted too deep, the stator coil might be damaged.*

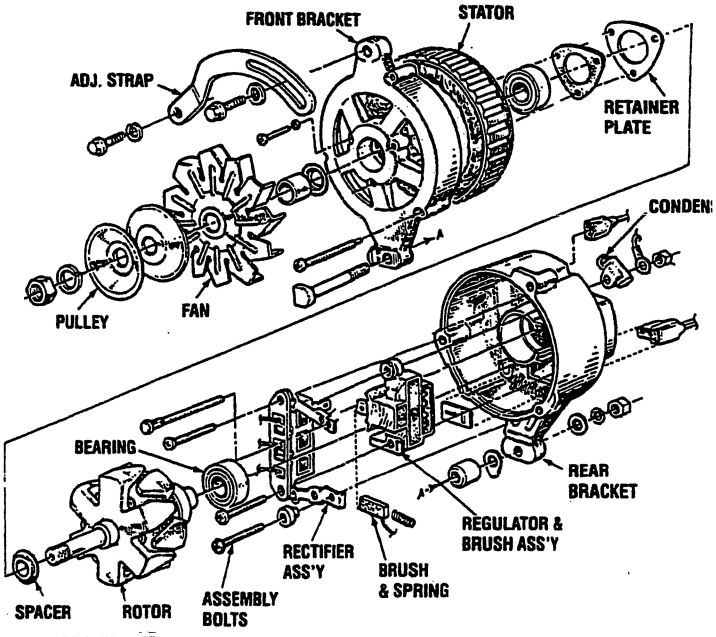
2. Hold the rotor in a vise and remove the pulley nut. Then remove the pulley, fan, spacer and seal. Next, remove the rotor from the front bracket and remove the seal.
3. Unsolder the rectifier from the stator coil lead wires and remove the stator assembly.

   NOTE: *Make sure that the solder is removed quickly (in less than five seconds). If a diode is heated to more than 150°C (310°F), it might be damaged.*
4. Remove the condenser from terminal B.
5. Unsolder the plates B and L from the rectifier assembly.
6. Remove the mounting screw and B terminal bolt and remove the electronic voltage regulator and brush holder. The regulator and brush holder cannot be sepearated.
7. Remove the rectifier assembly.
8. Brush and brush spring replacement:

   When only a brush or brush spring is to be replaced, it can be replaced without removing the stator, etc. With the brush holder assembly removed, unsolder the pigtail of the brush.

NOTE: *If the terminals L and B of the rectifier assembly are bent, damage might result to the rectifier. Therefore, the plates B and L should be gently bent at the center.*





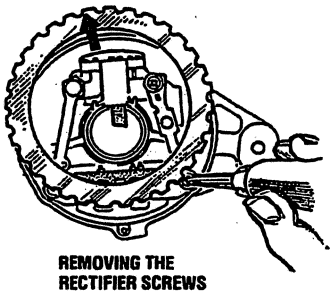
ALTERNATOR/REGULATOR SERVICE

An alternate method for removing the stator winding, brush holder regulator unit and the I.C. diode rectifier assembly from the rear bracket. With the front bracket and rotor assembly separated from the rear half of the alternator:

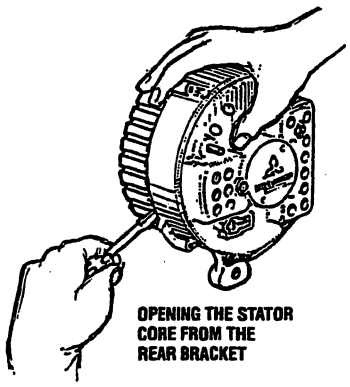
1. Insert a flat-bladed screwdriver between the stator core and the edge of the rear bracket on the same side as the brush-holder. Raise this side of the stator core away from the bracket so as to open a gap of about 1/2 inch.

   NOTE: *Be careful not to allow the screwdriver blade to enter far enough to touch the stator winding.*

2. Maintaining the 1/2 inch gap, insert the screwdriver between the stator core and the bracket on the rectifier side and move the stator laterally toward the brush-holder for a distance of 1/2 to 3/4 of an inch without lifting it from the bracket.
3. Insert a #2 Phillips screwdriver through this opening and remove the two screws holding the rectifier.



REMOVING THE RECTIFIER SCREWS



OPENING THE STATOR CORE FROM THE REAR BRACKET

4. Remove the nut anchoring the B terminal bolt and the capacitor mounted thereto on the outside rear of the bracket. Then remove the third Phillips screw holding the brush holder to the bracket.
5. Carefully withdraw stator, brush holder and rectifier from the rear bracket as one loosely connected unit.

   With the bracket out of the way, it is easy to unsolder the stator winding leads from the rectifier quickly to avoid heat damage to the diodes and I.C. chips. It is also easier to renew the brushes because there is no need to bend the connecting plates between the brush holder and the rectifier and possibly damage the rectifier.

When reversing this procedure, make sure that the stator winding leads are gently pushed back (from possible contact with the rotor body) after seating the stator into the rear bracket.

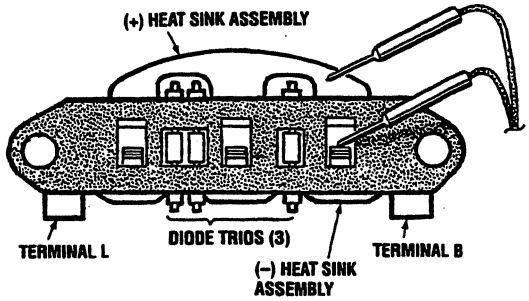
INSPECTION

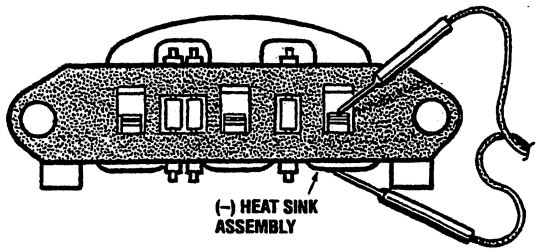
Diode

Diode troubles are classified as open-circuit and short-circuit. When the diode is open-circuited, no current flows. In the short-circuited diode, current flows in both directions.

Checking for Short Circuit

Check for continuity between the (+) heat sink and the stator coil lead joint terminal and between the (–) heat sink and the said terminal. If each test shows current flow in both directions, the diodes are short-circuited. Replace the rectifier assembly.



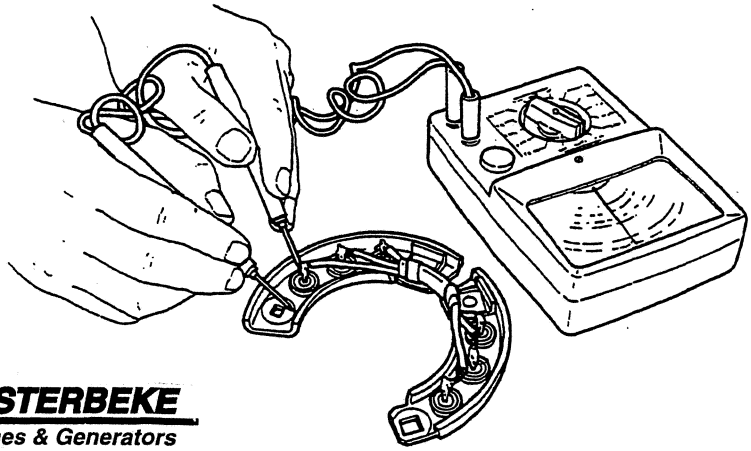


Checking for Open Circuit

To check for an open circuit in the diodes which have passed the short-circuit test, disconnect the diode leads and check with your ohmmeter between the diode lead and the body, reversing the leads. If no continuity is found, the diode is open.

Checking Diode Trio

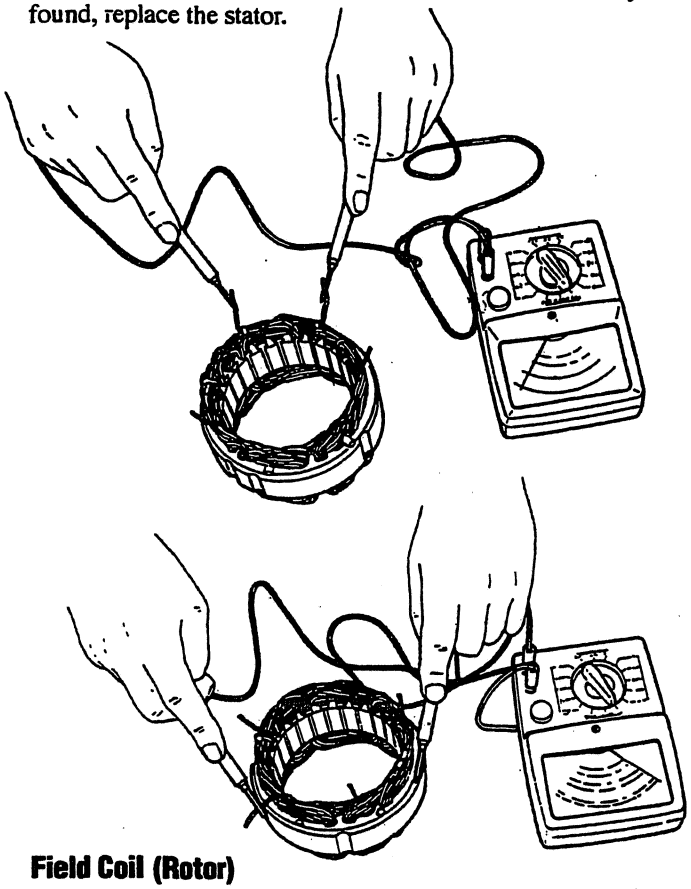
Check each of the three diodes for continuity. If any diode allows current flow in both directions or does not allow current to flow in one direction, replace the rectifier assembly.



ALTERNATOR/REGULATOR SERVICE

Stator

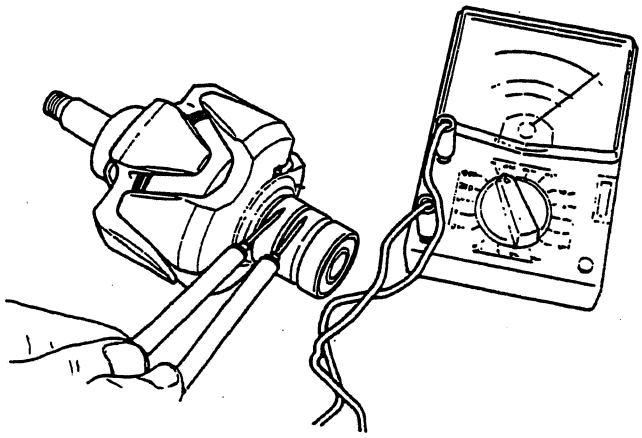
Disconnect the stator lead wires from the coil and check for continuity between the three leads with a circuit tester. If no continuity is found, the stator windings are open. Next, check for insulation between each lead and the core. If continuity is found, replace the stator.



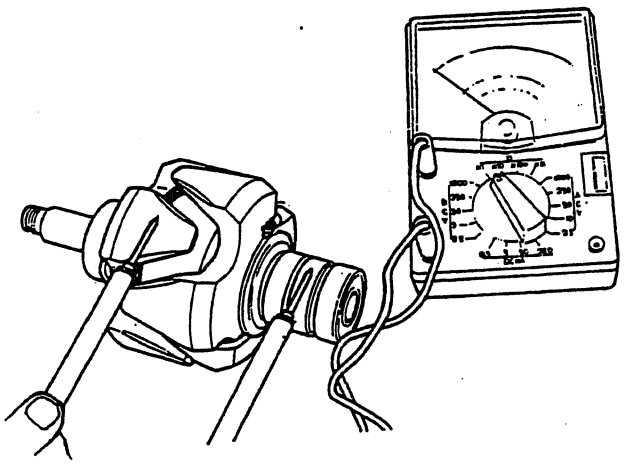
Field Coil (Rotor)

Check resistance between the slip rings. The resistance must conform to the specified value.

Resistance Value: 3.87Ω ± 10%



Check for continuity between the slip ring and the core. If there is continuity, it means that the coil or slip ring is grounded. Replace the rotor assembly.



Checking Brush and Brush Spring

Replace the brush if it has worn to the replacement value. Check the brush spring force. Also confirm that the brush moves smoothly in the brush holder.

	Standard Value	Replacement Required at
Brush Length (mm)	18	8
Brush Spring Force (g)	$370^{\pm 60}$	210

Checking the Slip Ring

Because the slip ring wears very little, the diameter must be measured with a micrometer. Replace the rings (rotor assembly) when wear reaches the replacement value.

	Standard Value	Replacement Required at
Slip Ring O.D.	33 mm	32.2 mm
Runout	0.03 mm or less	0.2 mm

The slip ring must be smooth with no surface oil. If necessary clean and polish with a fine crocus cloth.

REGULATOR

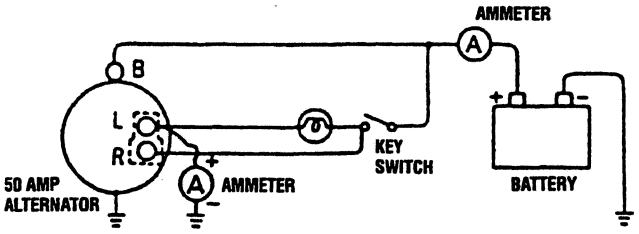
The regulator consists of a voltage regulator and a lamp relay; their wires are gathered into a connector. The voltage regulator is used to always keep the alternator output constant regardless of alternator speed and to cut off the flow of current to the field coil when necessary. The lamp relay is used on the Captain panel only to illuminate the panel light indicating no alternator charge. The 50A alternator has a built-in IC regulator. During alternator operation, field current is controlled automatically by the IC regulator.

1. Connect an ammeter (approx. 60A rating) between the battery positive terminal and its cable.
2. Connect a voltmeter between the generator terminal L and the ground. In this case, the voltmeter must indicate "O". If otherwise indicated, a defective alternator or faulty wiring is suspected.

3. Turn the starting switch key to the ON position, and the voltmeter will indicate a value considerably lower than the battery voltage. If the indication is near the battery voltage, a defective generator is possible.
4. With the ammeter short-circuited, start the engine.

> **⚠ CAUTION:** ***If the ammeter is not short-circuited, a large starting current will burn out the ammeter coil.***

5. Increase the engine speed to between 2000 and 3000 rpm and read the ammeter.
6. If the ammeter reading does not exceed 5A, read the voltmeter at that state (2000–3000 rpm). The voltmeter reading is the regulated voltage.
7. If the ammeter reading exceeds 5A, continue charging the battery until the ammeter reading drops to 5A or below; or replace the battery with a fully-charged one; or connect a 1/4Ω (25W) resistor in series to the battery to restrict charging current.
8. The IC regulator is of the temperature compensation type and, therefore, regulated voltage varies with temperature. It is necessary to measure the temperature of the rear bracket (surrounding the regulator) and to use the measurement for correction of regulated voltage.



CHECKING THE IC REGULATOR VOLTAGE

REASSEMBLY

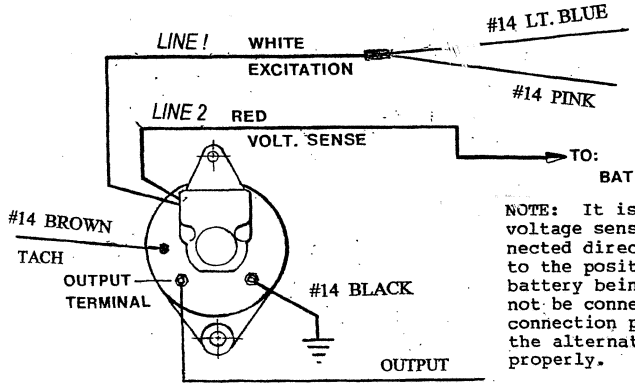
> **⚠ CAUTION:** ***Connect the alternator properly. Should the polarity be reversed, a powerful current would flow from the battery into the alternator, damaging the diodes and wiring harness.***

1. Install the alternator support bolt through the alternator leg (underside) into the engine casting.
2. Swing the alternator into position on the adjusting bracket and fasten. Lightly tighten.
3. Adjust belt tension.
4. Tighten both bolts and recheck belt tension.

Torque values:

Support bolt:	20 – 24 Nm (15 – 18 ft-lbs)
Adjusting bracket bolt:	12 – 14 Nm (9 – 10 ft-lbs)

NOTE: *Make certain the belts are perfectly aligned with the alternator and engine pulleys. If not, insert or remove spacers as needed, to align the alternator.*



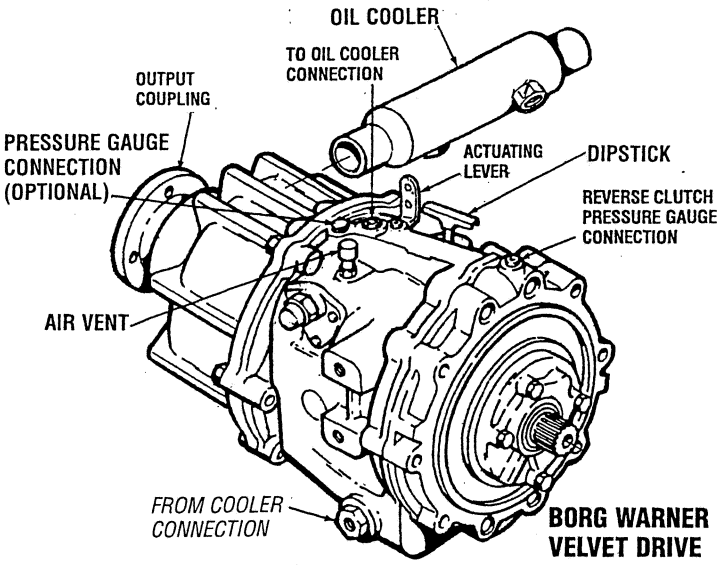
NOTE: It is mandatory for this voltage sensing wire to be connected directly and physically to the positive terminal of the battery being charged. It must not be connected to any other connection point. Otherwise, the alternator will not operate properly.

(*OPTIONAL*) 90 AMP ALTERNATOR. (*WIRING*)

CHECKING ALTERNATOR AFTER HOOK-UP

LINE #1	12.2 - 12.8V	12.2 - 12.8V	14.0 - 15.0V
LINE #2	0	3.0 - 5.0V	14.0 - 15.0V
OUTPUT	12.2 - 12.8V	12.2 - 12.8V	14.0 - 15.0V
	IGN OFF ENGINE NOT RUNNING	IGN ON ENGINE NOT RUNNING	ENGINE RUNNING (1500 RPM)

BORG WARNER VELVET DRIVE TRANSMISSION
OPTIONAL TRANSMISSION



SHIPMENT

For safety reasons, the transmission is ***not*** filled with transmission fluid during shipment and the selector lever is temporarily attached to the actuating shaft.

Before leaving the WESTERBEKE plant, each transmission undergoes a test run, with *Dextron III ATF* transmission fluid. The residual fluid remaining in the transmission after draining acts as a preservative and provides protection against corrosion for at least one year if properly stored.

