SERVICE MANUAL

25BEG(A) 60Hz AND 20BEG(A) 50Hz
20BEG(A) 60Hz AND 16BEG(A) 50Hz
MARINE GENERATORS
SINGLE and THREE PHASE

W70GA MARINE ENGINE

PUBLICATION NO.048088
REVISION 3
APRIL 2018

WESTERBEKE
NMMA
WESTERBEKE CORPORATION • MYLES STANDISH INDUSTRIAL PARK
150 JOHN HANCOCK ROAD • TAUNTON MA 02780-7319 • TEL. 1-508-823-7677
FAX 1-508-884-9688 • WEBSITE: WWW.WESTERBEKE.COM

⚠ 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

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

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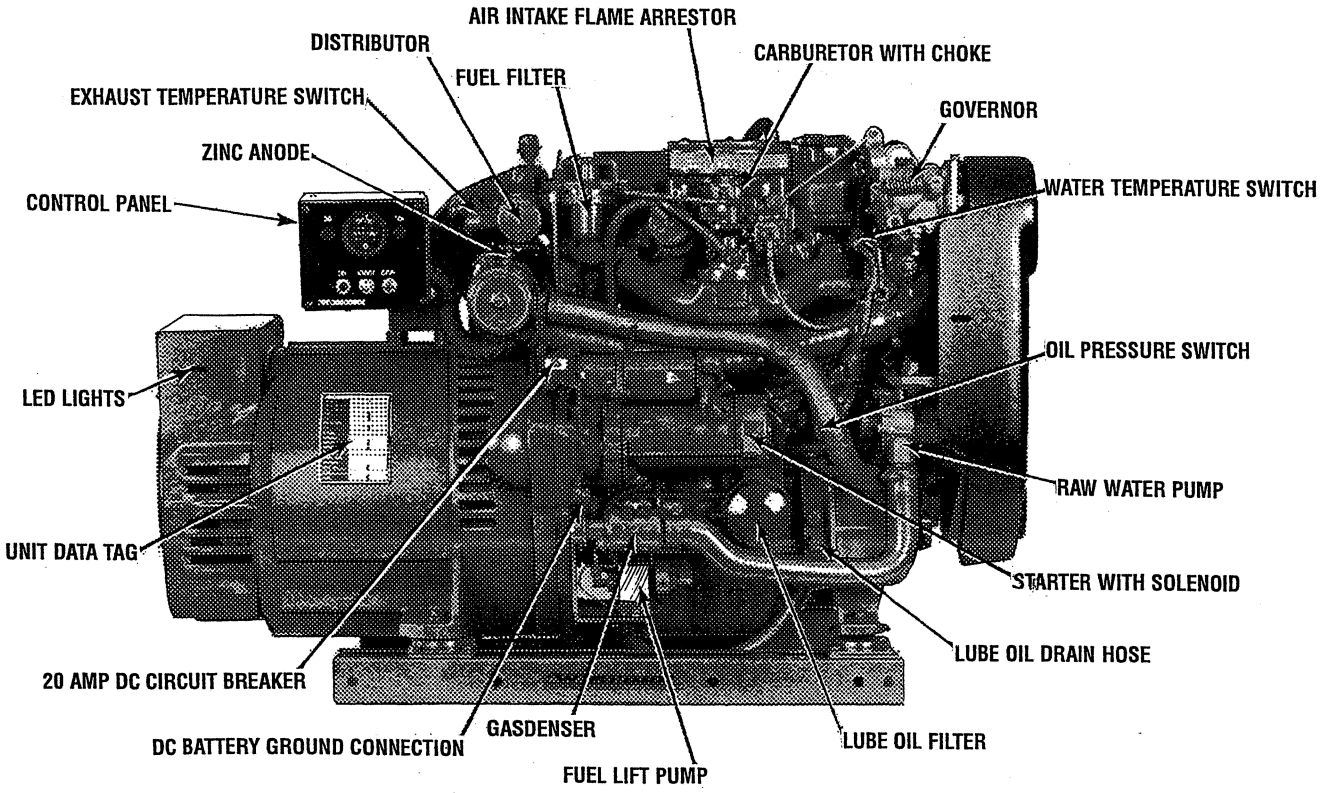
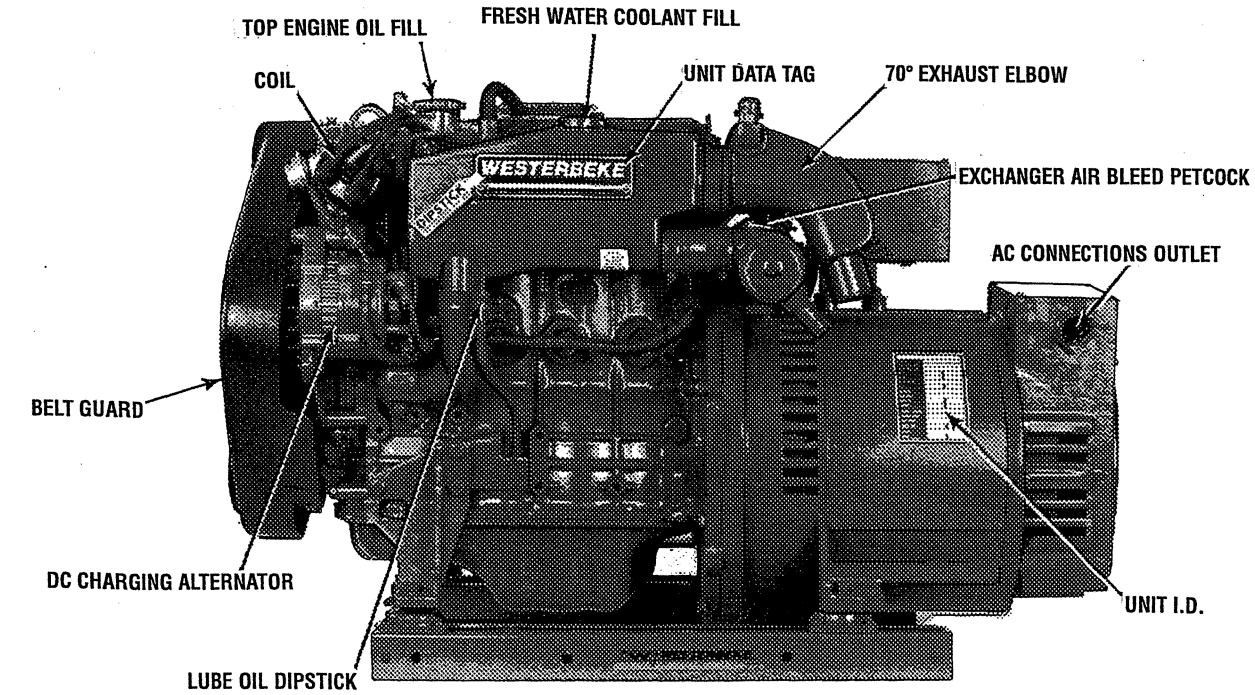
25KW AND 20KW BEG GENERATOR PARTS IDENTIFICATION

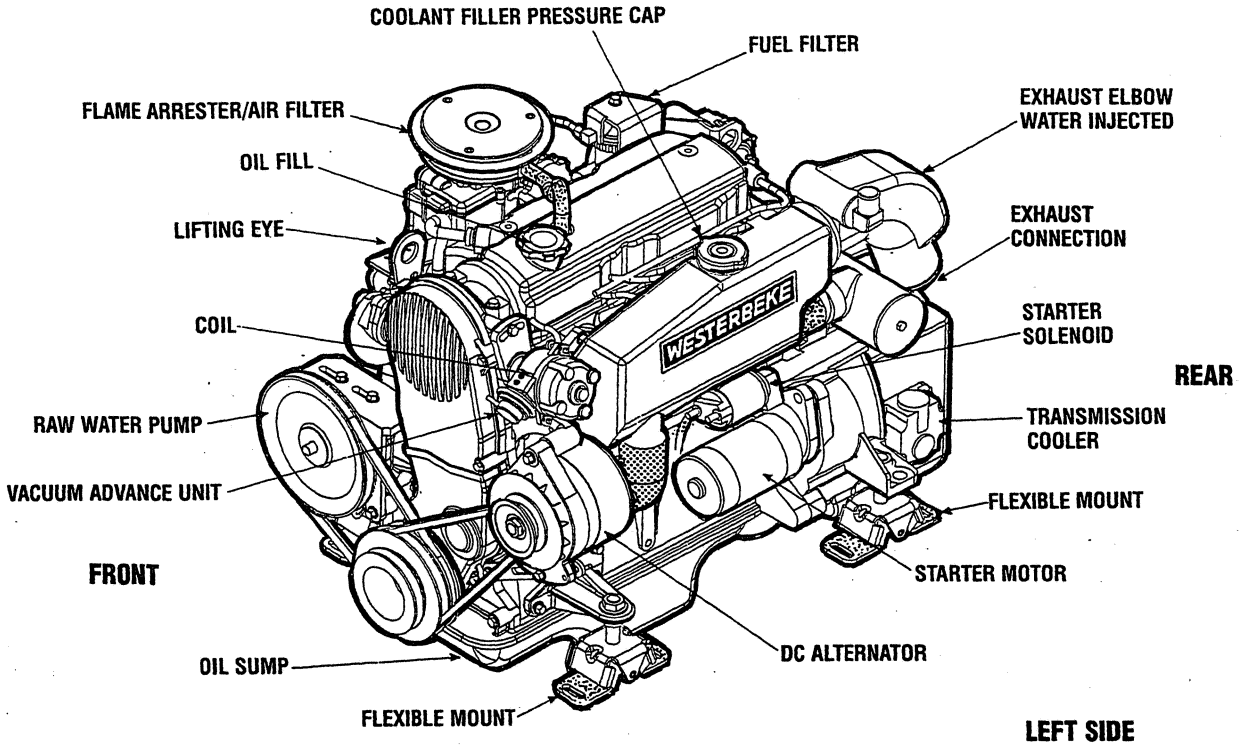
RIGHT SIDE

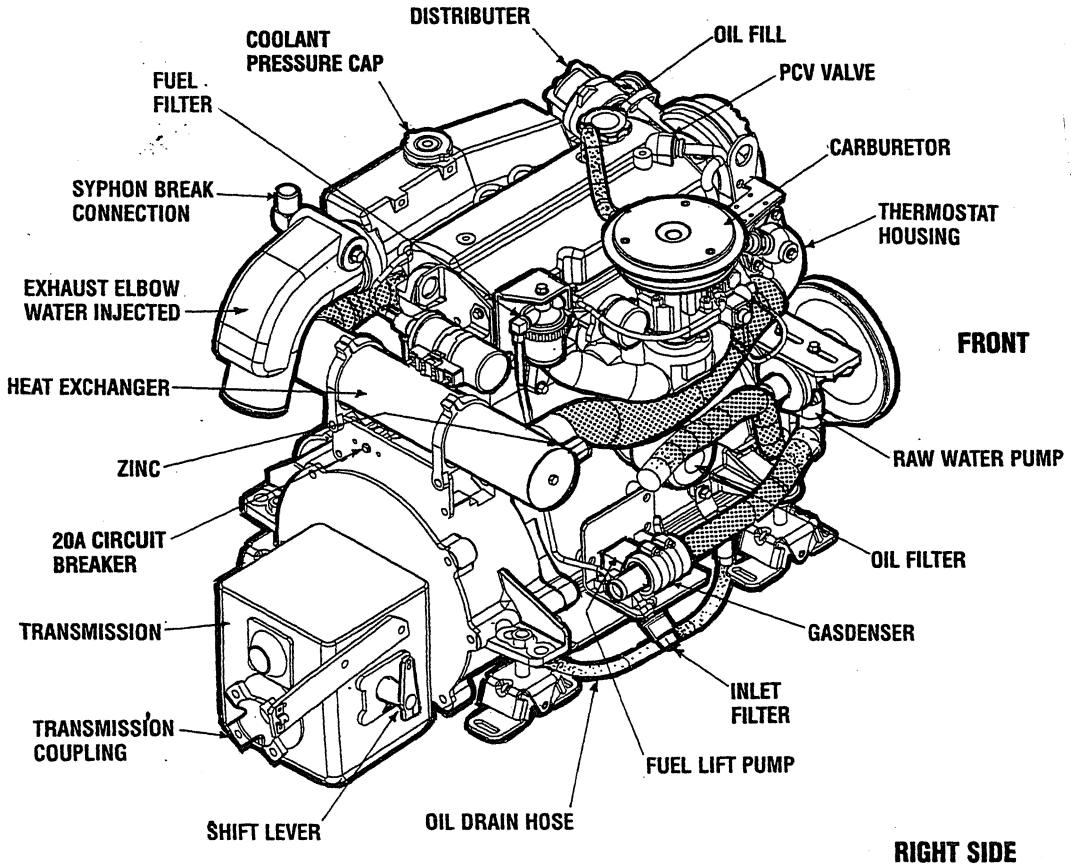


LEFT SIDE



W-70GA PARTS IDENTIFICATION





ENGINE DATA

DESCRIPTION

The engine is a "Square" type with a total displacement of 2184cc. It is a watercooled, four cylinder engine with a belt-driven overhead cam (OHC).

The main specifications are as follows:

COMBUSTION CHAMBER TYPE	**Multi-sphere type**
BORE X STROKE	**86mm x 94mm**
TOTAL DISPLACEMENT	**2184cc**
COMPRESSION RATIO	**8.6**
COMPRESSION PRESSURE	**11.5 kg/cm² - 270 rpm**

CYLINDER BLOCK

The cylinder block construction is an integral design where the block and cylinder liners are cast as one piece. The cylinder walls are double honed for a fine, precision surface. The cylinder block is deep-skirted with chambered cross sections to reduce noise. There are five main bering journals for crankshaft support.

CYLINDER HEAD

This WESTERBEKE engine is an overhead cam (OHC), cross-flow design. The rocker arm assembly bolts independently to the head, rather than using the head bolts. This makes it possible to remove the cylinder head without disassembling the rocker arm assembly (and vice-versa) resulting in improved serviceability. The intake and exhaust ports are located on opposite sides of the cylinder head (cross-flow) and the intake ports are designed to swirl the incoming fuel/air mixture.

CRANK MECHANISM

The piston is a tapered type with a recessed combustion surface, specifically designed for the engine. The piston pin is offset 1mm to the thrust side (direction of lateral pressure during combustion stroke) to decrease knocking noise.

On the crankshaft, the outside of the balance weight is made thicker to improve the effectiveness of a single weight, reducing the conventional eight weights to four.

As a result, the inertial weight is reduced, improving engine response. End play of the crankshaft is restricted by a thrust bearing at the No.3 main bearing journal.

VALVE MECHANISM

The valve mechanism employs the overhead camshaft (OHC). The rocker arm is offset against the exhaust stem to prevent carbon damage and irregular.

The valve spring is of the double coil type with unequal pitch inner and outer springs. It is necessary to set the shorter pitched side toward cylinder head at the time of installation.

The end play of the camshaft cannot be adjusted. Positioning of the camshaft and cylinder head are determined by the flange on the cam.

The adjustment of the belt is carried out by the tensioner and tension spring.

INTAKE AND EXHAUST SYSTEM

Both intake and exhaust manifolds are of aluminum, consisting of an independent branch pipe for each pair of cylinders.

COOLING SYSTEM

A centrifugal water pump is incorporated in the cylinder block, driven by the timing belt. A wax type thermostat is employed to ensure proper temperature control. Cooling is provided by a belt driven raw water pump and a heat exchanger.

LUBRICATION SYSTEM

A crescent type oil pump is driven directly by the crankshaft to feed oil under pressure. The oil filter is full-flow and a spin –on type.

FUEL SYSTEM

The carburetor is a down-draft, one stage, single barrel and the fuel pump is an electromagnetic type, It performs the pumping function through the reciprocating motion of a plunger.
A mechanical belt driven governor connected the to throttle arm of the carburetor controls the engine rotational speed, power output ands torque.

NOTE: *For additional information, refer to the ENGINE/GENERATOR SPECIFICATIONS in this manual*

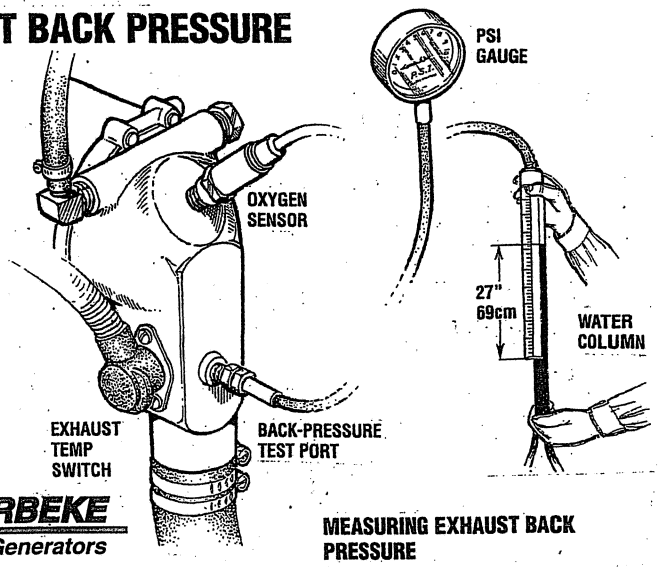
MEASURING EXHAUST BACK PRESSURE

Exhaust systems normally produce resistance to the flow of exhaust gases, causing back-pressure. Back-pressure must be kept within a certain limit. **Check the back-pressure before the generator is put back into service.**

To test exhaust pressure, connect either a water column or PSI tube to the test part on the exhaust elbow as shown.

Check the exhaust back-pressure before the generator is put into service. Measure the back-pressure after the engine has reached its normal operating temperature, and at the point where it is about to reach its rated load at either 1500 rpm (for 50Hz applications) or 1800 rpm (for 60Hz applications). Back-pressure should not exceed 1.5 psi (0.11 kg/cm²).

A water column can be made by taping one end of a clear plastic tube along a yardstick and fitting the other end of the tube with a 1/4" NPT pipe fitting.
Back-pressure should not exceed 27in (69cm) of water in the water column.



MEASURING EXHAUST BACK PRESSURE

TROUBLESHOOTING GUIDE

The following engine troubleshooting guide may be helpful in determining if a complete or partial overhaul is necessary.

Note: *The Engine Cooling and Engine Lubrication Troubleshooting Data are in those sections of this manual.*

Insufficient Power	**Insufficient Compression** Compression leakage from valve seat Seized valve stem Weak or broken valve spring Burned cylinder head gasket Cracked or distorted cylinder head Sticking, damaged, or worn piston ring Cracked or worn piston **Malfunction of Fuel System** **Malfunction of Ignition System**
Excessive Oil Consumption	**Oil Working Up** Worn or sticking piston ring or piston ring groove Worn piston or cylinder **Oil Working Down** Bad valve seal Worn valve stem or guide **Oil Leakage**
Difficult Starting	**Malfunction of Engine-related Components** Burned valve Worn piston, piston ring, or cylinder Burned cylinder head gasket **Malfunction of Fuel System** **Malfunction of Electrical System**
Abnormal Combustion	**Malfunction of Engine-related Components** Sticking or burned valve Weak or broken valve spring Carbon accumulated in combustion chamber **Malfunction of Fuel System** **Malfunction of Ignition System**
Poor Idling	**Malfunction of Engine-related Components** Poor valve-to-valve seat contact Failure of cylinder head gasket **Malfunction of Fuel System** **Malfunction of Ignition System**

Engine Noise	**Crankshaft or bearing related parts** Excessive main bearing oil clearance Main bearing seized or heat damaged Excessive crankshaft end play Excessive connecting rod bearing oil clearance Connecting rod bearing seized or heat damaged **Piston related parts** Worn Cylinder Worn piston or piston pin Seized piston Damaged piston ring Bent Connecting Rod **Malfunction of Ignition System** **Valve or timing related parts** Malfunction of HLA * Broken valve spring Excessive clearance between valve stem and guide Insufficient lubrication of rocker arm **Others** Malfunction of water pump bearing Malfunction of alternator bearing Malfunction of timing belt tensioner
Engine Misfires	Poor quality fuel. Incorrect timing. Dirty flame arrester. Cracked distributor cap. Faulty ignition wires. Spark plugs are worn. High exhaust back-pressure. Valve clearances are incorrect.
Engine Backfires	Spark plug wires are connected wrong. Incorrect timing. Engine is flooded. Dirty flame arrester. Cracked distributor cap. High exhaust back-pressure. Choke is stuck closed.

* *Tapet noise may occur if the engine is not operated for a period of time. Tapet noise should stop within 10 minutes after operating the engine.*

TROUBLESHOOTING GUIDE

Engine Overheats	Coolant loss. Pressure test cooling system. Faulty raw water pump impeller. Belts are loose or broken. Raw water pump worn. Faulty thermostat. Heat exchanger is clogged. Collapsed hose.
Low Oil Pressure	Low oil level. Faulty oil pressure sender Wrong SAE type oil in the engine. Faulty gauge Wrong type oil filter. Relief valve is stuck. Faulty oil pump. Faulty engine bearings.
Starting Battery	Loose alternator drive belt Faulty battery voltage regulator. Connections to the alternator are loose or faulty. Faulty alternator. No excitation to the regulator
High Oil Pressure	Faulty sender or gauge Dirty oil or wrong SAE type oil in the engine. Relief valve is stuck.
Blue Exhaust Smoke Discharge from the Engine	Lube oil is diluted. High lube oil level. Crankcase breather hose is clogged. Valves are worn or adjusted incorrectly. Piston rings are worn or unseated.
Black exhaust smoke Discharge from the Engine	Dirty flame arrester. Faulty carburetor. Idle mixture jet too rich. Accelerator diaphragm leaking. Valves are worn or incorrectly adjusted. Lube oil is diluted. Piston rings are worn or unseated.

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 worn plugs or fuel/carburetor problems.. 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 carburetor performance or worn plugs. They are caused also by defective electrical devices such as the battery, alternator or starter. 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.

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

The engine requires overhaul when oil consumption is high, blow-by evident, and compression valves are at minimum or below.

Engine compression should be 198.1 psi (14 Kg/cm²) at 400 rpm. Cylinder compression should not vary more than 28.0 psi (20Kg/cm²).

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

Before preparing for an engine overhaul, adjust the valve clearances to the correct specification, install a new cover gasket and test the engine.

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 the 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 parts that require no disassembly.
- Carefully inspect each parts after 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 the proper tools. Apply oil when necessary. Take special care to keep the fuel system parts free from the intrusion of dust and dirt.

GENERATOR CONTROL PANELS

DESCRIPTION

The generator mounted control panel is equipped with an **ON** switch (black), a **START** switch(white) and a **STOP** switch (red).

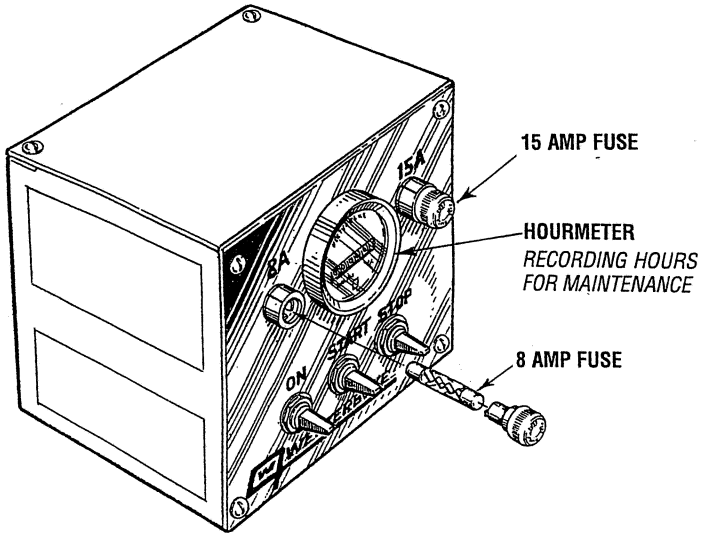
The *ON* switch provides power to the start circuit. This switch by-passes the protective oil pressure shutdown switch until the oil pressure reaches 5 - 10 psi.

The *START* switch energizes the start solenoid/starter which cranks the engine. This switch will **not** operate unless the **on** switch is depressed and held at the same time.

The *STOP* switch will turn off the engine/generator. This switch must be depressed until the stop sequence is complete.

The panel also has two fuses to protect the DC circuit:

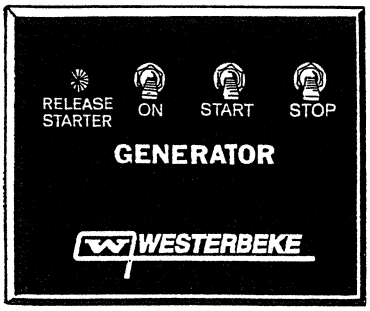
- *A 15 amp slow bluw fuse protects the start circuit.*
- *An 8 amp fuse protects the engine operating circuit and any optional remote start/stop or instrument panel.*



REMOTE START/STOP PANEL (OPTIONAL)

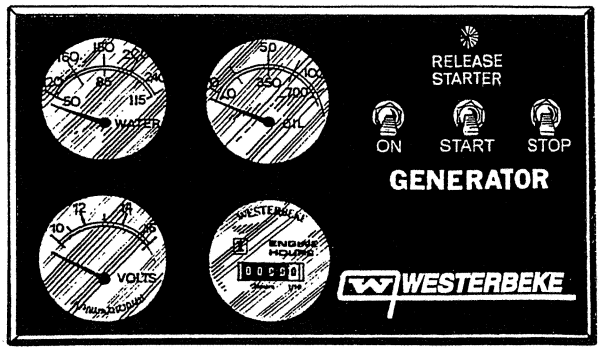
An optional remote start/stop panel is available for controlling the generator from a remote location.

This panel has the same **ON**, **START**, and **STOP** functions previously described. Also included is a green LED light which glows once the engine/generator has reached 600 rpm's. The purpose of the LED is to alert the operator to release the **START** switch. It is also an indication that the engine/generator is running.



REMOTE INSTRUMENT PANEL (OPTIONAL)

An optional remote instrument panel is available which includes a water temperature gauge, oil pressure gauge, DC charging voltmeter, operating hourmeter, and start/stop switches.



REMOTE INSTRUMENT PANEL INSTALLATION

The remote instrument panel has two sending units to be installed on the engine block, a *water temperature sender* and an *oil pressure gauge sender*. Plugged ports for each are located on the engine. The water temperature sender is installed in the thermostat housing and the oil pressure sender is adjacent to the oil pressure switch. Use sealing compound on the threads of both senders. Electrical connections for each sender are tied off next to the senders location (in the wiring harness).

The blue wire is for the oil pressure sender and the tan wire is for the water temperature sender. If there is a jumper between terminal board connections T-1 and T-2, it should be removed. Refer to the *REMOTE INSTRUMENT WIRING DIAGRAM* in this manual.

NOTE: *When installing the optional remote panels, it is the installers responsibility to comply with the U.S. Coast Guard standards 33 CFR part 183.*

GENERATOR ALARMS AND SHUTDOWN SWITCHES

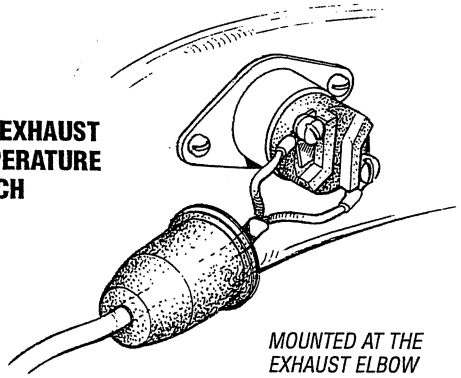
SAFETY SHUTDOWN SWITCHES

The engine is protected by three automatic shutdown switches. Should a shutdown occur, ***do not attempt to restart without finding and correcting the cause***. Refer to the heading *Engine starts, runs and then shuts down* in the *ENGINE TROUBLESHOOTING* section of this manual.

The following is a description of these automatic shutdown switches:

High Exhaust Temperature Switch

An exhaust temperature switch is located on the exhaust elbow. Normally closed, this switch will open and interrupt the DC voltage (shutting off the engine) should the switch's sensor indicate an excessive exhaust temperature (an inadequate supply of raw water causes high exhaust temperatures). This switch opens at 260-270°F (127-132°C). This switch resets at approximately 225°F (107°C).

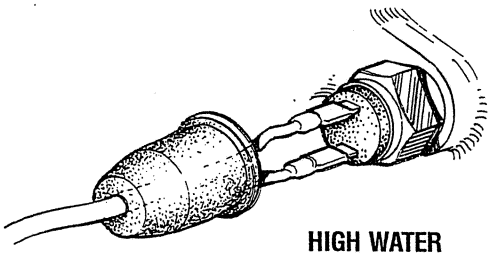


HIGH EXHAUST TEMPERATURE SWITCH

MOUNTED AT THE EXHAUST ELBOW

High Water Temperature Switch

A high water temperature switch is located at the thermostat housing. Normally closed, this switch, should the fresh water coolant's operating temperature reach approximately 210°F (99°C), will open and interrupt the DC voltage thereby shutting off the engine. This switch resets at 195°F (107°C).



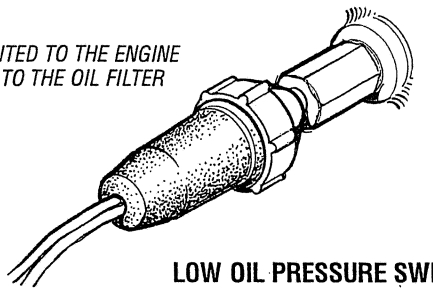
HIGH WATER TEMPERATURE SWITCH

LOCATED AT THE THERMOSTAT HOUSING UNDER THE GOVERNOR

Low Oil Pressure Switch

A low oil pressure shutdown switch is located off the engine's oil gallery. Normally open in a static state, this switch's sensor monitors the engine's oil pressure. Should the engine's oil pressure fall to 5-10 psi, this switch will open interrupting the DC voltage thereby shutting off the engine.

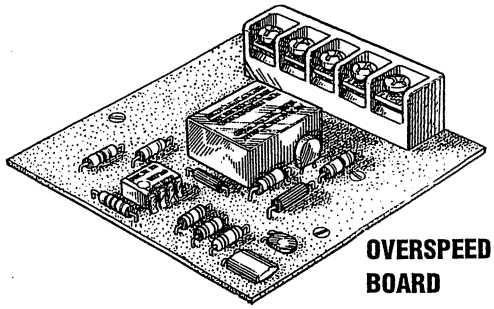
MOUNTED TO THE ENGINE NEXT TO THE OIL FILTER



LOW OIL PRESSURE SWITCH

Engine Circuit Breaker

The generator's engine is protected by an engine mounted manual reset circuit breaker (20 amps DC). Excessive current draw or electrical overload anywhere in the instrument panel wiring or engine wiring will cause the breaker to trip. In this event the generator will shut down because the opened breaker interrupts the DC circuit. If this should occur, check and repair the source of the problem. After repairing the fault, reset the breaker and restart the generator.



OVERSPEED TERMINAL BOARD

High RPM Shutdown Switch

An overspeed switch in the DC circuit shuts off the generators engine by grounding out the ignition system if the engine's speed reaches 2175 rpm(approximately). After correcting the problem, this switch can be reset by momentarily depressing the stop switch. Refer to the *WIRING DIAGRAMS* in this manual.

NOTE: *To by-pass the overspeed when troubleshooting a shutdown, lift T5 and connect it onto and with T4.*

Do not leave the switch in this configuration as overspeed protection will be lost.

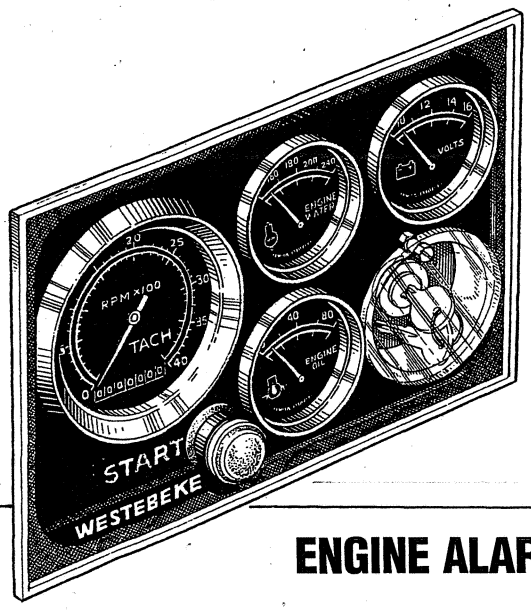
GASOLINE ENGINE INSTRUMENT PANEL

NOTE: *Be certain to install the instrument panel in a location that is accessible and where the gauges can be continually monitored by the helmsman.*

DESCRIPTION

The marine gasoline engine is equipped with an [optional] key start instrument panel. This panel connects to the engine wiring harness thru a 15 foot plug-in harness.

Included separately is an alarm buzzer with a 4 pin plug-in harness. This alarm buzzer will sound when the ignition key is turned on and should silence when the engine has started and the oil pressure rises above 5 psi. The installer is responsible for installing this alarm buzzer in a dry location where it will be audible to the operator with the engine running.



The following is a description of the panel components.

Tachometer - Registers revolutions per minute of the engine and measures the engines total elapsed time in hours and 1/10 hours. Refer to *TACHOMETER* for calibration.

Key switch - Turned to the 2 o'clock position [on], the key switch energizes the panel. {Illuminates the gauges and activates the start button.]

Prestart Button - A "push-to-start" rubber booted pushbutton that is energized by the key switch. Pressing this button activates the fuel lift pump.

Start Button - Identical to the prestart button, the start button, when pressed, energizes the starter which cranks the engine.

Oil Pressure Gauge - Measures the engines oil pressure in pounds per square inch. The alarm buzzer will sound a ***pulsating signal*** if the oil pressure falls below 10 psi. This alarm will briefly sound when the engine is first started as the oil comes to pressure.

Voltage Gauge - Measures the voltage in the DC circuit [the amount the battery is being charges 13V to 14V].

Water Temperature Gauge - Indicates the temperature of the engine coolant. If the coolant temperature reaches 210°F [99°C], the alarm buzzer will sound a ***continuous signal***.

NOTE: *The water temperature gauge will register the last reading when the engine is shut down. The true temperature will register when the power is turned back on.*

ENGINE ALARMS AND CIRCUIT BREAKER

ENGINE CIRCUIT BREAKER

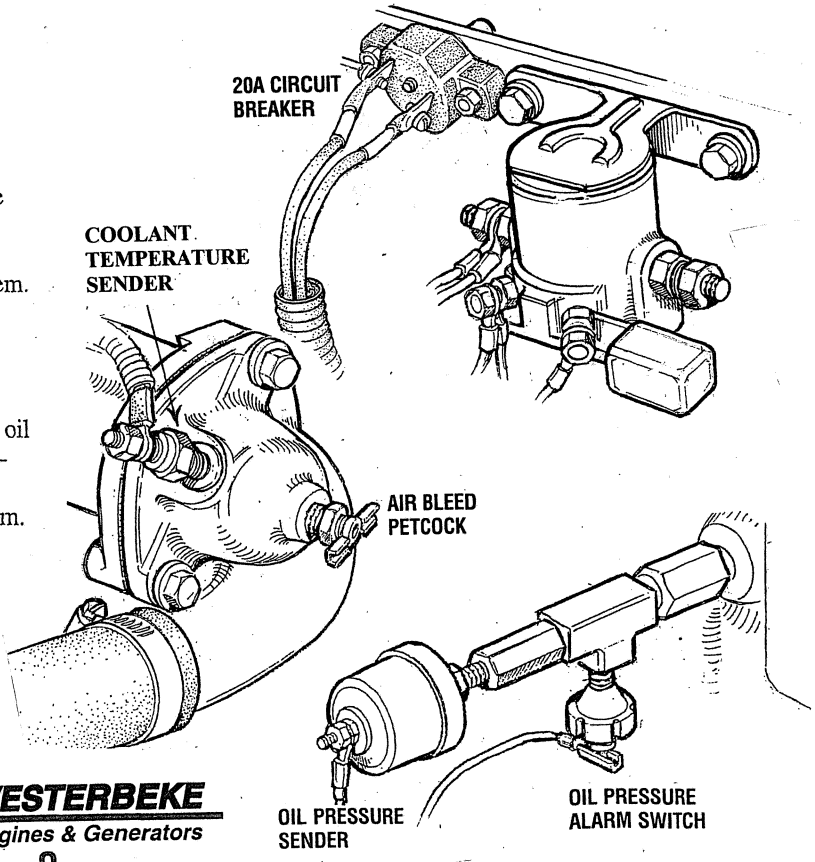
The DC harness on the engine is protected by an engine-mounted manual reset circuit breaker (20 amps DC). Excessive current draw or electrical overload anywhere in the instrument panel wiring or engine wiring will cause the breaker to trip. In this event most engines will shut down because the open breaker disconnects the fuel supply. If this should occur, check and repair the source of the problem. After repairing the fault, reset the breaker and restart the engine.