TRANSMISSION FLUID

Check the transmission fluid level on the dipstick. If the transmission has not been filled, fill with *Dextron III* and continue to use this fluid. During the first 25 hours of operation, keep a lookout for any leakage at the bell housing, output shaft and transmission cooler. This fluid should be changed after the first 25 hours and approximately every 300 operating hours thereafter and/or at winter lay-up.

> ⚠ **CAUTION:** ***Be certain the transmission is filled and the correct size cooler is properly installed before starting the engine.***

SHIFT LEVER POSITION

The gear shift control mechanism and linkage must position the actuating lever on the transmission exactly in Forward (**F**), Neutral (**N**), and Reverse (**R**) shifting positions. A detent ball located behind the transmission lever must work freely to center the lever in each position. The gear shift positions at the helm must be coordinated with those of the Velvet Drive actuating lever through shift mechanism adjustments. An improperly adjusted shift mechanism can cause damage to the transmission. The shifting mechanism and transmission actuating lever should be free of dirt and well lubricated to ensure proper operation.

Shifting Into Gear

Place the gear shift in Neutral before starting the engine. Shifting from one selector position to another selector position may be made at any time below 1000 rpm and in any order. Shifts should be made at the lowest *practical* engine speed. Start the engine and set the throttle at idle speed; allow the transmission fluid to warm up for a few minutes.

Neutral

Move the gear shift lever to the middle position. You should feel the detent. This centers the actuating lever on the transmission. With the control in this position, hydraulic power is completely interrupted and the output shaft of the transmission does not turn.

NOTE: *Some transmissions are equipped with a neutral safety switch. Unless the transmission actuating lever is perfectly aligned in neutral, the engine starter will not activate.*

Forward

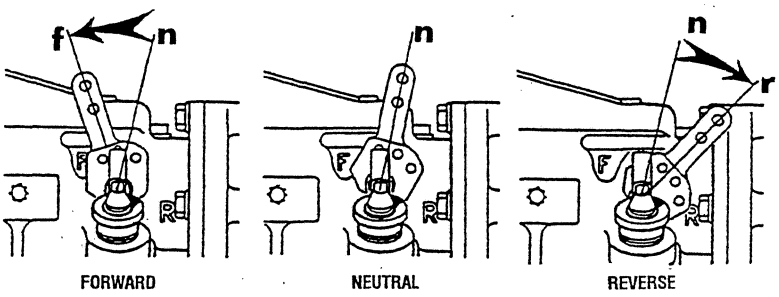
Move the gear shift lever to the forward position. You should feel the detent. The actuating lever on the transmission is in the forward position. The output shaft and the propeller shaft move the boat in a forward direction.

Reverse

Move the gear shift lever to the reverse position. You should feel the detent. The actuating lever on the transmission is in the reverse position. The output shaft and the propeller should move the boat in a reverse direction (astern).

NOTE: *Moving the transmission actuating lever from Neutral Position to Forward is always toward the engine. Reverse is always away from the engine. If boat moves backwards with the gear shift control in the forward position, shut off the engine! This problem may be a result of incorrect movement of the actuating lever by the gear shift lever.*

BORG WARNER VELVET DRIVE TRANSMISSION



TRANSMISSION ACTUATING LEVER POSITIONS

DAILY OPERATION

- ☐ Check the transmission fluid.
- ☐ Visually check the gear shift linkage and transmission.
- ☐ Start the engine in neutral. Allow a few minutes at idle for the fluid to warm.

  NOTE: *Too low an idle speed will produce a chattering noise from the transmission gear and damper plate. In such cases the idle speed should be increased.*

- ☐ Shift into gear.

> ⚠ **CAUTION:** ***Shifting gears above 1000 rpm can cause damage to the engine damper plate. Pulling the throttle back to idle when shifting gears will save wear on the transmission and the damper plate.***

INSPECTION

- ☐ Visually check for oil leaks at the hydraulic connections. Check for wear on the hydraulic lines and replace if worn.
- ☐ Lubricate the detent ball and shift cable attachments.
- ☐ Inspect the shift linkage.
- ☐ Inspect the transmission bolts; retorque if necessary.

> ⚠ **CAUTION:** ***Clutch failure will occur if the transmission shift lever does not fully engage the detent ball positions.***

CHANGING THE TRANSMISSION FLUID

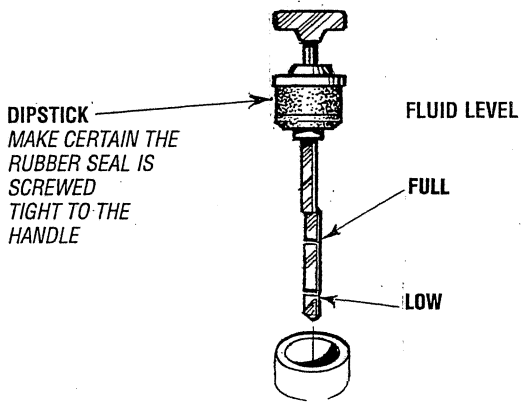
After the initial 50 hour change, the transmission fluid should be changed at every 300 operating hours thereafter or at winter haul-out. However, the fluid must be changed whenever it becomes contaminated, changes color, or smells rancid.

- ☐ Remove the oil filler cap and dipstick.
- ☐ Remove the oil cooler return line and allow the oil to drain into a container.
- ☐ Reconnect the oil cooler return line.
- ☐ Use a suction pump to remove the transmission oil through the filler cap/dipstick hole.
- ☐ Clean off the transmission and properly dispose of the used fluid.
- ☐ Refill the transmission with *DEXTRON III ATF*. The quantity will vary depending on the transmission model and the installation angle. Fill through the dipstick hole.
- ☐ Check the dipstick for the proper fluid level.
- ☐ Replace the oil filler cap and dipstick. (Press the dipstick into place and turn clockwise until finger-tight.)
- ☐ Run the engine, shutdown and recheck the fluid level.

> ⚠ **WARNING:** ***Never pull out the dipstick while the engine is running. Hot fluid will splash from the dipstick hole. This could cause severe burns.***

Oil Capacity

Approximately 2.5 quarts (2.36 liters) will fill most transmissions to the oil level fill mark on the dipstick. Many variables have a direct relationship to the oil capacity. Additional oil will be required to fill the oil cooler and the cooler lines. The angle of installation will make a difference in the quantity of oil required to fill the transmission.



Oil Temperature

A maximum oil temperature of 190°F (88°C) is recommended. Discontinue operation anytime sump oil temperature exceeds 230°F (110°C).

PRESSURE GAUGE

An optional mechanical pressure gauge can be installed at the control panel to constantly monitor the pressure of the transmission fluid. A normal reading at 2000 rpm in forward gear should indicate 95 – 120 lb-in² (6.7 – 8.4 kg-cm²) and be constant.

BORG WARNER VELVET DRIVE TRANSMISSION

MAINTENANCE

Transmission maintenance is minimal. Keep the exterior housing clean, check the fluid level as part of your regular routine, and change the fluid every 300 operating hours.

Periodically inspect the transmission and the cooler for leaks and corrosion. Make certain the air vent is clear and when checking the fluid level look for signs of water contamination (fluid will appear as strawberry cream).

Lay-up/Winterize

Storage requires special care. Follow these procedures:

- ☐ Drain the water from the transmission oil cooler and replace it with a proper mixture of antifreeze coolant.

  NOTE: *This operation will usually occur when the engine raw water cooling system is properly winterized.*

- ☐ Clean up the transmission and touch-up unpainted areas (use heat resistant paint).
- ☐ Fill the transmission with *Dextron III ATF* fluid to prevent internal corrosion. (Extended storage only, 12 months or more).
- ☐ Loosen attaching hardware from the transmission output flange and propeller shaft coupling flange before removing the boat from the water. Separate the flanges and spray with lubricant.
- ☐ Inspect the gear shift cable, linkage, and attachments. Look for corrosion of the end fittings, cracks or cuts in the conduit, and bending of the actuator rods. Lubricate all moving parts.

  NOTE: *If the transmission is to be stored for a long time (twelve months or more), it should be topped off with fluid to prevent internal corrosion. Reduce the fluid level before putting the engine back into service.*

WARRANTY NOTES

Service manuals are available from your *BORG WARNER* dealer.

For assistance, contact:

Richmond and Velvet Drive
1208 Old Norris Road
Liberty, SC 29657
Tel.: (800) 583-4327

BORG WARNER is aware of the shock loads that can be placed on its gears as the result of mechanical propeller operation or fully reversing of the propeller blades while shifting. Therefore torque loads and directional changes should be made at low engine speeds. If it is found that a failure was caused by a shock load, any warranty claim will be denied.

> ⚠ **CAUTION:** ***System-related noises or vibrations can occur at low engine speeds which can cause gear rattle resulting in damage to the engine and/or transmission. BORG WARNER is not responsible for total system-related torsional vibration of this type.***

If any problems occur with the transmission, see *TRANSMISSION TROUBLESHOOTING* in this manual.

OIL COOLERS

The continued flow of raw water through the cooler will, in time, erode the inside of the cooler causing cross leaks to occur. These internal cooler leaks will cause one of the following two problems:

1. Transmission fluid will leak into the flow of raw water and be discharged overboard through the engine exhaust. *A loss of transmission fluid will cause the transmission to fail.*
2. The raw water will leak into the transmission fluid causing an increase in transmission fluid. This contaminated fluid will appear as strawberry cream. *The transmission will eventually fail.*

Either case requires an immediate response:

1. Install a new oil cooler.
2. Refill the transmission with *DEXTRON III ATF.*

If water has contaminated the fluid, the transmission fluid needs to be cleaned out and replaced with fresh fluid. It will take several fluid changes to get rid of the contamination. Check your dipstick each time until it appears as pure transmission fluid. Change the transmission filter and clean out the fluid lines that connect to the cooler.

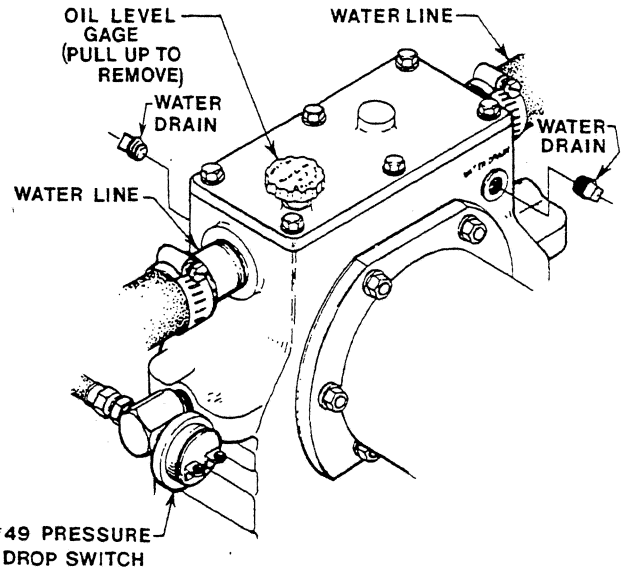
If the transmission fails to shift properly, it will most likely need the attention of a qualified transmission service facility.

A transmission cooler may last ten years or more but, in some circumstances, depending on operating hours, tropical waters, maintenance, etc. it might only last half that time.

WESTERBEKE recommends having a spare cooler aboard.

WALTER V-DRIVE TRANSMISSION

OPERATION



A pressure drop warning light is mounted on the instrument panel on V-drives equipped with an oil circulating pump. The warning light will stay on until the boat gets under way and the engine speed increases to sufficient RPM for the pump to maintain pressure. This normally occurs at approximately 1200 RPM, but the actual speed may vary by as much as 400 RPM. Extended cruising at low RPM, such as when trolling, is not harmful to the V-drive, even though the warning light may stay lit. Normal operation is between 6 to 12PSI. The light will go on when the oil pressure drops below 2PSI. Loss of oil and/or insufficient oil level are the major causes of pressure drop. The oil level should immediately be restored, and while running the boat, the unit should be checked for leaks. If the oil level is normal and the light stays lit when the boat reaches normal cruising speed, the wiring should be checked for loose and/or corroded connections. If the wiring is correct and the light remains lit, the #49 pressure drop switch, which is mounted on the side of the V-drive (see illustration), should be checked for proper operation. The switch can easily be removed and an accurate oil pressure gauge installed in its place. If the pressure is normal, the switch should be replaced. If the pressure is below normal, the oil lines should be checked for blockage. The pump should be inspected and replaced if necessary. The pump is standard on the RV-48 and an optional feature on other models (not available on the RV-10).

A clatter or rattle in the V-drive at low RPM is due to the overriding of the propeller during the compression stroke of the engine. Although annoying, it is not harmful. It may be reduced by adjusting the idle speed and/or tuning up the engine for smoother operation.

The oil level should be checked several times during the season, especially on V-drives without pumps

WATER DRAIN

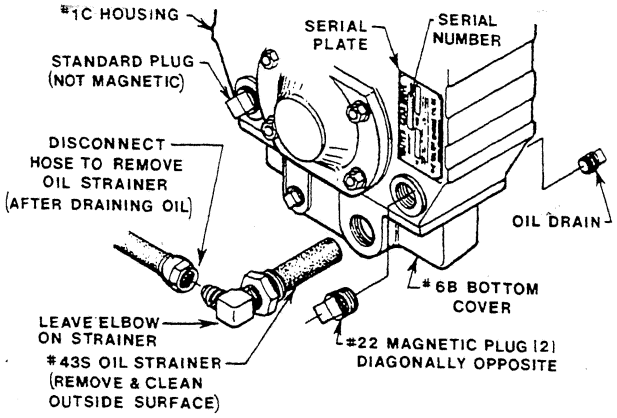
For protection from freezing during winter lay-up, remove the small pipe plugs (located diagonally opposite) on the front and back of the housing marked Water Drain (see illustration). On the RV-10 only, one of the water lines going into the water-cooled bottom cover must be disconnected to drain the water.

FLANGE AND ENGINE REALIGNMENT

When the boat is launched after being in drydock, the line-up of the V-drive to the propeller shaft flange and the engine to the V-drive should be rechecked and corrected if necessary. Some engines with rubber mounts may sag and must be raised with adjustments or shims for proper alignment

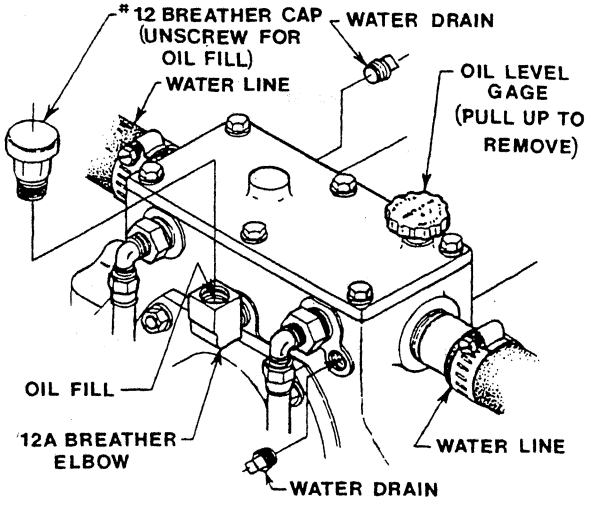
OIL CHANGE AND JOINT LUBE

After the first 100 hours of operation and every season and/or 500 hours thereafter, the oil should be changed. Run the boat to warm up the V-drive to operating temperature. Turn off the engine. Remove the plug in the #6B bottom cover that is opposite the #43S oil strainer. Reinstall after draining. Disconnect the oil hose leading from the #43S strainer (leave the elbow on the strainer). Unscrew the strainer and clean the outside surface. Reinstall the strainer and reconnect the oil hose. Unscrew the two magnetic plugs that are located on diagonally-opposite corners of the main housing.



The plugs can be checked to see if they are magnetic only after removal. Touch the inside face with a metallic object, such as a screwdriver. Clean them and reinstall. Usually, there are four plugs in the bottom part of the main housing. Only two of these are magnetic. The other two need not be removed (see illustration). Refill with SAE 30 motor oil to the proper level (see INSTALLATION - OIL FILL). The Zerk fitting on the external universal joint should be greased with a light alemite lub

OIL FILL



Pull out the oil level gauge. Unscrew the breather cap and fill the V-drive with SAE 30 motor oil through the breather elbow. On the RV-10 only, the oil may be added by removing the plug in the top cover. See table below for approximate oil capacities. The amount varies with the angle of installation. The oil level should be checked with the oil level gauge fully inserted in the unit. The proper level is between the H and L marks on the gauge. Add a 2-ounce tube of Molykote (molybdenum disulfide), which is supplied with each V-drive for extra lubrication and break-in. It provides protection against scoring or galling of gears, bearings and other moving parts. Additional Molykote after break-in is not required. Reinstall the breather cap. The oil level should be rechecked after the unit has been run and allowed to sit for about a minute. Add oil if necessary.

	RV-10	RV-20	RV-30	RV-40	RV-48
Oil capacity (Approx.)	1 pint	2 pints	3 pints	4 pints	4 pints

ZF MARINE TRANSMISSIONS

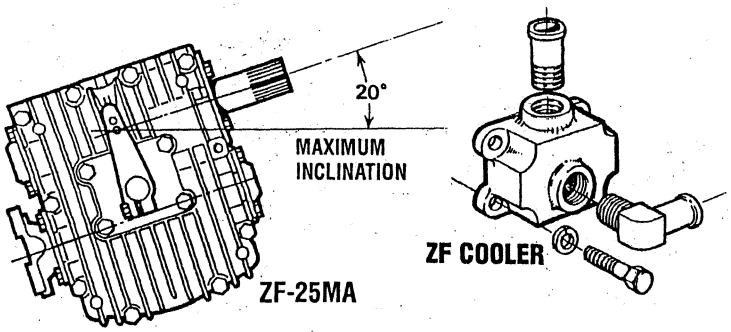
DESCRIPTION

The information below is specific to the ZF Transmissions, the *TRANSMISSION TROUBLESHOOTING SECTION* applies to all models.

CONNECTION OF GEAR BOX WITH PROPELLER

ZF recommends a flexible connection between the transmission gearbox and the propeller shaft if the engine is flexibly mounted, in order to compensate for angular deflections. The installation of a special propeller thrust bearing is not required, since the propeller thrust will be taken by the transmission bearing, provided the value specified under *SPECIFICATIONS* is not exceeded. However, the output shaft should be protected from additional loads. Special care should be taken to prevent torsional vibration. When using a universal joint shaft, make certain to observe the manufacturers instructions.

Even with the engine solidly mounted, the use of flexible coupling or "DRIVESAVER" will reduce stress in the gearbox bearings caused by hull distortions, especially in wooden boats or where the distance between transmission output flange and stern gland is less than about 800mm.



⚠ CAUTION: ***The position of the mechanism behind the actuating lever is factory-adjusted to ensure equal shift lever travel from neutral position to A and B. If this mechanism is in any way tampered with, the transmission warranty will be void.***

NOTE: *When installing the transmission, make certain that shifting is not impeded by restricted movability of the Bowden cable or rod linkage, by unsuitably positioned guide sheaves, too small a bending radius, etc. In order to mount a support bracket for shift cable to secure to, use the threaded pillar nuts located on the transmission housing above the shift lever. Refer to the model's parts list.*

CONTROL CABLES

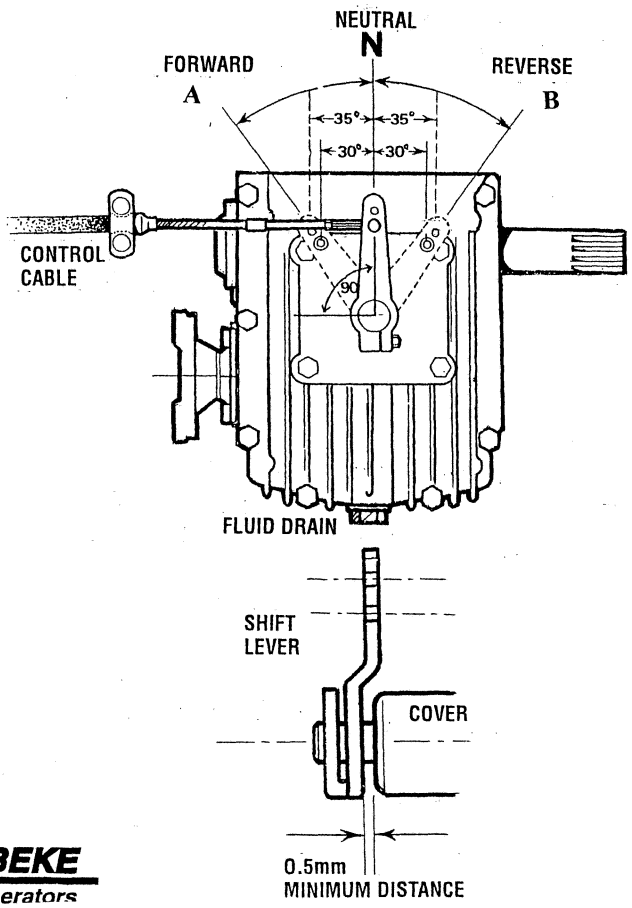
The transmission is suitable for single lever remote control. Upon loosening the retaining screw, the actuating lever can be moved to any position required for the control elements (cable or rod linkage). Make certain that the shift lever does not contact the actuating lever cover plate: the minimum distance between lever and cover should be 0.5mm.

The control cable or rod should be arranged at right angle to the actuating shift lever when in the neutral position. The neutral position of the operating lever on the control console should coincide with the neutral position of this lever.

The shifting travel, as measured at the pivot point of the actuating lever, between the neutral position and end positions **A** and **B** should be at least **35mm** for the outer and **30mm** for the inner pivot point.

A greater amount of shift lever travel is in no way detrimental and is recommended. However, if the lever travel is shorter, proper clutch engagement might be impeded which, in turn, would mean premature wear, excessive heat generation and clutch plate failure. This would be indicated by slow clutch engagement or no engagement at all.

NOTE *Check for proper lever travel at least each season.*

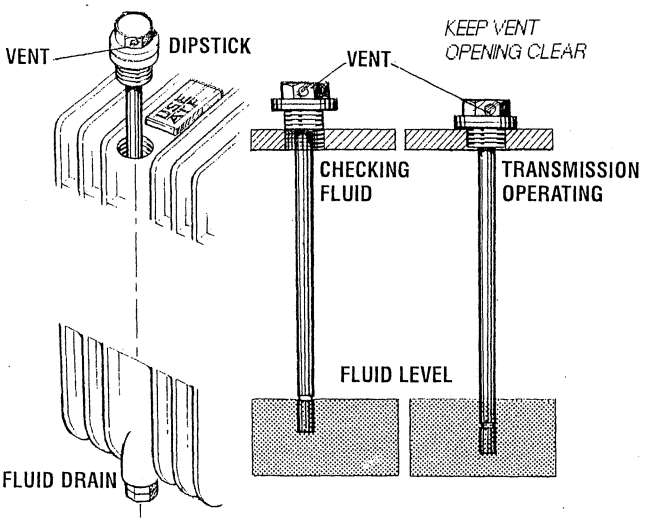


ZF MARINE TRANSMISSIONS

INITIAL OPERATION

All ZF marine transmissions are test-run on a test stand with the engine at the factory prior to delivery. For safety reasons the fluid is drained before shipment.

Fill the gearbox with Automatic Transmission Fluid (DEXRON II or DEXTRON III). The fluid level should be up to the index mark on the dipstick. To check the fluid level, just insert the dipstick, do not screw it in. Screw the dipstick into the case after the fluid level is checked and tighten. Do not forget the sealing ring under the hexhead of the dipstick. Check for leaks and change the fluid after the first 25 hours, also make a visual inspection of the coupling, oil cooler and hoses, and shift cables.



FLUID CHANGE

Change the fluid for the first time after about 25 hours of operation, then every 250 operating hours or at least once a year or when you change engine oil.

Removing the fluid

Push a suction pump hose down through the dipstick hole to the bottom of the housing and suck out the fluid. (If space allows, use the transmission drain). Remove the drain plug from the bottom of the transmission and allow the fluid to drain into a container, then reinstall the plug with its sealing washer. Wipe down the transmission and properly dispose of the used fluid. After running the engine, shut down and recheck the fluid level.

DRAIN PLUG TORQUE **20 - 25 ft/lbs**

NOTE : *When changing the fluid, take care not to lose the drain plug sealing washer. The drain plug will leak without this sealing washer.*

> ⚠ **WARNING:** ***Never pull out the dipstick while the engine is running. Hot fluid will splash from the dipstick hole. This could cause severe burns.***

LOCKING THE PROPELLER

Locking of the propeller shaft by an additional brake is not required: use the gear shift lever position opposite your direction of travel for this purpose. Never put the gear shift in the position corresponding to the direction of travel of the boat.

WHEN UNDER SAIL OR BEING TOWED

Rotation of the propeller without load, such as when the boat is being sailed, being towed, or anchored in a river, as well as operation of the engine with the propeller stopped (for charging the battery), will have no detrimental effects on the transmission

DAILY OPERATION

- ☐ Check the transmission fluid.
- ☐ Visually check the gear shift linkage and transmission.
- ☐ Start the engine in neutral, allowing a few minutes at idle to warm the fluid.
- ☐ Shift into gear.

NOTE : *Too low an idle speed will produce a chattering noise from the transmission gear and damper plate. In such cases the idle speed should be increased*

For additional information refer to the following text in this Transmission Section: *SHAFT COUPLINGS, MAINTENANCE AND TRANSMISSION TROUBLESHOOTING.*

ZF TRANSMISSIONS SPECIFICATIONS

General	(ZF Standard Transmission) Case hardened helical gears, with a servo-operated multiple disc clutch
Gear Ratio (optional) **Note:** There are a variety of gear ratios available. Only a few are listed.	ZF 25M (1.88:1 or 2.27:1 or 2.73:1) ZF 25MA (2.22:1 or 2.73:1) ZF 30M (2.14:1)
Fliud Quantities (approximate)	ZF 25M - 1.58 pints (0.75 litres) ZF 25MA - 1.58 pints (0.75 litres) ZF 30M - 1.90 pints (0.90 litres)
Lubricating Fluid	ATF - Type A or Dextron - II or III
Propeller Shaft Direction of Rotation	Right-hand rotation for above models listed.

THE BT GENERATOR

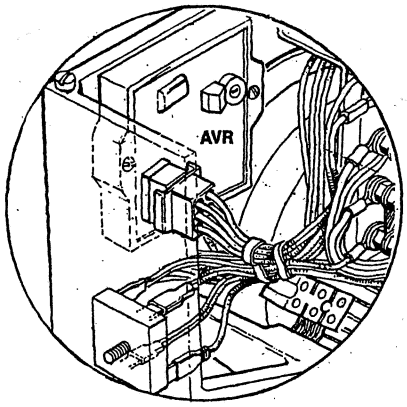
DESCRIPTION

The BT generator is a four-pole, brushless, self-excited generator which requires only the driving force of the engine to produce AC output. The copper and laminated iron in the exciter stator are responsible for the self-exciting feature of this generator. The magnetic field produced causes an AC voltage to be induced into the related exciter rotor windings during rotation. Diodes located in the exciter rotor rectify this voltage to DC and supply it to the windings of the rotating field. This creates an electromagnetic field which rotates through the windings of the main stator, inducing an AC voltage which is supplied to a load. A step down transformer is connected in parallel to the AC output of the main stator. An AC voltage is produced in the auxiliary windings of the transformer and the main stator and is, in turn, supplied to a full-wave bridge rectifier. The rectifier produces a DC voltage to further excite the exciter stator windings, enabling the generator to produce a rated AC output.

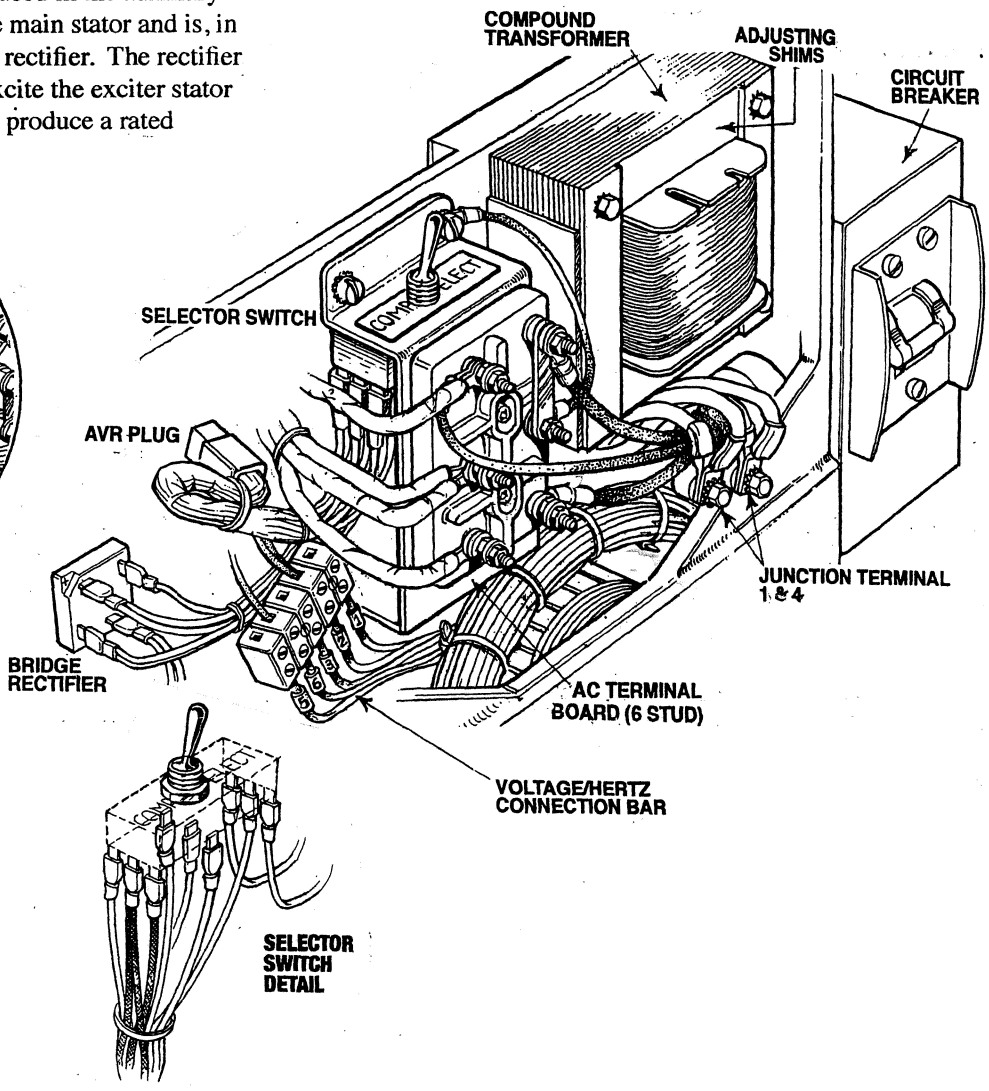
The generator's data plate gives the voltage, current and frequency rating of the generator. An AC wiring decal is affixed to the inside of the louvered cover at the generator end. A diagram of the various AC voltage connections is provided on the decal. These diagrams are also illustrated in this manual.

VOLTAGE REGULATOR (AVR)

A solid state voltage regulator that works in tandem with the transformer regulator to produce a more stable AC output is available



BT [6 STUD] W/OPTIONAL AVR



BT GENERATOR TROUBLESHOOTING CHARTS

PRELIMINARY CHECKING

Before electrical testing check for proper engine speed/hertz adjustment. Low engine speed will cause low AC voltage output, high engine speed-high AC output.

Before testing, get a clear explanation of the problem that exists, be certain it relates to generator components.

Due to the simplicity of the generators design troubleshooting is relatively simple and field testing and repairing can be accomplished with basic tools and repair parts which should include the following:

A quality multimeter [multitester] capable of reading less than one ohm and with a specific diode testing function.

Basic electrical tools including cutters, soldering iron, wire stripper/crimper, terminals connectors, etc.

Repair parts such as diodes, suppressors, fuses, bridge rectifier, etc.

TROUBLESHOOTING SEQUENCE

The **bold** letters and numbers refer to the components of the *internal wiring schematics* and also to the *component resistance charts* in the following pages

LOW VOLTAGE (60-100 VOLTS-AC/60Hz - 115-200VOLTS/50Hz) TEST COMPONENTS IN THE FOLLOWING ORDER:

F Selector Switch (6 stud only)

B Exciter Rotor:
2 Diodes (6), **3** Field Windings, **1** Exciter Windings **a b c**

A Exciter Stator Windings **1-1+2**

NO AC VOLTAGE OUTPUT (EXTREMELY LOW VOLTAGE 1-5 VOLTS) TEST COMPONENTS IN THE FOLLOWING ORDER:

C Main Stator Windings **1+2**

B Thermister **4**

2 Diodes (**4-6** open/shorted)

D Compound Transformer Winding **1+2**

B Rotor Field Winding **3**

RESIDUAL VOLTAGE TEST COMPONENTS IN THE FOLLOWING ORDER:

A Exciter Stator Windings **1-1+2**

G Bridge Rectifier

D Transformer Aux. Winding **3**

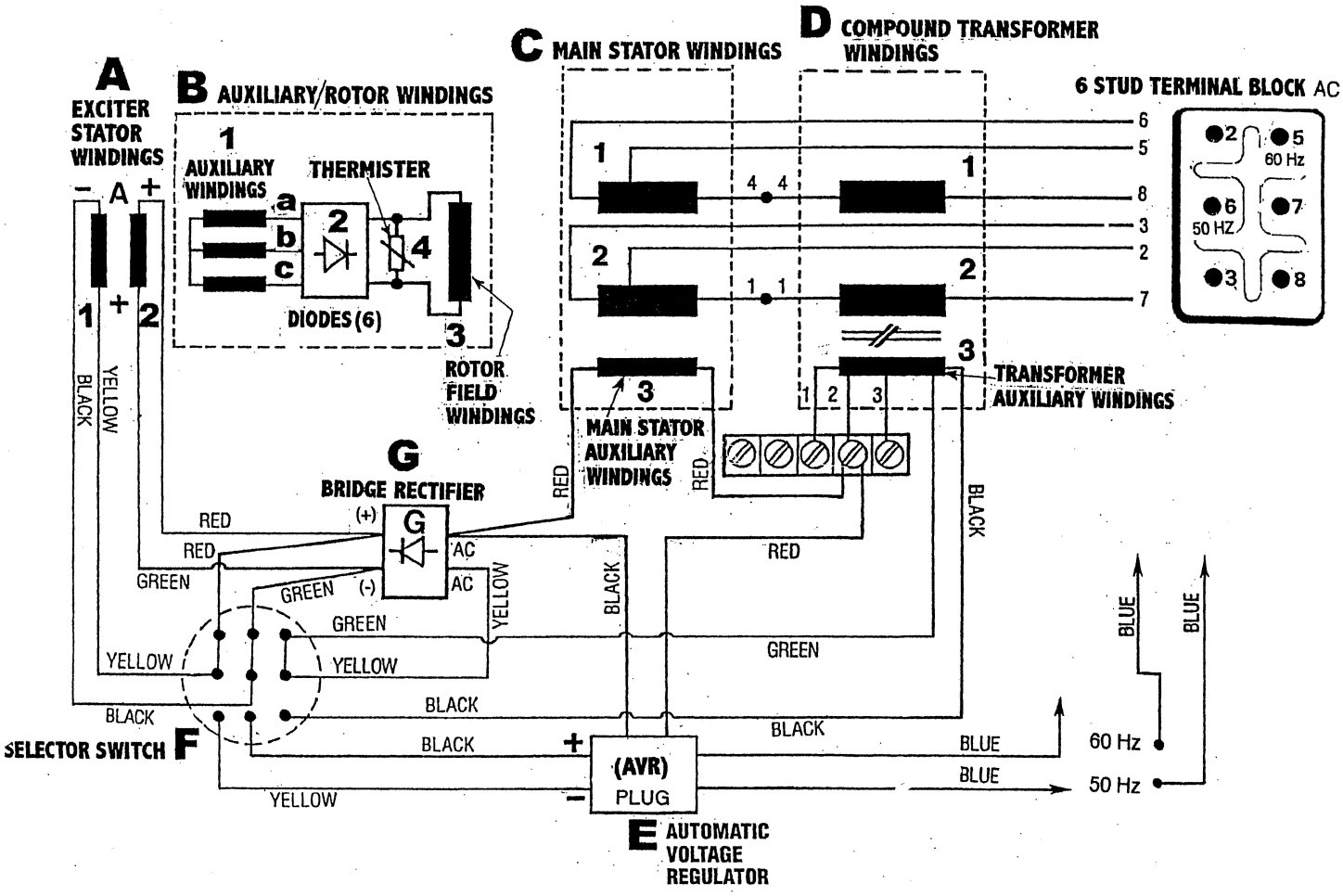
C Main Stator Aux. Winding **3**

Check Also: *Circuit connections from the transformer to the connections on the Bridge Rectifier.*

INTERNAL WIRING SCHEMATIC (6 STUD) BT GENERATOR

W/OPTIONAL VOLTAGE REGULATOR

REFER TO THE TROUBLESHOOTING CHART ON PAGE 3 FOR THE RECOMMENDING COMPONENT TESTING SEQUENCE



COMPONENT RESISTANCE (IN OHMS)

A EXCITER STATOR WINDINGS
1 and **2**....11.5 Ω
1....49.4 Ω
2....12.9 Ω

B EXCITER ROTOR AND FIELD WINDINGS
1 a b c auxiliary windings are measured in pairs:
a-b...1.5 Ω, **b-c**....1.5 Ω, **c-a**....1.5 Ω
2 Diodes (6)....Ω/Infinite
3 Rotor Field Windings....9.7 Ω
4 Thermister....Infinite

C MAIN STATOR WINDINGS
1 and **2**....0.4 Ω
3 Main Stator Aux. Windings....1.3 Ω

D COMPOUND TRANSFORMER WINDINGS
1 and **2**....0.4 Ω
Compound Transformer Aux. Windings **3**....4.3 Ω
E Voltage Regulator (optional)
F Selector Switch
G Bridge Rectifier

EXCITER CIRCUIT VOLTAGES (NOMINAL)

Voltages measured across the AC and DC connections on the Bridge Rectifier

AC into Bridge Recitifier: No Load 20 VAC - Full Load 55 VAC

DC out of Bridge Recitifier: No Load 8 VDC - Full Load 18 VDC

Note: *Resistance readings and voltage checks can be accessed easily for the components in the exciter circuit* ***A, G, C-3*** *and* ***D-3*** *by locating the color coded wires at the connection points shown on the above schematic. When checking winding resistance values be sure to lift both of the component's electrical connections.*

MEASURING RESIDUAL VOLTAGE

NO-LOAD VOLTAGE

The amount of no-load voltage produced by the generator can be an indicator of where in the generator the problem/fault may lie.