LOW OIL PRESSURE ALARM SWITCH

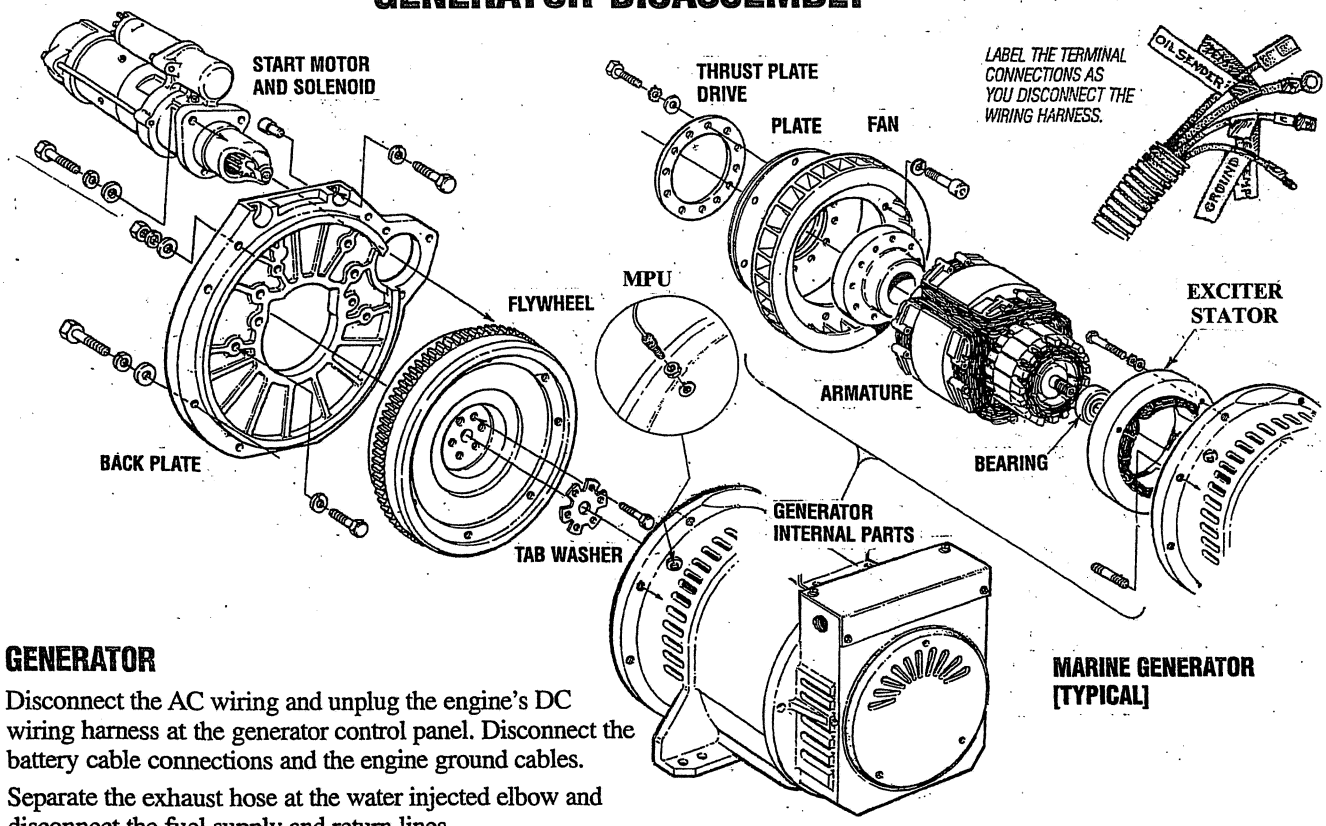
Allow oil pressure alarm switch is located off the engine's oil gallery. This switch's sensor monitors the engine's oil pressure. Should the engine's oil pressure fall to 5 -10 psi (0.4 - 0.7 kg/cm²), this switch will activate a pulsating alarm.

COOLANT TEMPERATURE SWITCH

A coolant temperature switch is located on the thermostat housing. This switch will activate a continuous alarm if the coolant's operating temperature reaches approximately 210°F (99°C).



GENERATOR DISASSEMBLY



MARINE GENERATOR [TYPICAL]

GENERATOR

Disconnect the AC wiring and unplug the engine's DC wiring harness at the generator control panel. Disconnect the battery cable connections and the engine ground cables.

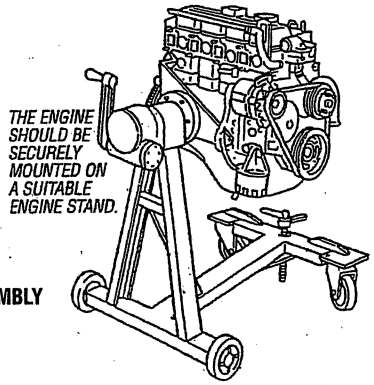
Separate the exhaust hose at the water injected elbow and disconnect the fuel supply and return lines.

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

Drain the engine oil and the coolant from the engine.

Carefully support and then unbolt the generator backend from the engine. See *SPECIAL TOOLS - GENERATOR* in this manual.

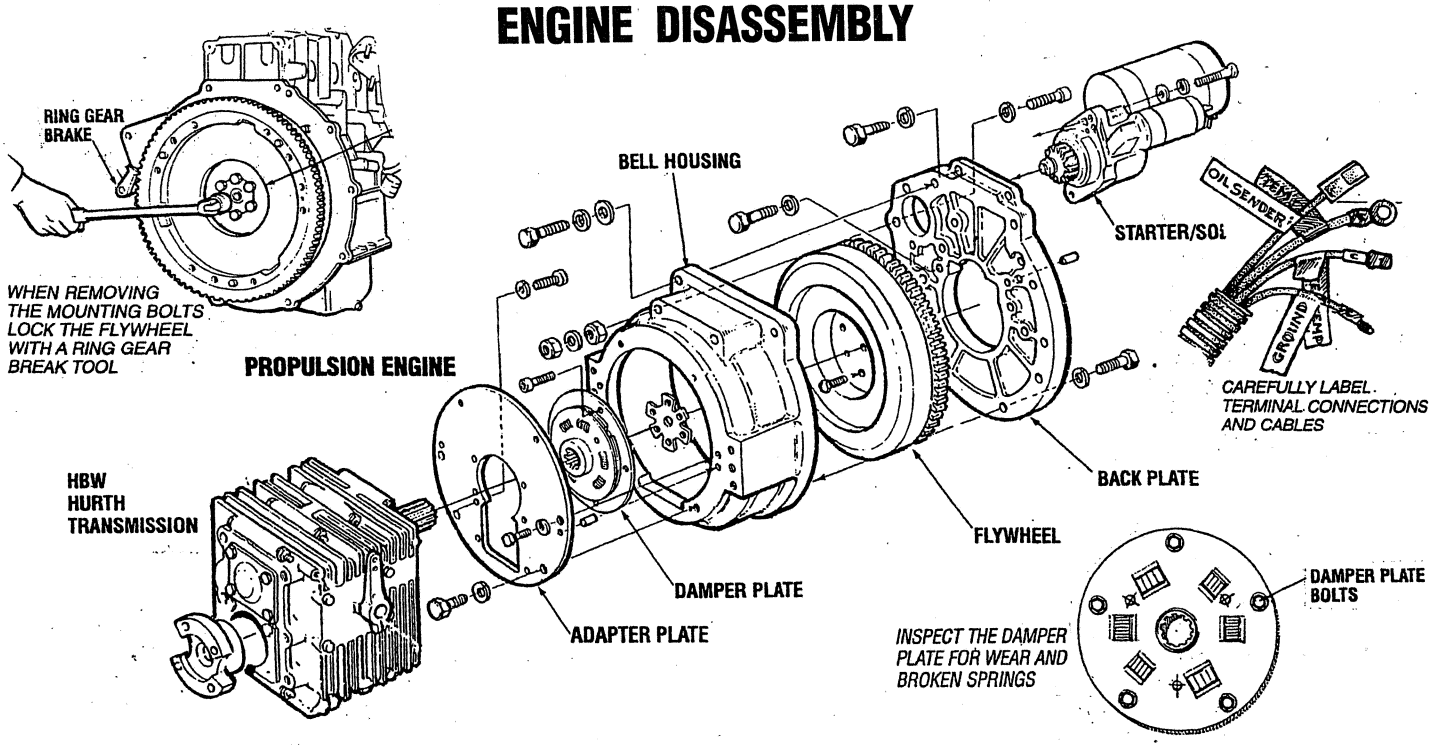
Additional generator information will be found in the *GENERATOR* section of this manual.



FOR MAIN ENGINE DISASSEMBLY SEE THE FOLLOWING PAGE

NOTE: Remove the MPU before disassembly of the generator to prevent damaging the MPU.

ENGINE DISASSEMBLY



PROPULSION ENGINE

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.*

Transmission

If the transmission is not being rebuilt, it should be visually inspected. Flush out and pressure test the oil cooler and replace the coolant hoses. Inspect and lubricate the gear shift linkage and the propeller shaft coupling. Clean and repaint the transmission and change the transmission fluid.

For transmission service and maintenance, refer to your transmission manual. To rebuild a transmission, contact your WESTERBEKE dealer or an authorized transmission service center.

MAIN ENGINE PARTS DISASSEMBLY

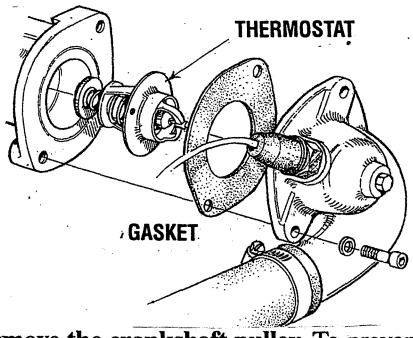
- Clean or wash the engine exterior.
- Do not remove or disassemble the parts that require no disassembly.
- When disconnecting sensor wires, label and tape the ends.
- Perform disassembly in a proper order using proper tools. Keep disassembled parts in order. Apply oil when necessary. Take special care to keep the fuel system parts from intrusion of dust and dirt.
- Parts must be restored to their respective components from which they were removed at disassembly. This means that all parts must be set aside separately in groups, each marked for its component, so that the same combination or set can be reproduced at assembly.
- 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.

NOTE: *Mount the engine on a suitable stand or work bench.*

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.**

ENGINE DISASSEMBLY

8. **Remove the thermostat assembly.** Leave the temperature sender in place.

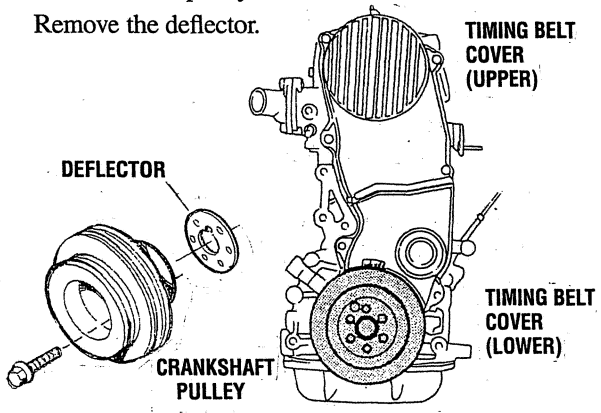


9. **Remove the crankshaft pulley.** To prevent the crankshaft pulley from rotating, insert two bolts into the gap at the rear end of the crankshaft.

   Remove the six bolts that secure the drive plate and loosen the timing pulley lock bolt.

   Using a 6mm hex wrench, remove the six bolts holding the crankshaft pulley.

   Remove the deflector.



10. **Remove the following parts and assemblies.**

    Fuel pump/gasket

    The carburetor and governor with the gasket and insulator

    Spark plugs

    Dipstick

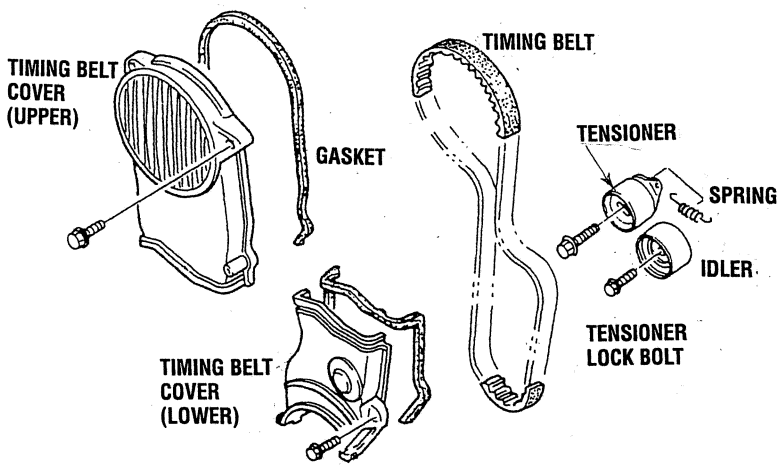
    The distributor assembly/High tension leads

    The exhaust manifold

    Oil filter and oil pressure switch

NOTE: *All assembled parts should be carefully arranged in order of reassembly. Mark or label the parts as needed to insure proper reassembly.*

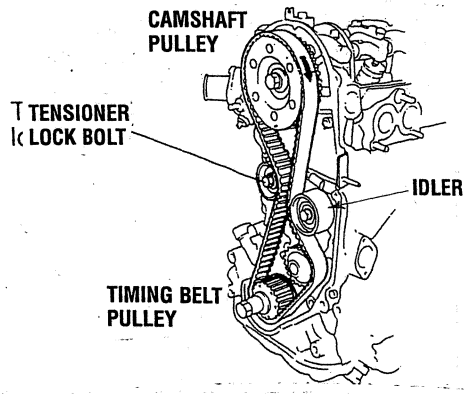
REMOVE THE TIMING BELT ASSEMBLY



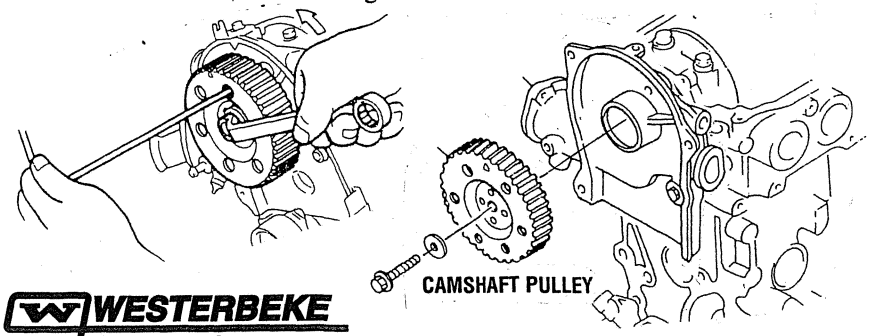
11. **Remove the timing belt covers, upper and lower.**
12. **Loosen the timing belt tensioner lock belt and remove the spring.**
13. **Remove the bolts to remove the timing belt tensioner and remove the timing belt.**

NOTE: *Mark the normal rotation of the belt (clockwise as viewed from the front - belt end of the engine) on the belt.*

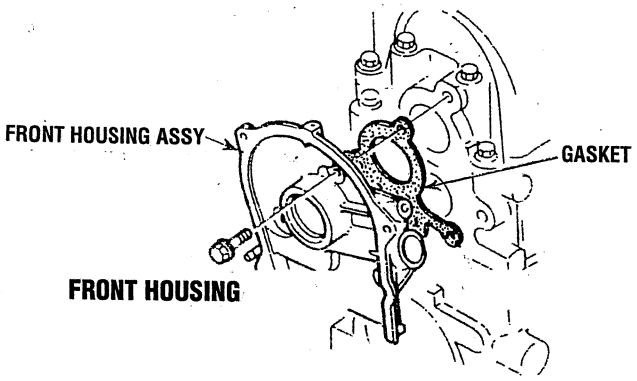
For *INSPECTION* and *ASSEMBLY,* refer to *TIMING BELT* in this manual.



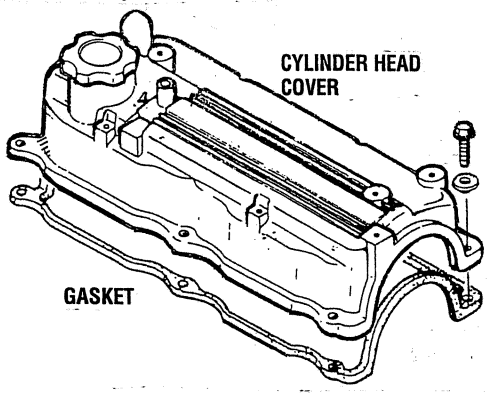
14. **Remove the camshaft pulley.** Remove the pulley by inserting a T-wrench or similar tool to prevent it from turning.



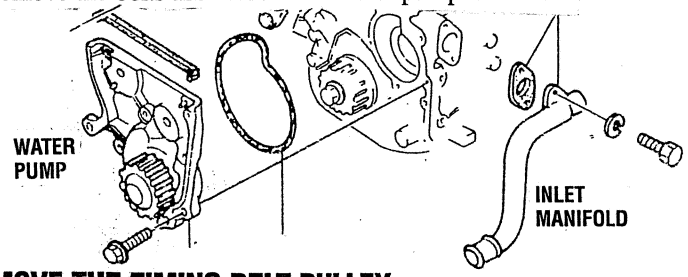
ENGINE DISASSEMBLY/INSPECTION



1. Remove the front housing assembly by removing the bolts and nuts.
2. Remove the inlet manifold.
3. Remove the cylinder head cover.



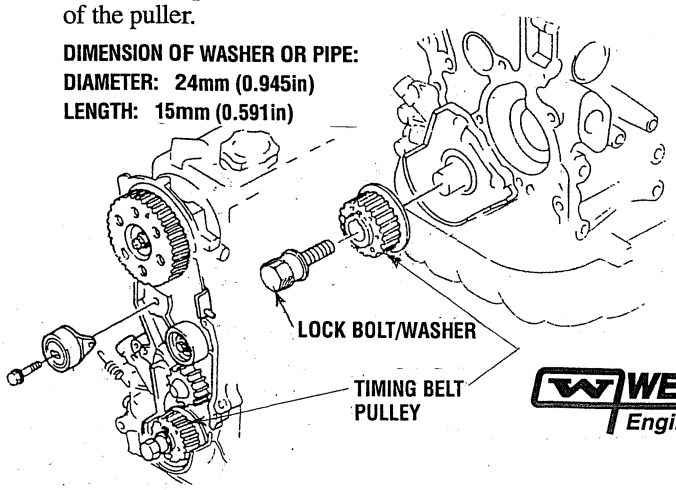
4. Remove the bolts and remove the water pump as a unit.



REMOVE THE TIMING BELT PULLEY

1. Remove the lock bolt and lock washer.
2. Using a plastic hammer, strike the whole peripheral of the spacer on the front side of the pulley.
3. Attach a pulley puller on the spacer. Bring a suitable washer or pipe into contact with the end of the center bolt of the puller.

DIMENSION OF WASHER OR PIPE:
DIAMETER: 24mm (0.945in)
LENGTH: 15mm (0.591in)

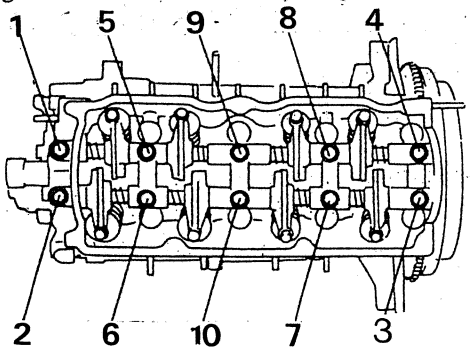


4. Screw in the pulley puller, and remove the spacer and taper ring together.

   NOTE: *While screwing in the pulley, hit the whole peripheral of the spacer with the plastic hammer.*
5. Remove the timing belt pulley.
6. Remove the woodruf key.
7. Disassemble the spacer from the pulley puller.

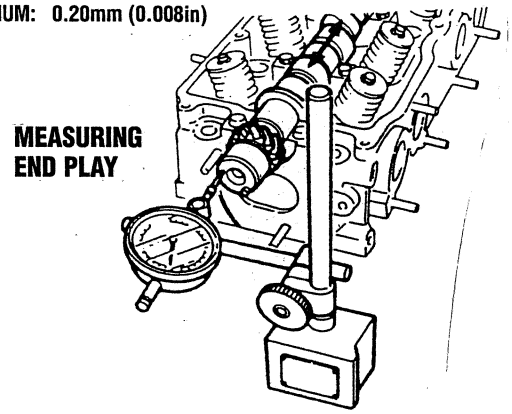
REMOVE THE ROCKER SHAFT ASSEMBLY

1. Loosen the rocker shaft assembly bolts in several increments, not all at once. Use the sequence indicated in the diagram.



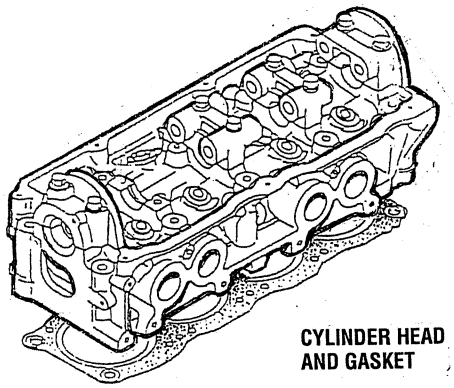
2. Inspect the end play by moving the camshaft forward and backward using a magnet base and dial gauge.

END PLAY: 0.08 - 0.16mm (0.003 - 0.006in)
MAXIMUM: 0.20mm (0.008in)

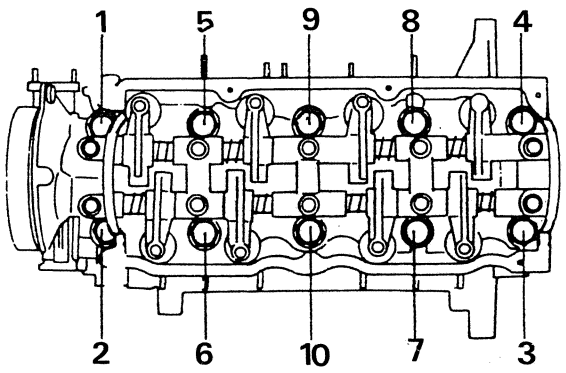


NOTE: *If the end play exceeds specifications, replace the camshaft and/or cylinder head.*

REMOVE THE CYLINDER HEAD ASSEMBLY AS A UNIT



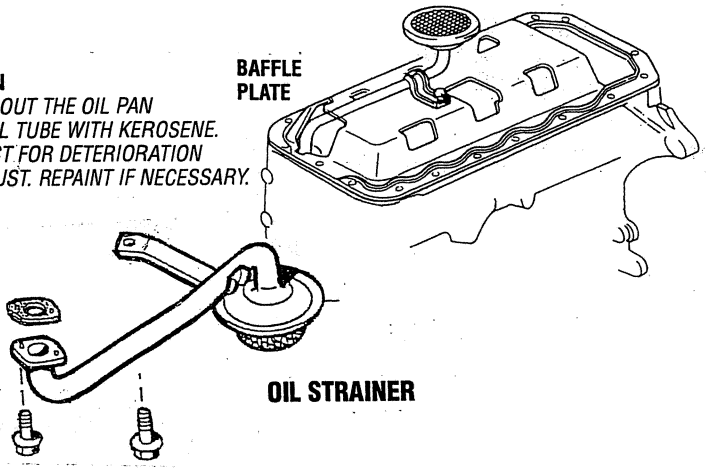
ENGINE DISASSEMBLY/INSPECTION



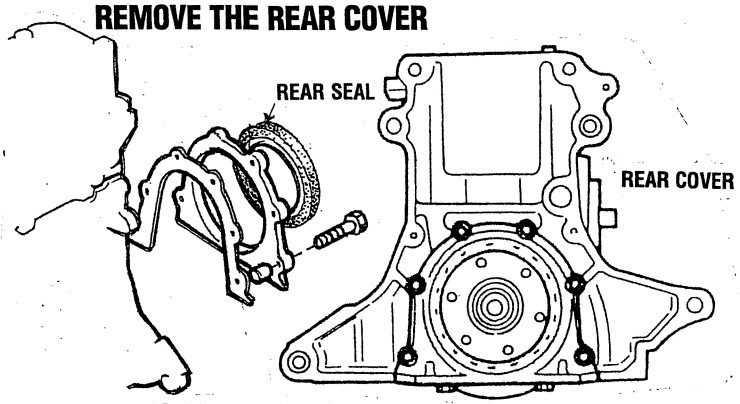
1. Loosen the cylinder head bolts in several increments to remove, following the numerical sequence indicated above.

REMOVE THE OIL PAN, GASKET AND BAFFLE PLATE

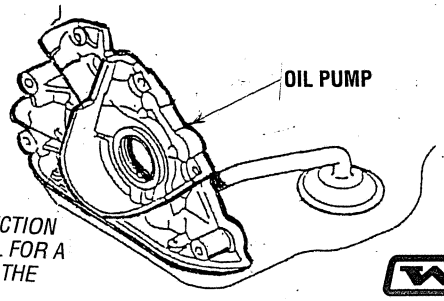
1. Remove the bolts and remove the oil strainer.



REMOVE THE REAR COVER



REMOVE THE OIL PUMP



REFER TO THE LUBRICATION SECTION OF THIS MANUAL FOR A BREAKDOWN OF THE OIL PUMP

INSPECT THE END PLAY OF THE CONNECTING ROD LARGE END

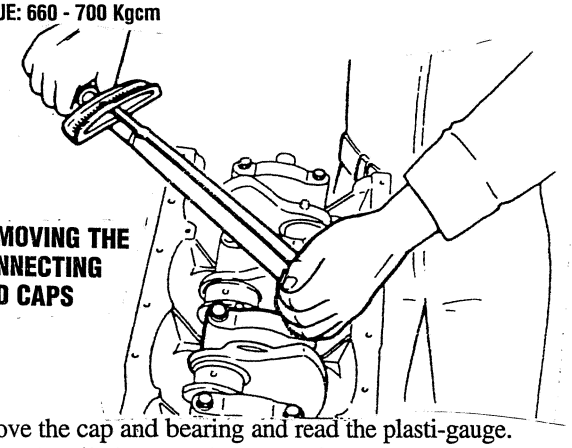
1. Use a magnet base and a dial indicator.

   STANDARD: 0.110 - 0.262mm (0.004 - 0.010in)
   LIMIT: 0.30mm (0.012in)

   NOTE: *Replace if the measured value exceeds the limit.*

2. Inspect the oil clearance on the bearing of the connecting rod large end.
   a. Remove the connecting rod cap nuts and remove the cap and bearing.
   b. Clean any oil off the crank pin and bearing surfaces.
   c. Using a piece of plasti-gauge, set it in the longitudinal direction of the crank pin. Do not set the plasti-gauge over the oil port.
   d. Install the cap and bearing and tighten the nuts to the specified torque.

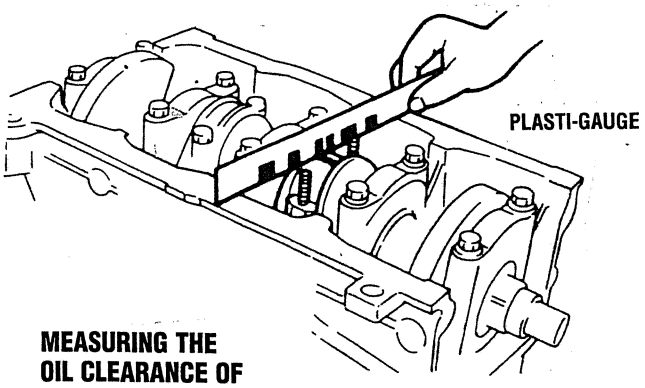
   TORQUE: 660 - 700 Kgcm



   e. Remove the cap and bearing and read the plasti-gauge. Inspect the oil clearance by comparing he measured value with the standard value.

   STANDARD VALUE: 0.027mm (0.001in)
   MAXIMUM LIMIT: 0.10mm (0.004in)

   f. Remove the plasti-gauge.

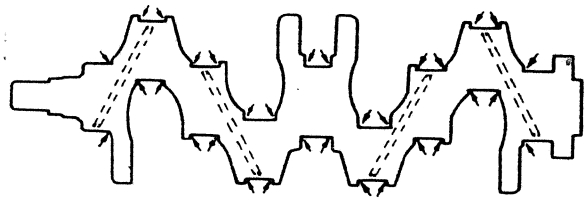


MEASURING THE OIL CLEARANCE OF THE LARGE END BEARING

g. If the oil clearance exceeds the limit, replace the bearing set with a new one and measure again.

If the replaced bearing set exceeds the limit, grind the crank pin and use an under-size bearing to obtain the oil clearance required.

CONNECTING ROD BEARINGS - UNDERSIZE (U.S.):
AMOUNT OF UNDERSIZE
0.25mm (0.009in)
0.50mm (0.019in)
0.75mm (0.029in)

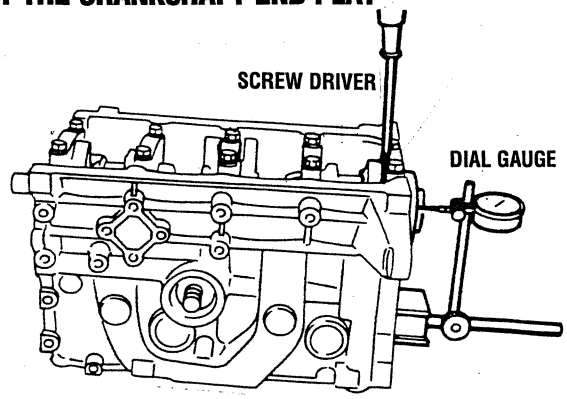


R DIMENSION: 3mm R

REMOVE THE PISTON AND CONNECTING ROD ASSEMBLIES

1. Remove the cap nut and remove the connecting rod cap bearing.
2. Force the piston and connecting rod out (downward) by tapping gently with the handle of a hammer.
3. Force the remaining piston and connecting rod assemblies out in the same manner as mentioned above.

INSPECT THE CRANKSHAFT END PLAY

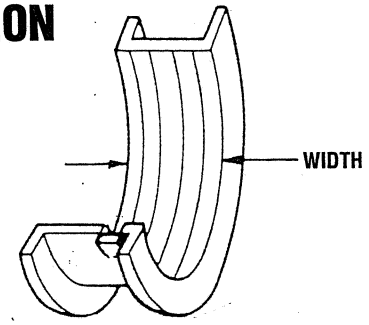


1. Check the end play by moving the crankshaft forward and backward as shown using a magnetic base and dial gauge to measure the amount.

STANDARD: 0.08 - 0.282mm (0.003 - 0.011in)
LIMIT: 0.30mm (0.012in)

2. Adjust the end play at the center main bearing if the measured value exceeds the limit.

NOTE: *The undersize center main bearings are classified into the following three types. The center main bearings vary in width as shown in the table.*



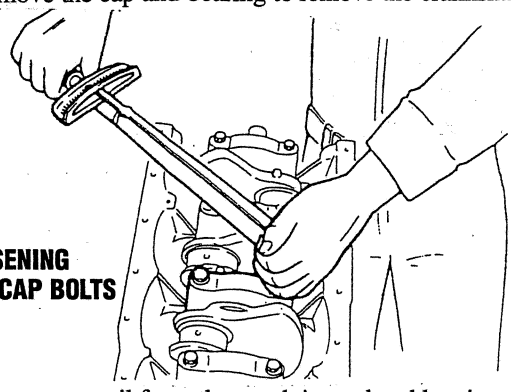
UNDERSIZE PARTS	WIDTH
0.25mm (0.009in)	28.04 - 28.09mm (1.106 - 1.107in)
0.50mm (0.019in)	28.12 - 28.17mm (1.108 - 1.109in)
0.75mm (0.029in)	28.20 - 28.25mm (1.111 - 1.113in)
STANDARD	27.94 - 27.99mm (1.1008 - 1.103in)

3. Inspect the bearing oil clearance of the crankshaft journal.

a. Loosen the main bearing cap bolts, alternating between the two bolts of one cap, turning each bolt a few turns at a time.

b. Remove the cap and bearing to remove the crankshaft.

b. Remove the cap and bearing to remove the crankshaft.

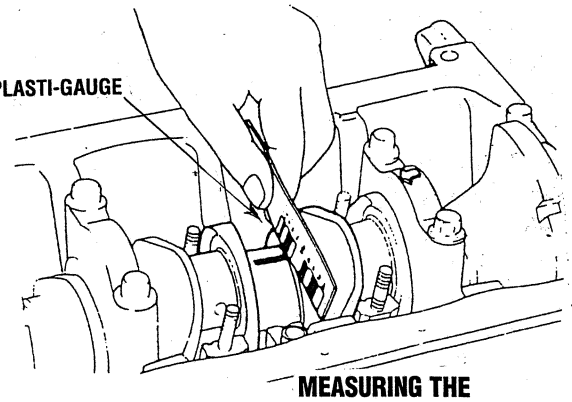


LOOSENING THE CAP BOLTS

c. Remove any oil from the crank journal and bearing surfaces.

d. Install the crankshaft and set the plasti-gauge in the longitudinal direction of the crank journal. Do not set the plasti-gauge over the oil port.

Install the cap and bearing and tighten the bolts.



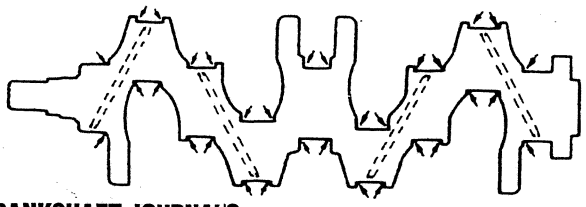
MEASURING THE CRANKSHAFT JOURNAL OIL CLEARANCE

e. Remove the cap and bearing. Check the oil clearance by comparing the measured value with the standard value.

STANDARD: 0.032 - 0.049mm (0.0012 - 0.0019in)
LIMIT: 0.08mm (0.003in)

Replace the bearing set if the oil clearance exceeds the allowable limit, and remeasure the clearance.

If the oil clearance provided by the replaced bearing set exceeds the limit, grind the crank journal and use the undersize bearing to obtain the oil clearance required.



CRANKSHAFT JOURNALS

R DIMENSION: 3mm R

CONNECTING ROD BEARINGS - UNDERSIZE (U.S.)
AMOUNT OF UNDERSIZE:
0.25mm (0.009in)
0.50mm (0.019in)
0.75mm (0.029in)

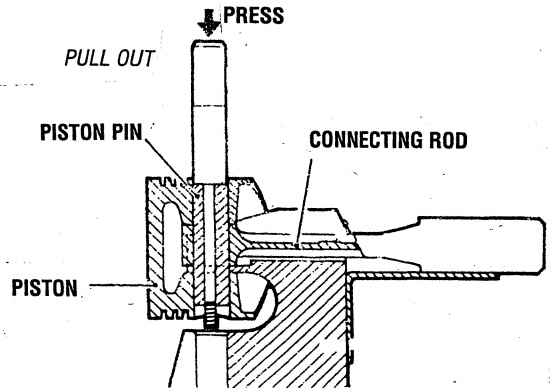
2. Disassemble the piston and connecting rod assembly.

a. Remove the piston rings from the piston using a piston ring installation tool (commercial product).

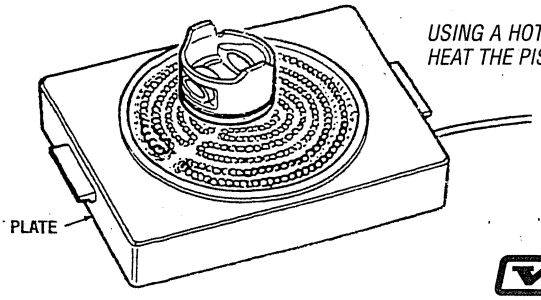
b. Remove the piston pin from the piston using the piston pin setting tool.

If the piston pin is tight in the piston, immerse the piston in hot water or use a hot plate.

c. Disassemble the remaining piston and connecting rod assembly in the manner mentioned above.



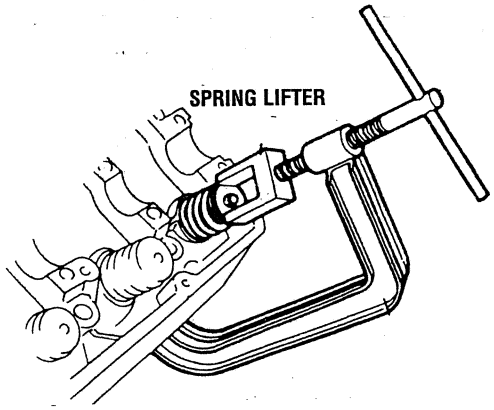
Heat the piston to 122° – 158° F (50° – 70° C).



USING A HOT PLATE TO HEAT THE PISTON

3. Disassemble the cylinder head assembly.

a. Compress the valve spring and remove the valve retainer using a valve spring lifter and pivot.



b. Remove the valve spring and upper and lower valve spring seats by loosening the valve spring compression.

c. Remove the valve from the valve guide.

d. Remove the valve seal.

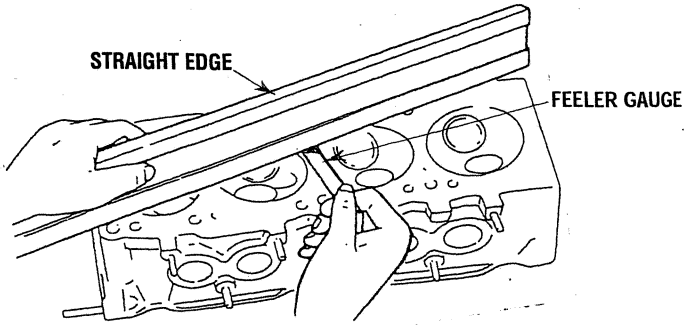
e. Remove the remaining valve assemblies by repeating the above procedure.