Residual Voltage 10-14 Volts **[6 Stud]**

This voltage is the AC voltage produced by the generator from magnetism in the exciter stator field. This voltage is measured between the AC Neutral and Hot leg(s) with no-load on the generator running at 60 hertz.

The presence of residual voltage is an indication that the following generator components are OK.

Exciter Rotor **B-1 a, b, & c** and **B-2**

Rotating Field **B-3**

Main Stator **C-1** and **C-2**

Compound Transformer **D-1** and **D-2**

The fault lies in one or more of the following components in the exciter circuit.

Exciter Stator A-1 [and A-2 if applicable]

Bridge Rectifier G

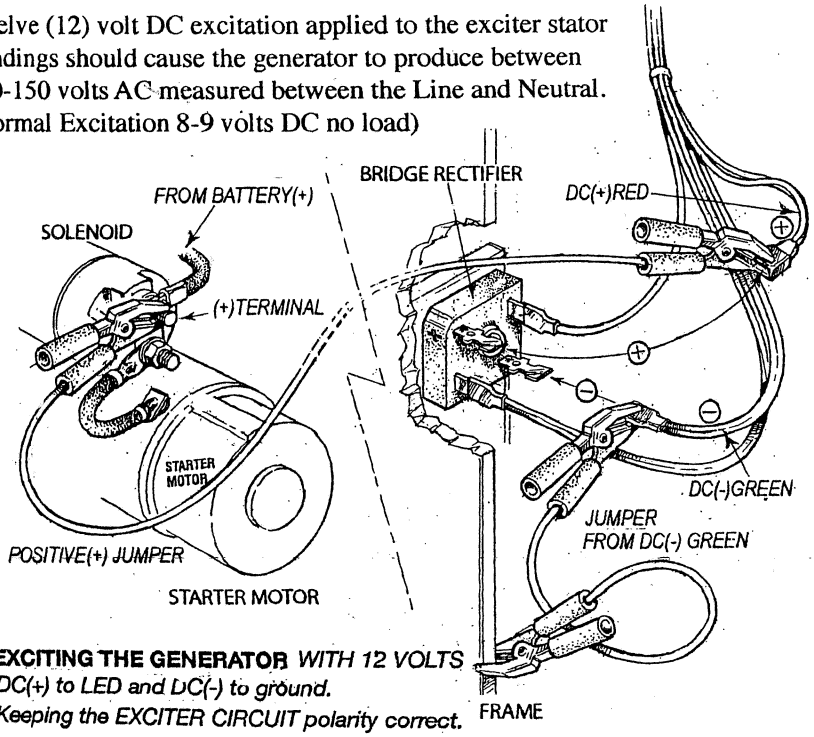
Selector Switch [if applicable]

Main Stator Auxiliary Windings C-3

Compound Transformer Auxiliary Winding D-3

12 VOLT EXCITATION

Twelve (12) volt DC excitation applied to the exciter stator windings should cause the generator to produce between 140-150 volts AC measured between the Line and Neutral. (Normal Excitation 8-9 volts DC no load)



EXCITING THE GENERATOR *WITH 12 VOLTS DC(+) to LED and DC(-) to ground. Keeping the EXCITER CIRCUIT polarity correct.*

Correct voltage produced with 12 volts excitation indicates the fault is in one or more of the above listed components **G, C-3 or D-3.**

If the generator does not produce the correct voltage [140-150V with excitation, then also include the rotor components as possible faults. The Absence of any voltage from the generator indicates a fault with the main stator windings **C-1** and **C-2** and/or the compound transformer windings **D-1** and **D-2** or possibly a shorted **thermister.**

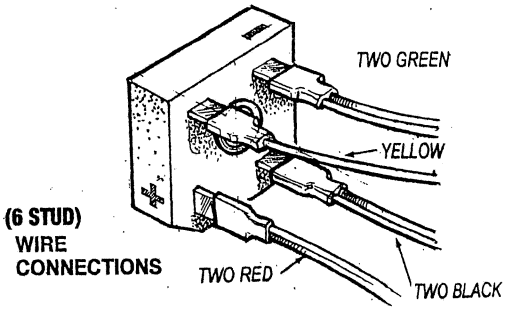
Apply 12 volt DC excitation to the exciter stator windings as illustrated. A fault in the main stator and/or compound transformer windings such as a short will cause the generator engine to load down and the shorted windings to eventually produce smoke as the excitation is continued.

Voltage output greater than residual and less than rated output 35-100 volts indicates a fault in the exciter rotor/field **B-1, B-2** or **B-3**. Excitation of the generator should produce a partial rise in voltage output and, when removed, the voltage will return to the original low output.

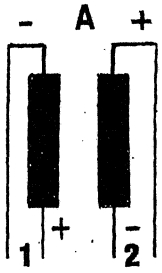
BRIDGE RECTIFIER WIRING

The illustration below shows the color coded wires at the two AC terminals and the color coded wires at the (+) and (-) DC terminals.

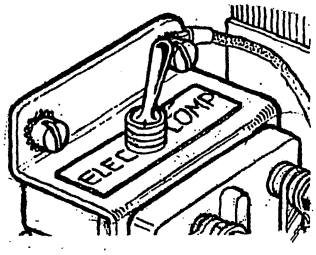
Note: *When removing or reinstalling connections, maintain correct polarity connection on the (+) and (-) DC terminals.*



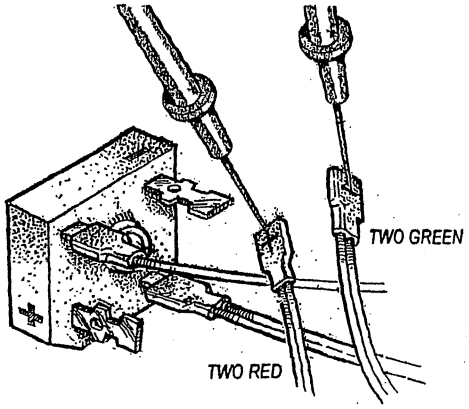
TESTING EXCITER STATOR WINDINGS



6 STUD STATOR WINDINGS

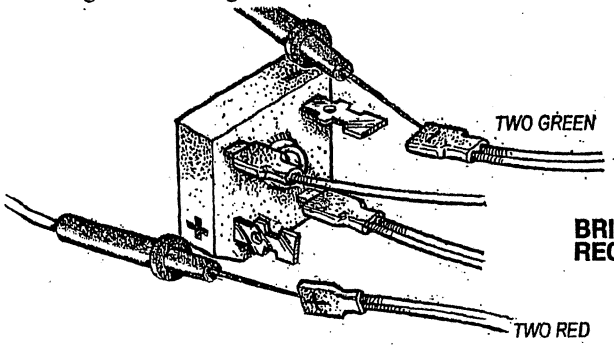


SELECTOR SWITCH



WINDINGS A-1 AND A-2 TESTING RESISTANCE

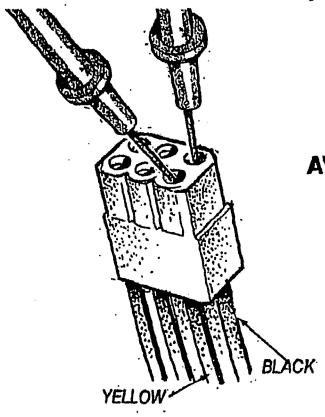
Resistance readings for exciter windings **A-1** and **A-2** with the selector switch in the COMP position are taken between the positive (+) and negative (-) leads lifted off the bridge rectifier. Neither of these two leads should have continuity to the generator case/ground. **A-1 & A-2** – 11.5 Ω



BRIDGE RECTIFIER

WINDINGS A-1 TESTING RESISTANCE

Resistance readings for exciter stator windings **A-1** with the selector switch in the ELEC position is taken between the yellow wire and the black wire at the AVR plug. **A-1** – 53.0 Ω



AVR PLUG

WINDINGS A-2 TESTING RESISTANCE

Resistance readings for exciter winding **A-2** with the selector switch in the ELEC position is taken between the green wire lifted off the negative (-) terminal of the bridge rectifier and the red wires lifted off the positive (+) terminal of the bridge rectifier. **A-2** – 13.5 Ω

Note: *The white striped wiring on earlier model generators has been changed to solid colors on current generators, the colors, however, remain the same.*

TESTING THE BRIDGE RECTIFIER (meter FLUKE multimeter)

1. Set the meter on Ohms scale and connect the positive lead to point **#4**. Take the negative lead and momentarily touch point **#1, #2, #3** and **#5**. There should be no Ohm value registered on the meter.

2. Remove the positive lead from point **#4** and connect the negative lead to it. Momentarily touch points **#1, #2** and **#3.** The Ohm meter should register an arbitrary value at each point it touches.

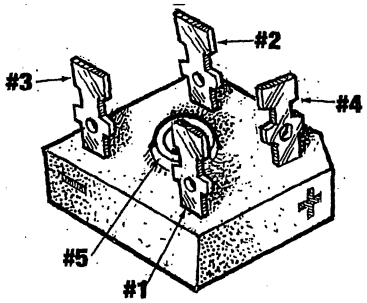
3. Leave the negative lead on point **#4,** touch point **#5** with the positive lead. The meter should register no Ohm value.

4. Place the positive lead on point #1 and the negative lead on point #3. The meter should register and Ohm value. Reverse these connections and the meter should register an Ohm value.

If the rectifier fails any of these tests replace the rectifier as it is defective.

Note: *The AC-DC terminals location may vary on some bridge rectifiers but + and – are clearly marked.*

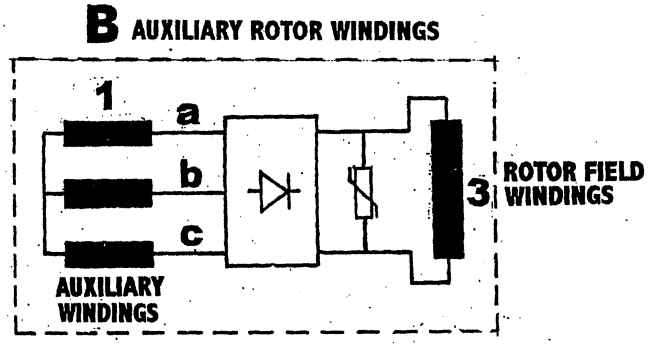
BRIDGE RECTIFIER



Note: The AC & DC terminal locations may vary . The DC + will always be clearly marked.

TESTING EXCITER ROTOR WINDINGS

REFER TO THE WIRING SCHEMATICS TROUBLESHOOTING GUIDES AND COMPONENT RESISTANCE CHARTS IN THIS MANUAL



TESTING AUXILIARY WINDINGS 1 a b and c

Locate the three terminal points on the exciter rotor for these auxiliary winding groups. Position the exciter rotor as shown in the illustration and count off the porcelain knobs from the 12 o'clock point either left or right to locate terminal points **a**, **b** and **c**. Measure the resistance value between the pairs of terminal points **a** & **b**, **b** & **c** and **c** & **a**. There is no need to unsolder these connections unless a faulty reading appears. If this occurs, unsolder and verify the winding fault. There should be no continuity found between any of the three terminal points and the rotor shaft/case ground.

Auxiliary windings **1-a**, **b** and **c**
6 Stud – 1.5 Ω

TESTING ROTOR FIELD WINDINGS 3

Refer to the illustration or diagram of the exciter rotor. The field winding connections are noted as the (+) and (-) connections of the red & white striped wires. Measure the resistance value with your ohmmeter between these two connection points. These connections need not be unsoldered unless a faulty reading appears. If this occurs unsolder the connection and verify the resistance reading. With these connections lifted, there should be no continuity to the rotor shaft. This would indicate a short to ground with these field windings.

Field Windings **3**
6 Stud – 9.7 Ω

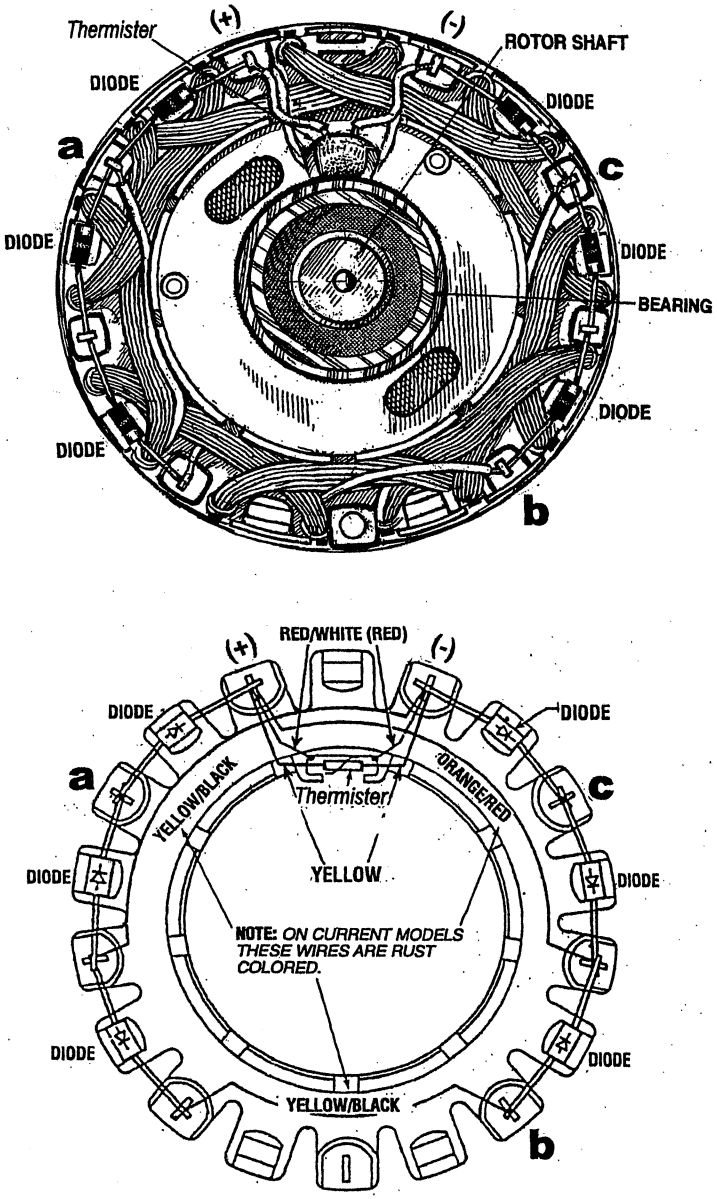
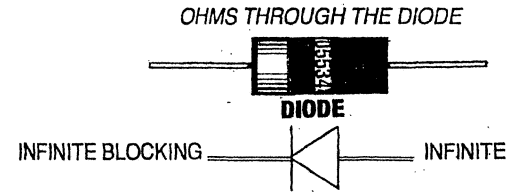


ILLUSTRATION AND DIAGRAM OF THE EXCITER ROTOR

TESTING DIODES AND THERMISTER

REFER TO THE WIRING SCHEMATICS TROUBLESHOOTING GUIDES AND COMPONENT RESISTANCE CHARTS IN THIS MANUAL



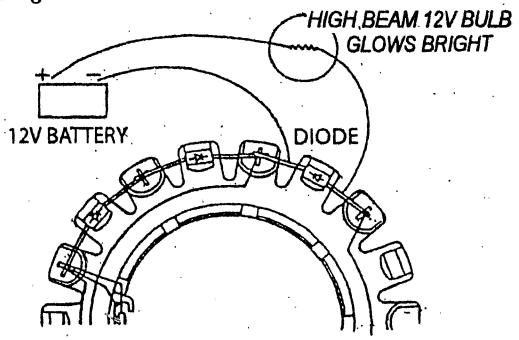
TESTING DIODES

Six diodes are mounted on the exciter rotor; they rectify the AC voltage produced by the three groups of the auxiliary windings to DC voltages and supply this DC voltage to the rotating field windings.

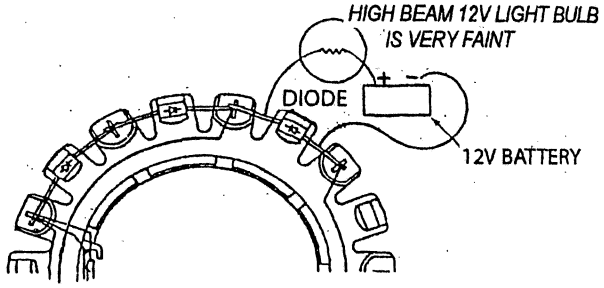
The diodes can be easily checked in place with the use of a common automotive 12-volt high beam headlight bulb, some jumper leads and the generator's 12 volt starting battery.

A short or an open in a diode can easily be found with the above without having to unsolder and isolate each diode to check it with an ohmmeter.

Note: *Attempting to check diodes in place with an ohmmeter will give erroneous readings on the diodes due to the auxiliary winding's connections.*



When leads are put across the diode, as illustrated, voltage passes through the diode allowing the headlight to glow brightly.



Reverse the leads across the diode. The diode should block voltage passing through it, and the headlight should not glow, or it may glow faintly.

1. Should the bulb not glow with leads connected in both directions, the diode is open internally.
2. Should the bulb glow with leads connected in both directions, the diode is shorted internally.

In both 1. and 2. above, the diode should be replaced. Check the resistance value of the rotating field winding and the integrity of the thermister connected across the + and – connections of the rotating field winding.

TESTING THE THERMISTER

The thermistor is located on the Exciter Rotor and connects between the + and – connection for the rotating field winding resistance: Infinite.

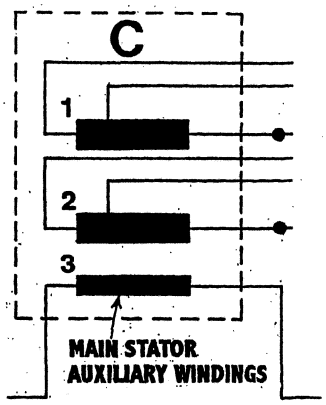
The Thermister is a voltage absorber when amperage load changes take place with the generator to help prevent/or reduce light flicker if open circuited, it has no affect on the operation of the generator other than a flicker in the lights when amperage load changes take place not occurring before. Should the thermister short it will negate the affects of the rotating field winding on the stator windings and no AC output voltage will be produced.

When exciting the generator in an effort to locate the cause of a very low or no AC output and the cause is a shorting thermister. There will be no loading of the drive engine. No growling from the AC generator. However as the excitation is allowed to continue the short will produce heat in the thermister and some electrical smell/smoke visible in the area of the rotor rear carrier bearing. The thermister can be removed and the generator operation restored other than for light flicker until a replacement is installed.

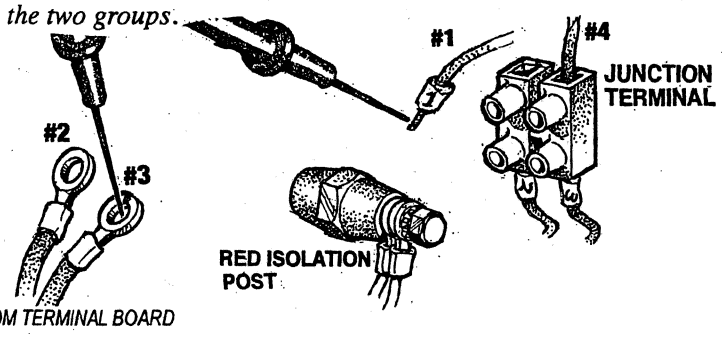
TESTING STATOR WINDINGS

VERY LOW VOLTAGE, OR NO VOLTAGE

REFER TO THE WIRING SCHEMATICS TROUBLESHOOTING GUIDES AND COMPONENT, RESISTANCE & CHARTS IN THIS MANUAL

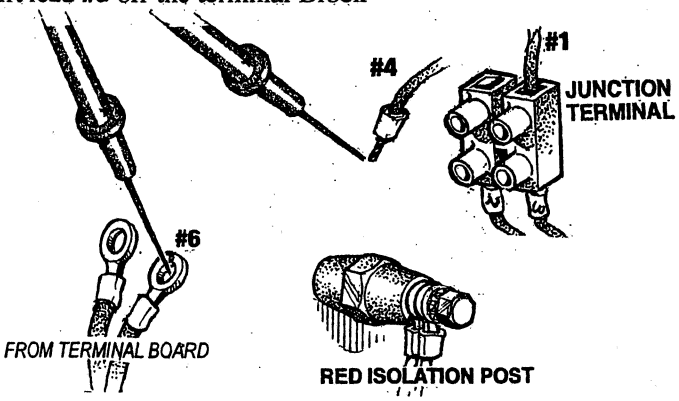


Continuity Test: *No continuity should be found between the lifted leads to the case/ground or between the connections of the two groups.*



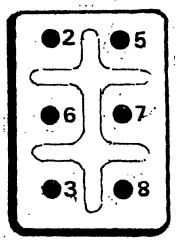
MAIN STATOR WINDINGS C

Windings Group C-1: The resistance value is measured between lifted **#4** from Junction Terminal or Red Isolation Post below the transformer and lead **#6** lifted off the AC terminal Block. To totally isolate this winding group. Also, lift lead **#5** off the terminal Block



Windings Group C-2: The resistance value is measured between the lifted lead **#1** from the Junction Terminal or Red Isolation Post below the transformer and lead **#3** lifted off the AC Terminal Block. To totally isolate this winding group. Lift lead **#2** off the terminal Block.

Main stator windings **C-1** – 0.4Ω **C-2** – 0.4Ω (6 Stud)



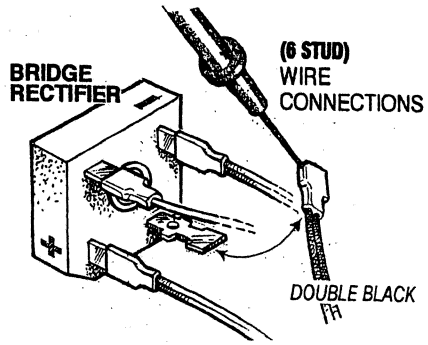
AC TERMINAL BLOCK (6 stud)

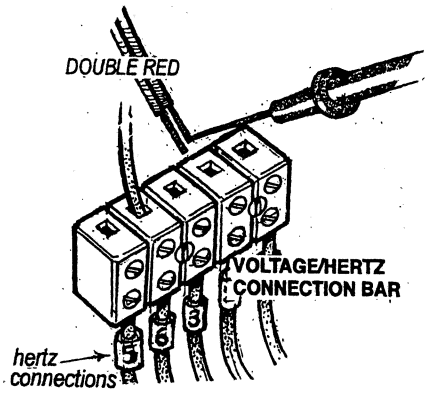
MAIN STATOR AUXILIARY WINDINGS C-3 (6 STUD)

Resistance is measured between the lifted double black AC connection on the bridge rectifier and the lifted double red connection on the Voltage/Hertz Bar.

Main stator auxiliary windings **C-3 6 Stud** – 1.3Ω

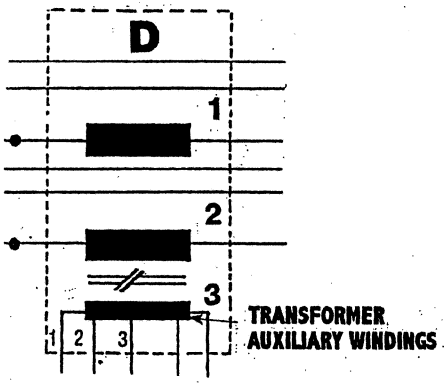
Continuity Test: *No continuity should be found from either of these leads to the case/ground or to either of the transformer groups.*





COMPOUND TRANSFORMER

REFER TO THE WIRING SCHEMATICS TROUBLESHOOTING GUIDES AND COMPONENT, RESISTANCE & CHARTS IN THIS MANUAL



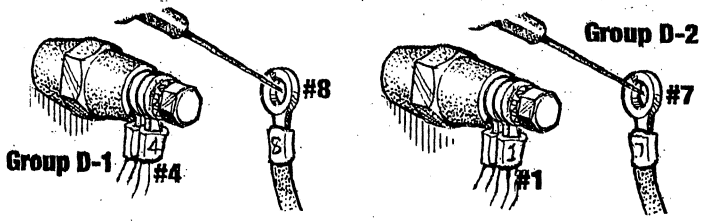
COMPOUND TRANSFORMER D (6 STUD) MEASURING RESISTANCE

Windings Group D-1: Resistance value is measured between lifted lead **#4** from the isolation post and lead **#8** lifted off the AC terminal block. (illustrated below)

Windings Group D-2: Resistance value is measured between lifted lead **#1** from the isolation post and lead **#7** lifted off the AC terminal block.

Compound Transformer Windings Resistance
D-1 & D-2 – 0.4Ω

Continuity Test: *No continuity should be found from either of these leads to the case/ground or to either of the transformer groups.*

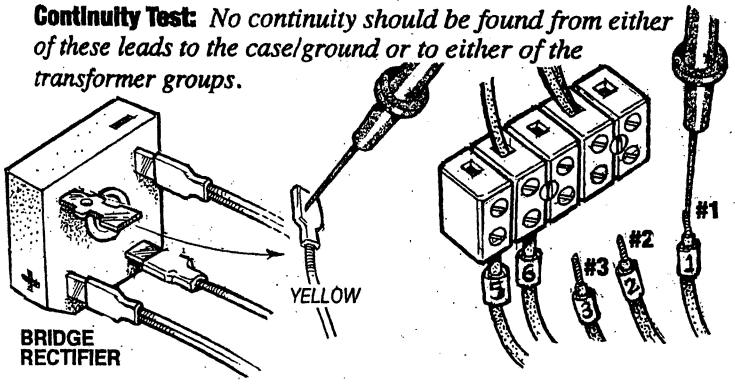


TRANSFORMER AUXILIARY WINDINGS D-3 (6 STUD)

Resistance value is measured between the yellow wire lifted off the AC terminal of the bridge rectifier (with the selector switch in the ELEC position) and the **#1** red lead lifted off the Voltage/Hertz connection bar. Off this same bar, lift the **#2** and **#3** red leads that come from the auxiliary windings to totally isolate these windings.

Transformer Auxiliary Windings Resistance
D-3 – 4.3 Ω

Continuity Test: *No continuity should be found from either of these leads to the case/ground or to either of the transformer groups.*



VOLTAGE ADJUSTMENTS

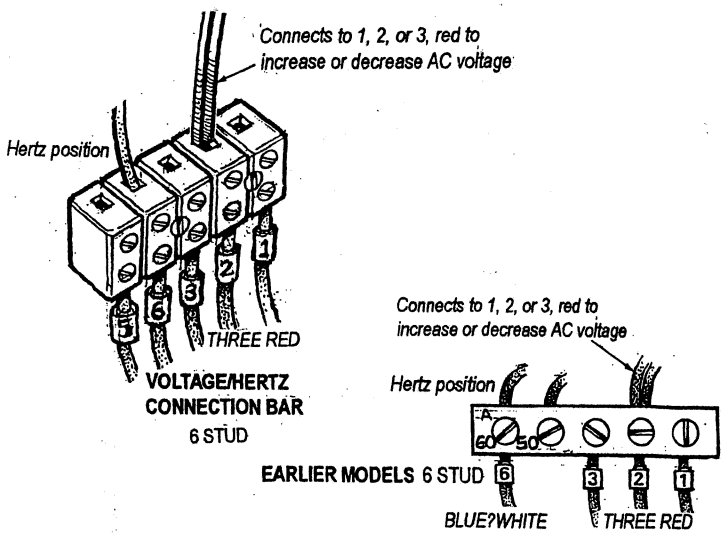
NO-LOAD VOLTAGE ADJUSTMENT

Voltage adjustment is made with the generator regulation being governed by the compound transformer.

1. The selector switch [if applicable] must be in the comp position
2. To confirm no-load voltage, start the generator and apply a momentary (moderate) load to excite the transformer. The voltage produced by the generator after the momentary load is removed is no-load voltage. Note the voltage output from the generators 120 volt leg(s) (230 volt 50 hertz). The no-load voltage should be between 121-124 volts at 61.5-62 hertz (232-236 volts at 51.5-52 hertz).
3. To raise or lower the voltage, shims of varying thickness (non-conductive material) are placed or removed from under the steel laminated bar on top of the compound transformer. The material used for shimming should not soften at temperatures in the 176° (80° C) range. A small reduction in no-load voltage (1 to 3 volts) can sometimes be accomplished by gently tapping the top of the laminated steel bar to reduce the gap between the existing shims and the transformer core. Varying the shim thickness by .001 inch (0.025mm) will change the No Load voltage by 4-6 volts.

FULL-LOAD VOLTAGE ADJUSTMENT

The three red connections coming into these two components can be used to increase AC voltage to the bridge rectifier or lower it by moving the single/double red connection on the other side from #3 to #2 or #1 to increase and from #1 to #2 or #3 to decrease. Increasing AC voltage to the rectifier will increase excitation and the AC output. Decreasing AC voltage to the rectifier will lower excitation and the AC output. These



connections are generally used to increase excitation when at full amperage load the AC output of the generator falls below acceptable levels 108 volts – 60 hertz or 210 volts – 50 hertz. Note: Hertz/Speed drop is not the issue. No-load voltage may need to be adjusted when these connections are moved.

Note: *Do not use these adjustments to compensate for overload conditions being placed on the generator/engine (inductive-motor type loads). Loss of generator hertz/speed, the result of this type of overload, will cause a drop in voltage output.*

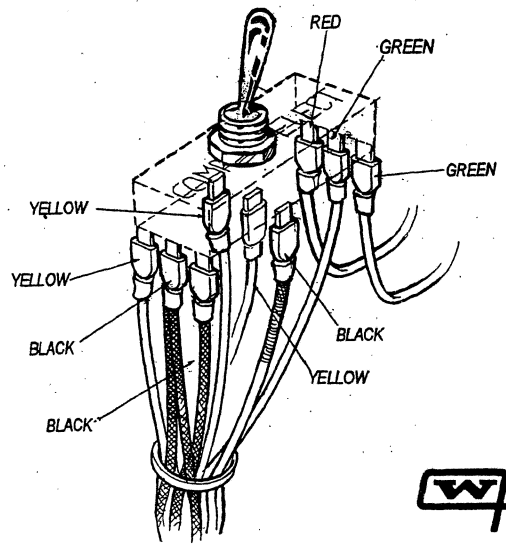
CHANGING FREQUENCY/HERTZ

When changing generator Frequency/Hertz in the field refer to the models Operator Manual or Service Manual for the proper procedures. These procedures will vary greatly depending on the many different generator models.

AVR SELECTOR SWITCH AND PLUG CONNECTIONS (6 STUD)

SELECTOR SWITCH AND CONNECTIONS

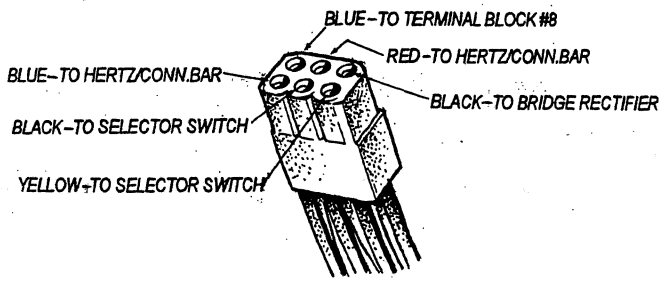
This switch is normally set in the COMP position. If an optional AVR is installed, the switch is toggled to the ELEC position.



Note: *With the selector switch in ELEC position the exciter stator windings are divided, one group is excited through the bridge rectifier and the other group through the A.V.R.*

A.V.R. PLUG AND CONNECTIONS

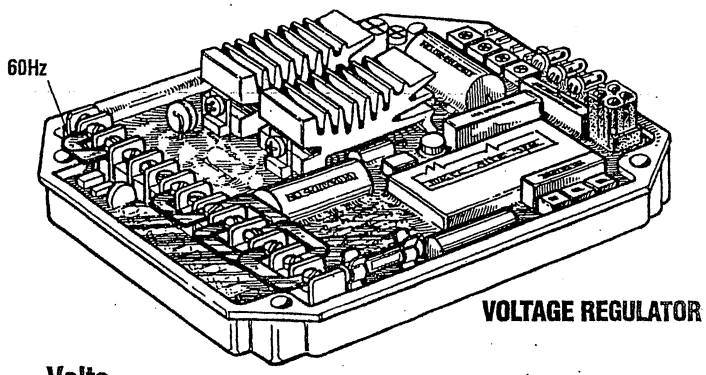
Note: *Striped wires were used on early model generators. The colors will, however, matchup to the current solid color wires.*



BT GENERATOR VOLTAGE REGULATOR ADJUSTMENTS (3 PHASE)

Description

The voltage regulator is an advanced design which ensures optimum AC generator performance. It is equipped with complete protection circuitry to guard against operating conditions that could be detrimental to the AC generator.



VOLTAGE REGULATOR

Volts

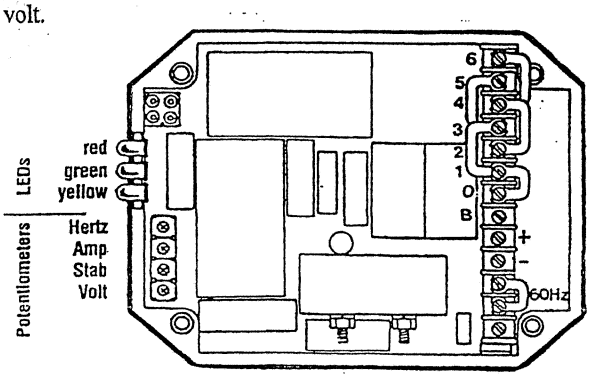
This potentiometer is used to adjust output voltage. At proper engine operating speed the output voltage should be held at ±1% from a no-load condition to a full rated generator output and from power factor 1.0 - 0.8 with engine drive speed variations up to -6%. Prior to starting the engine, turn the VOLT and STAB trimmers (using a mini phillips screwdriver) fully in a counter clockwise (Minimum) direction until you feel them hit their stops. Turn the AMP and HERTZ trimmers completely clockwise (Maximum) in the same manner. With the generator running at no-load, at normal speed, and with VOLT adjust at minimum, it is possible that output voltage will oscillate. Slowly rotate the VOLT adjust clockwise. The voltage output will increase and stabilize. Increase the voltage to the desired value. In this situation, only the green LED will stay lit.

Stability

This potentiometer permits variation of the regulator's response to generator load changes so as to limit overcompensation and obtain a minimum recovery time to the normal voltage output.

In order to adjust the regulator stability the generator must be running at no-load and the output must be monitored.

Turn the STAB adjust slowly clockwise until the voltage starts to fluctuate. At this point rotate the STAB adjust counterclockwise until the voltage is stable within 1 or 2 tenths of a volt.



VOLTAGE REGULATOR DIAGRAM

Amp-Hertz

These two adjustments are used in conjunction with the two protection circuits in the voltage regulator that are indicated by the illumination of colored LED lights.

1. Delayed overload protection (yellow LED).
2. Low speed protection (red LED).

Both systems have an intervention threshold which can be adjusted using the respective potentiometer. Each of the two circuits are able to cause an adequate reduction in excitor voltage to safeguard the excitor windings and prevent their overheating.

The overload protection system has a delay which permits temporary overloading of the generator during times such as motor start-up or other similar load surge demands. The regulator also has a third LED (green), that glows during generator operation to indicate correct operation of the regulator with the generator.

Setting the Overload Protection

In order to set the AMP overload protection, the generator must be loaded to its full output rating.

1. Load the generator to its rating, then decrease the speed of the engine by 10.10% (54 Hertz on 60 hertz units, 45 hertz on 50 hertz units).
2. Rotate the AMP adjustment counterclockwise until it hits its stop. Wait about 15-20 seconds after which the AC output of the generator should drop and the yellow LED light should come on.
3. Slowly rotate the AMP adjustment clockwise until the output voltage increases to approximately 97% of the voltage output at the start of the adjustment. At this point the yellow LED light should come on.
4. Return to nominal speed, the yellow LED will turn off and the generator voltage will rise to its normal value. Should this not happen, repeat the adjustment.

NOTE: *When changing from 60 hertz to 50 hertz operation, remove the 60 hertz jumper bar from the regulator board.*

Setting the Underspeed Protection

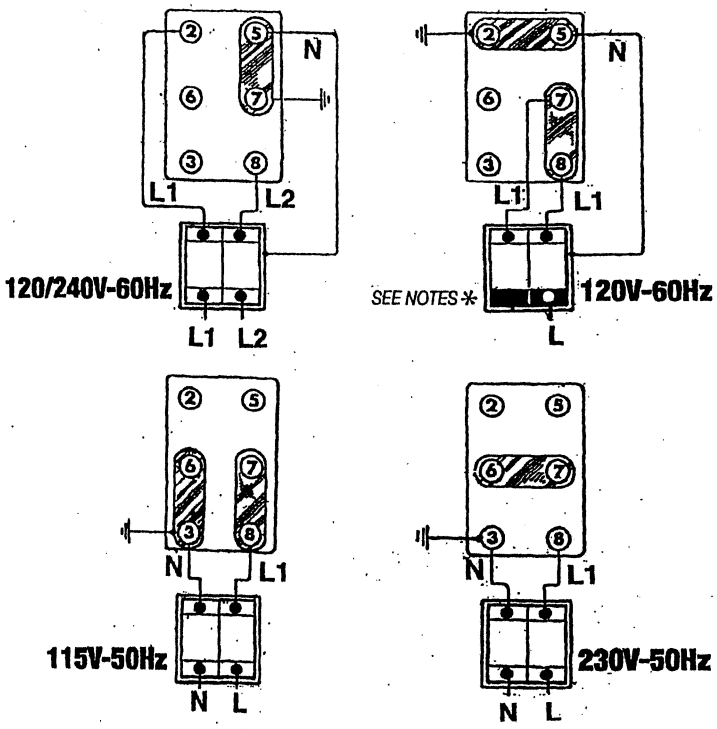
NOTE: *If the unit is operating at 60 Hertz ensure that the jumper strap is in place on the regulator board between the two 60 Hertz terminals. In order to adjust the underspeed setting, the generator should be running at no-load.*

1. To adjust the underspeed (low frequency) protection circuit, lower the engine speed at 90% of its normal running speed (54 hertz on 60 hertz units, 45 hertz on 50 hertz units.
2. Rotate the Hertz adjustment counterclockwise slowly until the generator's AC output voltage starts to decrease and at the same time the red "LED" light comes on.
3. Increase the engine speed to its normal speed (frequency). The red "LED" light will go out and the AC voltage output will return to normal.