CYLINDER HEAD / VALVES
INSPECTION / REPAIR

INSPECTION

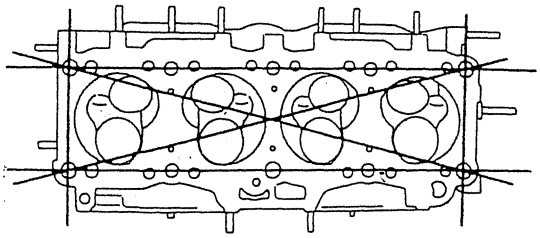
Clean off the cylinder head and remove any gasket fragments.

Inspect for damage, cracks, and leakage of water or oil.



Measure the cylinder head distortion in the six directions shown below using a gauge and straight edge.

Distortion: 0.15mm (0.006 in)



If the cylinder head distortion exceeds specification, grind the cylinder head surface.

If the cylinder head height is not within specification, replace it.

HEIGHT: 91.95—92.05mm (3.620—3.624in)
GRINDING LIMIT: 0.20mm (0.008in) MAX

NOTE: *Before grinding the cylinder head, first check the following. Replace if necessary.*

- *Sinking of valve seat*
- *Damage of manifold contact surface*
- *Camshaft oil clearance and end play.*

MANIFOLD MOUNTING SURFACE

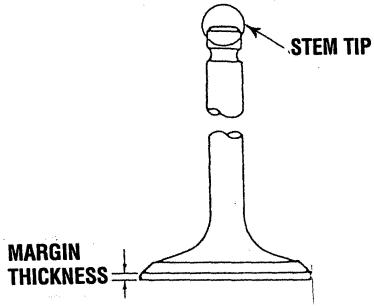
Use the same inspection procedure for the manifold mounting surface, measuring distortion with a gauge and a straightedge in several directions.

DISTORTION (GRINDING LIMIT): 0.20mm (0.008in)

VALVE AND VALVE GUIDE

1. Inspect each valve for the following. Replace or resurface if necessary.
   (1) Damage or bent stem
   (2) Roughness or damage to face
   (3) Damage or uneven wear of stem tip
2. Check the valve head margin thickness. Replace if necessary.

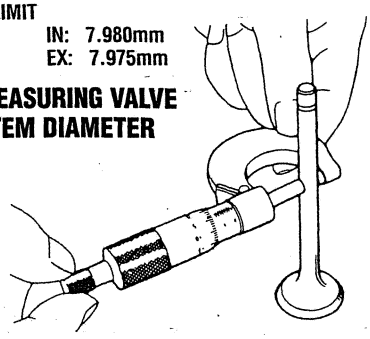
VALVE HEAD MARGIN THICKNESS
IN: 0.5 mm (0.020in) MIN.
EX: 1.0mm (0.039in) MIN.



3. Measure the valve stem diameter.

DIAMETER (STANDARD)
IN: 8.030—8.045mm (0.3161—0.3167in)
EX: 8.025—8.040mm (0.3159—0.3165in)
LIMIT
IN: 7.980mm
EX: 7.975mm

MEASURING VALVE STEM DIAMETER



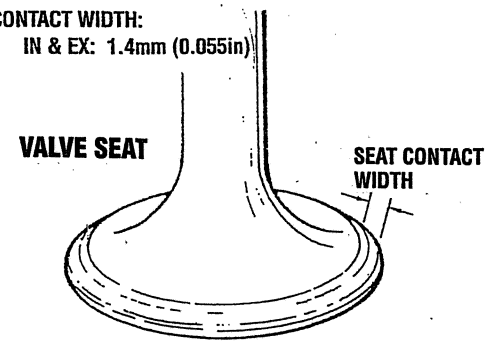
VALVE GUIDE I.D.
IN: 8.07-8.09mm (0.3177-0.3185in)
EX: 8.07-8.09mm (0.3177-0.3185in)

VALVES SEAT
INSPECTION / REPAIR

VALVE SEAT

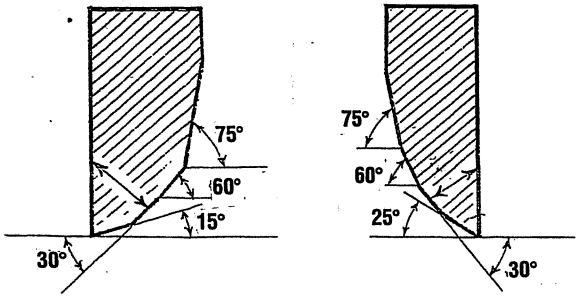
1. Inspect the contact surface of the valve seat and valve face for the following.
   (1) Roughness
   (2) Damage
2. If necessary, resurface the valve seat with an 80° valve seat cutter and/or resurface the valve face.
3. Check the seat contact width.

CONTACT WIDTH:
IN & EX: 1.4mm (0.055in)



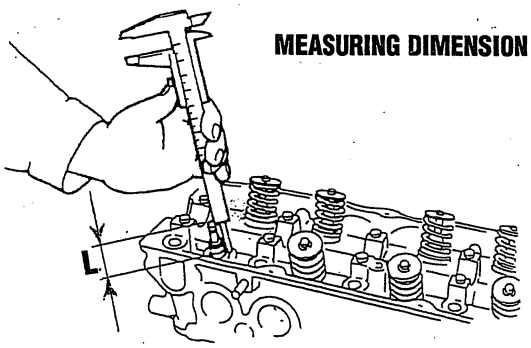
4. Check that the valve seating position is at the center of the valve face.
   (1) If the seating position is too high, correct the valve seat with a 60° cutter and a 30° cutter.
   (2) If the seating position is too low, correct the valve seat with a 25° (IN) cutter and a 15° (EX) cutter.
5. Seat the valve to the valve seat with a lapping compound.

VALVE SEAT ANGLES

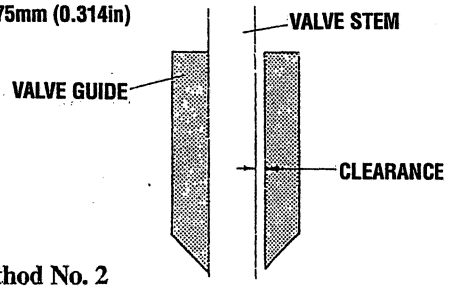


6. Check the sinking of the valve seat.
   Measure protruding length (dimension L) of each valve stem.
   Dimension L: 46.5mm (1.831in)
   (1) If **L** is within **46.5—47.0mm (1.831—1.850in)**, it can be used as is.
   (2) If **L** is within **47.0—48.0mm (1.850—1.890in)**, insert a spacer between the spring seat and the cylinder head to adjust.
   (3) If **L** is within **48.0mm (1.890in)**, replace the cylinder head.

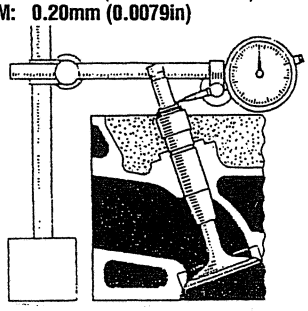
MEASURING DIMENSION L



7. Measure the valve stem to guide clearance.
   (1) **Method No. 1**
   Subtract the outer diameter of the valve stem from the inner diameter of the corresponding valve guide.
   LIMIT
   IN: 7.980mm (0.312in)
   IN: 7.975mm (0.314in)



   (2) **Method No. 2**
   Measure the valve stem play at a point close to the valve guide with the valve lifted slightly off the valve seat.
   CLEARANCE
   IN: 0.025-0.060mm (0.0010-0.0024in)
   EX: 0.030-0.065mm (0.0012- 0.0026in)
   MAXIMUM: 0.20mm (0.0079in)

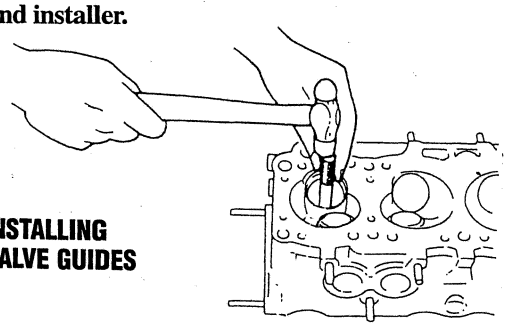


8. If the stem play exceeds specifications, replace the valve guide and/or the valve.

VALVES / VALVE GUIDE / VALVE SPRING
INSPECTION / REPAIR

REPLACEMENT OF THE VALVE GUIDE

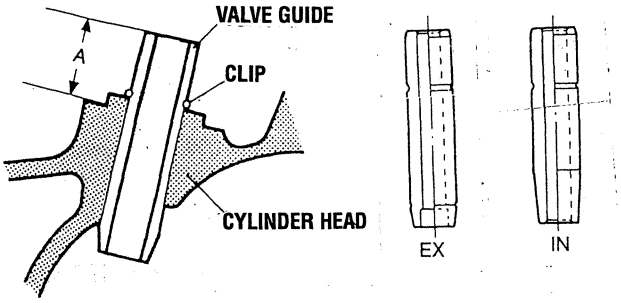
1. Pull the valve seal off the valve guide using pliers.
2. Remove the valve guide toward the side opposite the combustion chamber by using the **valve guide remover and installer.**



INSTALLING VALVE GUIDES

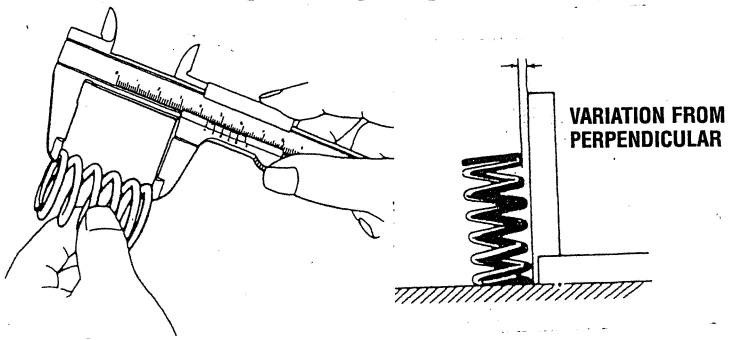
3. Fit the clip onto the valve guide. Use the **valve guide remover and installer** to tap the valve guide in from the side opposite the combustion chamber until the clip just contacts the cylinder head. The height of the valve guide must be **19.1—19.6mm (0.752—0.772in)** from the valve spring seat to the end of the valve guide (dimension A).

NOTE: *Although the shapes of the intakes and exhaust valve guides are different, use the exhaust valve guide on both sides as a replacement.*



VALVE SPRING

1. Inspect each valve spring for cracks or damage.
2. Check the free length and angle. Replace if necessary.

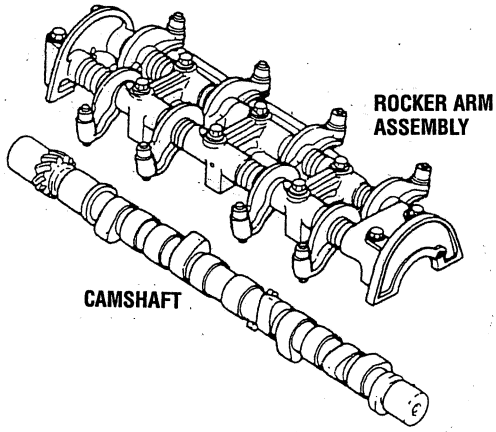


FREE LENGTH
OUTER: 50.4mm (1.98in)
INNER: 42.7mm (1.68in)

ANGLE
OUTER: 1.8mm (0.07in) MAX
INNER: 1.5mm (0.06in) MAX

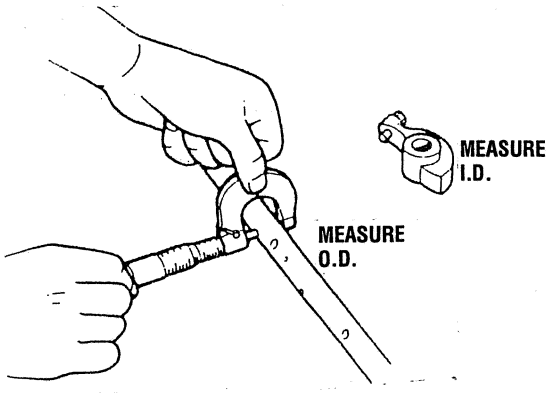
ROCKER ARM AND ROCKER ARM SHAFT

1. Check for wear or damage to the contact surface of the rocker arm shaft and the rocker arm. replace if necessary.
2. Check the oil clearance between the rocker arm and shaft. replace if necessary.



OIL CLEARANCE
STANDARD: 0.016 - 0.061mm (0.0006 - 0.0024in)
LIMIT: 0.10mm (0.004in)

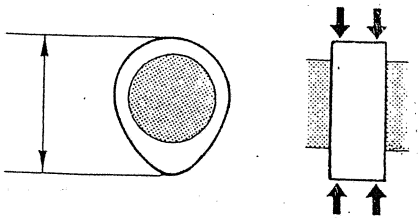
ROCKER ARM
I.D.: 16.000 - 16.027mm (0.630 - 0.631in)
O.D.: 15.966 - 15.984mm (0.629 - 0.6297in)



CAMSHAFT
INSPECTION / REPAIR

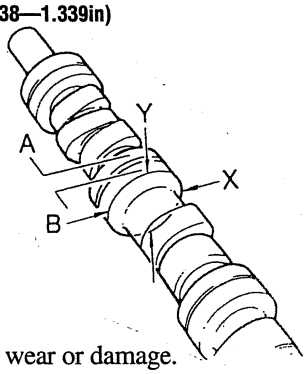
CAMSHAFT

1. Check the cam for wear or damage. Replace if necessary.
2. Check the cam lobe height at the two points as shown.



3. Measure wear of the journals in X and Y directions at the two points as shown.

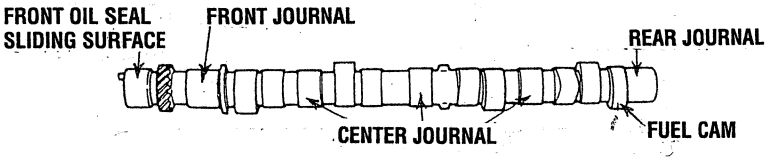
DIAMETER
FRONT AND REAR:
31.940—31.965mm (1.2575—1.2585in)
CENTER THREE JOURNALS:
31.910—31.935mm (1.2563—1.2573in)
FRONT OIL SEAL SLIDING SURFACE:
33.961—34.000mm (1.338—1.339in)
OUT-OF-ROUND:
0.05mm (0.002in) MAX.



INSPECTING THE CAMSHAFT

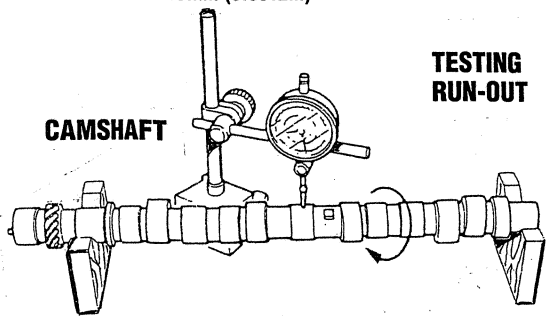
4. Inspect the fuel cam for wear or damage. Replace if necessary.

HEIGHT: 37.6mm (1.481in)
MINIMUM: 37.1 (1.452in)

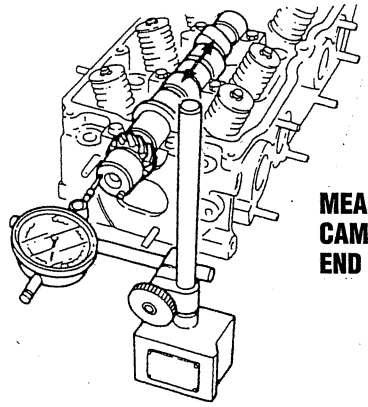


5. Check the camshaft runout. Replace if necessary. Set the front and rear journals on V-blocks and rotate the camshaft one full turn to measure deflection (runout).

RUNOUT: 0.03mm (0.0012in)



TESTING RUN-OUT CAMSHAFT



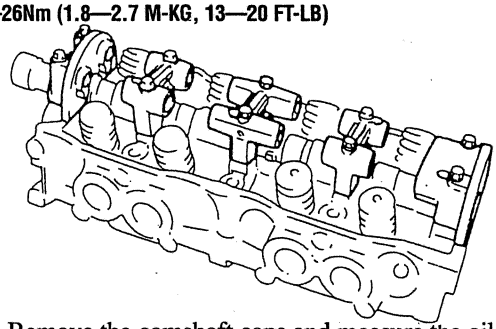
MEASURING CAMSHAFT END PLAY

6. Measure the camshaft end play. If the end play exceeds specification, replace the camshaft and/or the cylinder head.

END PLAY: 0.08—0.16mm (0.003—0.006in)
MAXIMUM: 0.20mm (0.008in)

7. Measure the oil clearance of the camshaft and camshaft caps.
   (1) Remove any oil, or dirt from the journals and bearing surface.
   (2) Set the camshaft onto the cylinder head.
   (3) Position plasti-gauge on top of the journals in the axial direction.
   (4) Place the camshaft caps and rocker arm shafts in position, and tighten them to the specified torque.

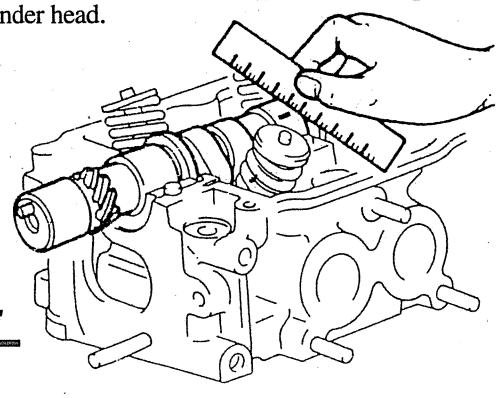
TIGHTENING TORQUE:
18—26Nm (1.8—2.7 M-KG, 13—20 FT-LB)



   (5) Remove the camshaft caps and measure the oil clearance at each cap.

OIL CLEARANCE FRONT AND REAR:
0.035—0.085mm (0.0014—0.0033in)
CENTER THREE JOURNALS:
0.0651—0.115mm (0.0026—0.0045in)
MAXIMUM: 0.15mm (0.0059in)

   (6) If the oil clearance exceeds specification, replace the cylinder head.



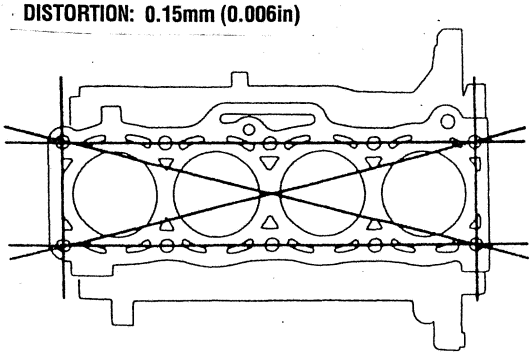
MEASURING WITH PLASTIGAUGE

CYLINDER BLOCK / PISTON
INSPECTION / REPAIR

DESCRIPTION

1. Inspect the entire cylinder block for cracks or damage, repair or replace if faulty.
   (1) **Leaking damage**
   (2) **Cracks**
   (3) **Scoring of wall**
2. Measure the distortion of the top surface of the cylinder block in the six directions as shown in the figure.

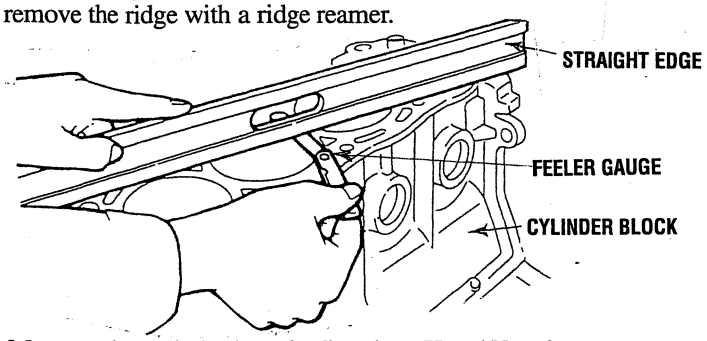
DISTORTION: 0.15mm (0.006in)



CYLINDER BLOCK
CHECK FOR WARPAGE ON TOP FACE

INSPECT FOR CRACKS, OIL OR COOLANT LEAKS. CLEAN OFF SCALE AND CARBON DEPOSITS

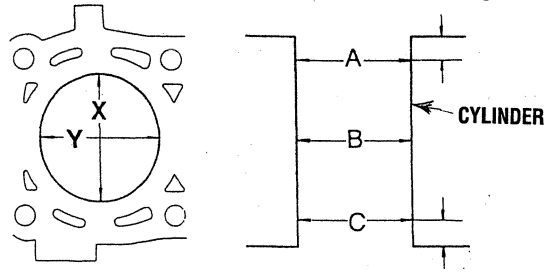
3. If the distortion exceed specification, repair by grinding, or replacing the cylinder block.
   GRINDING LIMIT: 0.20 mm (0.008in)
4. If the upper part of the cylinder wall shows uneven wear, remove the ridge with a ridge reamer.



5. Measure the cylinder bore in directions X and Y at three levels in each cylinder as shown.

Cylinder Bore **mm (in)**

Size	Bore
Standard	86.000—86.019 (3.3858—3.3866)
0.25 (0.010) oversize	86.250—86.269 (3.3957—3.3964)
0.50 (0.020) oversize	86.500—86.519 (3.4055—3.4063)



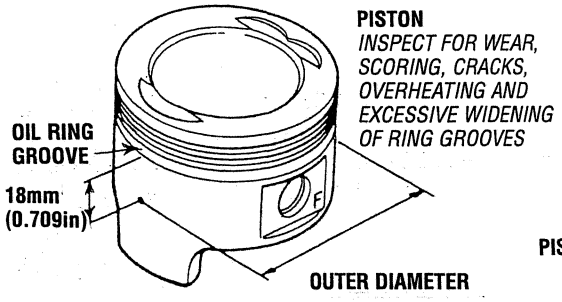
CYLINDERS
INSPECT FOR CRACKS, SCORES, OR RIDGES AT TOP OF RING TRAVEL

PISTON-PISTON RING
INSPECTION / REPAIR

PISTON

1. Inspect the outer circumferences of all pistons for seizure or scoring. Replace if necessary.
2. Measure the outer diameter of each piston at a right angle (90°) to the piston pin, **18 mm (0.709 in)** below the oil ring land lower edge.

   STANDARD VALUE: 85.944 - 85.964mm (3.3836 - 3.3844in)
   0.25mm OVERSIZE: 86.194 - 86.214mm (3.3935 - 3.3942in)
   0.50mm OVERSIZE: 86.444 - 86.464mm (3.4033 - 3.4041in)

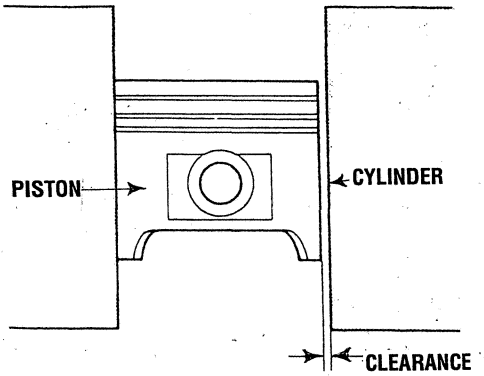


3. Check the piston to cylinder clearance.

   CLEARANCE: 0.036—0.075 (0.0014—0.0030in)
   MAXIMUM: 0.15mm (0.0059in)

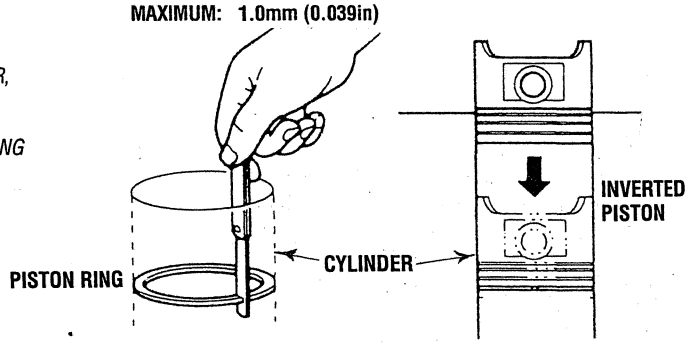
4. If the clearance exceeds the maximum, replace the piston or rebore the cylinders to fit oversize pistons.

   NOTE: *If the piston is replaced, replace the piston rings also.*



5. inspect the piston rings for damage, abnormal wear, or breakage. Replace if necessary.
6. Insert the piston ring into the cylinder by hand and push it to the bottom of the ring travel by using the piston.
7. Measure the ring end gap.

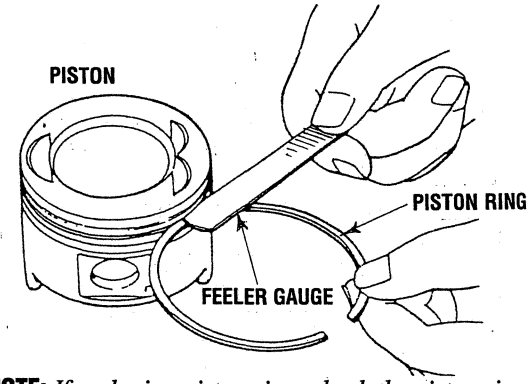
   END GAP TOP: 0.20-0.35mm (0.008-0.014in)
   SECOND: 0.15-0.30mm (0.006-0.012in)
   OIL RING: 0.20-0.70mm (0.008-0.028in)
   MAXIMUM: 1.0mm (0.039in)



8. Measure the piston ring to ring clearance around the entire circumference using a new piston ring.

   CLEARANCE TOP: 0.03—0.07mm (0.001—0.003in)
   SECOND: 0.03—0.07mm (0.001—0.003in)
   MAXIMUM: 0.15mm (0.006in)

   NOTE: *Measure the clearance around the entire circumference of the ring groove.*



NOTE: *If replacing piston rings check the piston ring gaps. New rings are packaged with detailed instructions that often supersede the service manual.*

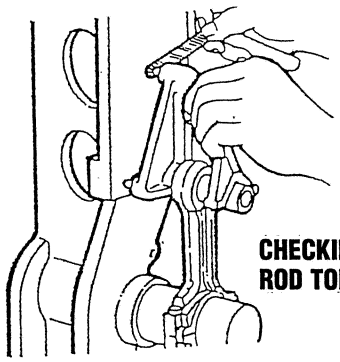
CONNECTING RODS
INSPECTION / REPAIR

CONNECTING RODS

1. Check the side surfaces of the big end and the small end of each connecting rod for cracking or any other damage. Replace if necessary.
2. Check the connecting rod for bending and torsion using a connecting rod aligner. If bending or torsion exceeds the specified limit, correct with a press or replace.

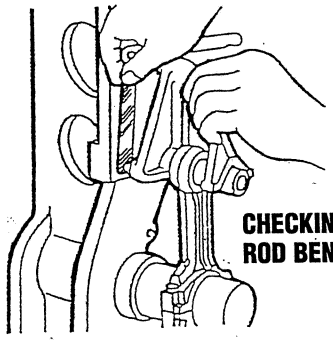
CONNECTING ROD BENDING LIMIT : 0.04mm (0.0016in) for every 100mm

CHECK FOR BEND OR TWIST.
CHECK BIG END THRUST CLEARANCE



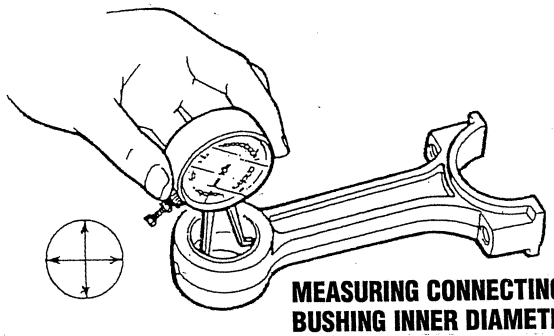
CHECKING CONNECTING ROD TORSION LIMIT

CONNECTING ROD TORSION LIMIT : 0.04mm (0.0016in) for every 100mm



CHECKING CONNECTING ROD BENDING LIMIT

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



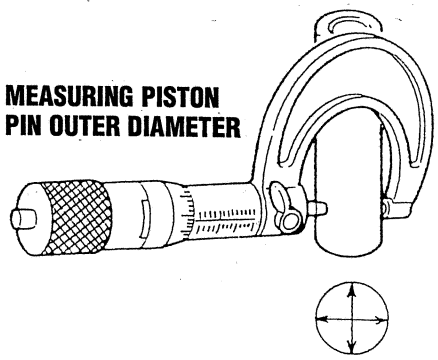
MEASURING CONNECTING ROD BUSHING INNER DIAMETER

3. Check the clearance between the connecting rod bearings and the piston pins.
   a. Measure the inner diameter of the bearings.

CLEARANCE BETWEEN THE SMALL END AND THE PISTON PIN: 0.015mm - 0.040mm (0.0006 - 0.0016in).

   b. Measure the outer diameter of the piston pins

PISTON PIN DIAMETER: 21.947 - 21.980mm (0.864 - 0.866in)



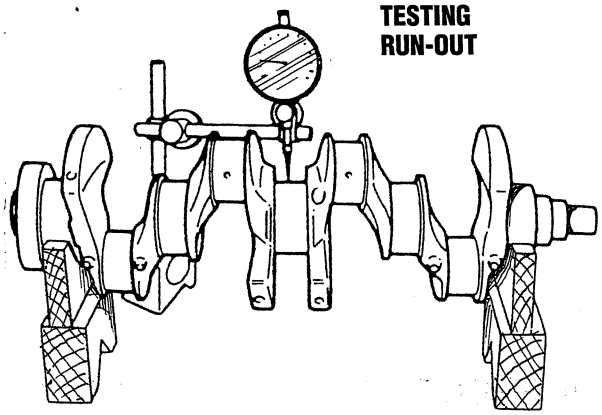
MEASURING PISTON PIN OUTER DIAMETER

CRANKSHAFT
DISASSEMBLY/INSPECTION

CRANKSHAFT

1. Check the journals and pins for damage, scoring, or oil hole clogging.
2. Set the crankshaft on V-blocks.
3. Check the crankshaft runout at the center journal. Replace if necessary

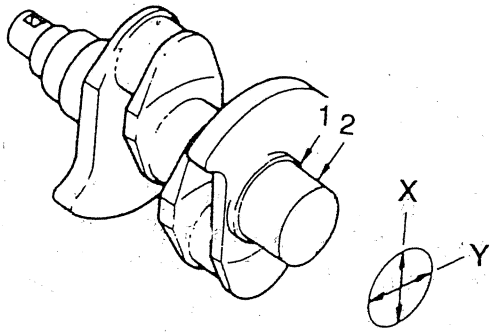
RUNOUT: 0.03mm (0.0012in) MAX.

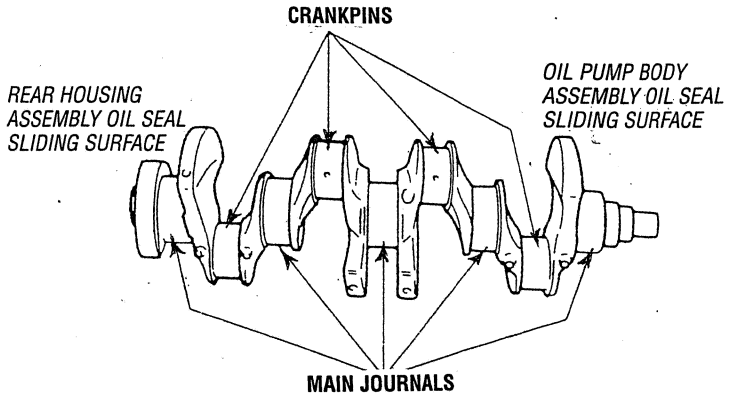


4. Measure each journal diameter in X and Y directions at two points.

MAIN JOURNAL
DIAMETER:
59.937 - 59.955mm (2.3597 - 2.3604in)
MINIMUM: 59.89mm (2.358in)
OUT OF ROUND: 0.05mm (0.0020in)

CRANK PIN JOURNAL
DIAMETER:
50.940 - 50.955mm (2.0055 - 2.0061in)
MINIMUM: 50.89mm (2.004in)
OUT OF ROUND: 0.05mm (0.0020in)





5. If the diameter is less than the minimum, grind the journals to match undersize bearings.

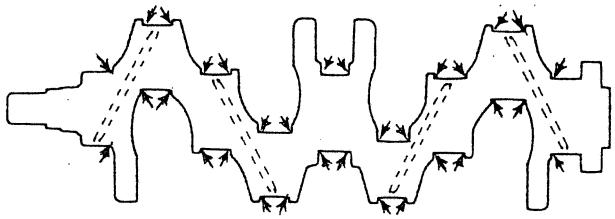
UNDERSIZE BEARING: 0.25mm (0.010in)
0.50 MM (0.020 IN), 0.75mm (0.030in)

MAIN JOURNAL DIAMETER UNDERSIZE MM (IN)

Bearing Size		Journal Diameter
0.25 Undersize	No.1,2,4,5	59.693 - 59.711 (2.3501 - 2.3508)
	No.3	59.687 - 59.705 (2.3499 - 2.3506)
0.50 Undersize	No.1,2,4,5	59.443 - 59.461 (2.3404 - 2.3410)
	No.3	59.437 - 59.455 (2.3400 - 2.3407)
0.75 Undersize	No.1,2,4,5	59.193 - 59.211 (2.3304 - 2.3311)
	No.3	59.187 - 59.205 (2.3302 - 2.3309)

CRANK PIN JOURNAL DIAMETER UNDERSIZE MM (IN)

Bearing Size	Journal Diameter
0.25 Undersize	50.690 - 50.705 (1.9957 - 1.9963)
0.25 Undersize	50.440 - 40.455 (1.9858 - 1.9864)
0.25 Undersize	50.190 - 50.205 (1.9760 - 1.9766)



ALWAYS CHAMFER THE POINTS MARKED WHEN GRINDING THE JOURNALS AND PINS

ENGINE ASSEMBLY

Take the following precautions:

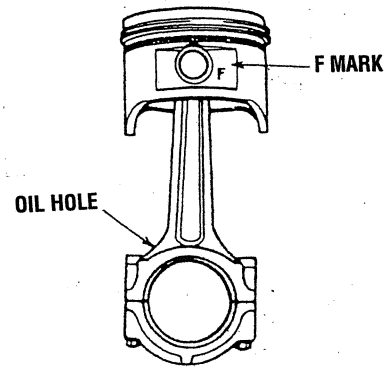
- Be careful not to mix bolts and nuts. Metric and S.A.E. bolts are used on various engine assemblies.
- During assembly, recheck clearances and insure that parts are being assembled in their proper order and facing in the correct direction in relation to the engine block, such as, pistons, piston rings, 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, etc.
- Tighten the bolts and nuts on important parts of engine to specified torques using a reliable torque wrench.
- Use liquid sealants when required on nuts, bolts and gaskets. Refrain from using tape sealants.

Be aware of these common problems that can occur during assembly.

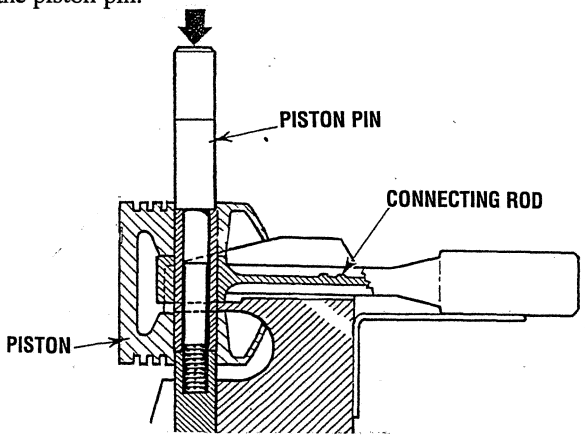
- **Insufficient Lubrication.** Heavily oil sliding and reciprocating parts, lightly oil head bolts and other fasteners, except those that penetrate into the water jacket. These fasteners should be sealed with Permatex No. 2 or the high-tack equivalent.
- **Reversed orientation.** Most gaskets, many bolt washers, and all thermostats are asymmetrical.
- **Mechanical damage.** Run fasteners down in approved torque sequences and 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 also be damaged during assembly, they should be positioned with great care.

INSTALL THE PISTONS AND CONNECTING RODS

1. Align the oil hole in the large end of the connecting rod opposite the **F** mark on the piston.
2. Apply a coat of engine oil to the circumference of each piston pin and to the small end of each connecting rod.

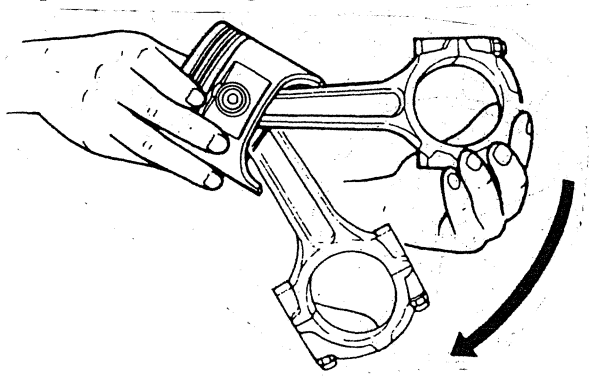


3. Set the piston pin setting tool in position as shown.
4. Press the upper part of the installer with a press to force in the piston pin.



CAUTION:

- Insert the piston pin from the direction of the **F** mark on the piston.
- The piston pin should go in until the lower end of the guide meets the bottom of the block.
- The pressing force is 5 - 15kN (500 - 1500 kg, 1100 - 3300 lb). If the piston pin cannot be pressed in within this range, replace the piston pin or the connecting rod.
- After pressing in the piston pin, inspect the oscillation torque of the connecting rod.



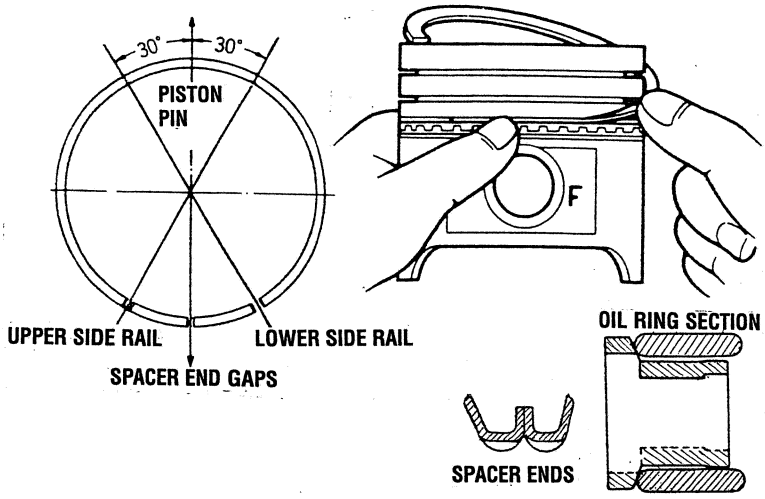
5. After pressing the piston pin in, swing the large end of the connecting rod upward and release it. The connecting rod must swing downward freely.

ENGINE ASSEMBLY

Follow these steps to install the three-piece oil ring on the piston.

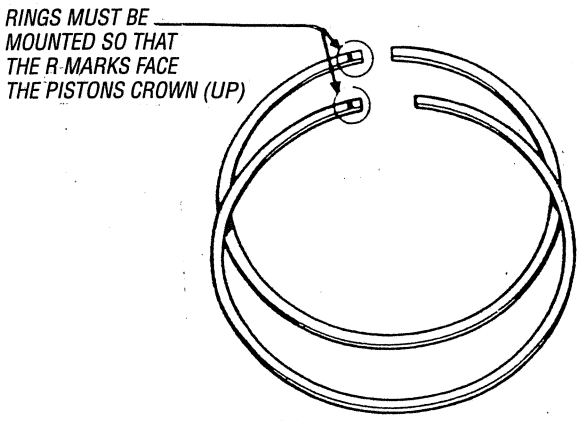
1. Apply a liberal coat of engine oil to the parts during installation.
2. Install the expander.
3. Install the upper rail.
   (a) Insert one edge between the groove and the spacer, applying a firm pressure with one thumb.
   (b) Then press the rail with the other thumb.
4. Install the lower rail in the same way as the upper.

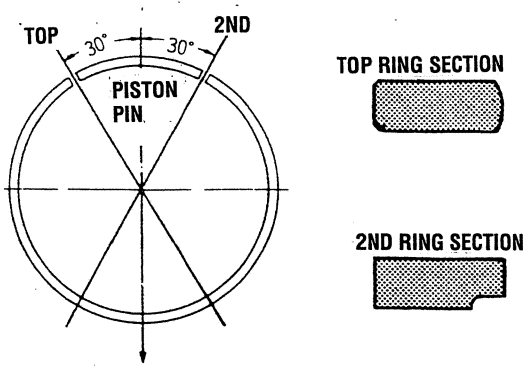
NOTE: *Be careful about the direction of the spacer opening, and after installation of the upper and lower rails, make certain they turn smoothly in both directions.*



Use this method to install the second and top rings.

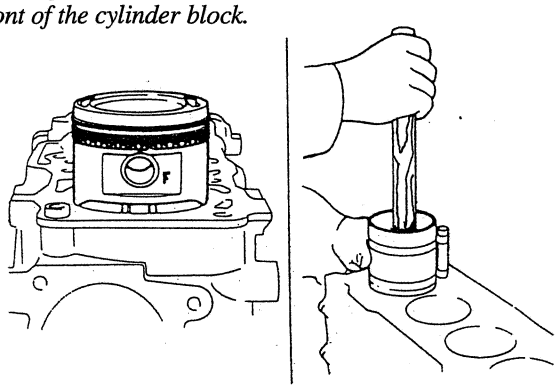
1. install the second ring to the piston first, then the top one, using a piston ring insertion tool (commercially available).
2. Apply a liberal coat of engine oil during installation.
3. Position the opening of each ring as shown.





4. Apply a liberal coat of engine oil to the cylinder walls, piston circumference and rings.
5. Clean the bearing mating surfaces of the connecting rods and caps and install the upper and lower bearings being certain to align he oil holes. Coat the surfaces with engine oil and insert each piston and connecting rod into the cylinder block by using a piston insertion tool.

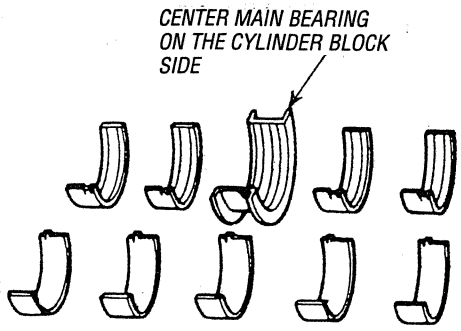
NOTE: *The pistons must be inserted so that the* ***F*** *marks face the front of the cylinder block.*



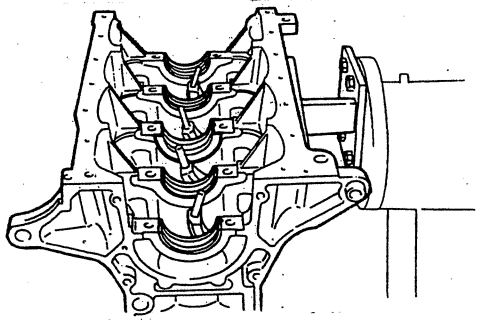
CRANKSHAFT ASSEMBLY

1. Install the crankshaft in the cylinder block, after checking the oil clearances of the crankshaft and main bearings and check the end play.

NOTE: *The shape of the center main bearing on the cylinder block side is different from that of the other main bearings.*

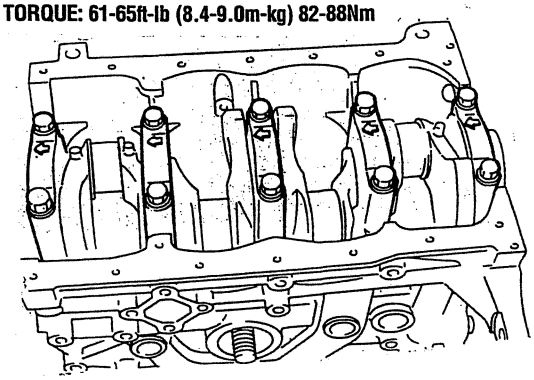


2. Remove any foreign material and oil from the journal and bearing.
3. Coat each bearing and bearing surface with clean engine oil and install the bearings.
4. Gently set the crankshaft in position.



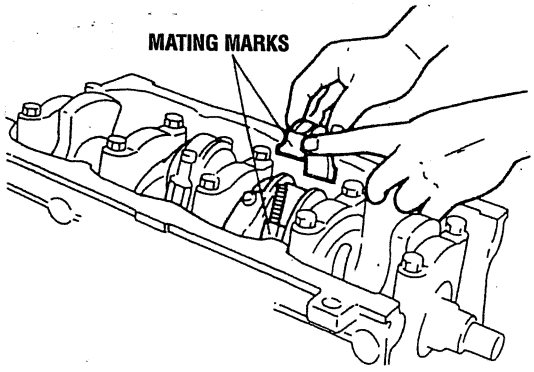
5. Install the main bearing caps in accordance with the numbers and arrows and tighten the bolts to the specified torque.

TORQUE: 61-65ft-lb (8.4-9.0m-kg) 82-88Nm



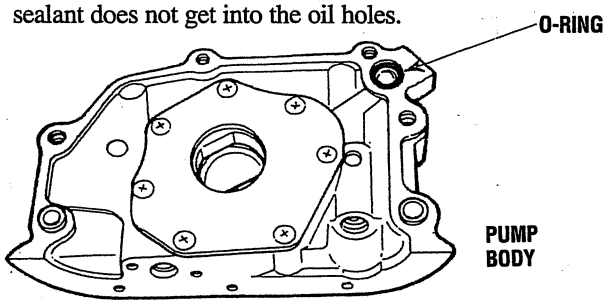
6. Align the connecting rod caps with the match mark.
7. Tighten the connecting rod cap nuts to the specified torque.

TORQUE 48.51ft-lb (6.6-7.0m-kg) 65-69Nm



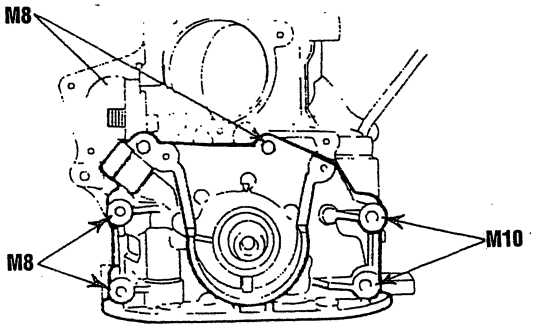
INSTALLING THE OIL PUMP

1. Coat the O-ring with grease and then install it into the oil pump body assembly.
2. Install the tubular dowel pins in place in the oil pump body and apply a continuous bead of sealant around the mating surface of the oil pump. Take care that the sealant does not get into the oil holes.



3. Coat the lip of the oil seal with fresh engine oil. When installing the oil seal, be careful not to damage the lip. Tighten the bolts to the specified torque.

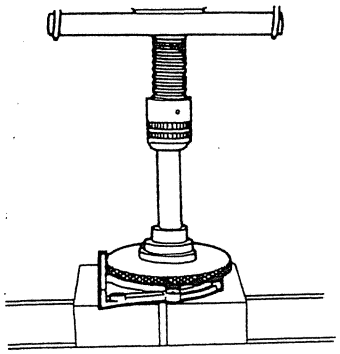
M-10 27-38ft-lb (3.8-5.3m-kg) 52Nm
M-8 14-19ft-lb (1.9-2.6m-kg) 25Nm



INSTALLING THE REAR COVER

1. Press the oil seal into the rear cover.

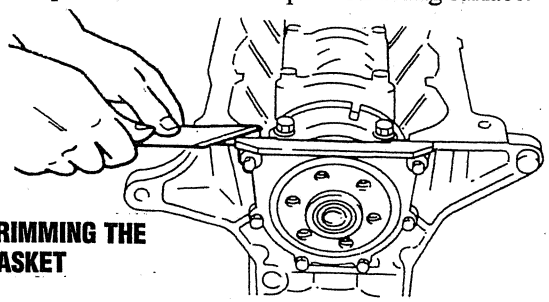
NOTE: *Coat the rear cover and the oil seal contact surfaces with fresh engine oil, then press into place with a pressing tool.*



2. Insert the tubular dowel pin on the cylinder block, and install the rear cover

   TORQUE: 61-87in-lb (7.0-10.0m-kg) 7-10Nm

3. Trim the rear cover gasket to the appropriate size if it protrudes over the oil pan contacting surface.

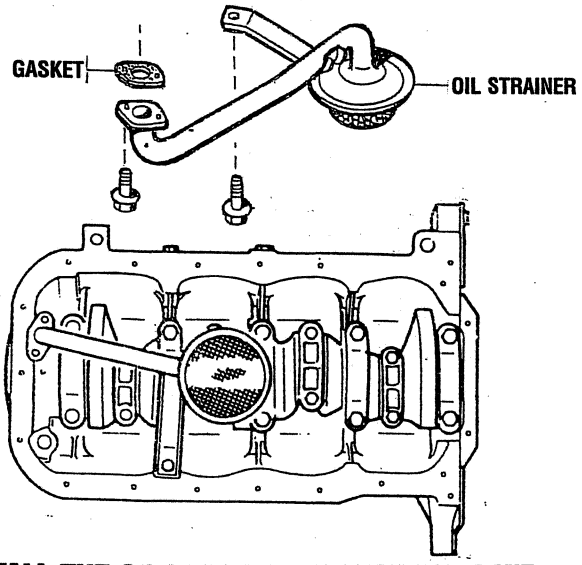


TRIMMING THE GASKET

INSTALL THE OIL STRAINER

1. Bolt the oil strainer in place.

   TORQUE: 69-104in-lb (80-120cm-kg) 8-12Nm



INSTALL THE OIL PAN WITH THE BAFFLE PLATE

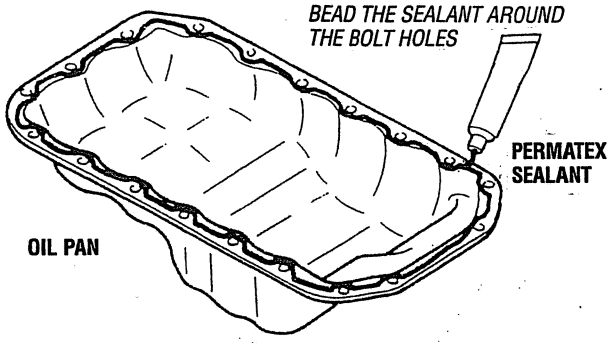
Installation Notes:

- Remove oil and dust from the mating surfaces of the oil pan and cylinder block with a cloth before coating the surfaces with sealant.
- Apply sealant all around the inner edge of the bolt holes **(2-4 mm bead)**.
- Overlap the sealant to ensure that you have covered the entire surface.
- Coat the sealant on either the block, the baffle plate or the oil pan, but not all.

  INSTALL THE BAFFLE PLATE TORQUE TORQUE TO:
  69-100in-lb (80-110cm-kg) 8-10Nm

  Finish tightening the oil pan bolts within 30 minutes after applying sealant.

  TORQUE TO: 61-78in-lb (7.0-10.0cm-kg) 7-10Nm

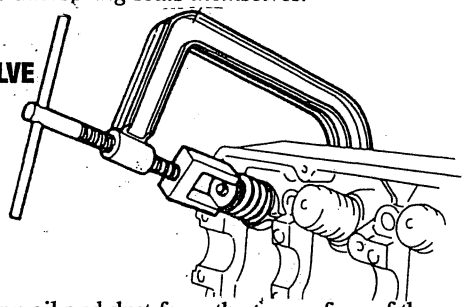


INSTALL THE CYLINDER HEAD

1. Install the valve seals by using the valve seat pusher.
2. Insert the valves into the valve guides.
3. Install the lower valve spring seats, inner and outer valve springs and upper valve spring seats.
4. Use the valve spring lifter and pivot the valve springs and install the retainers.

NOTE: *After installing the valve springs, tap the valve end so that the valve and spring seats themselves.*

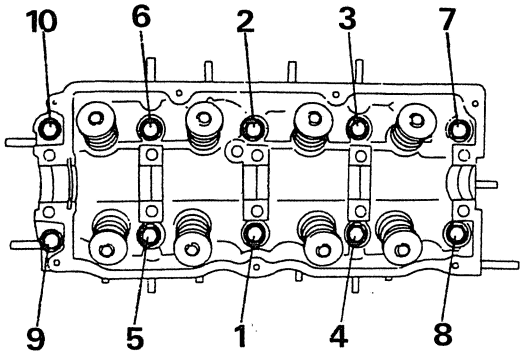
INSTALLING VALVE SPRINGS



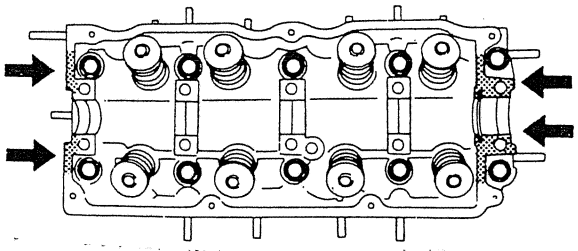
5. Clean any oil and dust from the top surface of the cylinder block.
6. Position a *new* cylinder head gasket and install the cylinder head on the block.

CYLINDER HEAD BOLTS - COLD TORQUE:
59-64ft-lb (8.2-8.8kg-m) 82-88Nm

NOTE: *Tighten the cylinder head bolts gradually in the order shown. Remember to use the newly styled surface treated plain washers.*

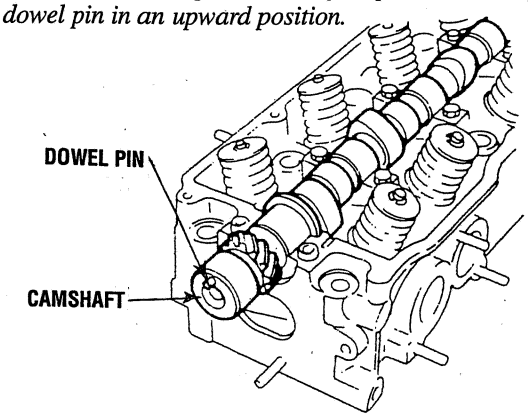


INSTALL THE CAMSHAFT



1. After cleaning the camshaft, coat with a sufficient amount of engine oil.
2. Coat the shaded areas with a thin layer of sealant (Three Bond Seal No. 4 or equivalent). Make sure no sealant runs out of the shaded area.
3. After cleaning the camshaft, gently set it in place.

NOTE: *When setting the camshaft in place, keep the camshaft dowel pin in an upward position.*

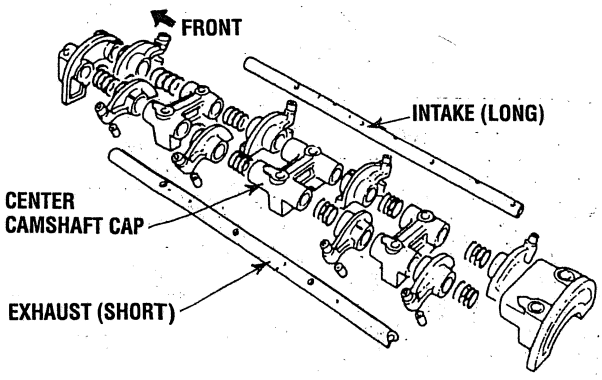


ASSEMBLE THE ROCKER SHAFT

Assemble the rocker arms and camshaft bearing caps as shown.

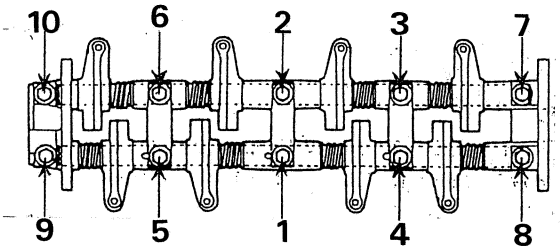
NOTE: *Be sure that the rocker arm shaft oil holes (in the center camshaft cap) face each other.*

NOTE: *Use the installation bolts for alignment.*



Assembly Notes:

- When assembling, coat liberally with engine oil.
- The rocker arms (intake and exhaust-front and rear) are not interchangeable.
- Rocker arms **No. 1** and **No. 3** are the same and **No. 2** and **No. 4** are the same.



Apply a liberal coat of engine oil to the camshaft journals and rotating parts.

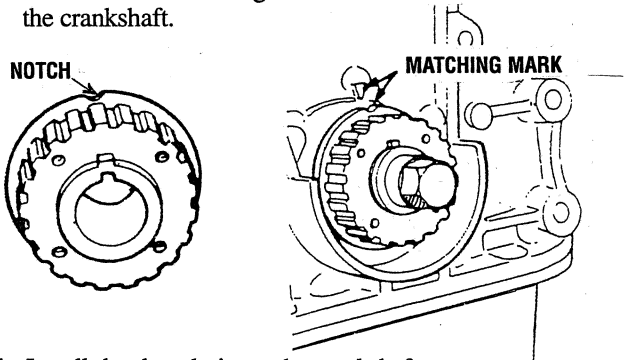
Install the rocker arm and rocker shaft assembly.

BOLT TORQUE: 13-20ft-lb (1.8-2.7m-kg) 18-26Nm

> **⚠ CAUTION:** ***When the rocker arm and rocker shaft assembly is tightened, it must be done evenly and in the same order.***

INSTALL THE CRANKSHAFT TIMING BELT PULLEY

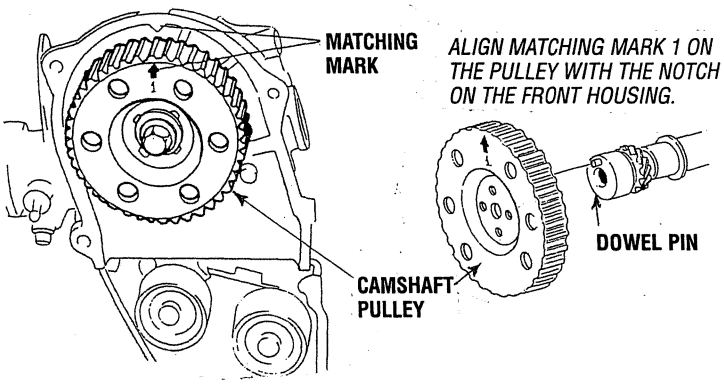
1. Turn the crankshaft so the dowel pin hole faces upward.
2. Prevent the crankshaft from moving by inserting two bolts at the rear of the crankshaft.
3. Place a thin coat of engine oil on the front end of the crankshaft.



4. Install the dowel pin on the crankshaft.
5. Align the notch of the crankshaft timing belt pulley with the mark on the oil pump body.
6. Install the tapered ring and tighten the lock bolt.

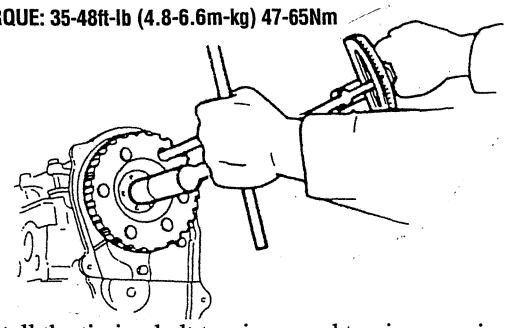
LOCK BOLT TORQUE: 116-123ft-lb (16-17m-kg) 157-167Nm

ENGINE ASSEMBLY



1. Install the camshaft pulley washer and lock bolt. Prevent the pulley from turning and tighten the lockbolt to the specified torque.

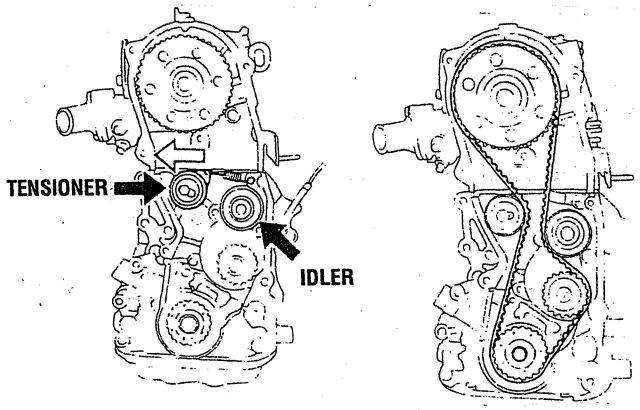
TORQUE: 35-48ft-lb (4.8-6.6m-kg) 47-65Nm



2. Install the timing belt tensioner and tensioner spring.
3. Install the timing belt.

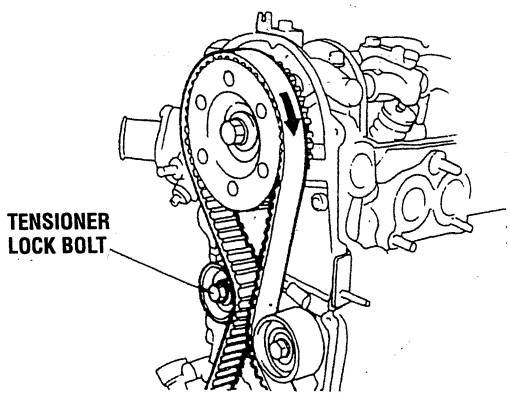
TORQUE: 27-38ft-lb (3.8-5.3m-kg) 37-52Nm

4. Position the tensioner all the way to the intake side, and temporarily secure it by tightening the lock bolt.



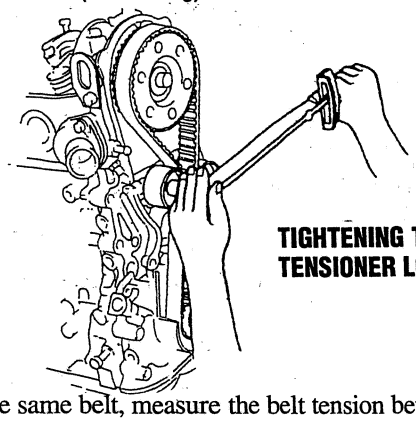
INSTALLING THE TIMING BELT

- *Be sure the timing belt is installed the correct direction as indicated on the timing belt.*
- *Be sure no looseness is evident at the belt tension side.*
- *Be sure no grease or dirt is on the timing belt surface.*



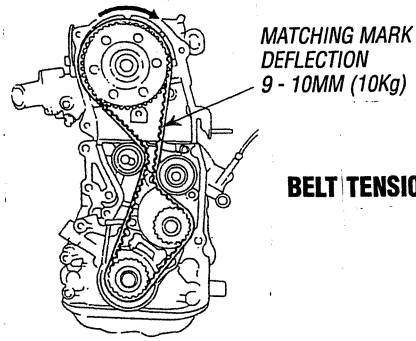
1. Loosen the timing belt tensioner lock bolt and apply spring tension to the belt.
2. Turn the crankshaft timing belt pulley two complete revolutions clockwise and then align the pulley at the **"TOP"** mark and tighten the tensioner lock bolt at the specified torque.

TORQUE: 27-38ft-lb (3.8-5.3m-kg) 39-52Nm



TIGHTENING THE TENSIONER LOCK BOLT

If re-using the same belt, measure the belt tension between the crankshaft pulley and the camshaft pulley. repeat steps if the belt tension is not within specified range.



BELT TENSION

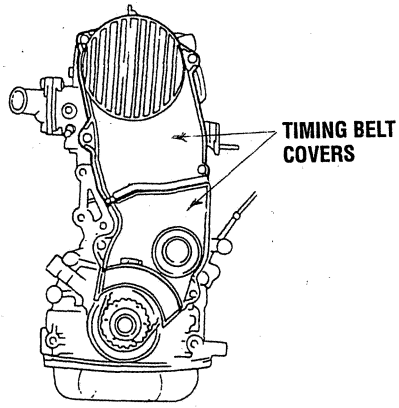
INSTALL THE TIMING BELT COVERS

1. Set the gasket in place and assemble the lower timing belt cover. Tighten the bolts to the specified torque.

TORQUE: 61-87in-lb (70-100cm-k) 7-10Nm

2. Install the lower and upper timing belt gaskets and covers.

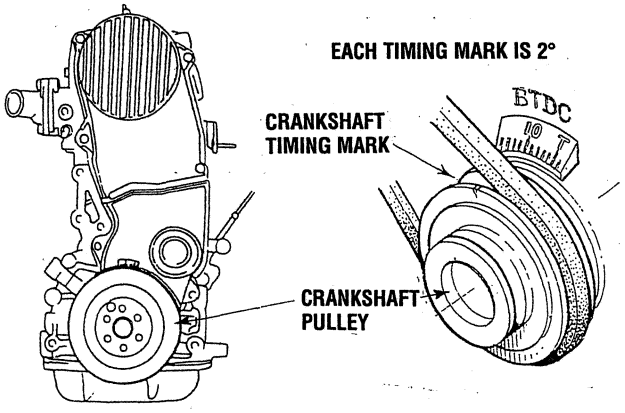
TORQUE: 61-87in-lb (70-100cm-kg) 7-10Nm



Install the crankshaft pulley by aligning the top of the timing indicator plate with the top mark, left one or two on the crankshaft pulley and tighten the six bolts.

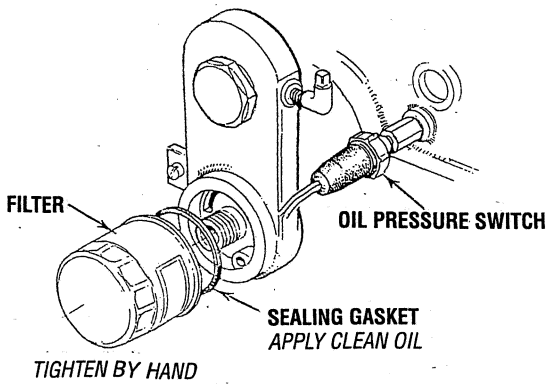
NOTE: *Make certain to use the plain washers to prevent the crankshaft from rotating.*

BOLT TORQUE: 104-148in-lb (1.2-1.7m-kg) 12-17Nm



4. Install the oil pressure switch using sealing tape on the threads.

TORQUE: 104-156in-lb (1.2-1.8m-kg) 12-18Nm

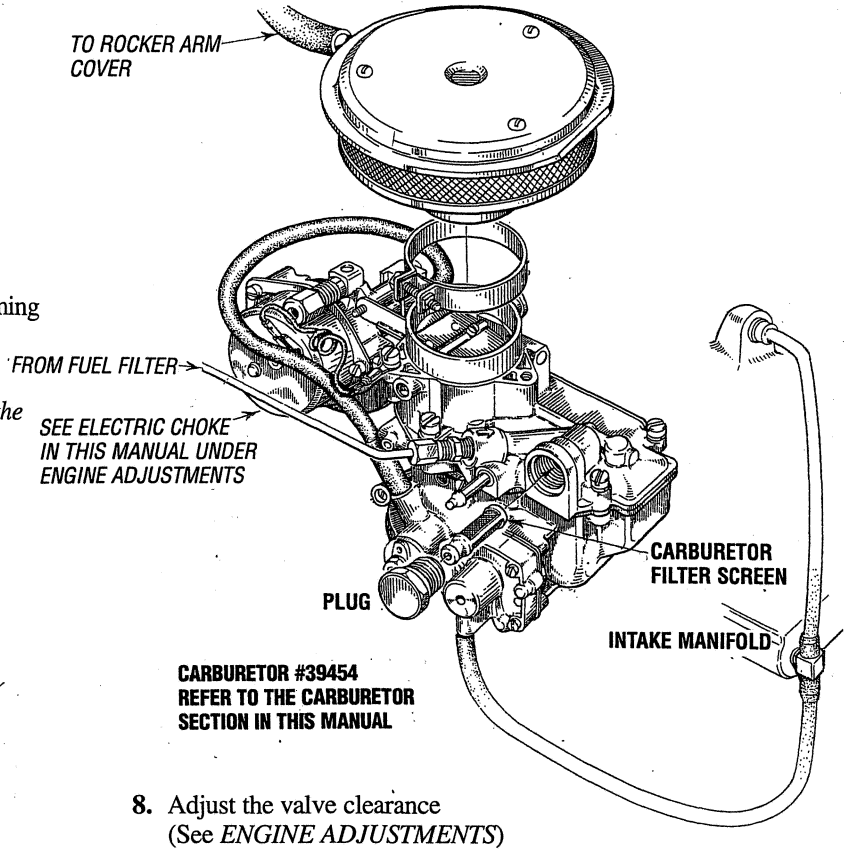


5. Install the oil cooler and oil filter.
6. Install the exhaust manifold, set the new gasket in place and tighten the exhaust manifold to the proper torque.

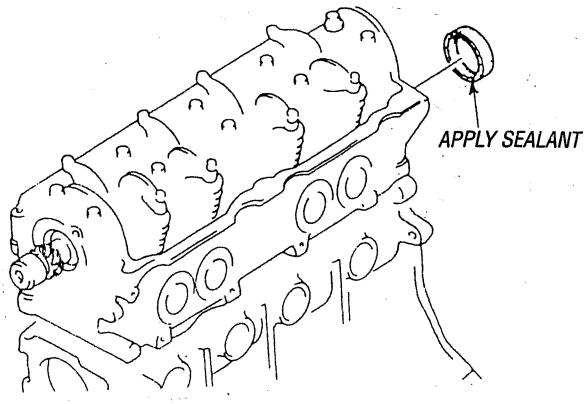
TORQUE: 16-21ft-lb (2.2-2.9m-kg) 22-28Nm

7. Install the intake manifold and carburetor.

TORQUE: 14-19ft-lb (1.9-2.6m-kg) 19-25Nm



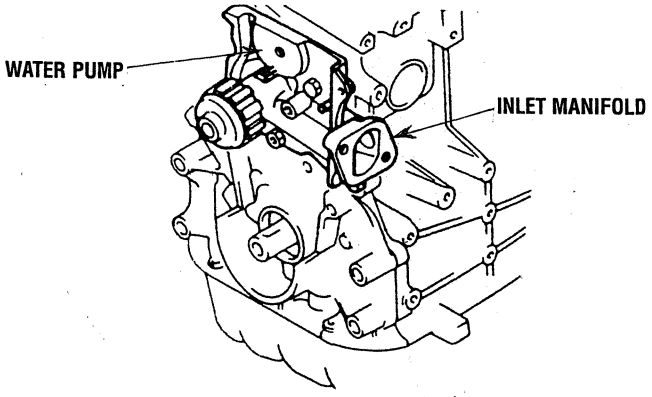
8. Adjust the valve clearance (See *ENGINE ADJUSTMENTS*)
9. Install the sealing cap. Applying a coat of sealant to the seal cap and install the seal cap into the cylinder head.



ENGINE ASSEMBLY

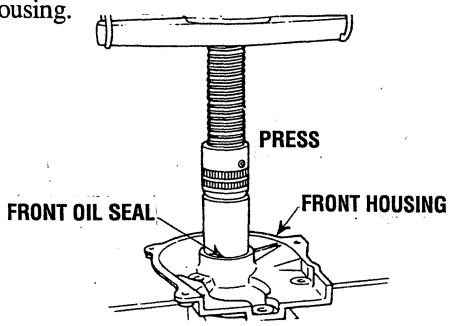
INSTALL THE WATER PUMP

1. Set the gasket in place and install the water pump assembly. Tighten the water pump bolts.
   TORQUE: 14-19ft-lb (1.9-2.6m-kg) 19-25Nm
2. Install the inlet manifold.
3. Set the gasket in place and tighten the manifold nuts.
   TORQUE: 14-22ft-lb (1.9-3.1kg-cm) 14-31Nm

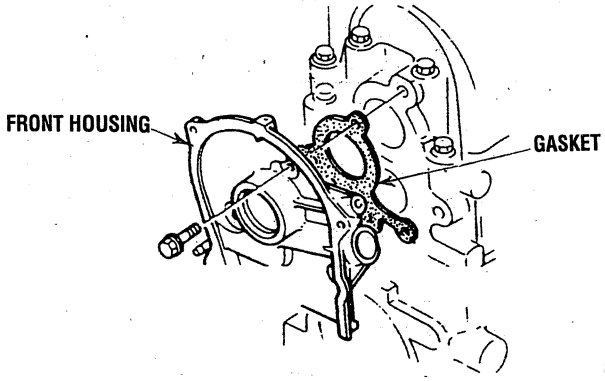


INSTALL THE FRONT HOUSING ASSEMBLY

1. Apply a thin coat of engine oil to the camshaft oil seal front housing and press the oil seal into the front housing.

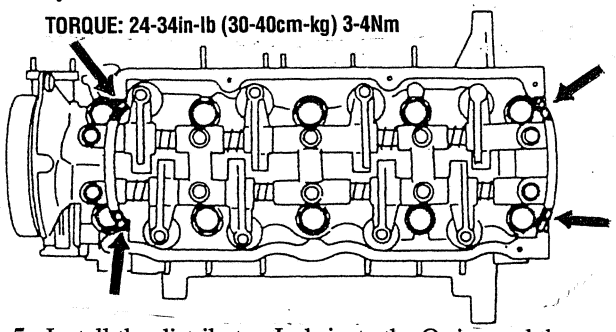


2. Set the front housing gasket in place on the engine. Coat the oil seal with fresh engine oil and install the front housing using a new gasket.
   TORQUE: 14-19ft-lb (1.9-2.6kg-cm) 19-25Nm

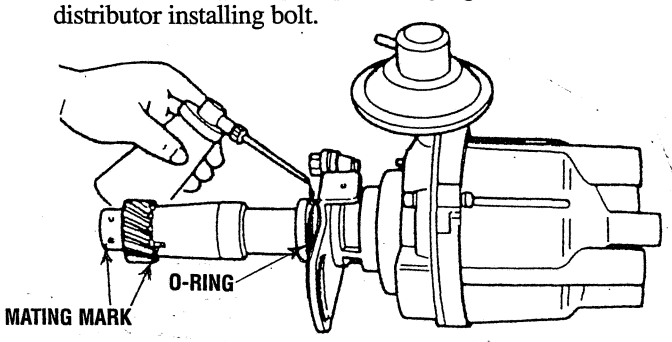


INSTALL THE REMAINING ENGINE COMPONENTS

1. Install the thermostat housing and thermostat.
2. Install the fuel lift pump.
3. Install the cylinder head cover.
4. Apply a coat of sealant to the shaded areas, install the cylinder head cover.
   TORQUE: 24-34in-lb (30-40cm-kg) 3-4Nm



5. Install the distributor. Lubricate the O-ring and the drive gear with engine oil and install it on the distributor. Match the distributor housing and drive gear mating marks. Install the distributor in the front housing with the marks facing straight up. Loosely tighten the distributor installing bolt.