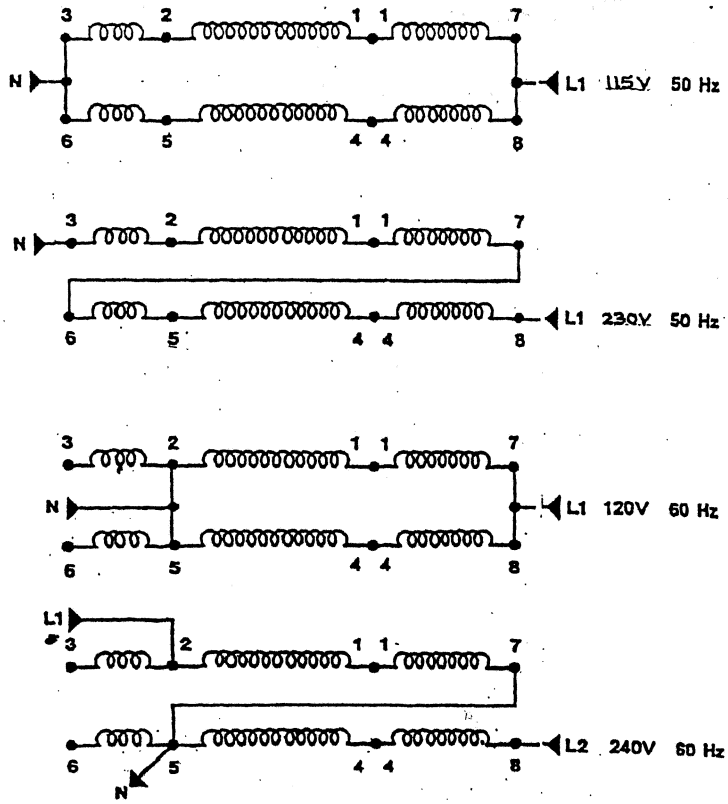
With the above adjustments made, the regulator should function normally.

AC TERMINAL BLOCK CONNECTIONS AND WINDING DIAGRAMS

AC TERMINAL BLOCK CONNECTIONS (6 STUD)



WINDING DIAGRAM (6 STUD)



NOTES

The winding diagrams show the connections necessary to obtain the correct voltage and frequency.

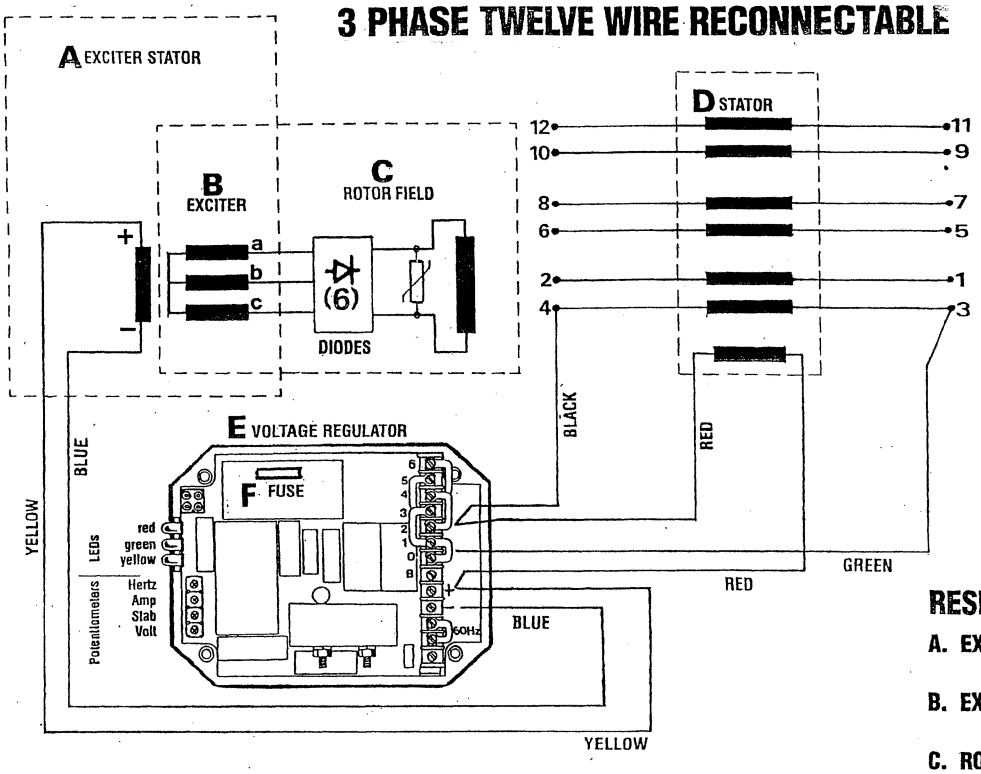
The Ground Wire that connects from the Neutral Stud to the Generator Frame must be moved when changing from 115V-50Hz to 230V-50Hz.

For Output Leads from the AC Terminal Block use terminal ends for ¼" studs that accept multi-strand copper wire sized for the rating from the hot lead connection.

* *When wiring 120/60hz, a jumper is required between the lead connections.*

BT GENERATOR INTERNAL WIRING

3 PHASE TWELVE WIRE RECONNECTABLE



RESISTANCE VALUES

A. EXCITER STATOR (17.9 ohm)

B. EXCITER ROTOR WINDINGS a b c (0.6 ohm)

C. ROTATING FIELD (2.49 ohm)

D. MAIN STATOR WINDINGS (0.05 ohm)
AUXILIARY WINDING (1.2 ohm)

E. VOLTAGE REGULATOR

F. AUXILIARY CIRCUIT FUSE

BT GENERATOR TROUBLESHOOTING/3 PHASE

NOTE: *AC generator troubleshooting must be performed with the engine operatin at 60 Hz.*

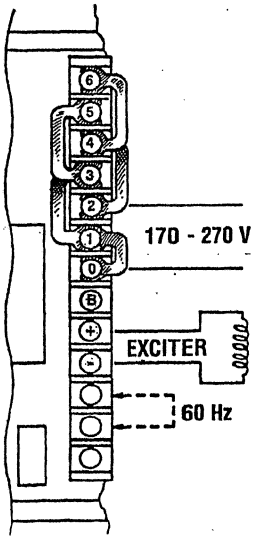
FAULT	PROBABLE CAUSE	
NO AC VOLTAGE OUTPUT AT NO LOAD.	1. Short or open in the main stator winding. 2. Shorted suppressor on exciter rotor. 3. Four or more shorted or open diodes on exciter rotor.	4. Open in exciter stator winding. 5. Open in rotating field winding.
RESIDUAL VOLTAGE PRODUCED AT NO LOAD 15 - 20 VOLTS AC.	1. Blown 6 AMP fuse auxiliary circuit AVR. 2. Faulty voltage regulator	3. Shorted or open main stator auxiliary winding.
LOW AC VOLTAGE OUTPUT AT NO LOAD 60 - 100 VAC.	1. Open or shorted diodes in. exciter rotor 1 to 3 diodes. 2. Shorted exciter rotor winding.	3. Faulty voltage regulator.
HIGH AC OUTPUT VOLTAGE 150 VAC OR HIGHER.	1. Faulty voltage regulator.	
UNSTABLE VOLTAGE OUTPUT.	1. STB pod on regulator needs adjustment.	2. Faulty voltage regulator.
AC VOLTAGE DROP UNDER LOAD 60 - 100 VOLTS AC.	1. Diode(s) on exciter rotor breaking down when load is applied (inductive) 1-3 diodes.	

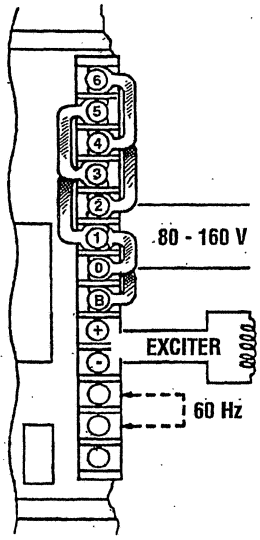
GENERATOR AC VOLTAGE CONNECTIONS (3 PHASE)

VOLTAGE REGULATORS THREE PHASE CONNECTIONS

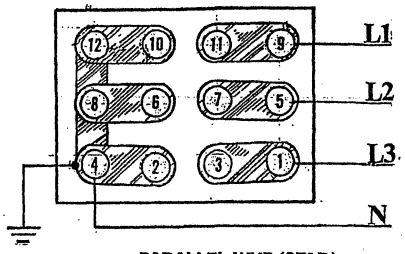
The regulator is equipped with seven numbered terminals (0 to 6) and their related brass jumpers. The illustrations shown connection points and jumpers for the 3 phase configuration of the generator. The sensing leads connect between pin #1 and pin #2 on the AC terminal block and connection #2 and #0 on the voltage regulator board.

NOTE: *Series Delta requires the installation of a jumper on the regulator board between terminal B and 0.*



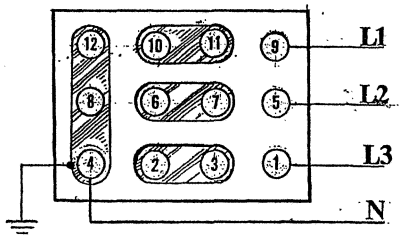


AC TERMINAL CONNECTIONS THREE PHASE 12 WIRE



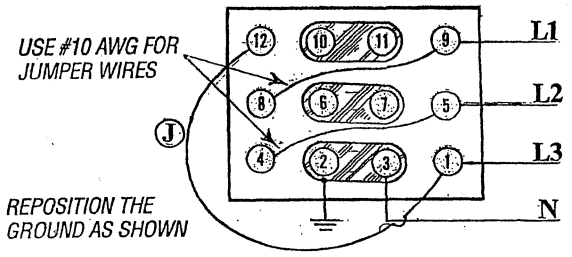
PARALLEL WYE (STAR)

L -N - 120 VAC	1Ø	60 HZ	L -L - 208 VAC	3Ø	60 HZ
L -N - 110 VAC	1Ø	50 HZ	L -L - 190 VAC	3Ø	50 HZ



SERIES WYE (STAR)

L -L - 450 VAC	3Ø	60 HZ	L -L - 380 VAC	3Ø	50 HZ
L -N - 265 VAC	1Ø	60 HZ	L -N - 230 VAC	1Ø	50 HZ

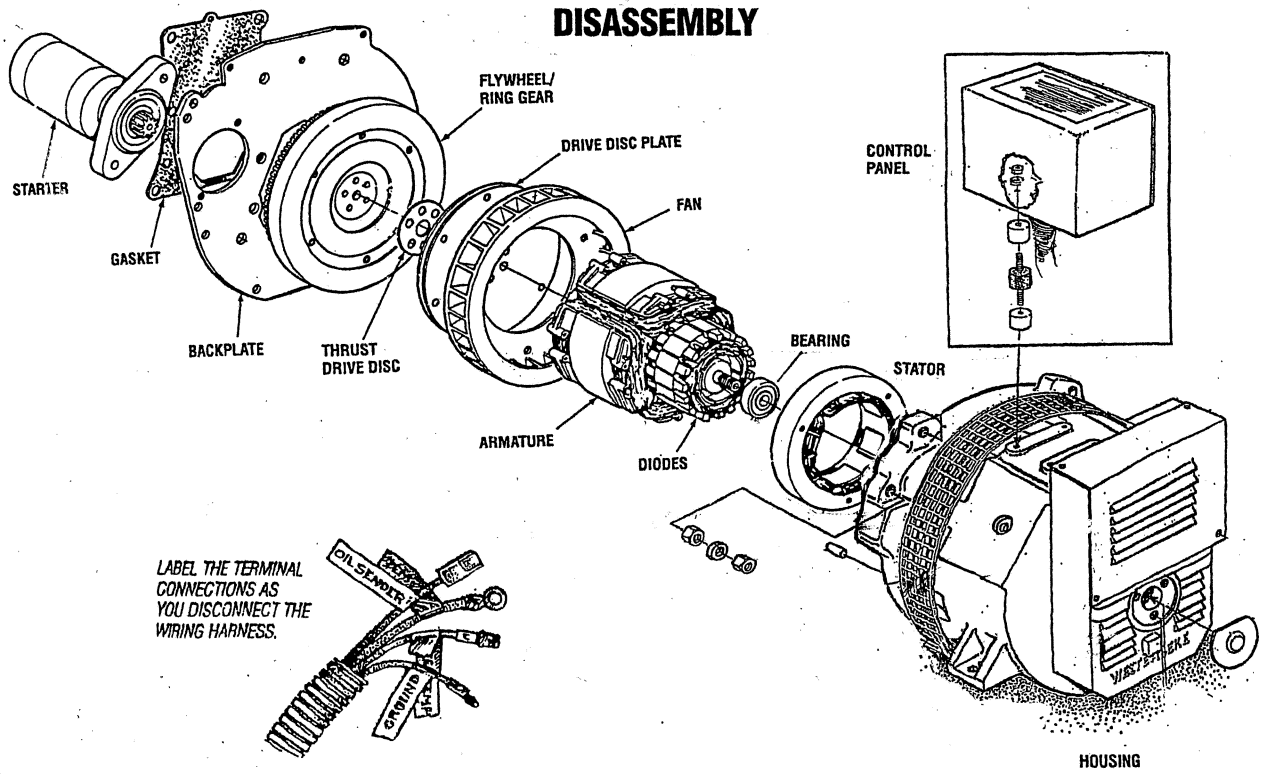


SERIES DELTA

L -L - 240 VAC	3Ø	60 HZ	L -L - 230 VAC	3Ø	50 HZ
L2, L3 -N - 120 VAC	1Ø	60 HZ	L2, L3 -N - 115 VAC	1Ø	50 HZ

BTD GENERATOR

DISASSEMBLY



CLEANING

Use compressed air to clean the exterior of the generator. Do not use liquids or water. Use **LOW** pressure air (25 psi maximum) to clear dirt and grease from the internal components.

DISASSEMBLY

1. Remove the starter motor. Remove the control box from the AC generator end.
2. Support the rear of the engine so that the rear support isolators for the generator can be unbolted.

   Reference the Special Tools - Generator page. These field fabricated tools will aide the service technician in the removal and installation of the AC Generator.
3. Install the lifting eye tool to the threaded bosses located under the control box and use this to support the weight of the AC generator end.
4. Unbolt the generator housing from the engine (8 bolts).
5. Using the Housing Puller Tool attached to the end bearing support web. Carefully draw the generator housing off the rotor, supporting the housing weight with the lifting eye. The rear support bearing may stay on the rotor shaft or be withdrawn with the housing.
6. Once the housing has cleared the rear support bearing, remove the puller and install the Pilot Tool and continue to remove the housing off the rotor. Take care not to drag the housings stator windings on the rotor laminations.
7. With the stator housing removed, support the rotor assembly with a sling and unbolt it with cooling fan from the flywheel.

Inspect and check all generator winding components and connections. Repair as needed. Inspect the rear rotor carrier bearing and replace as needed.

RESASSEMBLY

1. Reassemble carefully in the reverse order. Utilize the Disk Alignment Tool to properly locate the rotor/drive discs to the flywheel.

SPECIAL TOOLS - GENERATOR

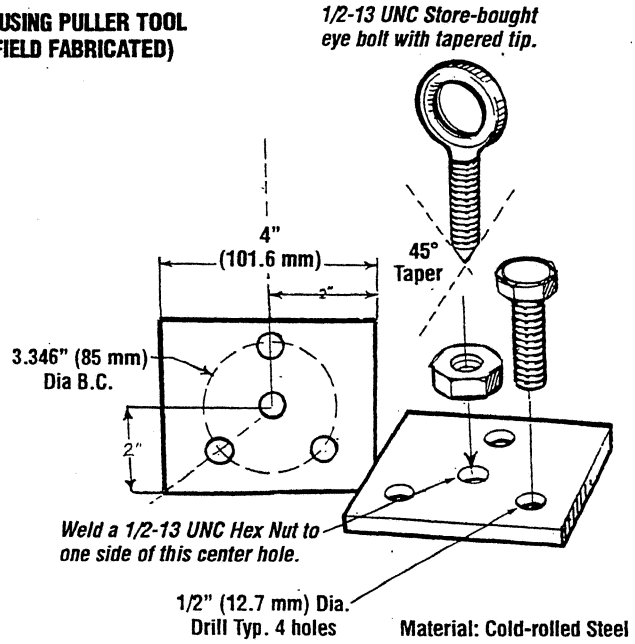
FIELD FABRICATED TOOLS

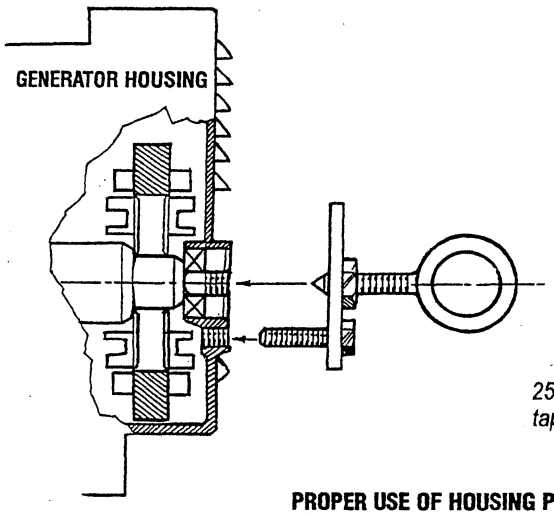
These drawings provide a means by which simple tools can be made to assist in the removal of the generator end from the engine and in the replacement of the generator end on the engine. A local machine shop should be able to fabricate these tools at a modest price, but first check with your local WESTERBEKE dealer to see if these tools are on hand for loan.

Housing Puller Tool

This tool allows the bearing in the generator housing to be gently pushed straight off the housing without any twisting. If a nut of the same specifications as that of the tapped hole in the pilot tool were to be welded on the end of the eye bolt, this tool would be able to pull the bearing back into place without any twisting. Please refer to these drawings before the generator end is removed.