6. Install the spark plugs and connect the high-tension leads.
   SPARK PLUG TORQUE: 11-17ft-lb (1.5-2.3m-kg) 15-23Nm
   SPARK PLUG GAP: ±0.0002in (0.8-0.05mm)

NOTE: *Loctite Anti-Seize applied to the threaded portion of the spark plugs will retard corrosion, making future removal of the spark plugs easier.*

7. Install the alternator bracket.
   TORQUE: 25-3ft-in (3.8-5.3m-Kg) 38-53Nm
8. Install the alternator.
   FLANGE BOLT TORQUE: 13-20ft-lb (1.9-3.1m-kg) 19-31Nm
9. Mount the heat exchanger and install the coolant hoses.

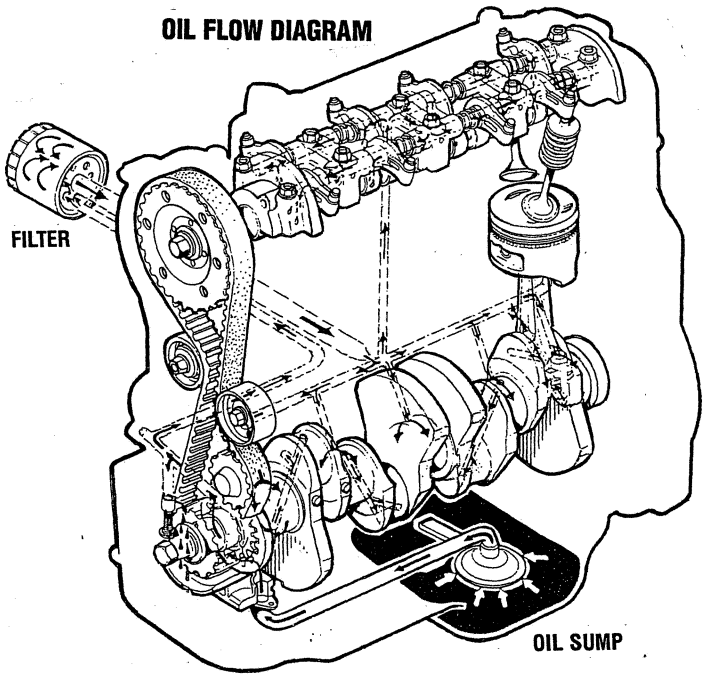
NOTE: *Refer to HEAT EXCHANGER SERVICE in this manual.*

10. Install the starter motor.
11. Install the remaining hoses and carefully attach the wiring harness to the pre-marked terminals.

LUBRICATING SYSTEM

DESCRIPTION

The lubricating system is a pressure feeding system using an oil pump. The engine oil is drawn from the oil sump by the oil pump, which drives the oil, under pressure, through the oil filter and various lubricating points in the engine. The oil then returns to the oil sump to repeat the continuous cycle. When the oil pressure exceeds the specified pressure, the oil pushes open the relief valve in the oil pump and returns to the oil sump, keeping the oil pressure within its specified range.



LUBRICATION TROUBLESHOOTING

OIL LEAKAGE:
- Loose drain plug.
- Faulty seat at oil pan and cylinder block.
- Damaged cylinder head cover.
- Loose oil pump body bolt, cylinder head cover bolt, or oil pan bolt.
- Damaged front housing gasket or cylinder head gasket.
- Faulty oil filter.
- Loose oil filter.
- Loose or damaged oil pressure switch.

OIL PRESSURE DROP:
- Oil leak
- Insufficient oil
- Worn and/or damaged oil pump gear
- Worn Plunger (inside oil pump) or weak spring
- Clogged oil strainer
- Excessive lubrication clearance between main bearing and connecting rod.

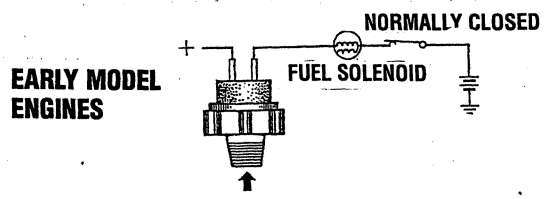
LOW OIL PRESSURE

The specified safe minimum oil pressure is 4.3 + 1.4 psi (0.3 + 0.1 kg/cm²). A gradual loss of oil pressure usually indicates worn bearings. For additional information on low oil pressure readings, see the *ENGINE TROUBLESHOOTING* chart.

OIL PRESSURE SWITCH/SENDER

The generator is fitted with an oil pressure shutdown switch. Should the engine's oil pressure drop below the safe minimum, the switch will shut the engine down to prevent damage by interrupting the DC voltage to the ignition coil.

> ⚠ **CAUTION:** ***Oil Pressure Switch - Do not use lock pliers, vise grips or pipe wrenches on the oil pressure switch. Use the correct socket which is available from Snap-On, Proto, New Britain and others. Damage to the switch will cause oil leaks and/or switch failure.***



TESTING OIL PRESSURE

To test the oil pressure, remove the oil pressure sender, then install a mechanical oil pressure gauge in it's place. After warming up the engine, set the engine speed at 1800 rpm and read the oil pressure gauge.

OIL PRESSURE BETWEEN 43 AND 59 PSI [294 - 392 KPA]

Note: *A newly started (cold) engine may have an oil pressure up to 70 or 80 psi. A warmed engine can have an oil pressure as low as 40 psi. Oil pressure will vary depending on the load placed on the generator.*

LUBRICATING SYSTEM

ENGINE OIL

Use a heavy duty engine oil with an API classification of SJ, SL, or SM. Change the engine oil and filter after an initial 50 hours of break-in operation. Then follow the oil change interval as specified in the **MAINTENANCE SCHEDULE** section of this manual and not be extended if synthetic oils are used.

An oil viscosity of SAE 15W-40 is recommended for this engine in all conditions and all seasons.

Westerbeke Corporation does not approve or disapprove the use of synthetic oils. If synthetic oils are use, engine break-in must be performed using conventional oil. Oil change intervals must be as listed in the **MAINTENANCE SCHEDULE** section of this manual and not be extended if synthetic oils are used.

NOTE: *The information above supersedes all previous statements regarding synthetic oil.*

CHANGING THE ENGINE OIL

The engine oil should be warm. Remove the oil drain hose from its attachment bracket and lower it into a container and allow the oil to drain, or attach a pump to the end of the drain hose and pump the old oil out. Make sure the oil drain hose is properly secured in its holder after all of the old oil has been drained.

Always observe the old oil as it is removed. A yellow/gray emulsion indicates the presence of water in the oil. Although this condition is rare, it does require prompt attention to prevent serious damage. Call a competent mechanic if water is present in the oil. Raw water present in the oil can be the result of a fault in the exhaust system attached to the engine and/or a siphoning through the raw water cooling circuit into the exhaust, filling into the engine.

> ⚠ **WARNING:** ***Used engine oil contains harmful contaminants. Avoid prolonged skin contact. Clean skin and nails thoroughly using soap and water. Launder or discard clothing or rags containing used oil. Discard used oil properly.***

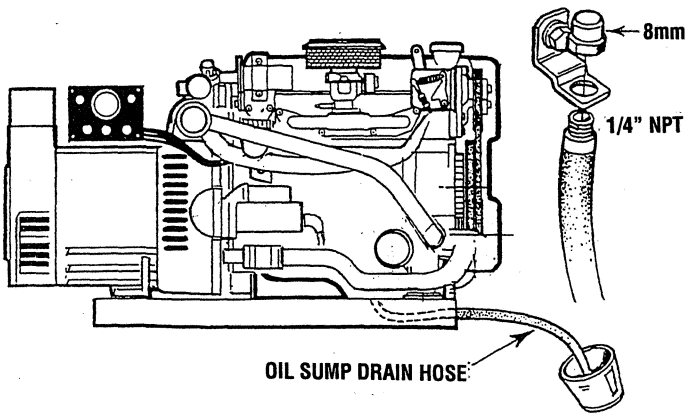
REPLACING THE OIL FILTER

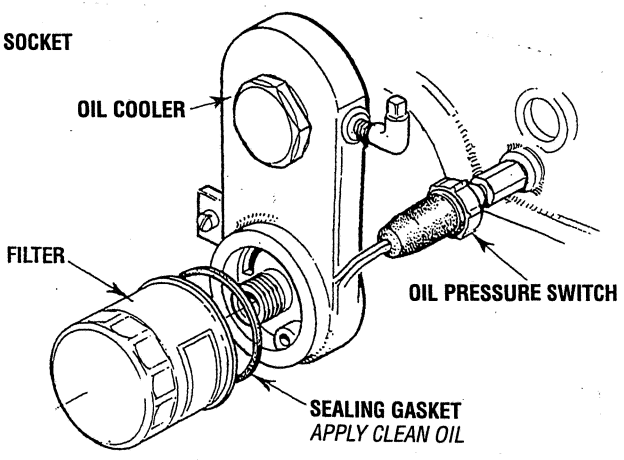
When removing the used oil filter, you may find it helpful to punch a hole in the upper and lower portion of the old filter to drain the oil into a container before removing it. This helps to lessen spillage. An automotive filter wrench should be helpful in removing the old oil filter. Place some paper towels and a plastic bag around the filter when unscrewing it to catch any oil that's in the filter. Inspect the old oil filter as it is removed to make sure that the rubber sealing gasket comes off with the old oil filter. If this rubber sealing gasket remains sealed against the oil filter adapter, gently remove it. When installing the new oil filter element, wipe the filter gasket's sealing surface on the oil filter adapter free of oil and apply a thin coat of clean engine oil to the rubber sealing gasket on the oil filter. Screw the filter onto the threaded oil filter stub, and tighten the filter firmly by hand.

NOTE: *Use genuine WESTERBEKE oil filters. Generic filters are not recommended.*

REFILLING THE OIL SUMP

Add fresh oil through the valve cover. After refilling the oil, run the engine for a few moments while checking the engine's oil pressure. Make sure there is no leakage around the new oil filter or from the oil drain system, and then stop the engine. Then check the quantity of oil with the lube oil dipstick. Fill to, but not over, the FULL mark on the dipstick.





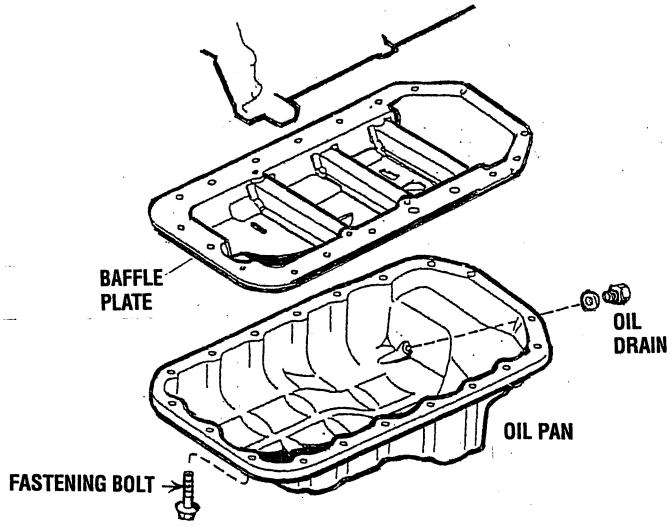
TIGHTEN BY HAND

REMOVAL INSPECTION AND INSTALLATION OF OIL PAN/OIL PUMPS

1. Disconnect the negative battery cable.
2. Drain the engine oil into a suitable container.
3. Remove the parts in the numbered sequence shown.
4. Install in the reverse order of removal.

Removing Oil Pan

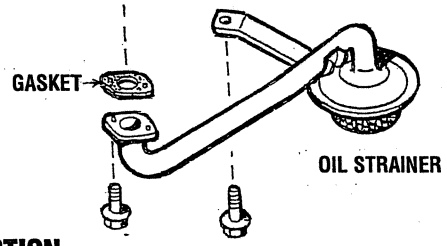
Insert a flat-tipped screwdriver between the oil pan and the baffle plate to separate.



Stiffener

After removal of the oil pan, remove the oil strainer and the bolts.

Insert a flat-tipped screwdriver between the baffle stiffener and cylinder block to separate.



INSPECTION

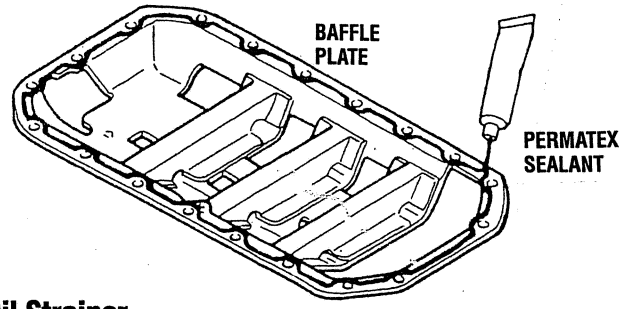
Check for the following problems. Repair or replace if necessary.

1. Cracks, deformation, damage (at bolt locations).
2. Damaged drain plug threads.

INSTALLING THE BAFFLE PLATE

1. Use a rag to remove any dirt or grease from the contact surface.
2. Apply sealant continuously only to the stiffener face **(thickness 2—4 mm (0.08—0.16 in)**, rimming the surface inside the bolt holes with the ends over lapped.
3. Install the stiffener.

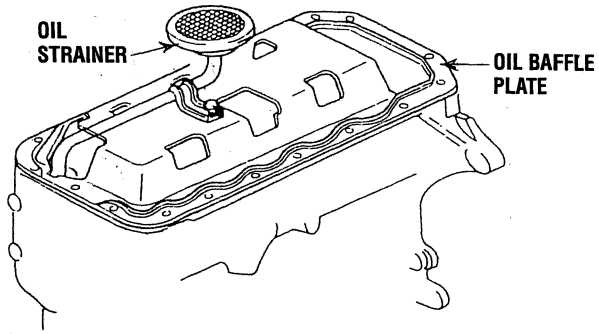
> ⚠ **CAUTION:** ***After the sealant has been applied, the stiffener must be secured within 30 minutes.***



Oil Strainer

Insert the oil strainer with a new gasket.

TIGHTENING TORQUE:
8—12Nm (80—120 CM-KG, 69—104 IN-LB)

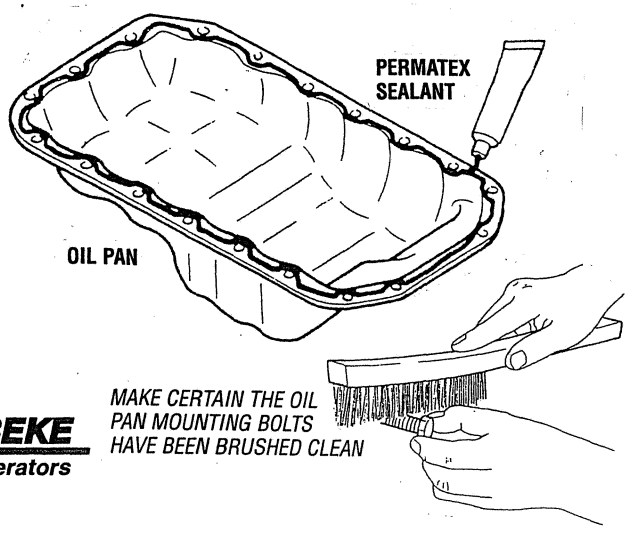


Oil Pan

1. Remove any dirt or grease from the contact surface.
2. Apply sealant continuously only to the oil pan **(thickness 2—4 mm (0.08—0.16 in)**, rimming the surface inside the bolt holes with the ends over-lapped.
3. Install the oil pan.

TIGHTENING TORQUE:
7—12Nm (70—120 CM-KG, 61—104 IN-LB)

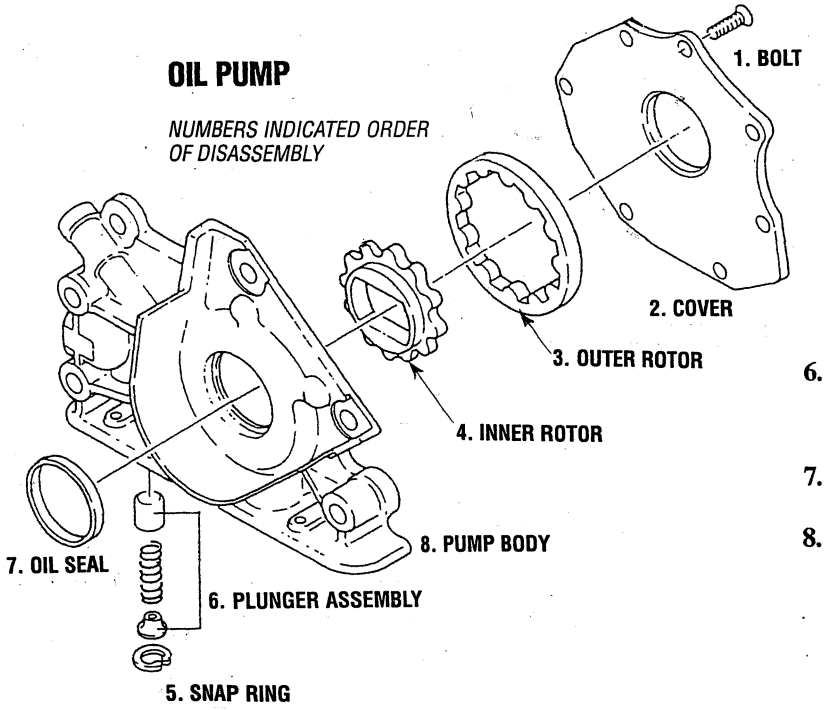
> ⚠ **CAUTION:** ***After the sealant has been applied, the pan must be secured within 30 minutes.***



LUBRICATION SYSTEM

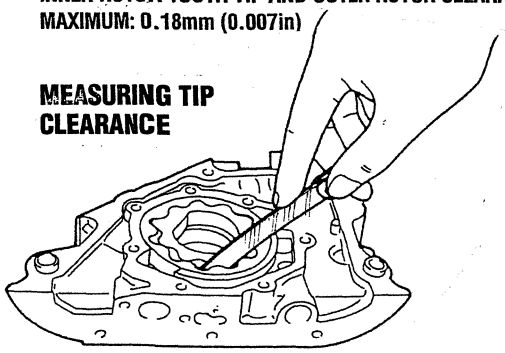
OIL PUMP

NUMBERS INDICATED ORDER OF DISASSEMBLY



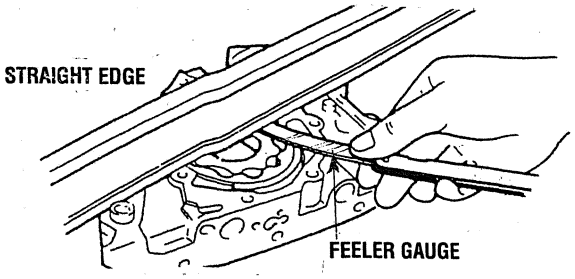
OIL PUMP INSPECTION

1. Check for distortion or damage to the pump body or cover.
2. Inspect for wear or damage to the plunger.
3. Inspect for weak or broken plunger spring.
   PLUNGER FREE LENGTH: STANDARD VALUE 46.4mm
4. Measure the tip clearance.
   INNER ROTOR TOOTH TIP AND OUTER ROTOR CLEARANCE
   MAXIMUM: 0.18mm (0.007in)

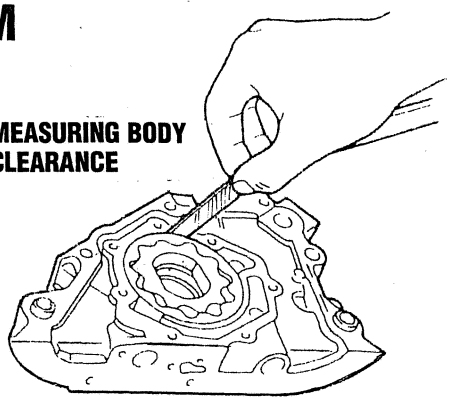


MEASURING TIP CLEARANCE

5. Measure the side clearance.
   SIDE CLEARANCE MAXIMUM: 0.10mm (0.004in)



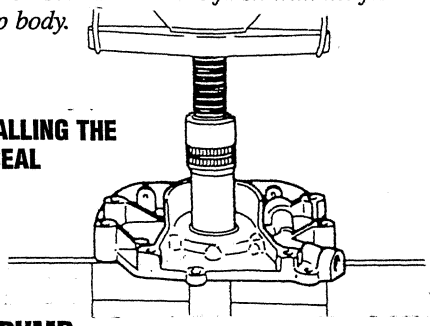
MEASURING SIDE CLEARANCE



MEASURING BODY CLEARANCE

6. Measure the body clearance.
   OUTER ROTOR TO PUMP BODY CLEARANCE
   MAXIMUM: 0.20mm (0.008in)
7. Repair or replace if necessary.
8. Inspect for damage or wear to the oil seal. If necessary, replace it.
   a. Remove the oil seal by using a screwdriver or similar tool to pry it out.
   b. Press in the new oil seal by using a pipe or round rod with an outer diameter of 45mm (1.77in).

NOTE: *Press the oil seal in until it is flush with the front end of the pump body.*

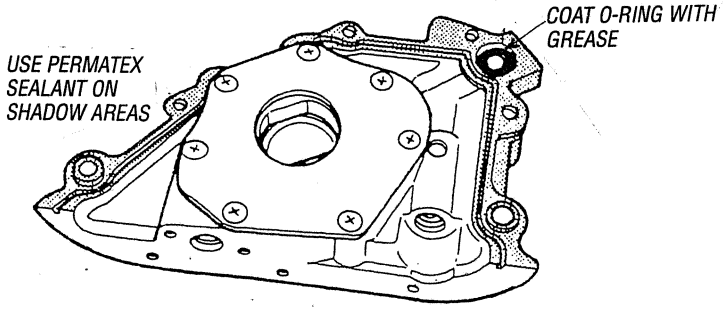


INSTALLING THE OIL SEAL

INSTALLING OIL PUMP

1. Apply a thin coat of grease to the O-ring and install it at the position shown below.
2. Apply a coat of sealant to the oil pump installation surface, indicated by shading.

   NOTE: *Be careful not to let sealant get into the oil hole.*
3. Coat the oil seal lip with engine oil and install the seal. Be careful not to damage the lip.
4. Install the oil pump.

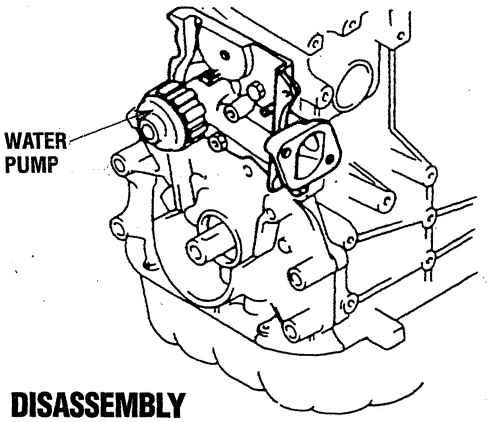


COOLING SYSTEM

COOLING TROUBLESHOOTING

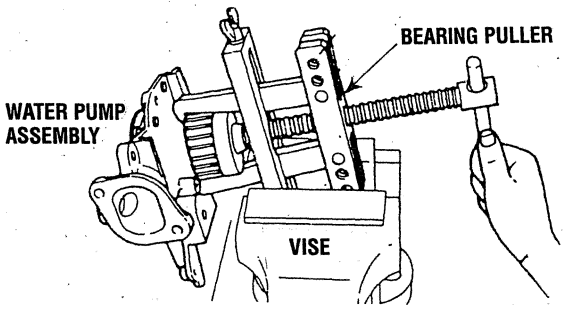
COOLANT LEAKAGE:	Failed Heat Exchanger
	Leakage from coolant hoses or heater hoses
	Leakage from water temperature switch
	Malfunction of water seal (water pump)
	Damaged or loose thermostat cover or gasket
	Loose cylinder head bolt
	Damaged cylinder head gasket
	Cracked cylinder block
CORROSION	Impurities in coolant
OVERHEATING	Water passage clogged
	Thermostat malfunction
	Blockage in heat exchanger
	Water pump malfunction
	Insufficient coolant
	Radiator cap malfunction

ENGINE WATER COOLANT PUMP

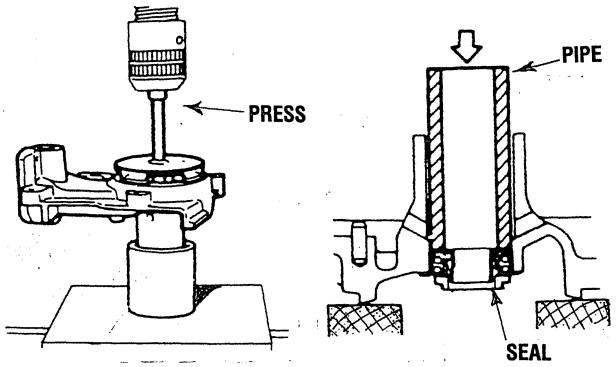


DISASSEMBLY

1. Remove the water pump from the engine as a unit by removing the belts.
2. With the pump on a bench, use a bearing puller as shown to remove the pulley.



3. Set the pulley on a support block and press the impeller off using a press and an iron rod between the press and the shaft.
4. Press the shaft and bearing assembly off using the press with the iron rod set between the assembly and the press.

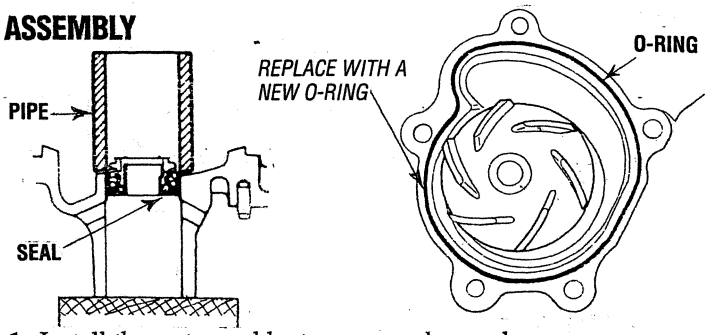


5. Use a pipe to remove the water seal.

INSPECTION

- Inspect the pump pulley and replace it with a new one if there is any damage to the timing belt grooves.
- Check the water pump body for cranking.
- Check the shaft/bearing it should rotate easily without any abnormal noise.
- Inspect for wear in areas where the impeller contacts the seal. Replace the seal if needed.

ASSEMBLY



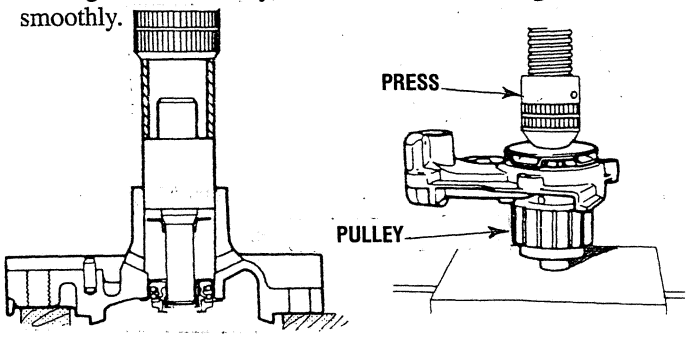
1. Install the water seal by tapping as shown above.

   NOTE: *Make certain the seal is not cracked. Take care not to damage the seal.*

2. Coat the seal with coolant.

   NOTE: *Replace the shaft and bearing as as assembly.*

3. Use a press to push the shaft and bearing assembly into place. Press with the pipe on the outer race of the bearing. After assembly, make certain the bearing turns smoothly.



4. Push the pump pulley into place using a press.
5. Press the impeller in so that it is flush with the end of the shaft.

RAW WATER PUMP

NOTE: *Since completely rebuilding a damaged or worn pump from individually purchased parts would almost match the price of a new pump, Westerbeke recommends that a new pump be purchased.*

Before disassembling the raw water pump, inspect the pump by rotating the drive shaft. If it is rough, frozen, or seems to have excessive play, a major overhaul may be needed.

Disassembly

The pump, as removed from the engine, will have hose attachment nipples threaded into its inlet and outlet ports. The nipples may be left in place or removed if they interfere with the pump disassembly. Note the port location and positioning if removed.

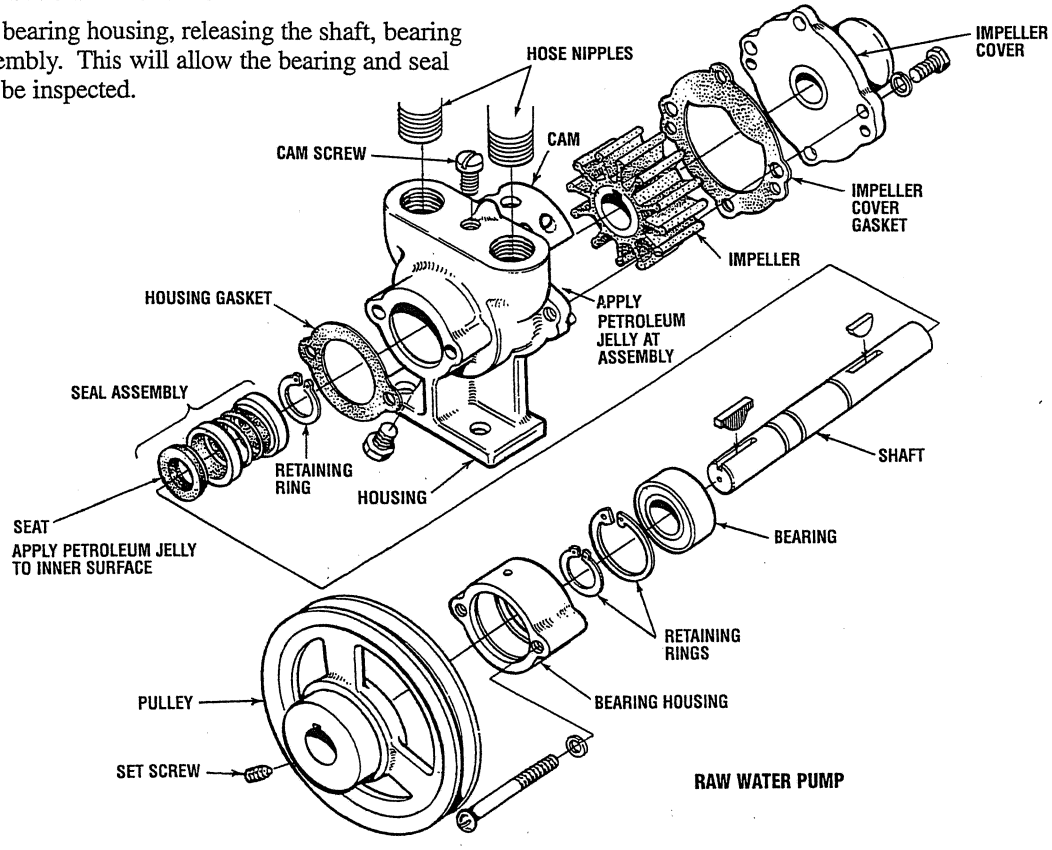
1. Loosen the set screw with an allen wrench and remove the water pump pulley from the shaft, taking care not to lose the key.
2. Remove the four impeller cover screws, the impeller cover and its gasket.

   NOTE: *Replacement of the impeller cover gasket is recommended, however, if you are going to reuse it, keep the gasket well lubricated until the pump is reassembled. If it's allowed to dry, the gasket will shrink and not be reusable.*
3. Pull out the impeller with long-nose pliers or a pair of screwdrivers.
4. Remove the cam screw and cam.
5. Remove the bearing housing, releasing the shaft, bearing and seal assembly. This will allow the bearing and seal assembly to be inspected.

   NOTE: *It may be necessary to use a drift and arbor press to press the bearing and seal assembly from the shaft.*
6. Inspect all parts and replace those showing wear or erosion.

> **⚠ CAUTION:** ***If any of the vanes have been broken off the impeller, they must be found to prevent blockage in the cooling circuit. They often can be found in the heat exchanger.***

7. Use the illustration to assist in reassembling the raw water pump.
   a. Apply a small amount of petroleum jelly to the seat's surface and to the impeller shaft at reassembly.
   b. When positioning the cam in the housing, use a small amount of Permatex #1 on the inner cam surface and cam screw head; remove any excess from the impeller housing.
   c. Apply a light film of silicon or petroleum jelly to the inner surface of the housing for the impeller.
   d. Apply a thin coating of lubricant to the impeller cover gasket.
8. When the pump is assembled, reposition and tighten the hose nipples into the pump housing; use Teflon sealant on the nipple thread. Assemble the pump to the engine and attach the hoses and the belt.



RAW WATER PUMP

FUEL SYSTEM

GASOLINE

> **⚠ CAUTION:** ***Only use unleaded fuel with an Octane rating of 89 of higher. Leaded fuels will cause harm to your engine and must not be used and can void the warranty.***
> ***The use of fuels with an Octane rating lower than 89 can adversely affect ther performance of the drive engine and AC/Amperage output of the AC generator.***

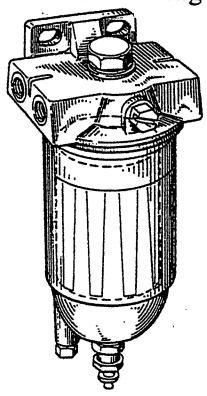
> **⚠ CAUTION:** ***Fuels containing up to 10% Ethanol are considered acceptable for use. Fuels containing higher levels of Ethanol are not acceptable for use, and the use of fuels containing Ethanol higher than 10% can void the warranty.***

GASOLINE/WATER SEPARATOR AND FILTER

A primary fuel filter of the water separating type must be installed between the fuel tank and the engine to remove water and other contaminants from the fuel before they can be carried to the fuel system on the engine.

Most installers include a type of filter/water separator with the generator installation package as they are well aware of the problems that contaminants in the fuel can cause.

These gasoline filters must have *metal* bowls (not "see-through") to meet U.S. Coast Guard requirements. The metal bowls have drain valves to use when checking for water and impurities.



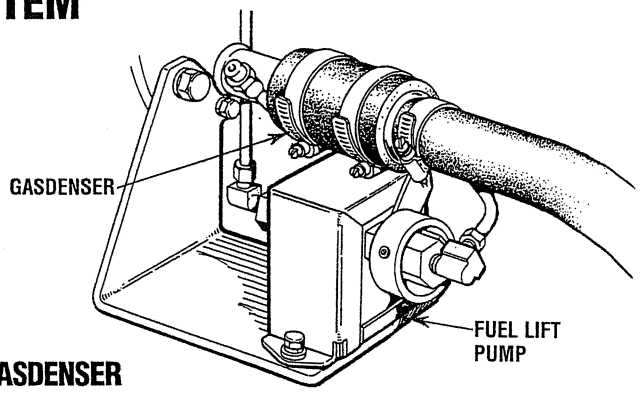
GASOLINE/WATER SEPERATOR & FILTER

FUEL LIFT PUMP

Periodically check the fuel connections to and out of the pump and make sure that no leakeage is present and that the fittings are tight and secure. The DC ground connection at one of the pump's mounting bolts should be clean and well secured by the mounting bolt to ensure proper pump operation.

The engine mounted fuel lift pump is maintenance free.

> **⚠ WARNING:** ***Fuel leakage at the fuel pump or its connections is a fire hazard and should be corrected. Make sure proper ventilation exists whenever servicing fuel system components.***



GASDENSER

The gasdenser consists of a portion of the fuel line that is coiled around the raw water intake line and insulated. It is located between the raw water intake and the raw water pump. The gasdenser cools the fuel to prevent vapor lock.

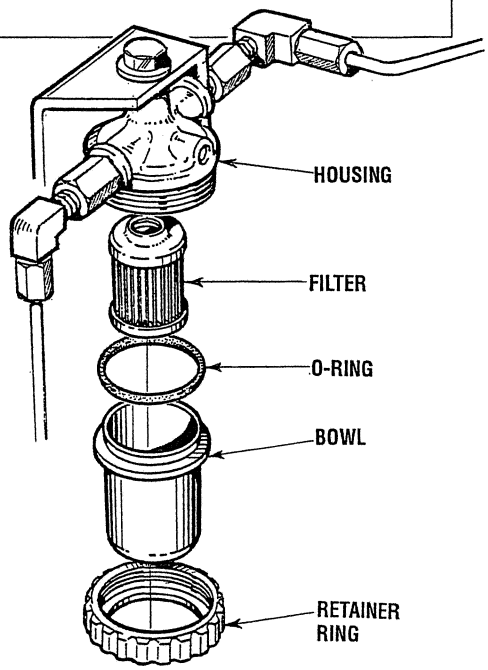
ENGINE FUEL FILTER

Periodically check the fuel connections and the filter bowl for leakage. Change the filter element after the first 50 hours. See *MAINTENACE SCHEDULE.*

Changing the Filter Element

1. Shut off fuel supply.
2. Unscrew the retainer ring that holds the filter bowl to the housing and allow bowl to come away from the housing.
3. Remove and replace the filter element and clean the bowl.
4. Replace the sealing "O" ring and reassemble the bowl to the housing. Thread the retainer ring on carefully so as not to cross thread. When retainer contacts the "O" ring, tighten 1/4 - 1/2 turnes by hand. Open the fuel supply and run the engine to inspect for leaks.

> **⚠ WARNING:** ***Fuel is present in the housing and lines. Use extreme care to prevent spillage.***



EXHAUST MANIFOLD / HEAT EXCHANGER

EXHAUST MANIFOLD

The exhaust manifold, which was disassembled from the cylinder head, should be inspected before reassembly.

1. Remove the exhaust elbows from the lower surface of the manifold. Clean and inspect for cracks and defects. Replace as needed.
2. Remove the exhaust nipples, elbows and plugs from the manifold.
3. Remove water connectors from the ends of the manifold and the end plates. Be sure to note the proper location and arrangement of each for proper alignment.
4. Examine all parts for defects, corrosion and wear and replace as needed.
5. Flush out the manifolds interior with a liquid cleaner and rinse thoroughly with fresh water.
4. Use a pipe cleaner to clear the passage that connects the coolant recovery tank tubing.
5. Flush out the coolant recovery tank and its connecting tube.

ASSEMBLY

1. If the manifold was removed as an assembly and left intact, it can be replaced on the cylinder head in the reverse order of removal.
   Do not reuse the gaskets; install new ones.

   If the manifold has been disassembled, follow the steps below:

   a. Loosely attach the elbows to the cylinder head and the manifold using new gaskets. Do not use any gasket sealant on these gaskets.

   b. Gradually tighten each fitting to make sure of proper alignment of all the parts. This should be done in three steps.

   BOLT TORQUE 12 - 17 ft-lb (1.6 - 2.4 m-kg) 16 - 24 Nm

   Reinstall the exhaust connections and plugs into the manifold using Loctite Anti-Seize on the threads.

   Check the manifold pressure cap. Open the valve by pulling it and make sure it closes when released. Make certain the upper and lower seals are in good condition. If any doubt, replace the cap.

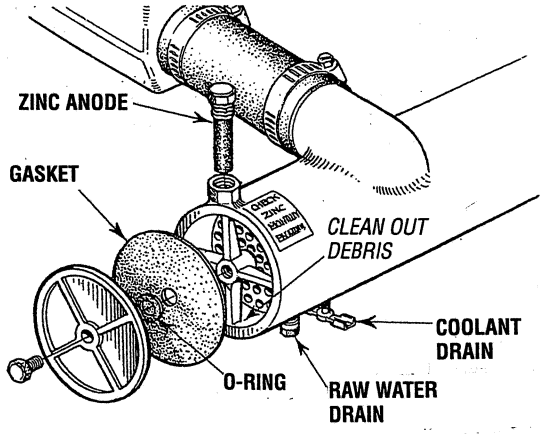
HEAT EXCHANGER

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. Clean out any zinc debris and pressure test the coolant and raw water passages.
4. When reassembling, install new gaskets and O-rings. Apply some lubricant to the new gaskets and to the petcocks and fittings as you install them.
5. Install a new zinc anode.

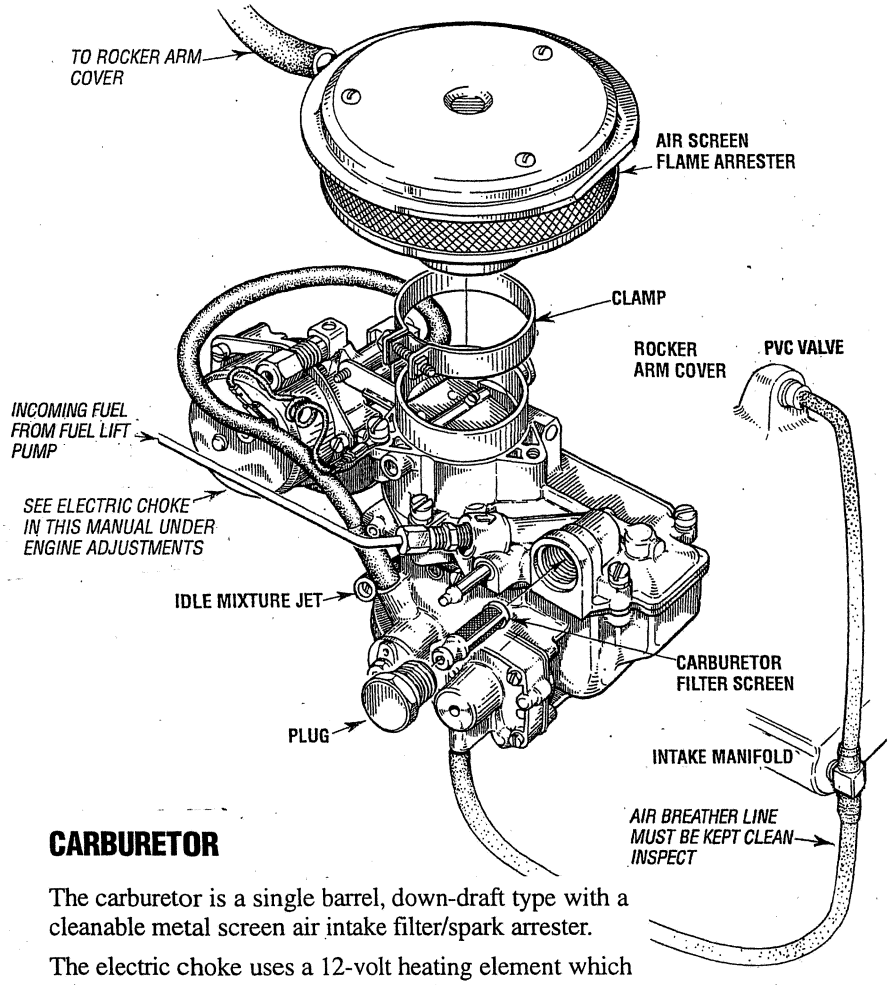
   NOTE: *The threads of the zinc anodes are pipe threads and do not require sealant. Sealant should not be used as it may insulate the zinc from the metal of the heat exchanger housing preventing electrolysis action on the zinc.*

6. Repaint the assembled heat exchanger with Westerbeke heat resistant spray enamel.



7. Reconnect all hoses, replacing them as needed.
8. Refill the system with coolant as detailed above.
9. Pressure test system and check for leaks.

CARBURETOR BEG #039454



CARBURETOR

The carburetor is a single barrel, down-draft type with a cleanable metal screen air intake filter/spark arrester.

The electric choke uses a 12-volt heating element which opens the choke automatically once the engine starts and remains running. Some hunting will occur when the generator is started, is on choke, and is running without a load on the generator. (The choke is factory set).

Air Screen/Flame Arrester

The air screen/flame arrester can easily be removed by releasing the hold-down clamp. Clean after the first 50 hours of operation, every 100 hours from then on. Clean the air screen in a water soluble cleaner such as GUNK.

Carburetor Filter Screen

Clean this filter element after the first 50 hours of operation, then clean and inspect every 250 operating hours. Replace the screen if necessary. Tighten the plug and make certain there are no leaks.

Idle Mixture Jet

Adjustment is performed with the generator operating. Screw the jet slowly in until it seats, then back it out 1-1/2 to 2 turns.

Note: *An idle mixture jet adjusted too far off its seat can induce a sooty exhaust discharge at engine start-up and shut-down.*

CARBURETOR REBUILDING KIT

Two (2) copper accelerator pump gaskets.

One (1) throttle shaft valve spring.

One (1) idle mixture screw O-ring.

One (1) choke lever spring.

One (1) rotary throttle shaft valve.

One (1) fuel filter element.

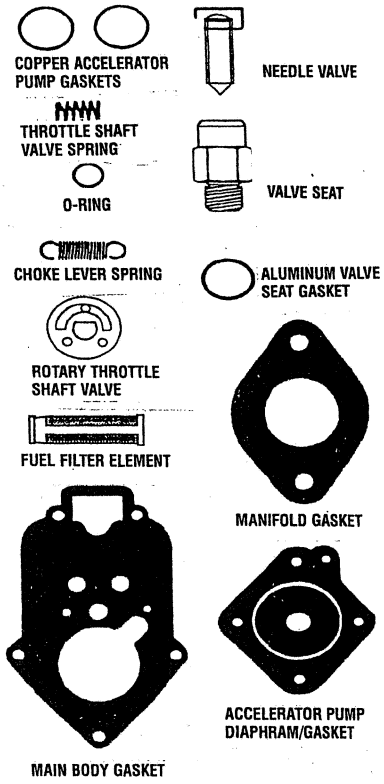
One (1) accelerator pump diaphram/gasket.

One (1) main body gasket.

One (1) manifold gasket.

One (1) needle valve and seat (two pieces to the set).

One (1) aluminum seat gasket.



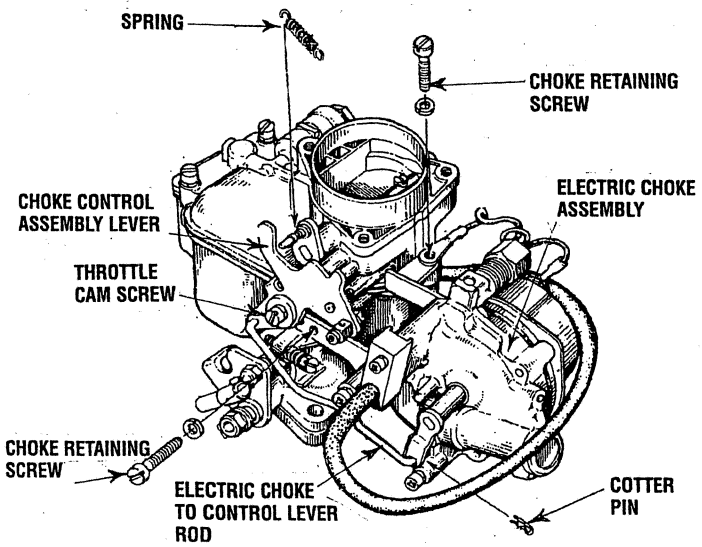
REBUILDING THE CARBURETOR

Use the following step by step instructions to clean and rebuild the model 03945 carburetor.

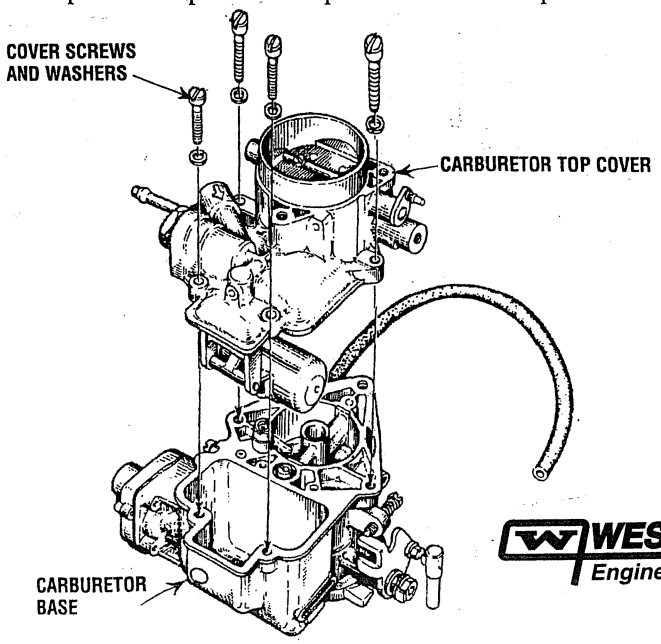
CARBURETOR BEG #039454

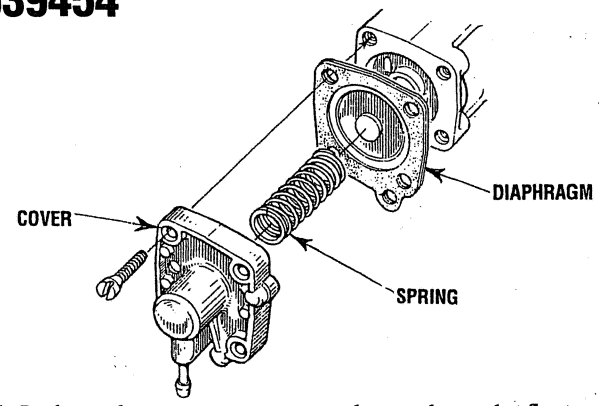
DISASSEMBLY

1. Loosen the flame arrester clamp and remove the flame arrester. Disconnect the electric choke wire, the vacuum hose attached to the manifold, the fuel supply line, and the throttle control linkage.
2. Remove the two nuts holding the carburetor to the manifold and lift the carburetor from the manifold.
3. Disconnect the vacuum hose at one end. Remove the cotter pin from the electric choke to control lever rod and disconnect the electric choke too control lever rod from the electric choke assembly.
4. Remove the two choke assembly retaining screws and their washers. Disconnect the electric choke assembly from the carburetor.

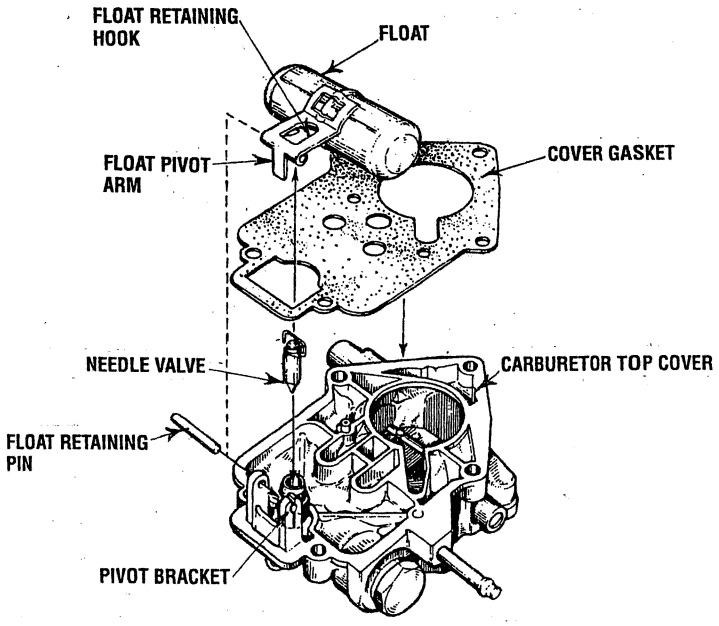


5. Remove the four cover screws and their washers. Lift the carburetor's top cover straight up and away from the carburetor's base. Take off the four screws holding the accelerator housing cover to the side of the carburetor's body. Remove the cover, accelerator diaphram and spring. Inspect the diaphram and replace it if cracked or porous.

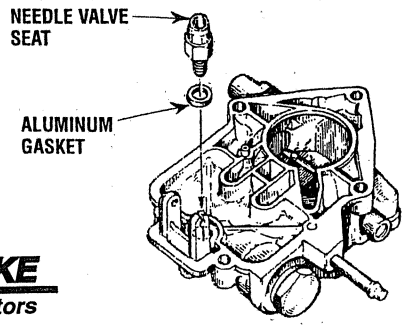




6. In the carburetor top cover, gently punch out the float retaining pin in the opposite direction of the split side of the pivot bracket and remove the float. **Make sure you catch the needle valve that hangs from the float retaining hook under the float's pivot arm and place it aside.**
7. Remove the old cover gasket.
8. Shake the float. If you can hear any sand-like particles moving inside the float, replace it.

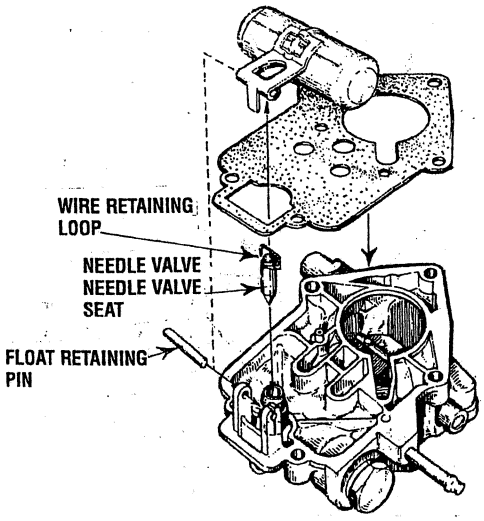


9. Remove the needle valve's seat with a 10 millimeter wrench. Make sure that the seats aluminum gasket is removed at this time. Screw in the new seat along with a new gasket.
10. Place a new carburetor cover gasket on the carburetor top cover. **Do not** use any gasket sealer on this gasket.

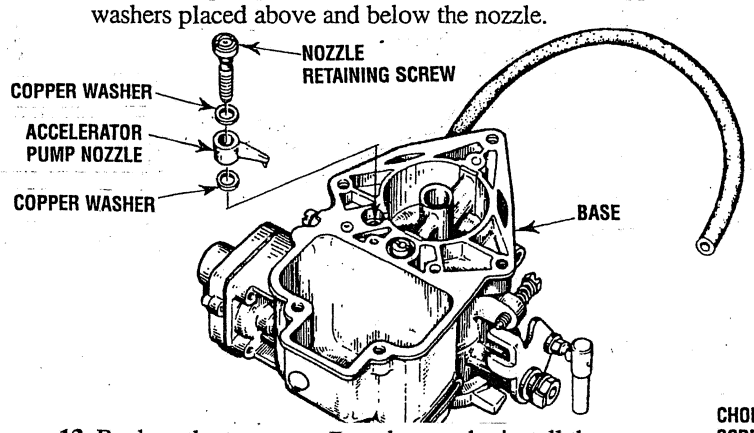


11. Gently place the needle valve in the needle valve seat. Replace the float and float retaining pin so that the needle valve's wire retaining loop hooks onto the float's retaining hook. Now check the float level distance from the housing mating surface with the **housing held vertically**.

DISTANCE –FROM MATING SURFACE: 4.76mm (3/16in)

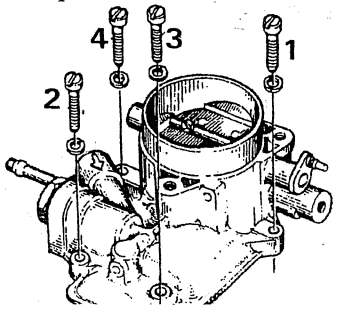


12. On the carburetor base, remove the retaining screw to the accelerator pump nozzle, the nozzle, and the two copper washers placed above and below the nozzle.

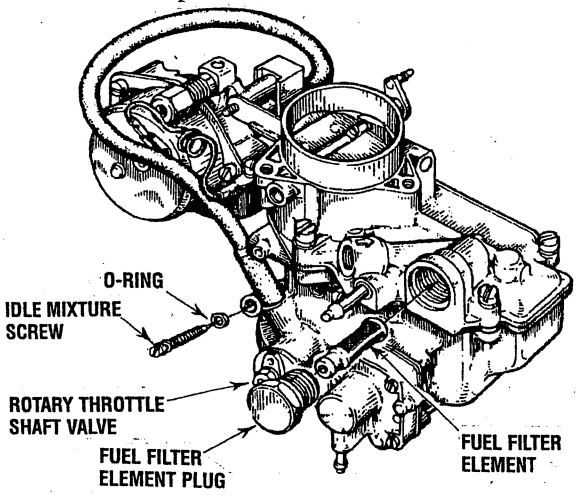


13. Replace the two copper washers and reinstall the accelerator pump nozzle. Snug down the nozzle's retaining screw. **Do not** overtighten the screw, Reinstall the accelerator pump diaphram, spring and housing. Snug down the four retaining screws.

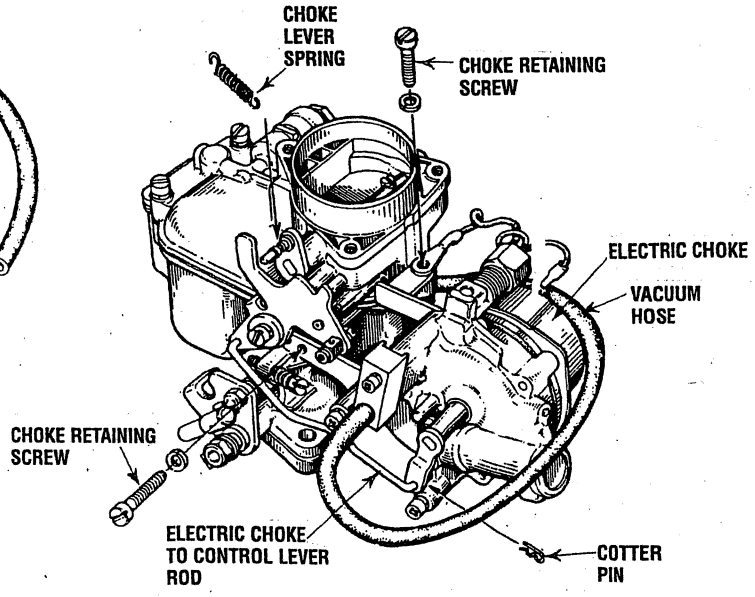
14. Place the carburetor top cover straight down on the carburetor base. Replace the four washers and hand tighten the four cover screws in the indicated order as shown. Snug down each screw. Over tightening these screws can strip the threads in the carburetor.



15. Reconnect the electric choke assembly to the carburetor and replace the two choke assembly retaining screws and their washers. Re-attach the electric choke to control lever rod to the electric choke assembly and insert the cotter pin. Re-attach the vacuum hose.



16. Replace the idle mixture screws O-ring, the rotary throttle shaft valve and the rotary shaft valve spring. remove the fuel filter element plug and replace the fuel filter element.



Now the carburetor is rebuilt. Make sure all the screws on the carburetor are properly tightened and replace the carburetor on the intake manifold using a new manifold gasket along with a gasket sealant. Replace the two nuts and tighten the carburetor to the manifold.

Reconnect the throttle control linkage, the fuel supply line, the vacuum hose, and the electric choke wire. replace the flame arrester on the carburetor and tighten the flame arrester clamp.

CARBURETOR #052563/BEGA MODELS 20/25KW

CARBURETOR

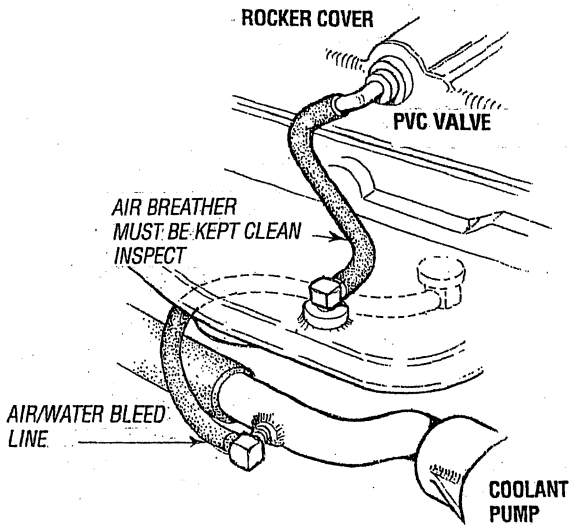
The carburetor is a single barrel, down-draft type with a cleanable metal screen air intake filter/spark arrester. The choke is operated by a 12-volt choke solenoid activated when the ON switch is depressed.

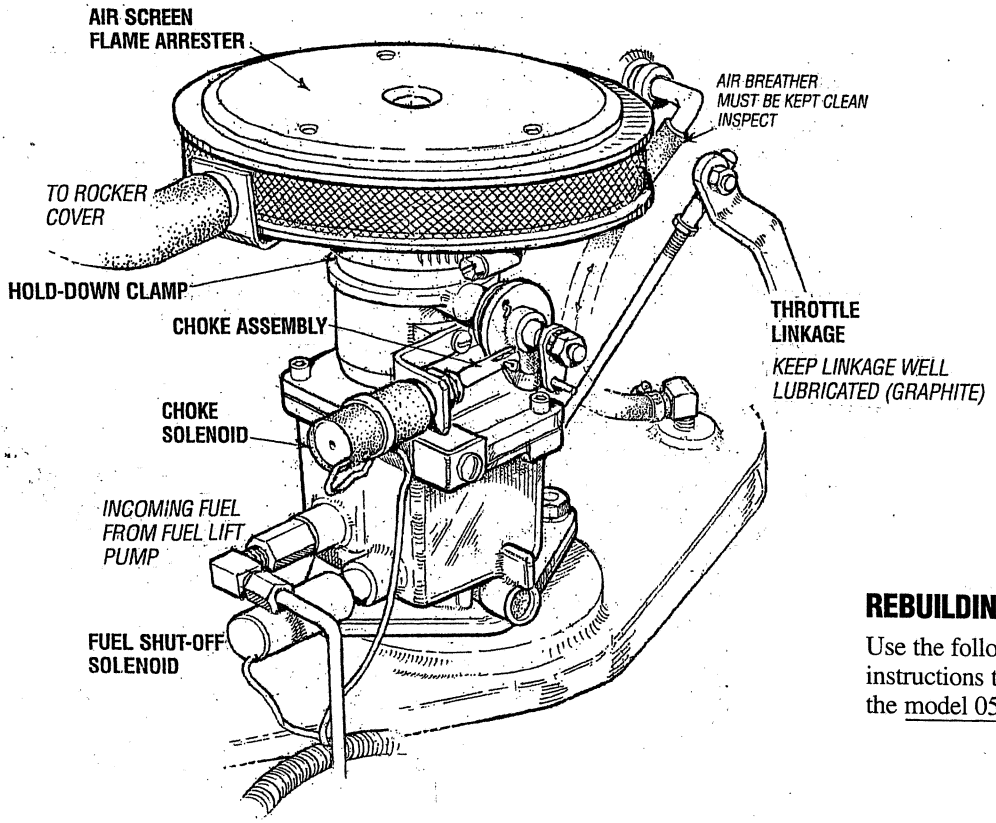
Air Screen/Flame Arrester

The air screen/flame arrester can easily be removed by releasing the hold-down clamp. Clean after the first 50 hours of operation, every 100 hours from then on Clean the air screen in a water soluble cleaner such as GUNK.

Fuel Filter

To ensure proper operation, there must be a Coast Guard approved filter/water seperator (10 microns or less) installed between the fuel supply and the engine. This filter must be of good quality and properly maintained.

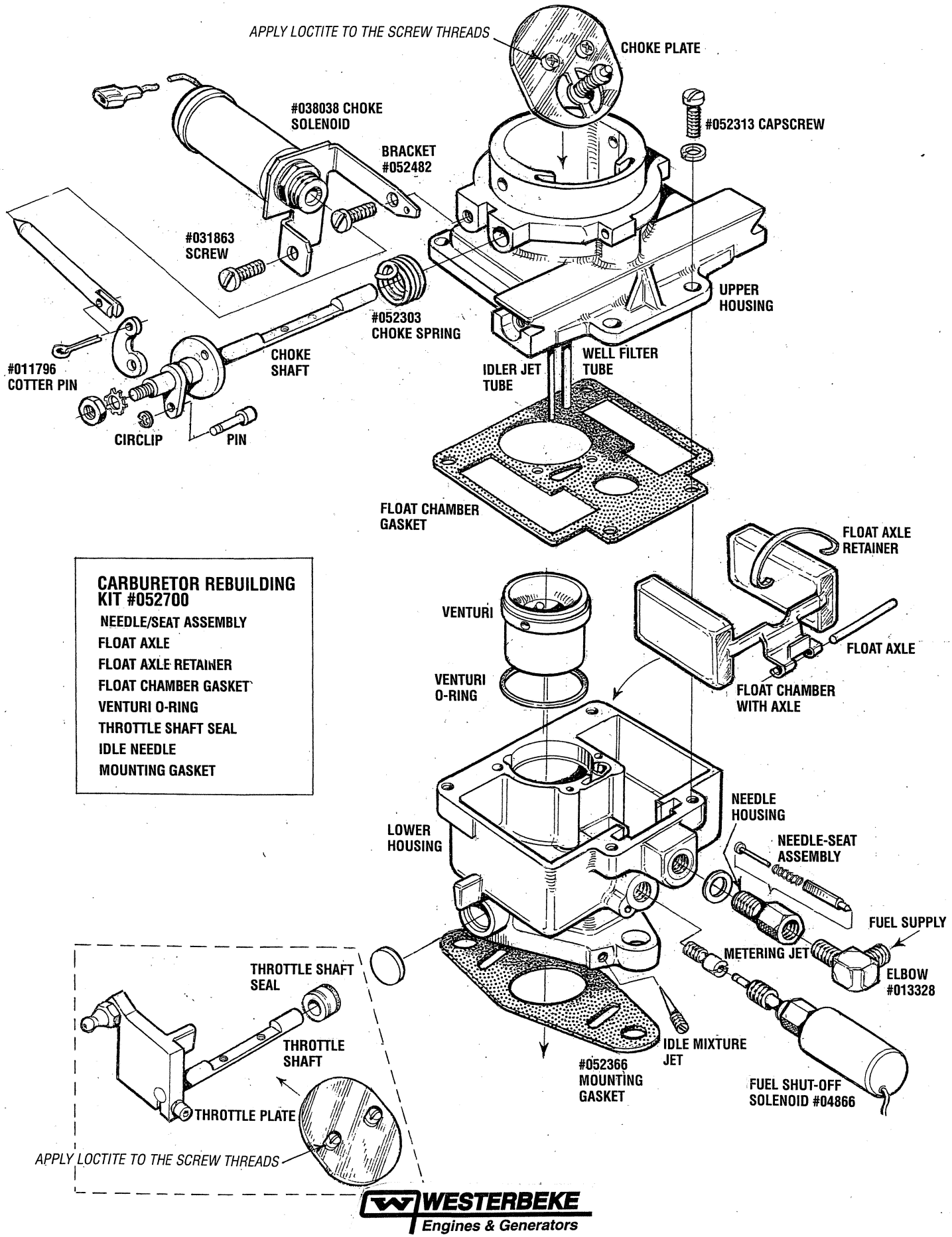




REBUILDING THE CARBURETOR

Use the following step by step instructions to clean and rebuild the model 052563 carburetor.

CARBURETOR #052563/BEGA MODELS 20/25KW



CARBURETOR REBUILDING KIT #052700

- NEEDLE/SEAT ASSEMBLY
- FLOAT AXLE
- FLOAT AXLE RETAINER
- FLOAT CHAMBER GASKET
- VENTURI O-RING
- THROTTLE SHAFT SEAL
- IDLE NEEDLE
- MOUNTING GASKET

CARBURETOR #052563/BEGA MODELS 20/25KW
REBUILDING INSTRUCTIONS

DISASSEMBLY

3. Remove the circlip and pin that secures the choke solenoid plunger to the choke shaft. Remove the two screws that secure the choke solenoid assembly to the carburetor and lift the assembly off the carburetor and at the same disconnecting the spring from the choke solenoids bracket.
4. Holding the choke closed, remove the two screws that attach the choke plate to the choke shaft. Remove the plate and withdraw the choke shaft from the housing.
5. Examine the choke shaft for wear wear and the choke return spring condition. Re-use or replace as needed.
6. Remove the fuel shut-off solenoid and the metering jet from the lower housing.
7. Remove the needle and seat assembly. Note this assembly consists of the needle, spring, pin and housing. Note the needle, spring pin and pin assembly position in the seat housing.
9. Remove the four screws securing the upper carburetor housing to the lower and seperate the two. Lift the floating chamber gasket off the lower housing.
9. Lift the floating axle retainer from the lower body and lift the float chamber and axle from the lower housing.
10. Carefully remove the venturi out of the lower body housing with its sealing O-ring.
11. Hold the throttle plate closed. Note its orientation for correct installation. Remove the plate's screws and remove the plate. Withdraw the throttle shaft from the lower body. Examine the shaft for wear. Re-use or replace as needed.
12. Remove the throttle shaft seal with brass retainer.
13. Remove the idle mixture the idle mixture jet from the lower housing.

Cleaning and inspection

Thoroughly clean all metal parts in a carburetor cleaning solvent. Blow dry metal parts and blow out all internal lower and upper housing passages with compressed air. Inspect all parts for wear or damage. Replace as needed. Clean the air intale screen/flame arrester and blow dry.

RESASSEMBLY

1. Assemble the throttle shaft seal into the brass housing and press into the lower body.
2. Carefully slide the throttle shaft into the lower housing, flat surface facing out. Install the throttle plate to the shaft, Apply a small amount of Loctite to the thread end of the securing screws. Make sure the beveled sides of the plate are next to the throttle body bore. Tap the plate lightky (plate closed) to center it and tighten the two screws.
3. Apply Loctite to one side of the idle mixture screws threads and thread it into the lower body until it seats. Back out one turn,
4. Install the metering jet and righten securely.
5. Install the float assembly with the axle and the axle retainer.
6. Holding the lower throttle housing and axle pin with needle and seat boss facing down, Thread the needle and seat assembly with a sealing washer into the body. Tighten securely.
7. Holding the axle in place using the axle retainer, invert the assembly so the float closes the needle against the seat. The float should be flush with the mating surface of this lower housing bracket to within + or - 1/32 inch. Adjust the float as needed by bending the adjustment tab on the float bracket.
8. Carefully install the O-ring to the venturi and insert the venturi into the lower body lining up the knob with the half moon opening in the lower body and fully seat the venturi into the lower body. The venturi should not extend more than 3/16 inch above the lower body casting.
9. Correctly position the float chamber gasket onto the lower housing and carefully lower the upper housing onto the lower. Install and tighten the four securing screws.
10. Instalk the choke shaft with the flat surface facing out., Place the choke plate onto the shaft with poppet and spring facing out, Secure in place with the two screws applying Loctite to the thread ends. Tighten securely.
11. Attach the choke solenoid and linkage to the choke shaft. Engage the choke return spring into the hole in the solenoids mounting bracket. Ensure the chojke plunger and choke shaft/plate moves freely.
12. Install the fuel supply elbow to the needle and seat fittting and tighten and position correctly.
13. Apply a small amount of Loctite to the inner threads of the fuel shut-off solenoid and thread it into its boss on the lower housing and tighten securely.

Re-install on the intake manifold usingnew mounting gasket. Connect the electric choke solenoid to its conmnection in the harness and reconnect the fuel supply to the carburetor. Check that there are no fuel leaks when the engine is test run and that the choke soleboid functions properly.

CARBURETOR TROUBLESHOOTING

THIS TROUBLESHOOTING CHART APPLIES TO BOTH MODEL WESTERBEKE BEG AND BEGA CARBURETORS

Problem	Probable Cause	Verification/Remedy
Hard Starting	1. Faulty choke.	1. Check choke adjustment and operation. Check choke cam for smooth radius.
	2. Fuel.	2. Check fuel supply and correct type.
	3. Fuel lift pump.	3. Replace fuel lift pump.
	4. Faulty idle jet adjustment.	4. Adjust idle jet.
Flooded	1. Carburetor float needle valve open or damaged.	1. Clean or replace the needle valve.
	2. Float in carburetor leaking.	2. Repair or replace float.
	3. Float chamber gasket damaged or securing screws are loose.	3. Replace gasket and/or tighten screws.
	4. Choke stuck.	4. Repair.
Poor Performance at at Generator Speed.	1. Main jet clogged.	1. Remove and clean.
	2. Carburetor inlet filter clogged.	2. Remove and clean.
	3. Fuel filter clogged.	3. Remove and clean.
	4. Air intake filter screen dirty.	4. Remove and clean.

ENGINE ADJUSTMENTS

SPARK PLUGS

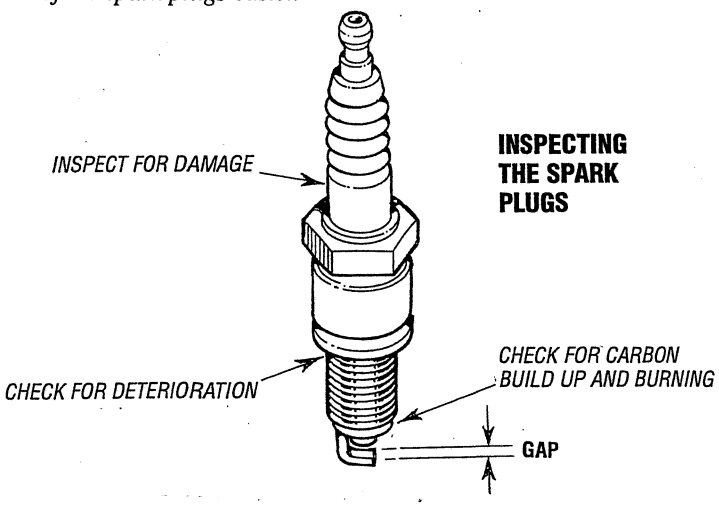
The spark plugs should be cleaned and regapped after the first 50 hour break-in period, then inspected every 250 hours thereafter and replaced as needed.

> **⚠ WARNING:** ***Do not remove the spark plugs while the engine is hot. Allow the engine to cool before removing them.***

SPARK PLUG GAP: 0.028 - 0.033 IN. (0.75 – 0.85 MM).

SPARK PLUG TORQUE: 10 – 15 LB-FT (1.5 – 2.31 KG-M).

NOTE: *Loctite Anti-Seize applied to the threaded portion of the spark plugs will retard corrosion, making future removal of the spark plugs easier.*



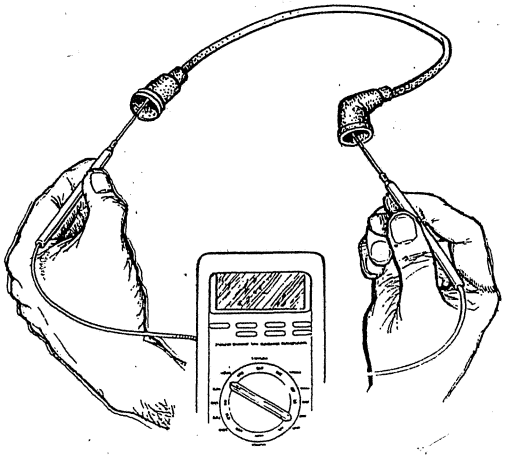
INSPECTING THE SPARK PLUGS

HIGH TENSION CORDS (IGNITION WIRES)

Check the ignition wires every 500 operating hours as engine compartment heat can deteriorate the wires.