HOUSING PULLER TOOL (FIELD FABRICATED)

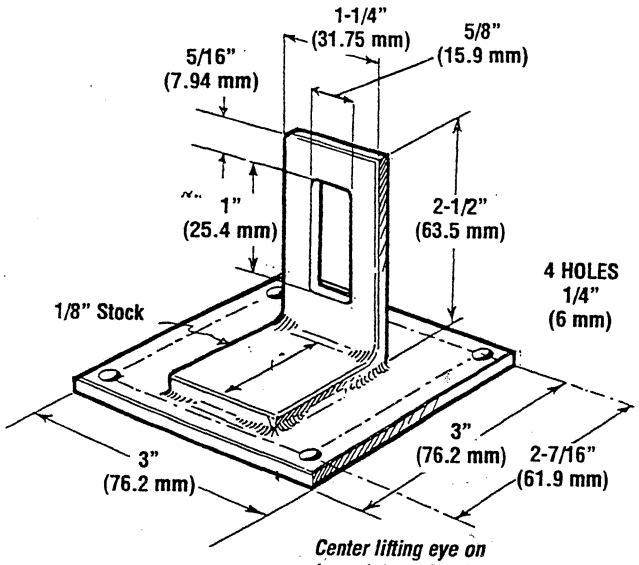




PROPER USE OF HOUSING PULLER

Lifting Eye Tool

This tool allows a mechanic to safely remove the generator end from the engine by attaching this Generator End Lifting Eye to the four screw holes located under the control panel. To use this Lifting Eye, remove the generator's control panel and screw the Lifting Eye to the generator end.



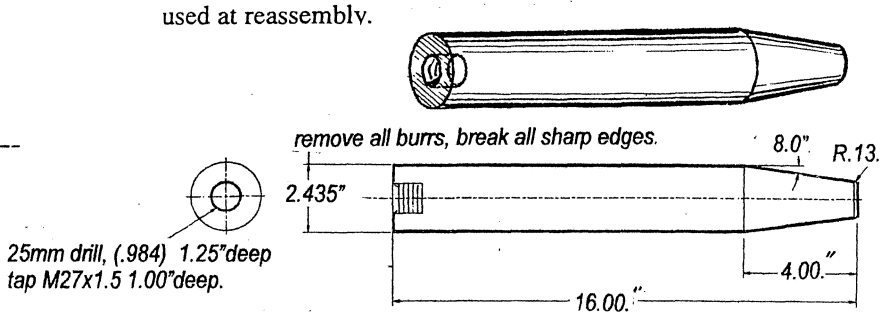
Disk Alignment Tool

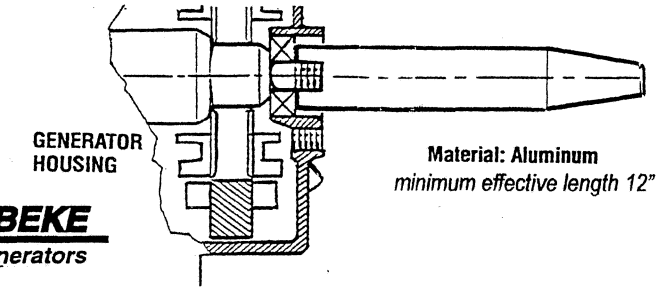
This tool allows a mechanic to safely remove and install the generator drive disks by aligning the disks with the Drive Plate Guide Pin. The Pin screws into the flywheel and acts as a guide. Also the pin helps to support some of the rotor and the drive plate's weight while removing or replacing these parts.

Material: One M8 bolt with the hex head machined off and a screwdriver slot cut in the machined end.

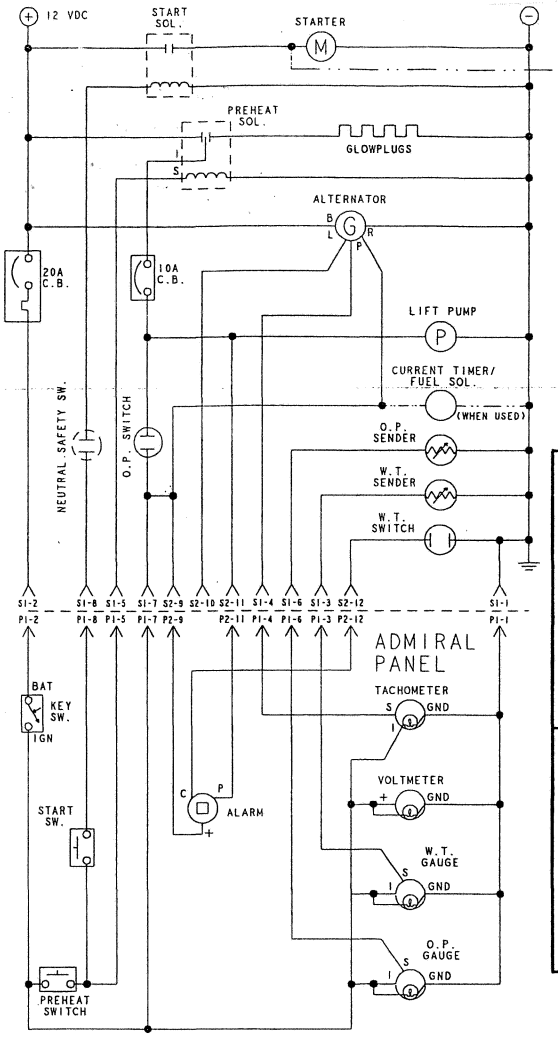
Pilot Tool

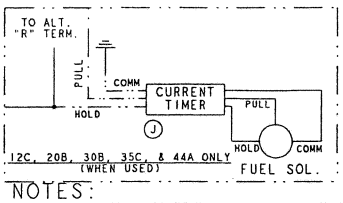
Screwed into the end of the rotor shaft, this tool can be used to pull the stator assembly away from the engine without damaging the stator windings. This tool can be used at reassembly.





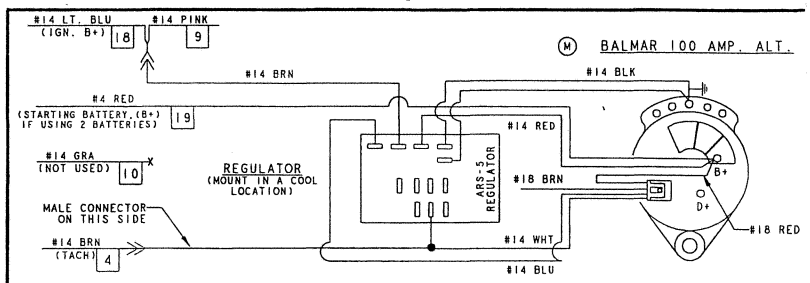
PROPULSION ENGINE WIRING SCHEMATIC #039144

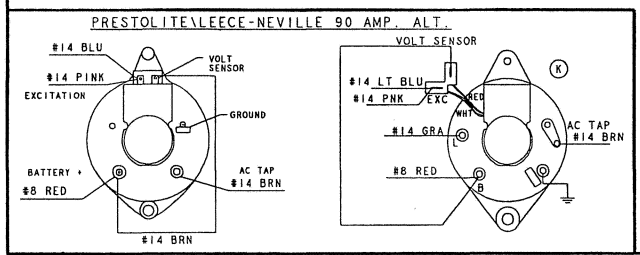


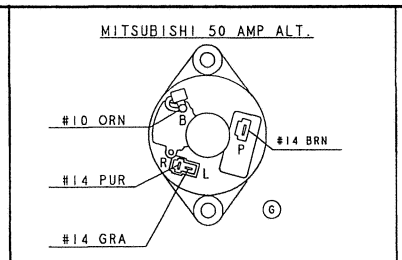


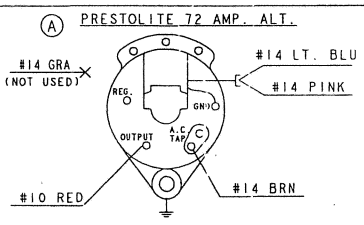
NOTES:

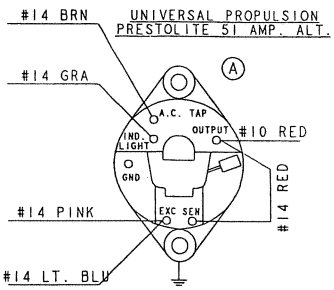
1. THIS PRODUCT IS PROTECTED BY A MANUAL RESET CIRCUIT BREAKER LOCATED NEAR THE STARTER. EXCESSIVE CURRENT WILL CAUSE THE BREAKER TO TRIP AND THE ENGINE WILL SHUT DOWN. THE BUILDER/OWNER MUST BE SURE THAT THE INSTRUMENT PANEL, WIRING, AND ENGINE ARE INSTALLED TO PREVENT CONTACT BETWEEN ELECTRICAL DEVICES AND SEAWATER.
2. AN ON-OFF SWITCH SHOULD BE INSTALLED BETWEEN THE BATTERY AND STARTER TO DISCONNECT THE BATTERY IN AN EMERGENCY AND WHEN LEAVING THE BOAT. A SWITCH WITH A CONTINUOUS RATING OF 175 AMPS. AT 12 VDC WILL SERVE THIS FUNCTION. THIS SWITCH SHOULD NOT BE USED TO MAKE OR BREAK THE CIRCUIT.
3. THE PINK WIRE AT PLUG 2 IS UNUSED AND SHOULD BE INSULATED, CAPTAIN PANEL ONLY.
4. THE GRAY WIRE AT PLUG 2 IS UNUSED AND SHOULD BE INSULATED, ADMIRAL PANEL ONLY.



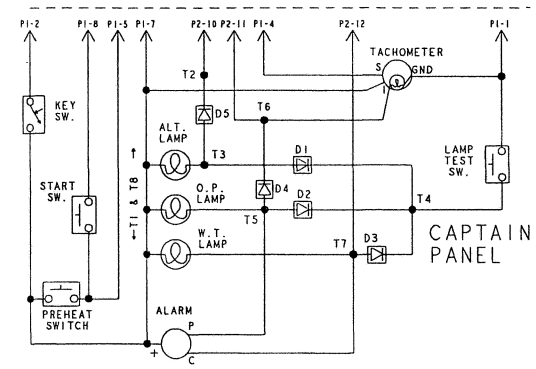


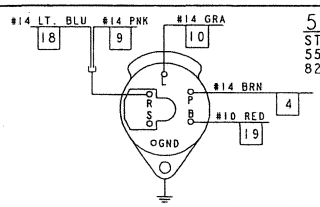






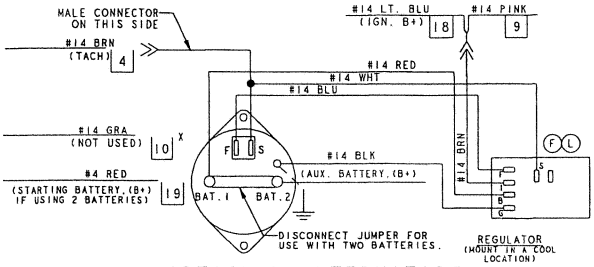
NOTE:
WIRE FOR BATTERY ATTATCHMENT WILL NEED TO BE UPGRADED TO AN 8 GAUGE FROM 10 GAUGE





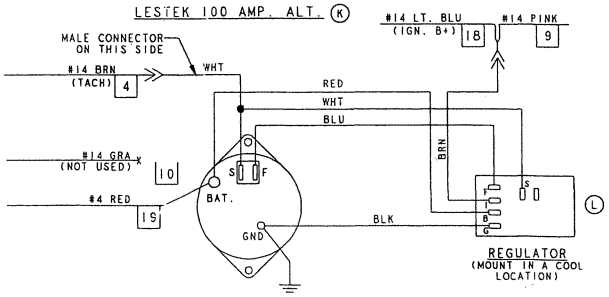
51 AMP. ALTERNATOR

STANDARD ALTERNATOR ON THE 55C, 63B, 63C, 64A, 71B, 82B, 108B, & 108C.

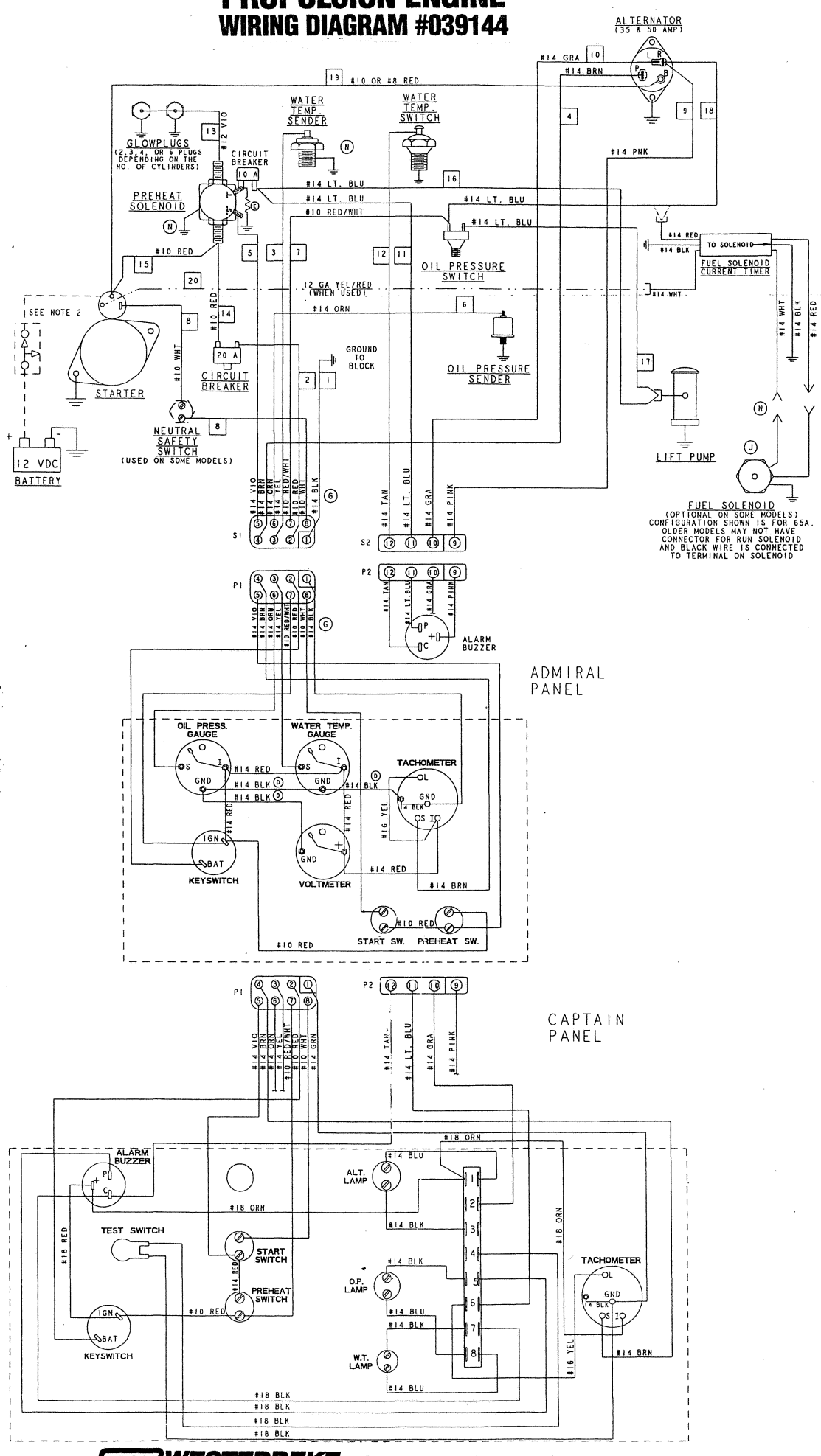


OPTIONAL ALTERNATORS D

135A, 160A, 190A, LESTEK/BALMAR ALTERNATORS
AVAILABLE ON THE M50B, 55C, 63B, 63C, 64A, 71B, 82B, 108B, & 108C ONLY.
H

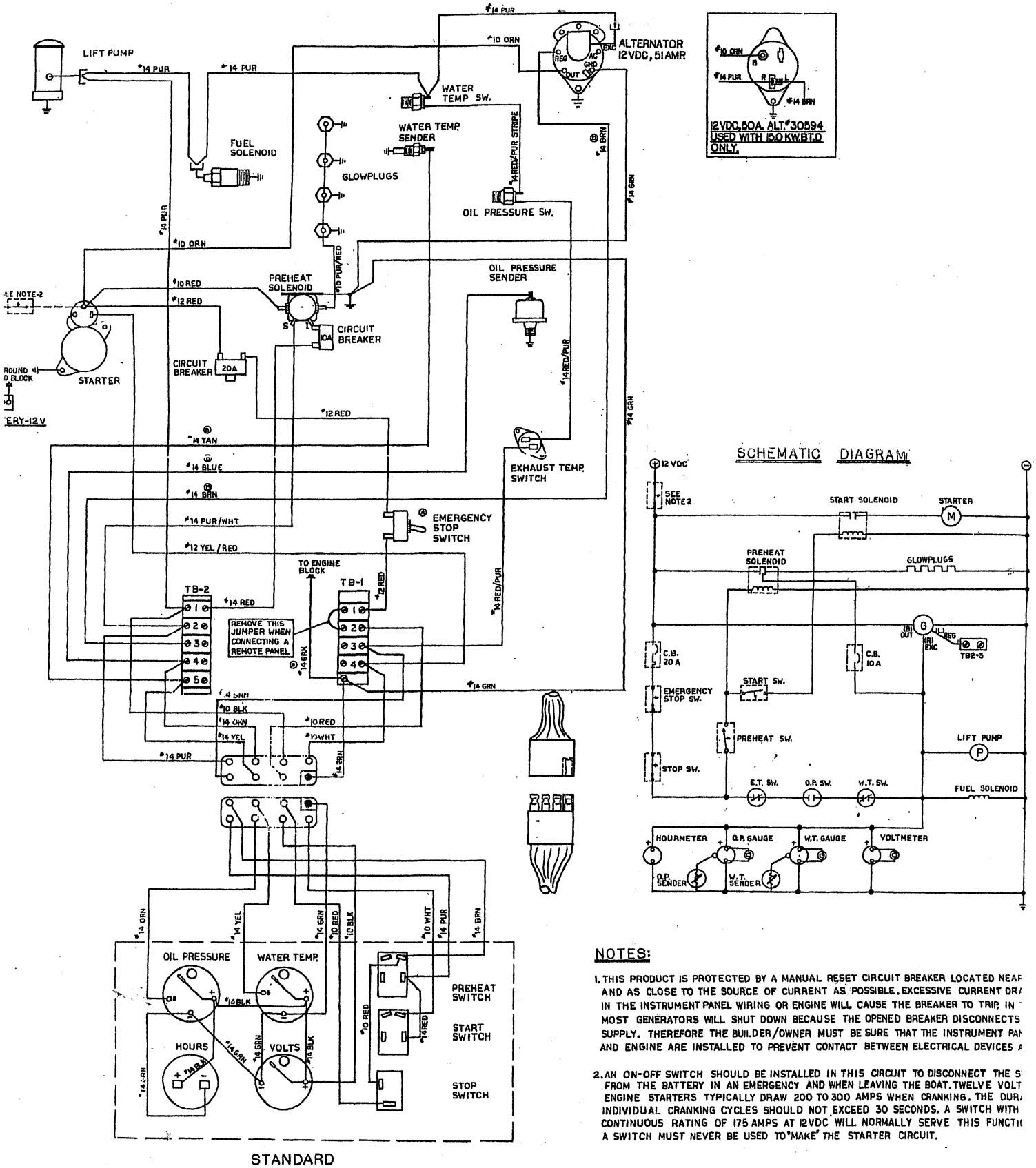


PROPULSION ENGINE
WIRING DIAGRAM #039144



15.0/12.0 BTD GENERATORS WIRING DIAGRAM

36411



STANDARD INSTRUMENT PANEL

NOTES:

1. THIS PRODUCT IS PROTECTED BY A MANUAL RESET CIRCUIT BREAKER LOCATED NEAR AND AS CLOSE TO THE SOURCE OF CURRENT AS POSSIBLE. EXCESSIVE CURRENT DRA IN THE INSTRUMENT PANEL WIRING OR ENGINE WILL CAUSE THE BREAKER TO TRIP. IN MOST GENERATORS WILL SHUT DOWN BECAUSE THE OPENED BREAKER DISCONNECTS SUPPLY. THEREFORE THE BUILDER/OWNER MUST BE SURE THAT THE INSTRUMENT PAN AND ENGINE ARE INSTALLED TO PREVENT CONTACT BETWEEN ELECTRICAL DEVICES A

2. AN ON-OFF SWITCH SHOULD BE INSTALLED IN THIS CIRCUIT TO DISCONNECT THE S FROM THE BATTERY IN AN EMERGENCY AND WHEN LEAVING THE BOAT. TWELVE VOLT ENGINE STARTERS TYPICALLY DRAW 200 TO 300 AMPS WHEN CRANKING. THE DURA INDIVIDUAL CRANKING CYCLES SHOULD NOT EXCEED 30 SECONDS. A SWITCH WITH CONTINUOUS RATING OF 175 AMPS AT 12VDC WILL NORMALLY SERVE THIS FUNCTI A SWITCH MUST NEVER BE USED TO "MAKE" THE STARTER CIRCUIT.