Check the resistance of each wire. Do not pull on the wire because the wire connection inside the cap may become seperated or the insulator may be damaged. When removing the wires from the spark plugs, grasp and twist the moulded cap, then pull the cap off the spark plug.

THE RESISTANCE VALUE IS 410 OHM PER INCH OF WIRE.



CHECKING RESISTANCE

DRIVE BELT ADJUSTMENT

The drive belt must be properly tensioned. Excessive drive belt tension can cause rapid wear of the belt and reduce the service life of the fresh water pump's bearing. A slack belt or the presence of oil on the belt can cause belt slipping, resulting in high operating temperatures.

The 25 and 20 BEG generators have two drive belts, one drives the governor and alternator and the other drives the raw water pump. The tension adjustment procedure for both belts is as follows:

1. Remove the belt guard.
2. To adjust the governor drive belt, loosen the two governor mounting bolts.

   To adjust the raw water pump/fresh water pump drive belt, loosen the two raw water pump mounting bolts.
3. With the belt(s) loose, inspect for wear, cracks and frayed edges, and replace if necessary.
4. To loosen or tighten the governor drive belt, slide the governor in or out as required, then retighten its mounting bolts.

   To loosen or tighten the raw water pump/fresh water pump drive belt, slide the raw water pump in or out as required, then retighten its mounting bolts.
5. The drive belts are properly adjusted if it can be deflected no less than 3/8 inch (10mm) and no more than 1/2 inch (12mm) as the belt is depressed with the thumb at the midpoint between the two pulleys on the longest span of the belt.

   NOTE: *Maintain a 22 lb pressure to the belt's outer face for proper belt operation. Spare belts should always be carried on board.*

> **⚠ WARNING:** ***Never attempt to check or adjust a drive belt's tension while the engine is in operation.***

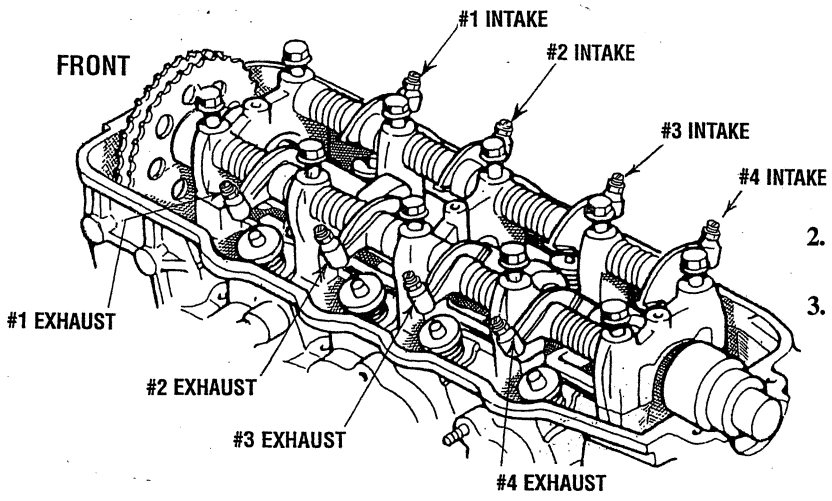
6. Operate the generator for about 5 minutes, then shut down the generator and recheck the belt(s) tension.
7. Replace the belt guard.

ENGINE ADJUSTMENTS

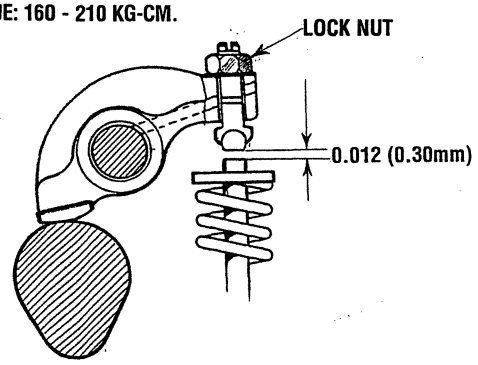
VALVE CLEARANCE ADJUSTMENT

NOTE: *Re-torque the cylinder head bolts before adjusting the engine's valves (see TORQUING THE CYLINDER HEAD BOLTS).*

1. Remove the rocker cover and gasket.
2. Position the No. 1 piston at Top Dead Center (TDC) of it's compression stroke. Adjust the Intake and Exhaust valves for cylinder #1 and the Intake valve for cylinder #2 and the exhaust valve for cylinder #3. Rotate the crankshaft 360 and adjust the remaining valves.



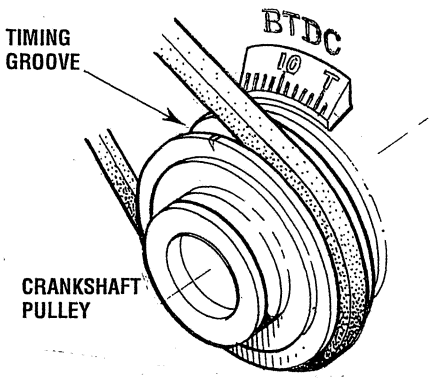
3. Replace the rocker cover and the rocker cover gasket.
   ROCKER COVER TORQUE: 2.9–5.1 LB-FT (0.4–0.7 KG-M).
4. Adjust all values to 0.012 (0.30mm) with the engine hot.
5. Tighten the lock nut.
   TORQUE: 160 - 210 KG-CM.



IGNITION TIMING

1. Attach a timing light to the #1 spark plug and mark the front crankshaft timing groove and the timing mark on the scale embossed on the engine's front cover.

   Each timing mark represents 2°.



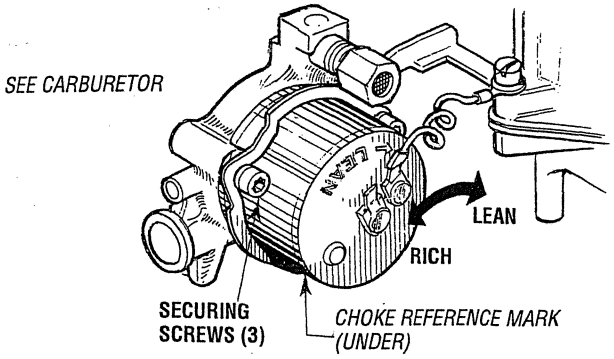
2. Start the engine and warm the engine to its normal operating temperature.
3. Using the timing light, align the timing groove in the front crankshaft pulley with the proper timing mark on the ignition timing scale embossed on the engine's front cover. Do this by loosening and slowly rotating the distributor body. Refer to the timing specifications:

   TIMING SPECIFICATIONS:
   25KW 20° BTDC AT 1800 RPM ±5°.
   20KW 12° BTDC AT 1800 RPM ±5°

ELECTRIC CHOKE (CARBURTOR #039454)

The electric choke uses a 12 volt heating element which opens the choke automatically when the engine starts and is running. Some hunting may occur when the generator is first started, when the choke is on, and when the generator has no-load on it.

The choke is adjusted with the engine off and cooled. Adjust the choke by loosening the three cover-securing screws and rotating the cover clockwise to **LEAN** the choke and counterclockwise to **RICH** the choke. the choke is initially set at the factory for an average of 70°F (21°C) room temperature. the choke may need re-adjustment at engine commissioning for the ambient temperature of the area the engine is operating in. The choke reference mark is located on the underside of the choke cover.



ENGINE ADJUSTMENT

ENGINE SPEED (HERTZ) ADJUSTMENT

Governor

The belt-driven, mechanically operated governor maintains the engine's rpm under various load conditions. Engine speed determines the hertz and voltage output of the generator.

Governor Adjustments

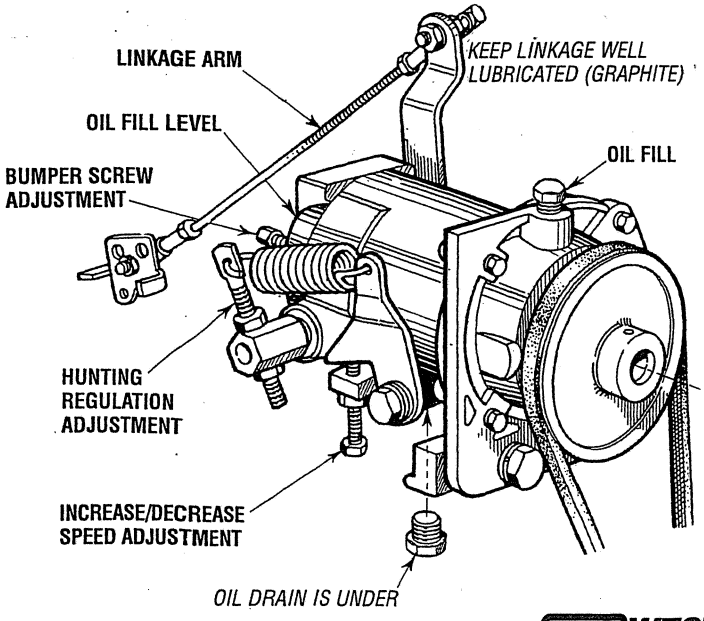
Operate the generator to bring the unit up to operating temperature before adjusting the governor.

NOTE: *If the governor is severely out of adjustment, manually adjust the linkage at no-load to obtain a safe output voltage before proceeding with the adjustment.*

There are three adjusting points on the governor (see illustration).

1. ***Increase/Decrease Speed Adjustment.*** This adjusting bolt sets the no-load speed of the engine. The linkage between the governor and the throttle lever should be adjusted to hold the throttle just slightly closed; about the width of the ball joint at the linkage arms and towards the closed position (when the engine is not running). Make sure this linkage moves freely and that the ball joint connectors are properly lubricated. Use graphite lube for this purpose. Disconnect the ball joint and apply graphite lube to the inside of the joint.
2. ***Hunting/Regulation Adjustment.*** If the variation in engine speed between no-load and full-load is too great, adjust this eye bolt to draw the spring closer to the lever hub. The increase/decrease speed bolt may need to be adjusted as well.

   If the governor surges under load, adjust this eye bolt to move the spring away from the lever hub (check speed adjustment).
3. ***Bumper Screw Adjustment.*** This screw is used to remove a no-load surge ONLY. ***NEVER*** turn the bumper screw into the governor so far that it increases the no-load speed.



Governor Maintenance

1. Periodically lubricate the linkage arm attaching points at the governor arm and throttle lever. Use a graphite lubricant or equivalent.

   NOTE: *Free movement of this linkage arm is important for proper governor/throttle operation.*
2. Governor oil capacity – 3 ounces 10W-30 synthetic oil.

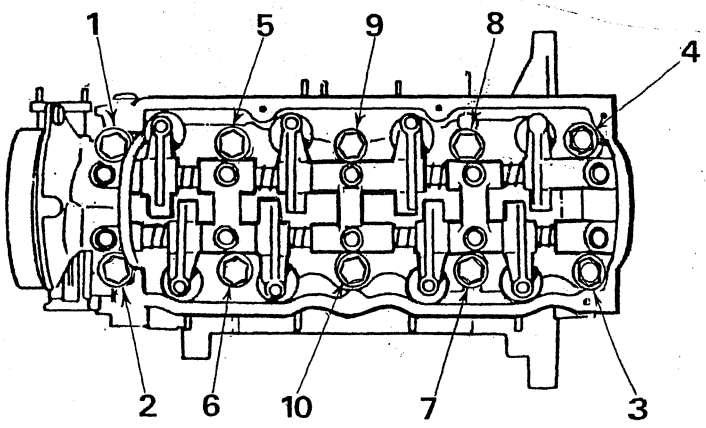
   NOTE: *Do not overfill the governor.*
3. Change the governor oil every 250 hours of operation.

   To change the oil, remove fill plug from the top of the governor. Then place a container under the governor and remove the drain plug. Note the governor illustration below. Allow all the oil to drain. Remove the allen head "Oil Fill Lever" plug from the rear of the governor. Add oil slowly into the governor till it starts to flow from this opening. Allow oil to stop flowing. Replace the allen head plug and the fill plug.
4. Periodically adjust the governor belt tension (see *DRIVE BELTS ADJUSTMENT).* Since belts stretch slightly, this stretching will, to some degree, affect the govenor's action.

TORQUING THE CYLINDER HEAD BOLTS

After the initial break-in period (approximately 50 hours), the cylinder head bolts should be re-torqued.

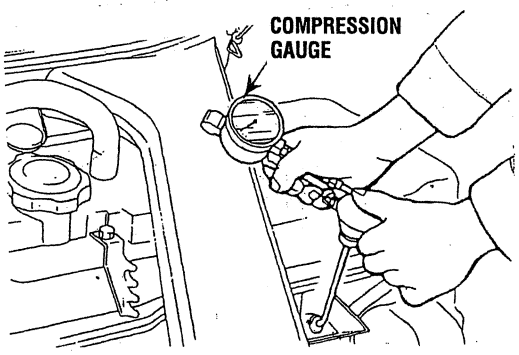
Tighten the cylinder head bolts according to the sequence shown. Make sure the engine is cold when this is done, and loosen one head bolt one-half turn and then tighten it between 55 - 59 lb-ft (8.2 - 8.8 Kg-m). Then proceed to the next head bolt in the sequence. Tighten the RS (rocker cover stud) securely.



ENGINE ADJUSTMENTS

TESTING ENGINE COMPRESSION

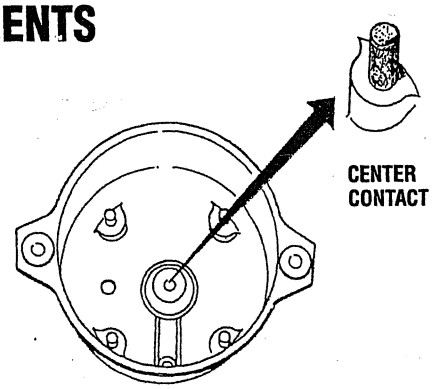
1. Make sure the battery is fully charged.
2. Warm up the engine to operating temperature.
3. After the engine is warm, turn it off for about 10 minutes to reduce the exhaust pipe temperature.
4. Remove all spark plugs.
5. Disconnect the primary wire connector from the ignition coil.



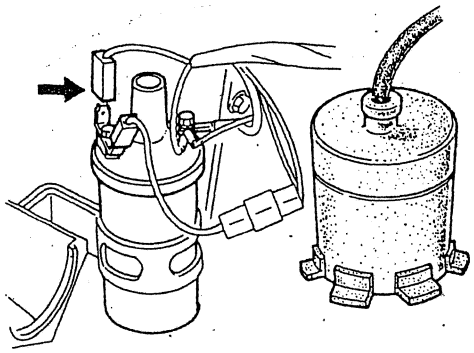
6. Connect a compression gauge to the No.1 spark plug hole.
7. With the throttle set at 400 rpm, crank the engine.
8. Check whether the gauge reads within the limits.

   COMPRESSION PRESSURE: 198.1 PSI (14Kg/cm²) AT 400 RPM.

   DIFFERENCE BETWEEN CYLINDERS: 29 PSI (2.0Kg/cm²).
9. Check each cylinder.
10. Refit the primary wire connector securely to the ignition coil.



DISTRIBUTOR



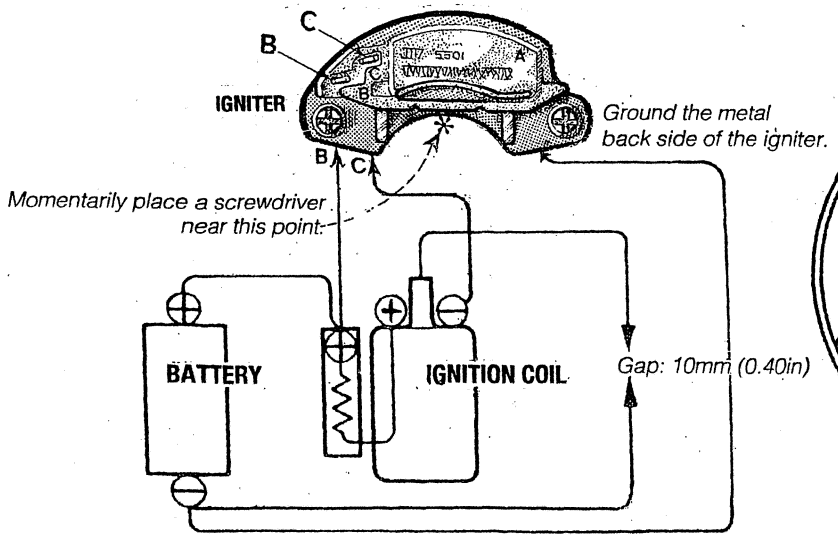
DISTRIBUTOR CAP INSPECTION

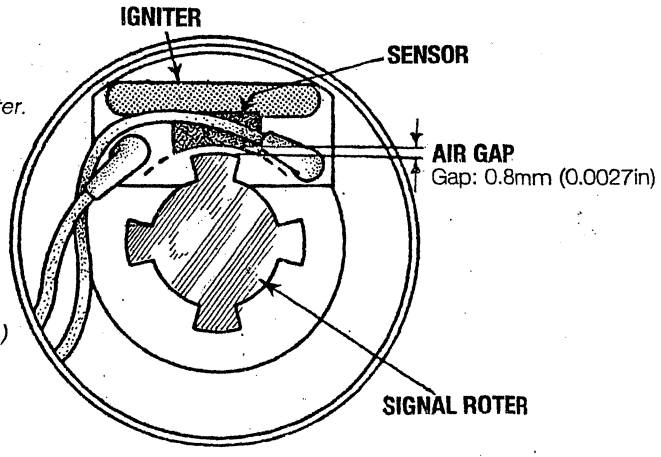
Check the following points. Replace if necessary.

1. Carbon or carbon deposits.
2. Burnt or corroded terminals.
3. Worn distributor center contact.

TESTING THE IGNITER

Reference the illustration below. Using AWG#16 wire, connect the igniter through a 12 VDC battery as shown. Momentarily place the tip of a metal screw driver near the middle of the pick-up of the igniter. Each time this is done, a spark should jump the gap. This will indicate a serviceable igniter.





Do not mix up the wire connections to terminals B and C as that would damage the igniter.

If the distributor is operated with the external resister left shorted, the igniter and coil will overheat.

TACHOMETER/HOUR METER

The tachometer/hour meter used in propulsion engine instrument panels contains two separate electrical circuits with a common ground. One circuit operates the hour meter and the other the tachometer. The hour meter circuit operates on 12 volts alternator charging voltage supplied to the (+) terminal on the back of the instrument.

The tachometer circuit operates on AC voltage 6-8 volts, fed from one of the diodes in the alternator and supplied to the tachometer input terminal while the engine is running, and the alternator producing battery charging voltage 13.0-14.8 volts DC.

The following are procedures to follow when troubleshooting a fault in either of the two circuits in a tachometer/hour meter.

Hour meter Inoperative

Check for the proper DC voltage between (+) and (-) terminals.

1. Voltage present - meter is defective - repair or replace.
2. Voltage not present - trace (+) and (-) electrical connections for fault. (Jump 12 volts DC to meter (+) terminal to verify the operation.)

Tachometer Inoperative

Check for the proper AC voltage between tachometer input terminal and (-) terminal with the engine running.

1. Voltage present - attempt adjusting meter through calibration access hole. No results, repair or replace meter.
2. AC voltage not present - check for proper alternator DC output voltage.
3. Check for AC voltage at tach terminal on alternator to ground.
4. Check electrical connections from tachometer input terminal to alternator connection.

Tachometer Sticking

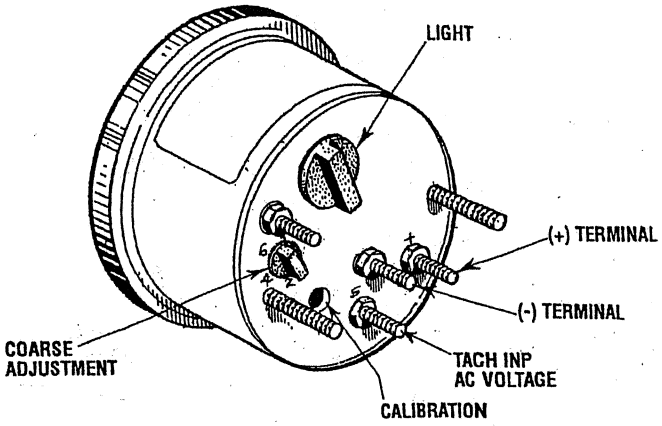
1. Check for proper AC voltage between "tachs inp" terminal and (-) terminal.
2. Check for good ground connection between meter (-) terminal and alternator.
3. Check that alternator is well grounded to engine block at alternator pivot bolt.

Tachometer Inaccurate

a. With a hand-held tach on the front of the crankshaft pulley retaining nut or with a strobe-type tach, read the front crankshaft pulley rpm at idle.

b. Using the CALIBRATION opening, fine adjust the tachometer using a 2mm (5/64). Zero the tachometer and then bring it to the RPM indicated by the strobe or hand tach, Check the rpm reading at idle and at high throttle. Adjust the tach as needed.

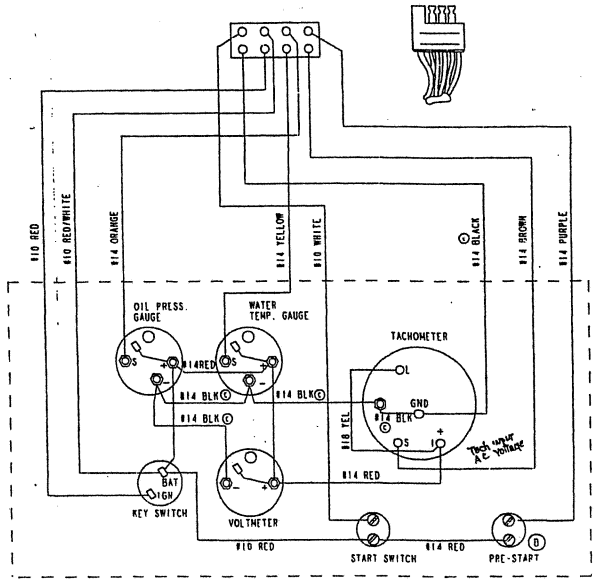
NOTE: *Current model tachometers use a coarse adjustment dial to set the tachometer to the crankshaft pulley rpms. The calibrating screw is then used for fine tuning.*



TACHOMETER CHECK (New Installation)

NOTE: *In a new installation having new instrument panels, the tachometer may not always be correctly calibrated to the engine's rpm. This calibration should be checked in all new installations.*

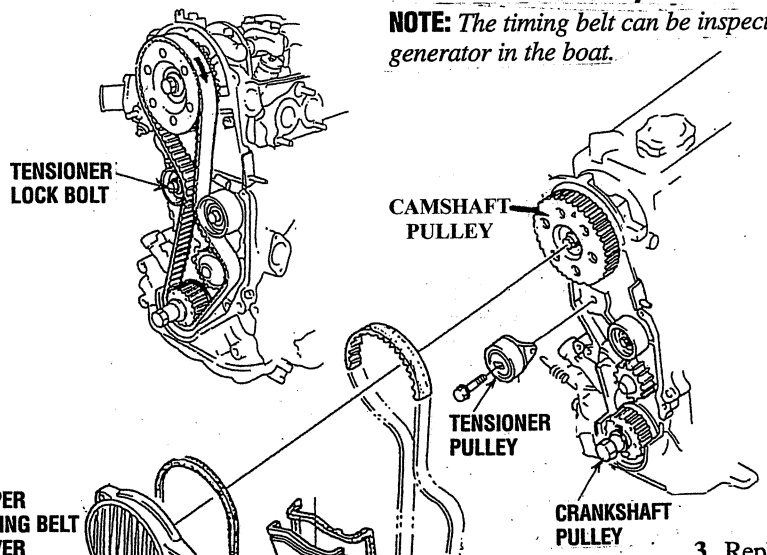
1. Warm up the engine to normal operating temperature. Remove any specks on the crankshaft pulley with a clean cloth and place a piece of suitable reflecting tape on the pulley to facilitate use of a photoelectric type tachometer.
2. Start and idle the engine.
3. Aim the light of the tachometer onto the reflecting tape to confirm the engine speed. Check the instrument panel tachometer reading. Adjust the tachometer in the panel by using the instrument coarse adjustment to calibrate the instrument reading to the closest R.P.M. that the photo tach is showing. Then use the fine calibration adjustment to bring the instrument to the exact reading as the photo tach.
4. Set the tachometer to the idle speed (the engine idle speed has been factory adjusted and the idle screws and high speed screws have been locked in place).

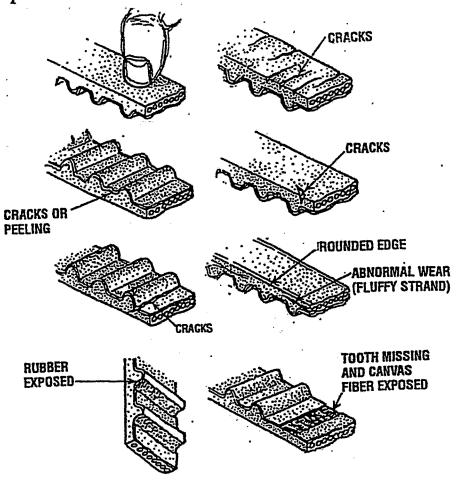


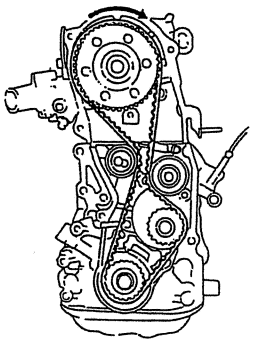
TIMING BELT

INSPECTION/INSTALLATION

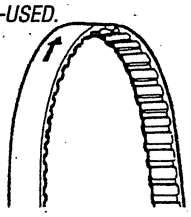
NOTE: *The timing belt can be inspected/replaced with the generator in the boat.*







MARK THE FORWARD ROTATION OF THE BELT TO PREVENT INCORRECT INSTALLATION IF THE BELT IS TO BE RE-USED.



DISASSEMBLY

1. Remove the tensioner spring after loosening the tensioner lock bolt.
2. Remove the timing belt.

NOTE: *Do not allow oil or water to contaminate the timing belt. Do not twist, turn inside out, or bend the belt.*

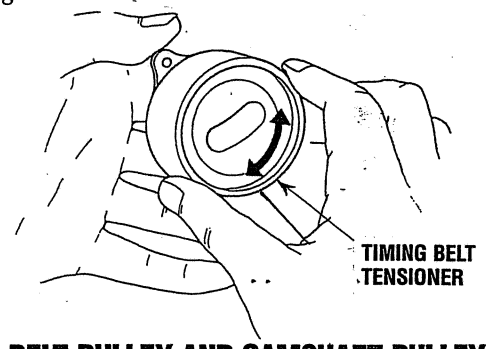
TIMING BELT INSPECTION

1. Replace the timing belt if there is any oil, grease, or moisture on it.
2. Check for damage, wear, peeling, cracks, and hardening. Replace if necessary.
3. Replace the belt if any of the above conditions exist.

TIMING BELT TENSIONER AND IDLER PULLEY

Check the timing belt tensioner and idler pulley for smooth rotation and abnormal noise. Replace if necessary.

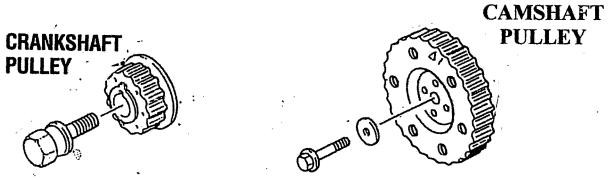
NOTE: *Do not clean the tensioner with cleaning fluids. If necessary, use a soft rag to wipe it clean, and avoid scratching it.*



TIMING BELT PULLEY AND CAMSHAFT PULLEY

Inspect the pulley teeth for wear, deformation, or other damage. Replace if necessary.

NOTE: *Do not clean the pulley with cleaning fluids. If necessary, use a rag to wipe it clean.*



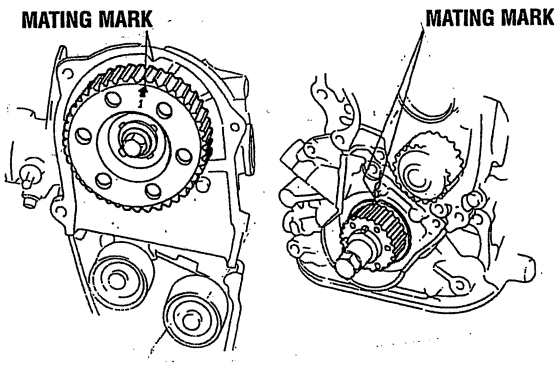
TIMING BELT COVER (LOWER AND UPPER)

Inspect the timing belt covers for damage or cracks. Replace if necessary.

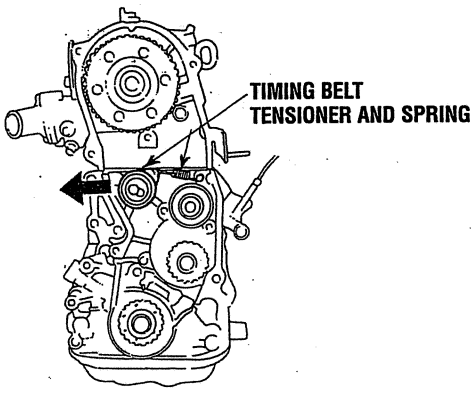
TIMING BELT
INSPECTION/INSTALLATION

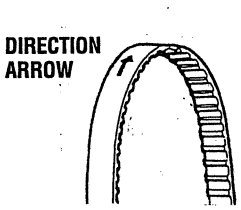
INSTALLATION

1. Align the timing mark on the timing belt pulley and camshaft pulley with the marks.
2. Remove all the spark plugs. This is to prevent compression when rotating the timing belt.

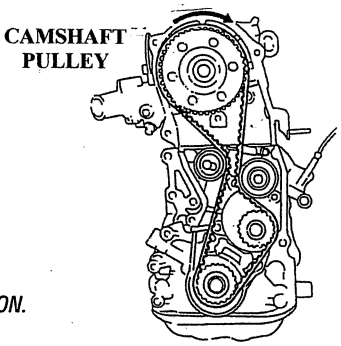


3. Install the timing belt tensioner and spring.
4. Position the timing belt tensioner all the way to the intake side, and temporarily secure it by tightening the lock bolt.

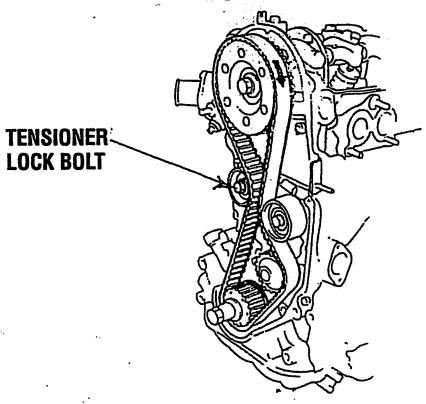




IF RE-USING THE TIMING BELT, INSTALL IT IN THE DIRECTION OF THE APPLIED ARROW - FORWARD ROTATION.



5. Install the timing belt on the crankshaft pulley and the camshaft pulley from the tension side (the right side as viewed from the front of the engine) so that tension is retained.
6. Loosen the tensioner lock bolt so that the tensioner spring applies tension.
7. Turn the crankshaft twice in the direction of rotation. This will apply equal tension to each side of the timing belt.



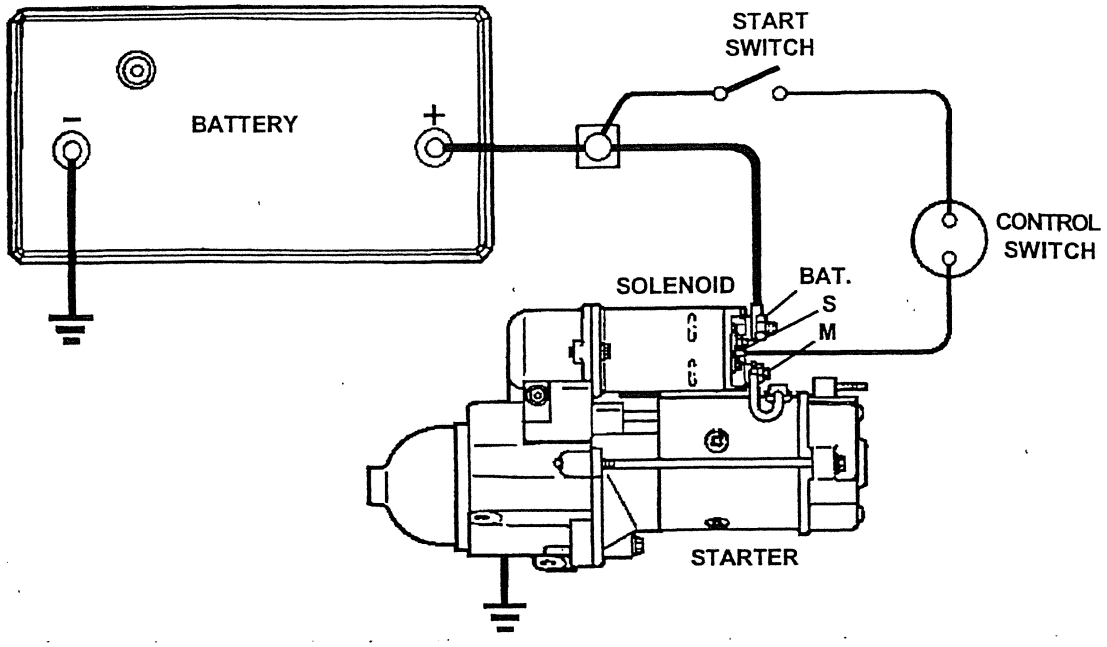


FIGURE 1. STARTER WIRING CIRCUIT

TROUBLESHOOTING

To independently test the starter it is necessary to remove it from the engine. However, before doing this, checks should be made to ensure that the problem is with the starter and not with the engine, battery, wiring or switches. When the other possible problem sources have been eliminated, then remove and test the starter. Comparison of test results with the Troubleshooting chart will aid in isolating the problem within the starter to specific components. This will determine the repair or repairs needed to restore the starter to serviceability.

Battery Test

Realistic testing, as well as successful operation, requires a fully charged battery capable of supplying the current needs of the starting system. Step one in troubleshooting the starting system is to test the battery. Follow the battery manufacturer's instructions.

Wiring and Switches

Visual Inspection

Visually inspect all wiring and switches in the starting circuit for damage and loose or corroded connections. This includes all ground connections. Clean and tighten the connections as required. Replace damaged wiring or components.

Continuity Check

Disconnect the field lead on the starter from the solenoid M terminal and insulate it carefully to prevent accidental contact. Set the transmission in neutral. Use a voltmeter to check for voltage at the solenoid S terminal while the start switch is held in the START position. If voltage is not present at the S terminal, use the voltmeter and the wiring diagram to trace the control circuit and locate the point of voltage loss and correct it as necessary.

Starter Removal

If the battery, wiring and switches are in satisfactory condition and the engine is known to be functioning properly, remove the starter for further testing.

Starter No-Load Test

With the starter removed from the engine, the no-load test can reveal damage that can be corrected by repair or it may indicate the need for component testing after the starter is disassembled. Repair and component test procedures are described in the *UNIT REPAIR* section. The no-load test is also used to test units for normal operation after repair or overhaul. Comparison of test results with the Troubleshooting chart will indicate what corrective action, if any, is required.

Test Hook-Up (Figure 2)

Connect the starter for the no-load test as shown in the illustration using suitable instruments, battery cables and connecting wiring. Do the following:

1. Secure the starter in a suitable test stand to check its operation.
2. Use a momentary contact, pushbutton switch in the test circuit for a quick release if very high current surges are encountered.
3. Make all connections or disconnections with the switch open and the carbon pile load turned off.
4. If sparking or current flow in the battery circuit is noted when making the connections, the starter solenoid switch contacts may be frozen shut (refer to *TROUBLESHOOTING*).
5. As the *last* step in making the test connection, ground the negative battery cable securely to a clean metal ground on the starter frame.
6. The carbon pile load is used to adjust the operating voltage for comparison with specifications. It may not be necessary in all cases but should be used to eliminate the need for interpolation of test data.

Test Procedure

⚠ CAUTION: ***Keep fingers and tools away from the opening in the D.E. (drive end) housing while testing. The strong shifting action of the solenoid could cause personal injury or damage as the drive pinion moves into the cranking position and spins.***

NOTE: *During the no-load test, close the switch and operate the starter for cycles of 30 seconds maximum. Between cycles, allow the starter to cool for at least two minutes, otherwise overheating and damage to the starter may result.*

1. Momentarily close the switch.
   a. If there is a high current flow and the starter fails to operate (zero rpm), release the switch immediately. Internal mechanical damage is indicated. Discontinue the test and refer to *TROUBLESHOOTING*.
   b. If there is no current flow and the starter fails to operate (zero rpm), release the switch immediately. An open circuit is indicated. Discontinue the test and refer to *TROUBLESHOOTING*.
   c. If there is a current flow and the starter operates, release the switch and proceed with the next step of the no-load test.
2. Close the switch and observe the voltmeter. Adjust the carbon pile load to obtain a 10 volt reading (20 volts on a 24-volt starter). Observe and record the ammeter and rpm readings. Release the switch.
3. Compare the ammeter and rpm readings to those listed under *SPECIFICATIONS* at the end of this section. If the readings are outside the limits shown, refer to *TROUBLESHOOTING* to determine the most likely causes. If the readings are within the limits, the starter is operating normally.