WIRING DIAGRAM ACTIVATION by KEYSWITCH
33685

NOTES:

NOTES ON BUILDER/OWNERS RESPONSIBILITY.

Ⓐ AN ON-OFF SWITCH MUST BE INSTALLED IN THIS LINE TO DISCONNECT THE STARTER CIRCUIT FROM THE BATTERY IN AN EMERGENCY & WHEN LEAVING THE BOAT. 12 VOLT DIESEL ENGINE STARTERS TYPICALLY DRAW 200 TO 300 AMPS WHEN CRANKING. THE DURATION OF INDIVIDUAL CRANKING CYCLES SHOULD NOT EXCEED 30 SECONDS. A SWITCH WITH CONTINUOUS RATING OF 175 AMPS AT 12 VDC WILL NORMALLY SERVE THESE FUNCTIONS, BUT SUCH A SWITCH MUST NEVER BE USED TO "MAKE" THE STARTER CIRCUIT.

OTHER NOTES:

Ⓑ WARNING; SENDER CONNECTION:
CONTACT WITH B+ MAY DAMAGE SENDER.

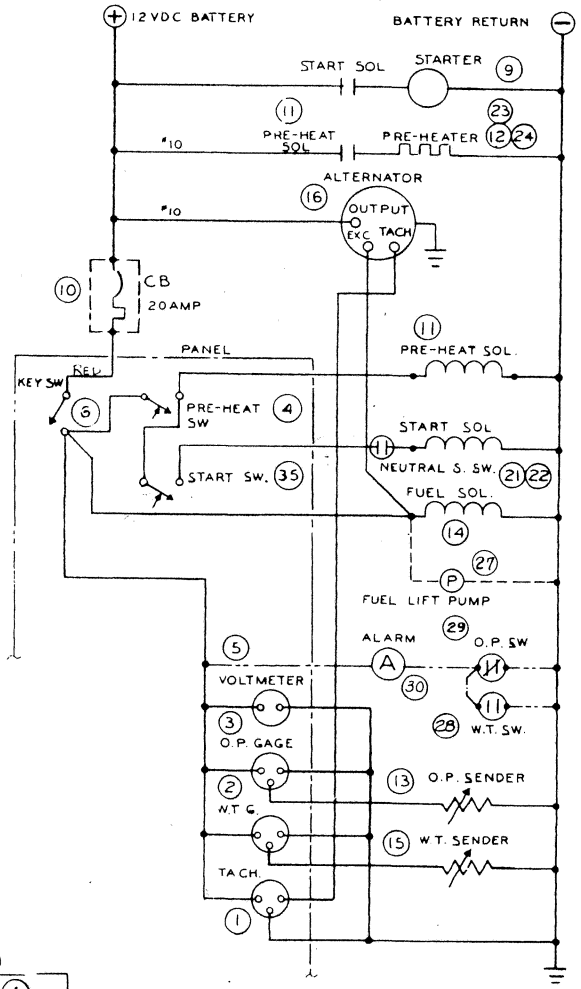
Ⓒ ALL RETURNS ARE THROUGH ENGINE BLOCK.

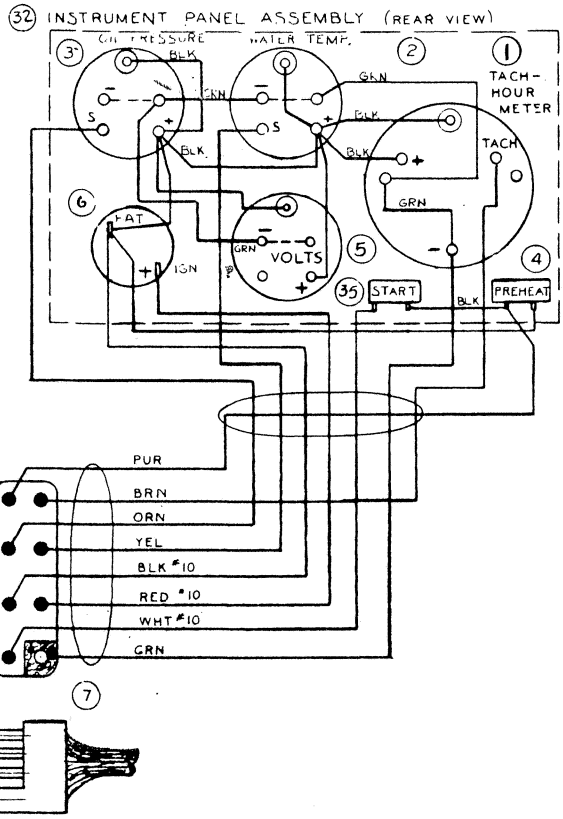
Ⓓ FOR WIRING OF AUXILLARY ALTERNATORS SEE THE FOLLOWING DIAGRAMS.
MOTOROLA 85 AMP, 11232
MOTOROLA 120 AMP, 11231
LEECE-NEVILLE 53 AMP, 16535
LEECE-NEVILLE 105 AMP, 16614

Ⓔ IF ADDITIONAL PRESSURE SWITCHES ARE REQ'D TO START BOAT ACCESSORES, A FLEXIBLE HOSE MUST BE RUN FROM THE OIL PRESSURE MANIFOLD TO A NEARBY BULKHEAD AND ALL PRESSURE SWITCHES MOUNTED AT THE BULKHEAD.

Ⓕ APPLY SILASTIC OR TIGHT WOUND PLASTIC/SPLICE ELECTRICAL TAPE AROUND CONNECTORS CONNECTED.

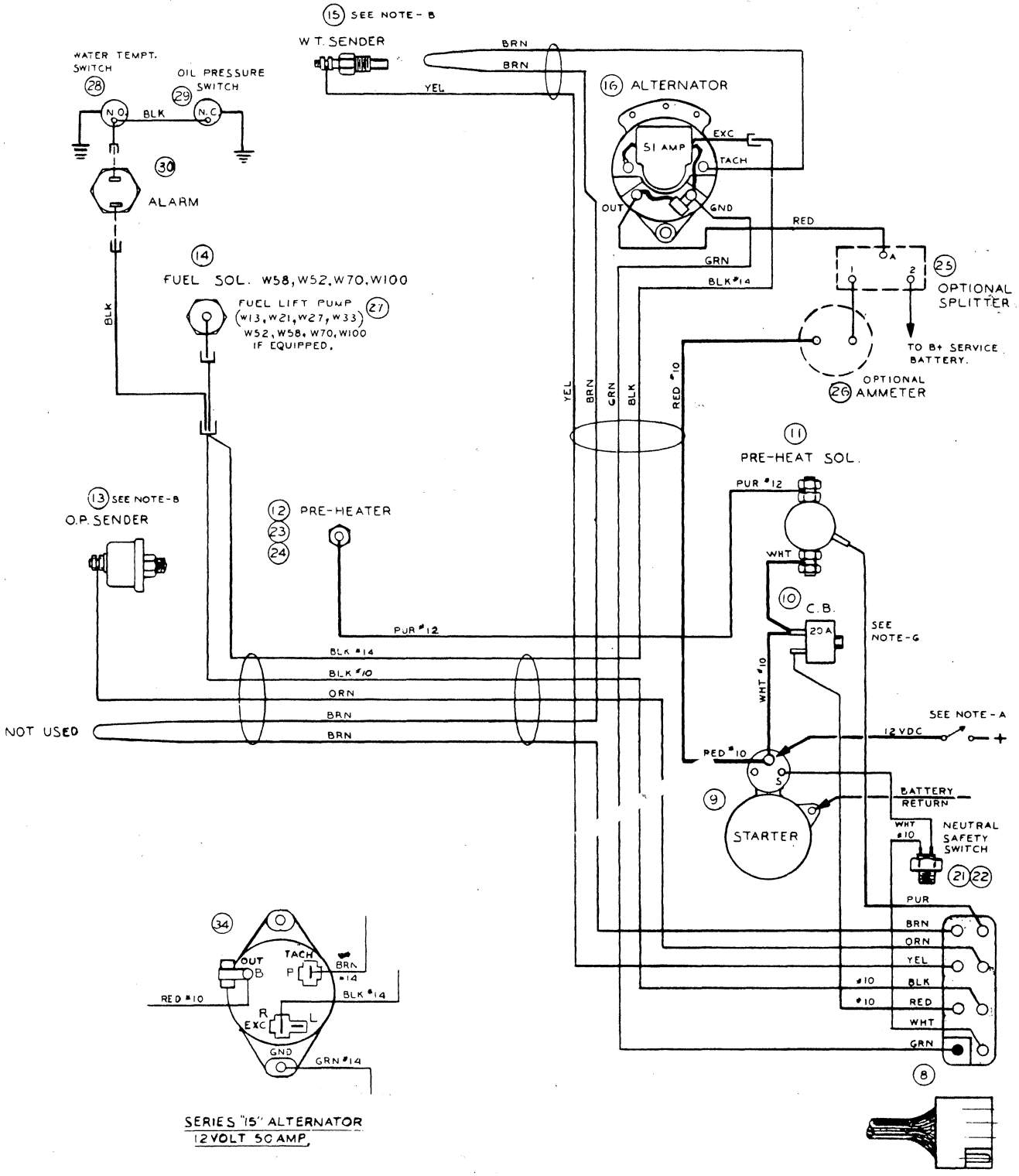
Ⓖ CAUTION:
THIS PRODUCT IS PROTECTED BY A MANUAL RESET CIRCUIT BREAKER LOCATED NEAR THE STARTER AND AS CLOSE TO THE SOURCE OF CURRENT AS POSSIBLE. EXCESSIVE CURRENT DRAIN ANYWHERE IN THE INSTRUMENT PANEL, WIRING, OR ENGINE WILL CAUSE THE BREAKER TO TRIP. IN THIS EVENT, MOST ENGINE MODELS WILL SHUT DOWN BECAUSE THE OPENED BREAKER DISCONNECTS THEIR FUEL SUPPLY. THEREFORE THE BUILDER/OWNER MUST BE SURE THAT THE INSTRUMENT PANEL, WIRING AND ENGINE ARE INSTALLED TO PREVENT CONTACT BETWEEN ELECTRICAL DEVICES AND SALT WATER.





WIRING DIAGRAM *ACTIVATION by KEYSWITCH*

33685



ENGINE SPECIFICATIONS

(15.0 / 12.0 BTD Drive Engine) General Information

Type	Fresh water cooled with exchanger system, 4-stroke, inline, vertical, indirect injected type diesel
Number of Cylinders	Four - Inline, vertical
Bore & Stroke, in mm(in.)	84 x 94 (3.307 x 3.701)
Piston Displacement, in cc(cu.in.)	2084 (127.1)
Compression Ratio	20:1
Compression Pressure at 150 - 200 RPM, in kg/cm_2 (psi)	31 (440) Normal 25 (355.5) Mininum
Rotating Horse Power	46 HP at 3000 RPM (max.) 42 HP at 3000 RPM (cont.)
Idle Speed, in RPM	700 - 850 (neutral)
No Load Maximum Speed, in RPM	3220
Cruise Speed, in RPM	2000 - 2500
Firing Qrder	1 - 3 - 4 - 2
Direction of Rotation	Counterclockwise (as viewed from flywheel end)
Fuel	No.2-D SAE J313, Cetane #45 or higher. Diesel fuel according to ASTM D975
Oil Grade	API Category CF, CF-4, CG-4, CH-4 CI-4 or better. SAE 10W-40 or 15W-40
Dimensions, in inches (mm) (Standard Unit)	Length 36.72 (932.6) Width 18.13 (460.5) Height 23.99 (609.3)
Weight Dry, in lbs.(kg) (Standard Unit)	535 (242.6)
Cylinder Sleeves	Dry type made of special cast iron.
Number of Piston Rings	Two compression rings, one oil scraper with spring expander.

ENGINE SPECIFICATIONS W-46

Valve Arrangement	Overhead
Valve Timing	Intake - Open 30° BTDC Close 50° ABDC
	Exhaust - Open 74° BBDC Close 30° ATDC
Valve Clearance (Intake and Exhaust - Cold), in inches (mm)	0.009 - 0.010 (0.25)
Starter	12-Volt reduction type 1.6 KW

FUEL SYSTEM

Fuel Lift Pump	12-Volt plunger type, replaceable filter element.
Capacity, in qts.(cc)	0.23 (225) free flow every fifteen seconds or better.
Fuel Lift Capacity, in ft.(m)	4 (1.2)
Fuel Injection Timing	23° ±1 BTDC
Fuel Injection Pump	DPA Injection Pump J3942F580 (late) J3942F490 (early)
Type	Distributor type, automatic advance with mechanical governor. Self bleeding.
Fuel Injectors	Bosch type, spray angle 0 degrees
Injection Pressure, in psi (kg/cm2)	1706 +142 -0 (120 +10 -0)
Fuel Filter	Spin-on replaceable paper element type #24363.

LUBRICATION SYSTEM

Oil Pump	Trochoid type
Oil Pressure, in psi (kg/cm2)	Idle 20-30 (1.75 - 2.46) Idle-rated rpm 30-60(2.46-4.21)

(continued)

ENGINE SPECIFICATIONS W-46

Relief Valve	Externally-mounted on oil filter adapter.
Oil Filter	Spin-On, Full-flow, replaceable, #35828
Oil Sump Capacity, in qts (ltrs)	7 (6.6)
Filter Capacity, in qts (ltrs)	1 (.94)
Oil Cooler	Fresh water cooled, full flow.

FRESH WATER COOLING SYSTEM

Circulating Pump	Centrifugal type with metal impeller, belt driven.
Capacity, in qts. (ltrs) per minute at 3000 RPM pump speed	81.6 (81)
Thermostat, in °F. (°C)	180° (82°) wax type
Cooling System Capacity, in qts (ltrs)	10.0 (9.5) approximate

COOLING SYSTEM - RAW WATER

Raw Water Pump	Positive displacement neoprene type impeller. Gear driven, 1/2 npt inlet-outlet.
Flow Rate, in gal.(ltrs) per minute at 3000 rpm engine speed, measured at discharge into exhaust elbow	9.5 - 10.0 (35.9 - 37.8)
Heat Exchanger	Copper - tube type with removable end caps and zinc anode.

DC ELECTRICAL SYSTEM

System	12-Volt, DC, negative ground
DC Alternator	50-Amp, 12-Volt, internal voltage regulator
Glow plugs	Sheathed type, one per cylinder, 10.5 Volts, 8.3 Amps.

(continued)

ENGINE SPECIFICATIONS W-46

Starter	12-Volt, 1.6 KW, reduction type
Starter Current Draw	Cranking Cold 225-250 Amps
Transmission (standard)	Mechanical, 1.88:1
Optional	Variety of transmission and reduction ratios available; consult Master Distributor.
Propeller Recommendation (using standard transmission (1.88:1)	18-inch diameter x 10 pitch, two blade; or 18-inch diameter x 8 pitch, three blade. Propeller should allow engine to reach its rated speed (3000 RPM $\pm$ 100) at full open throttle underway.

GENERATOR SPECIFICATIONS 15.0/12.0 BTD

General	Brushiess, four-pole, revolving field. Pre-lubricated, single bearing design. Reconnectable, single-phase transformer regulation (optional solid-state voltage regulation)
Voltage	120 or 120/240 Volts-60 Hertz 230 Volts - 50 Hertz
Voltage Regulation	±5% no load to full load
Frequency Rotation	±3 Hertz(5%)no load to full load
Rating - Single Phase **60 Hertz (1800 rpm)** **15KW**	120 Volts 125 Amps 120/240 Volts 125/62.5 Amps
50 Hertz (1500 rpm) **12KW**	230 Volts 52 Amps

THREE PHASE

General	Brushless, six pole, revolving field. Sealed lubricated single bearing design. 12 Lead reconnectable for low voltage WYE, high voltage Delta. Solid State voltage regulator with protection circuitry.
Rating - Three Phase **60 Hertz** **50 Hertz**	
Voltage – 3 Phase (60 Hertz)	Low Voltage WYE 208 volts High Voltage WYE 480 volts Delta 240 volts
Voltage – 3 Phase (50 Hertz)	High Voltage WYE 380 volts Delta 230 volts
Amperage – 3 Phase (60 Hertz)	Low Voltage WYE 99 volts High Voltage WYE 43 volts Delta 86 volts
Amperage – 3 Phase (50 Hertz)	High Voltage WYE 43 volts Delta 75 volts
Generator Cooling Air Requirements, (60 Hertz) at 1800 RPM	225-250 cfm (6.37-7.08 cmm)

NOTE: *Increase air supply 15% for 50 Hertz operation (1500 rpm)*

Engine Combustion Air Requirements, (60 Hertz) at 1800 RPM	67 cfm (1.89 cmm)

Ambient Temperature Generator Compartment 122° F(50°C) Maximum

NOTE: *Forced ventilation should be provided as needed to maintain generator compartment ambient temperature below 122°F.*

1217-10/2017