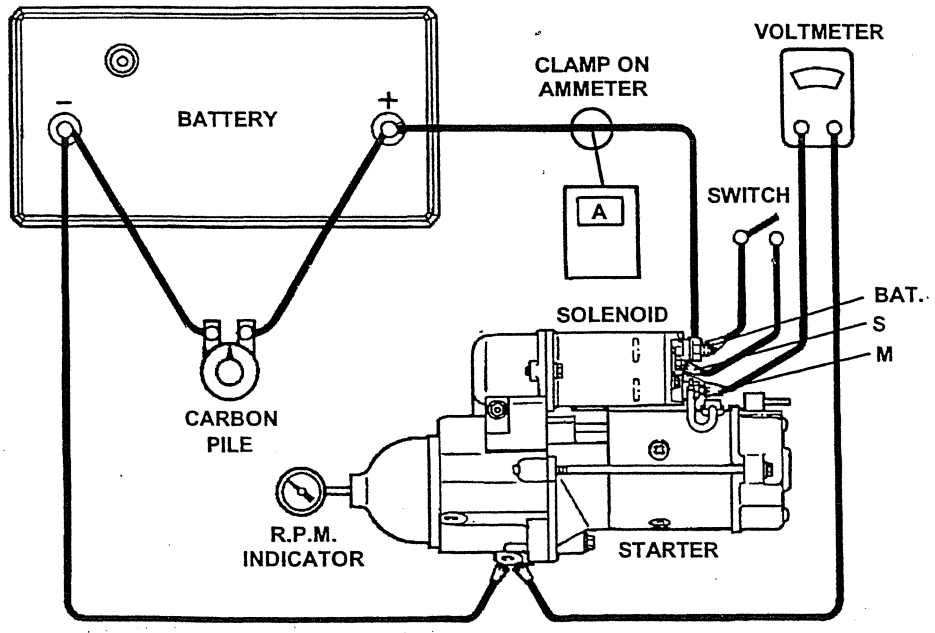


FIGURE 2. STARTER NO-LOAD TEST HOOK-UP

Troubleshooting

If the results of the no-load test are outside the limits, refer to the following *TROUBLESHOOTING* chart for the probable cause and its remedy. The problems listed in the chart apply specifically to the no-load test and do not necessarily apply to operation under other circumstances.

PROBLEM	PROBABLE CAUSE	VERIFICATION/REMEDY*
Normal current and speed.	a. Starter OK.	a. Recheck battery, switches and wiring, including battery cable loss. Check if starter operation on engine is slow or sluggish.
Current flow with test circuit switch open.	a. Solenoid switch contacts stuck closed.	a. Test and, if necessary, replace solenoid assembly.
Failure to operate with very low or no current.	a. Open solenoid wiring. b. Open field circuit. c. Open armature coil(s) or high insulation between commutator bars. d. Broken brush spring(s) or worn brushes.	a. Inspect and test solenoid assembly. b. Inspect and test frame and field assembly. c. Inspect armature. d. Inspect brushes and brush springs.
Failure to operate with high current.	a. Frozen bearing or other damage to drive train. b. Direct ground in terminals or fields.	a. Inspect bearings, armature, drive shaft and related drive parts. b. Inspect and test frame and field assembly, solenoid assembly, armature and brush installations for shorts.
Low speed with high current.	a. Excessive friction in bearing(s) or gear reduction unit, bent armature shaft or loose pole shoe, bent drive shaft. b. Shorted armature. c. Grounded armature or fields.	a. Inspect bearing, armature, drive shaft, and gear reduction gears. b. Inspect and test armature. c. Inspect and test frame and field coil assembly and armature.
Low speed with normal (or low) current.	a. High internal electrical resistance caused by poor connections, defective leads or dirty commutator. b. Causes listed under *Failure to operate with very low or no current.*	a. Inspect internal wiring, electrical connections and armature commutator. b. Remedies listed under *Failure to operate with very low or no current.*
High speed with high current.	a. Shorted fields.	a. Inspect and test field and frame assembly.

* Refer to the *UNIT REPAIR* section for required disassembly, inspection, test, and if necessary, repair or replacement instructions.

STARTER REPAIR

NOTE: *Always install fasteners at their original locations. If it is necessary to replace fasteners, use only the correct part numbers or equivalent. If the correct part number is not available, use only a fastener of equal size and strength. Use a torque wrench to tighten fasteners when a torque value is specified. Torques specified are for dry, unlubricated fasteners unless otherwise specified.*

Introduction (Figure 3)

Figure 3 shows the starter broken down into its component parts and assemblies. Do not attempt to disassemble the following components which are serviced as assemblies:

Solenoid assembly (1)

Clutch Drive assembly (2)

Brush Holder assembly (3)

Armature assembly (13)

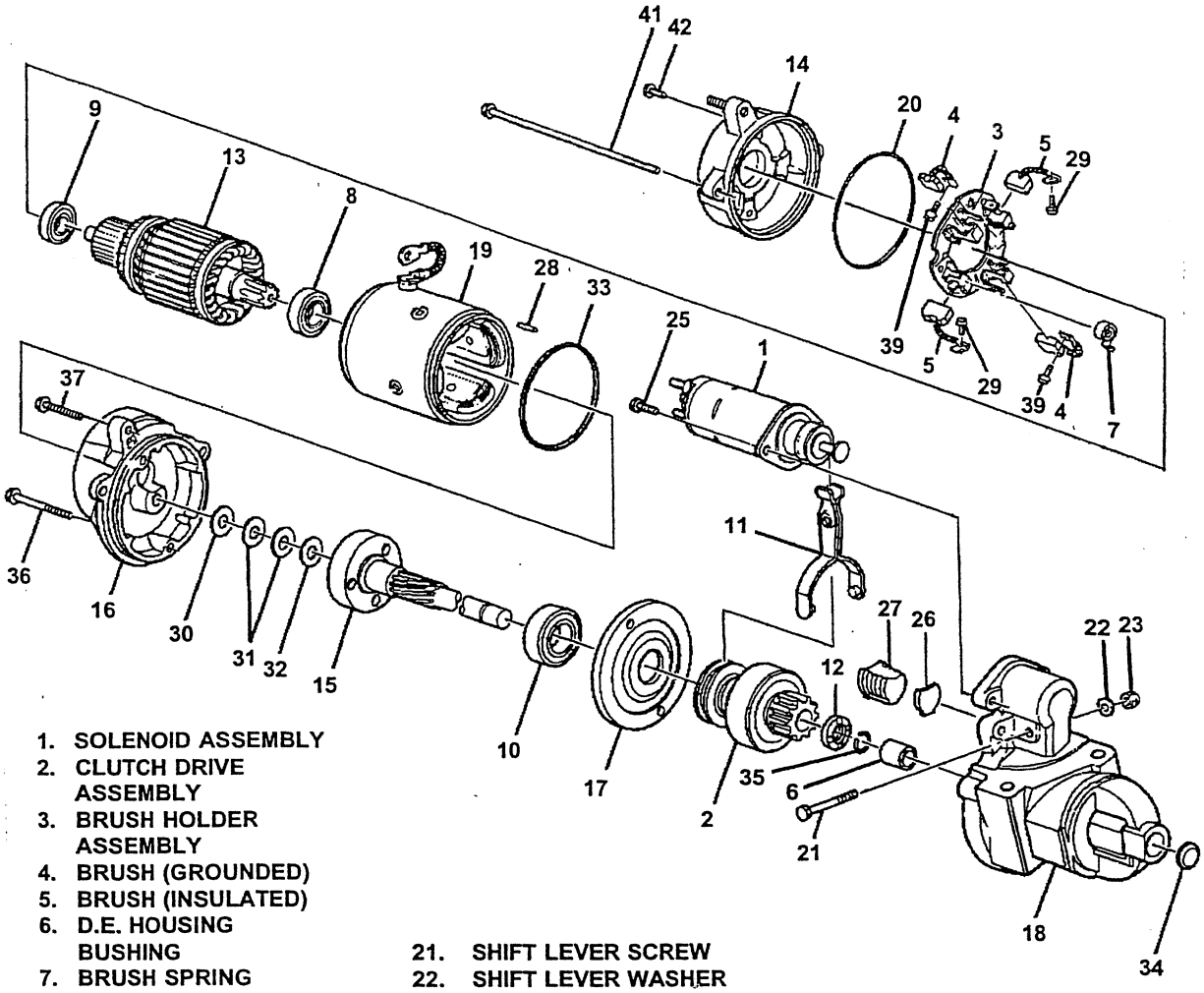
Frame and Field assembly (19)

This section provides instructions for complete disassembly of the starter as would be the case for overhaul. If the starter is not due for an overhaul, and repair affecting specific parts only is required, the starter may be disassembled only to the extent necessary to gain access to these parts. Parts removed from the starter as subassemblies or groups need not be disassembled for such limited repair unless they contain the affected parts. Total disassembly is recommended however, to ensure that all parts can be thoroughly cleaned and inspected.

In this section the starter is broken down by main groups. These groups are then disassembled into individual parts and assemblies. Illustrations accompany the text to show specific operations. To see the parts relationship of the *complete* starter, refer back to Figure 3.

To begin, make a mark completely down one side of the starter to ensure proper alignment of all its components at assembly. Use a colored pencil or marker that will show on all parts.

STARTER MOTOR



1. SOLENOID ASSEMBLY
2. CLUTCH DRIVE ASSEMBLY
3. BRUSH HOLDER ASSEMBLY
4. BRUSH (GROUNDED)
5. BRUSH (INSULATED)
6. D.E. HOUSING BUSHING
7. BRUSH SPRING
8. D.E. ARMATURE BEARING
9. C.E. ARMATURE BEARING
10. CENTER SUPPORT BEARING
11. SHIFT LEVER
12. PINION STOP
13. ARMATURE
14. C.E. FRAME
15. DRIVE SHAFT
16. ARMATURE SUPPORT BRACKET
17. DRIVE SHAFT SUPPORT
18. DRIVE HOUSING
19. FRAME & FIELD ASSEMBLY
20. C.E. FRAME O-RING
21. SHIFT LEVER SCREW
22. SHIFT LEVER WASHER
23. SHIFT LEVER NUT
25. SOLENOID SCREW
26. PLATE (IF USED)
27. DRIVE HOUSING PLUG
28. DOWEL PIN
29. INSULATED BRUSH SCREW
30. WASHER (FIBER)
31. WASHER (THIN; ONE OR TWO MAY BE USED)
32. WASHER (THICK)
33. FRAME SEAL
34. BUSHING PLUG (IF USED)
35. STOP RING
36. DRIVE HOUSING BOLT (LONG)
37. DRIVE HOUSING BOLT (SHORTER ON SOME MODELS)
39. GROUNDED BRUSH SCREW
41. THRU BOLT
42. BRUSH PLATE SCREW

FIGURE 3. STARTER ASSEMBLY

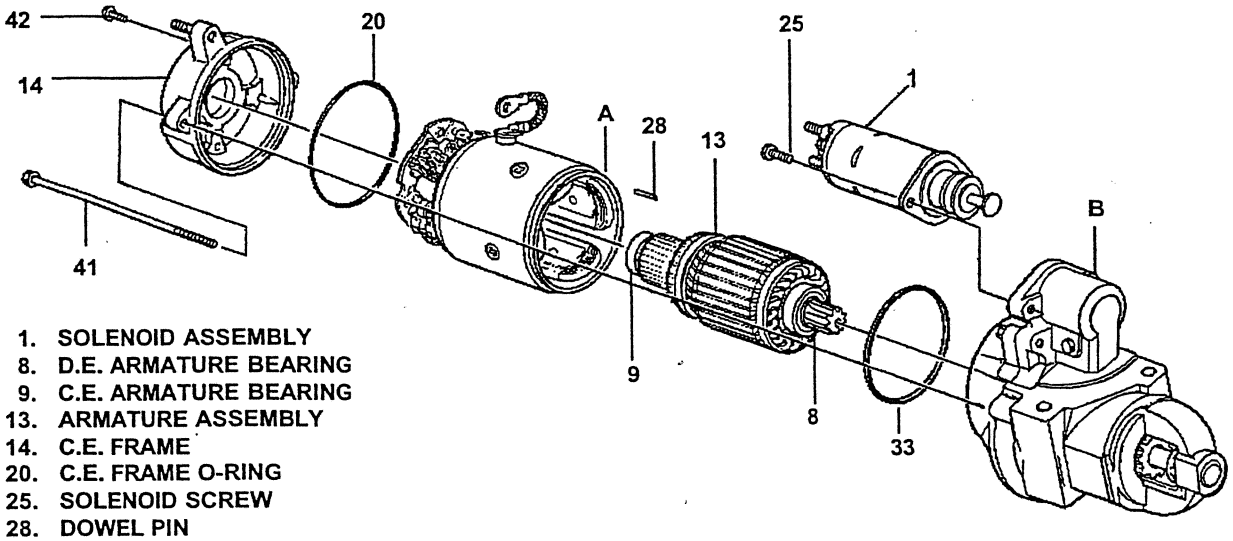
General Disassembly (Figure 4)

Remove or Disconnect:

1. The motor lead on the frame, field and brush holder group (A) from the solenoid assembly (1). Reinstall the nut on the solenoid terminal.
   a. Remove the nut on the solenoid, slip off the motor lead and reinstall the nut.
2. Thru bolts (41).
3. Brush plate screws (42).
4. C.E. frame (14) and O-ring (20).

   Important:

   a. In the following step, use care not to lose the small dowel pin (28) installed between the frame, field and brush holder group (A) and the gear reduction and drive group (B). This dowel pin is required for assembly and must be saved. If the dowel pin should be lost, it must be replaced with a 2 mm (0.079 in.) dia. x 10 mm (0.394 in.) long pin procured or manufactured locally.
5. Frame, field and brush holder group (A), dowel pin (28) and frame seal (33).
   a. The armature assembly (13) may come off with the frame, field and brush holder group (A) or may be retained by the gear reduction and drive group (B).
6. Armature assembly (13) with bearings (8 and 9).
   a. Do not remove the bearings from the armature assembly unless replacement is required (refer to *CLEANING, INSPECTION AND REPAIR*).
7. Solenoid screws (25).
8. Solenoid assembly (1).
   a. Pivot the inside end of the solenoid assembly (1) out of engagement with the shift lever in the gear reduction and drive group (B) and withdraw the solenoid assembly.



1. SOLENOID ASSEMBLY
8. D.E. ARMATURE BEARING
9. C.E. ARMATURE BEARING
13. ARMATURE ASSEMBLY
14. C.E. FRAME
20. C.E. FRAME O-RING
25. SOLENOID SCREW
28. DOWEL PIN
33. FRAME SEAL
41. THRU BOLT
42. BRUSH, PLATE SCREW
A. FRAME, FIELD & BRUSH HOLDER GROUP
B. GEAR REDUCTION & DRIVE GROUP

FIGURE 4. ELECTRICAL GROUP

Disassembly of Frame, Field and Brush Holder Group (Figure 5)

Remove or disconnect:

1. Insulated brush screws (29).
   a. Move the brush holder assembly (3) [with the brushes (4 and 5)] away from the frame and field assembly (19) slightly to reach across with a screwdriver and remove the screws (29).
2. Frame and field assembly (19).
3. Grounded brush screws (39).
4. Brushes (4 and 5), if replacement is required.
   a. Grasp the brush end of each brush spring (7) with needle nose pliers, twist the spring end away from the brush (4 or 5) and withdraw the brush.
5. Brush springs (7), if replacement is required.
   a. Grasp the brush end of each brush spring (7) with needle nose pliers, twist the spring end away from the brush socket on the brush holder assembly (3) and remove the spring.

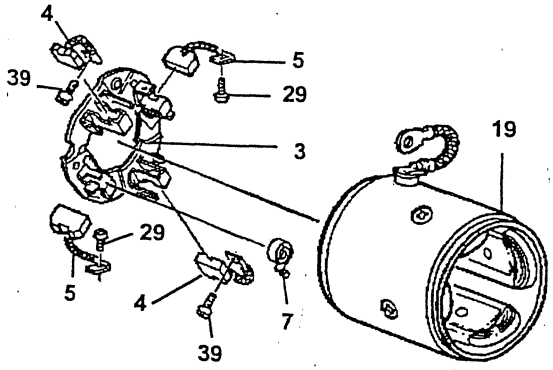
NOTE: *At this stage of disassembly, all electrical components can be inspected, and if required, independently tested as specified in CLEANING, INSPECTION AND REPAIR.*

Disassembly of Gear Reduction and Drive Group (Figure 6)

Remove or disconnect:

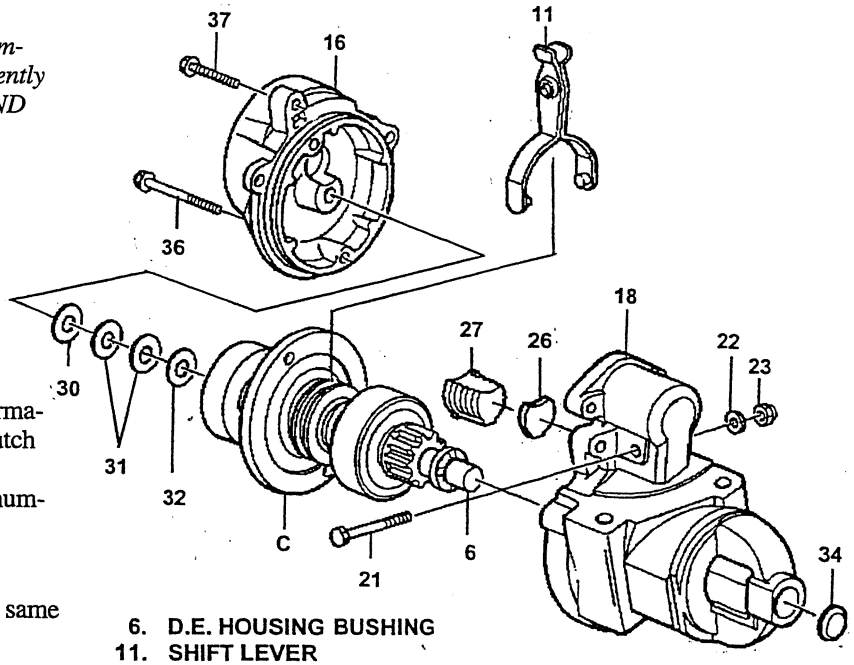
1. Housing bolts (36 and 37).
2. Armature support bracket (16).

   Important:
   a. The washers (30 through 32) may stick to the armature support bracket or to the drive shaft and clutch group (C) as the armature support bracket is removed. In either case, note the position and number of each of these washers.
3. Washers (30 through 32).
   a. Save the washers; they are to be installed in the same position and number at assembly.
4. Drive housing plug (27) and plate (26).
   a. Pry out the drive housing plug using a large screwdriver.
5. Shift lever nut (23), washer (22) and screw (21).
6. Remove the shift lever (11) and the drive shaft and clutch group (C) from the drive housing (18) together, then separate them.
   a. Do not remove the bushing plug (34) or the bushing (6) from the drive housing (18) unless replacement is required (refer to *CLEANING, INSPECTION AND REPAIR*).



3. BRUSH HOLDER ASSEMBLY
4. BRUSH (GROUNDED)
5. BRUSH (INSULATED)
7. BRUSH SPRING
19. FRAME & FIELD ASSEMBLY
29. INSULATED BRUSH SCREW
39. GROUNDED BRUSH SCREW

FIGURE 5. FRAME, FIELD AND BRUSH HOLDER GROUP



6. D.E. HOUSING BUSHING
11. SHIFT LEVER
16. ARMATURE SUPPORT BRACKET
18. DRIVE HOUSING
21. SHIFT LEVER SCREW
22. SHIFT LEVER WASHER
23. SHIFT LEVER NUT
26. PLATE (IF USED)
27. DRIVE HOUSING PLUG
30. WASHER (FIBER)
31. WASHER (THIN; ONE OR TWO MAY BE USED)
32. WASHER (THICK)
34. BUSHING PLUG (IF USED)
36. DRIVE HOUSING BOLT (LONG)
37. DRIVE HOUSING BOLT (SHORTER ON SOME MODELS)
C. DRIVE SHAFT & CLUTCH GROUP

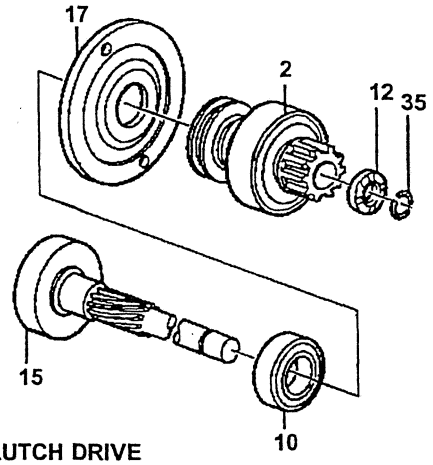
FIGURE 6. GEAR REDUCTION AND DRIVE GROUP

Disassembly of Drive Shaft and Clutch Group (Figures 7 and 8)

Disassembly of the drive shaft and clutch group is not required unless it is necessary to clean, inspect or replace one or more parts of the group separately. Then proceed as follows:

Remove or disconnect:

1. Stop rings (35) and pinion stop (12).
   a. Position the drive shaft and clutch group on the work bench with the internal gear end down.
   b. Using an open tube slightly larger than the shaft (see Figure 8), drive the pinion stop (12) toward the clutch drive assembly (2) until it clears the stop rings (35).
   c. Using care not to scratch the drive shaft (15), pry the stop rings out of the shaft groove and slide them off the end of the shaft.
   d. Inspect the edges of the shaft groove for burrs that may have been formed through repeated cranking cycles. Such burrs may make removal of the pinion stop and clutch drive assembly (2) difficult. If burrs are found, use a suitable file to carefully remove the burrs only – not the base metal. Thoroughly clean away metal filings.
   e. Slide the pinion stop (12) off the drive shaft (15). Discard the old pinion stop (12) and stop rings (35). New parts must be used at assembly.
2. Clutch drive assembly (2) from drive shaft (15).
3. Drive shaft support (17) from drive shaft (15).
   a. Do not remove the bearing (10) from the drive shaft (15) unless replacement is required (refer to *CLEANING, INSPECTION AND REPAIR*).



2. CLUTCH DRIVE ASSEMBLY
10. CENTER SUPPORT BEARING
12. PINION STOP
15. DRIVE SHAFT
17. DRIVE SHAFT SUPPORT
35. STOP RINGS (2 PCS)

FIGURE 7. DRIVE SHAFT AND CLUTCH GROUP

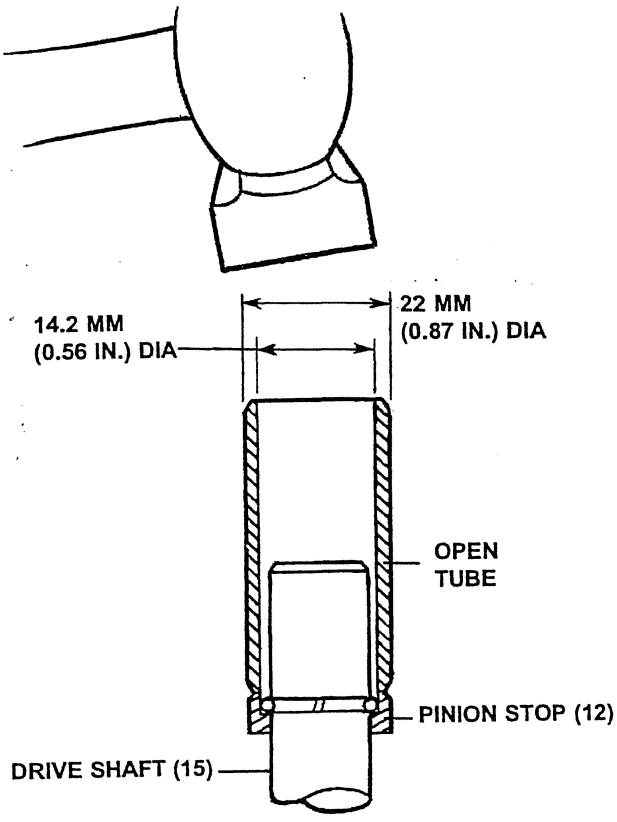


FIGURE 8. REMOVING PINION STOP

CLEANING, INSPECTION, TESTING AND REPAIR

Cleaning

NOTE: *Do not clean or immerse starter parts in grease dissolving solvents. Solvents will dissolve grease packed in the drive assembly and may damage the armature or field coil insulation.*

Clean:

1. All starter parts with a soft cloth prior to testing.

Inspection (Figure 3)

Inspection in the following steps refers to visual inspection of the starter parts and assemblies to determine their serviceability. Electrical tests for certain assemblies are described in *COMPONENT ELECTRICAL TESTING.*

Inspect:

1. All parts for cracks, distortion other structural damage. Replace parts or assemblies which are cracked, bent or otherwise damaged.
2. Threaded parts for stripped, crossed or otherwise damaged threads. Replace parts with thread damage that cannot be cleaned up using a suitable tap or die. Replace any hardware items that have damaged threads.
3. The solenoid assembly (1) for a cut or torn boot. If the boot is damaged, replace the solenoid assembly.
4. The clutch drive assembly (2) for the following. Replace the clutch drive assembly if damaged:
   a. Pinion gear turns roughly or turns in both directions.
   b. Pinion gear teeth broken or showing evidence of step wear.
   c. Deep scoring or other damage to the shift lever collar.
5. The brush holder assembly (3) for the following. Replace the brush holder if damaged:
   a. Loose riveted joints.
   b. Cracked or broken insulation.
6. Brushes (4 and 5) for excessive wear.
   a. The minimum allowable brush length is 12 mm (0.472 in.). Replace excessively worn brushes in sets.
7. The D.E. housing bushing (6) for scoring or other damage. Replace a damaged bushing (refer to *REPAIR PROCEDURES*).
8. Ball bearings (8, 9 and 10) as follows:
   a. Hold the armature (13) or drive shaft (15) and slowly rotate the outer bearing race by hand.
   b. Check that the bearing turns freely without binding or the feel of flat spots.
   c. Replace damaged bearings (refer to *REPAIR PROCEDURES*).
9. Armature assembly (13) for the following:
   a. Gear teeth that are broken, or that show evidence of step wear or root interference.
   b. Rough commutator surface. Polish with a No. 400 grit polishing cloth if necessary. Thoroughly clean metal dust from between the commutator bars. If the commutator surface cannot be repaired in this manner, replace the armature assembly. Do not turn the commutator in a lathe.
   c. Worn commutator. Replace the armature assembly if the commutator OD is less than 35 mm (1.378 in.) or if the undercut depth at any point is less than 0.2 mm (0.008 in.). Do not undercut the insulation.
10. Drive shaft (15) for the following. Replace the drive shaft if damaged:
    a. Scored or damaged shaft where it turns in the bushing (6).
    b. Internal gear with teeth broken or showing evidence of step wear.
    c. Damaged spline. The clutch drive assembly must slide smoothly and easily over the full length of the spline.

Component Electrical Testing (Figures 9 and 10)

Perform the following electrical tests on the solenoid assembly (1), armature assembly (13) and frame and field assembly (19) to determine their serviceability.

1. Using a suitable ohmmeter, check the windings of the solenoid assembly (1) for continuity as follows:
   a. Check the resistance of the solenoid pull-in and hold-in windings in series by measuring the resistance between the motor terminal (see Figure 9) and the solenoid case. The resistance should be approximately 0.95 ohms for 12-volt starters and approximately1.75 ohms for 24-volt starters.
   b. An extremely high resistance reading indicates a break or fault in the winding continuity. A very low resistance reading indicates a short or ground in the winding circuit. Either condition is cause for replacement of the solenoid assembly.
2. Check the armature (13) as follows for shorts, opens or grounds using suitable test equipment and instruments (test lamp must be 110 volts or less).
   a. Rotate the armature in a growler holding a steel strip such as a hacksaw blade against the armature. If a short circuit is present, the steel strip will vibrate in that area.
   b. Check the armature for grounds using a test lamp or ohmmeter. There shall be no continuity between the armature shaft and any point on the commutator.
   c. Check for opens by visually inspecting the points where the armature conductors join the commutator. A poor connection often will be indicated by signs of arcing or burning of the commutator.
   d. Replace armatures which are shorted, grounded or show evidence of opens.
3. Check frame and field assembly (19) for grounds or opens using a test lamp (110 volts max.) or ohmmeter, as follows:
   a. Check that there is continuity (no opens) between the field terminal that connects to the solenoid, and the connection points for the insulated brushes on the field coil straps.
   b. Check that there is no continuity (no grounds) between the frame and the field terminal that connects to the solenoid.
   c. Replace frame and field assemblies that have grounds or opens.

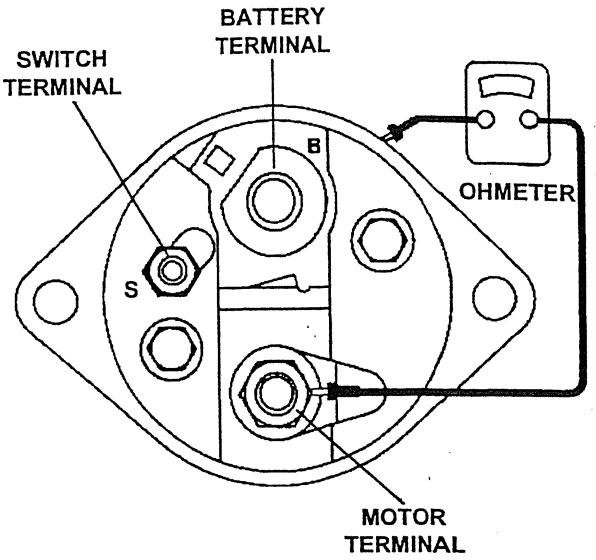


FIGURE 9. SOLENOID TERMINALS

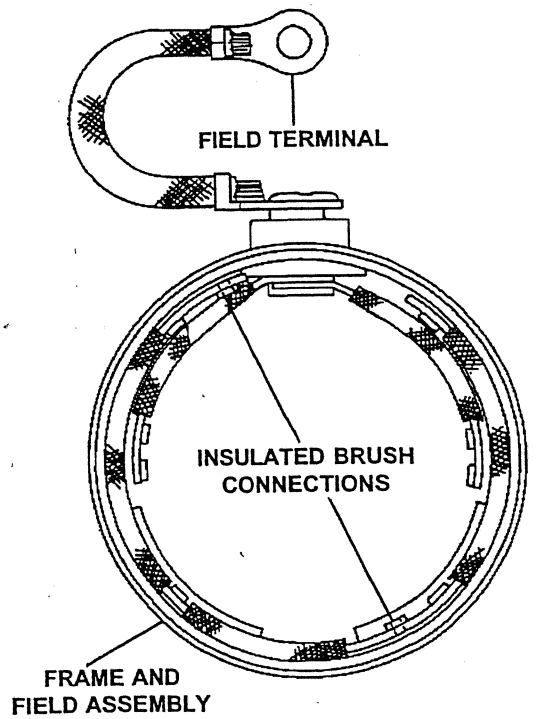


FIGURE 10. FRAME AND FIELD ASSEMBLY

Repair Procedures (Figures 3 and 11)

1. If necessary, replace the bearings (8 and 9, Figure 3) on the armature (13) as follows:

   NOTE: *Ball bearings which are removed from the armature must be replaced with new bearings. The removal procedure causes internal damage to the bearings.*

   Remove or disconnect:

   a. C.E. and/or D.E. bearings (8 and/or 9) from the shaft of the armature (13) using a suitable bearing puller.

   Install or Connect:

   b. New C.E. and/or D.E. bearings (8 and/or 9) to the armature assembly (13) using a tube that bears on the bearing's inner race only. Press on the bearing until the inner race bottoms out against the shoulder on the armature shaft.

2. If necessary, replace the center support bearing (10, Figure 3) on the drive shaft (15) as follows:

   NOTE: *Ball bearings which are removed from the drive shaft must be replaced with new bearings. The removal procedure causes internal damage to the bearings.*

   Remove or disconnect:

   a. The center support bearing (10) from the drive shaft (15) using a locally fabricated tool as shown in Figure 11.

   Install or Connect:

   b. The center support bearing (10) from the drive shaft (15) using a locally fabricated tool (Figure 11). With the drive shaft in a suitable support fixture, place the tool bolt ends through the access holes in the wide end of the drive shaft and squarely press the bearing off of the surface on the center shaft.

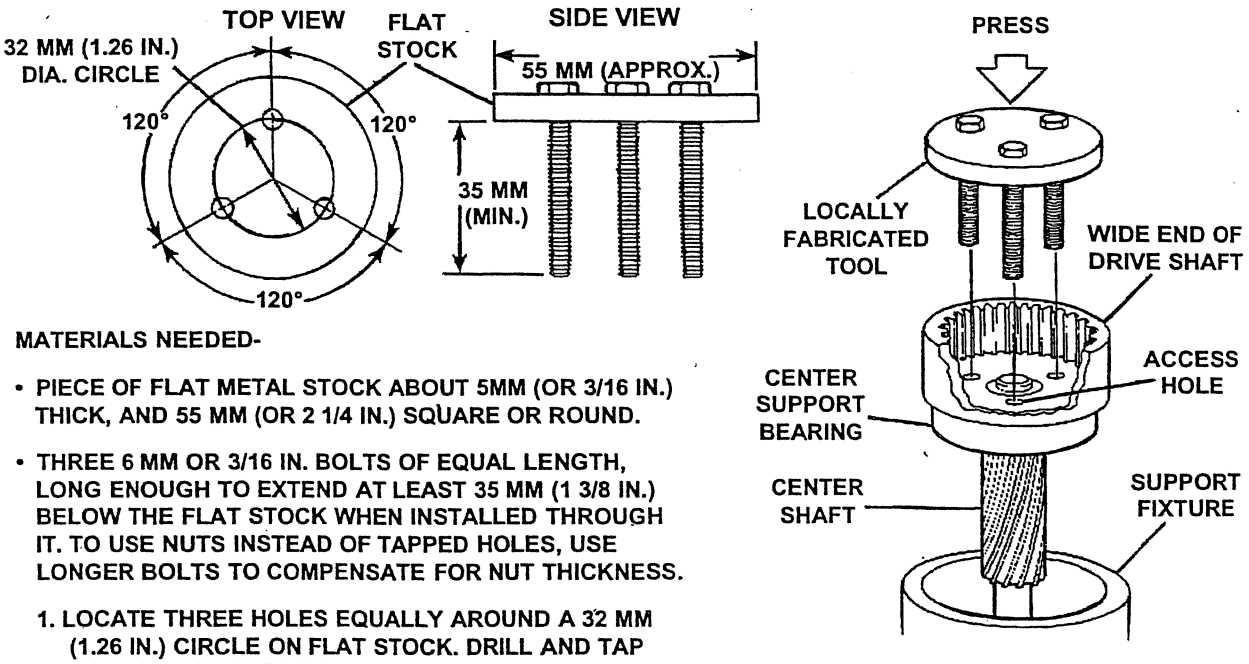
3. If necessary, replace the bushing (6, Figure 3) in the drive housing (18) as follows:

   a. From inside the drive housing (18), drive out the plug (34) if present. Use a file to clean away remnants of the old stake to allow installation of a new plug. Clean away any metal shavings.

   b. Using a suitable open tube, press out the bushing (6).

   c. Using a suitable open tube, press the new bushing (6) into the drive housing (18) until the end of the bushing is flush with the inside of the housing.

   d. Install a new plug (34), if used, to the drive housing. Stake housing material over the plug at three places, equally spaced.



MATERIALS NEEDED-

- PIECE OF FLAT METAL STOCK ABOUT 5MM (OR 3/16 IN.) THICK, AND 55 MM (OR 2 1/4 IN.) SQUARE OR ROUND.
- THREE 6 MM OR 3/16 IN. BOLTS OF EQUAL LENGTH, LONG ENOUGH TO EXTEND AT LEAST 35 MM (1 3/8 IN.) BELOW THE FLAT STOCK WHEN INSTALLED THROUGH IT. TO USE NUTS INSTEAD OF TAPPED HOLES, USE LONGER BOLTS TO COMPENSATE FOR NUT THICKNESS.

1. LOCATE THREE HOLES EQUALLY AROUND A 32 MM (1.26 IN.) CIRCLE ON FLAT STOCK. DRILL AND TAP HOLES AS NEEDED TO MATCH BOLT THREADS.
2. INSTALL BOLTS IN FLAT STOCK AND TIGHTEN. ENDS OF INSTALLED BOLTS SHOULD PASS THROUGH ACCESS HOLES IN END OF DRIVE SHAFT WITHOUT BINDING.

FIGURE 11. TOOL FOR REMOVING CENTER SUPPORT BEARING

ASSEMBLY

Lubrication During Assembly

1. The armature bearings (8 and 9, Figure 3) and drive shaft support bearing (10) are permanently lubricated. Do not add lubricant to these bearings. Lubricate the following just before or during assembly (avoid excessive grease):
   a. D.E. housing bushing (6) (in drive housing).
   b. The pivot hole and working surface on the ends of the shift lever (11).
   c. The internal gear, shaft and spline on the drive shaft (15).

Drive Shaft and Clutch Group (Figures 7 and 12)

1. If disassembled, position the drive shaft on the work surface with the internal gear end down and assemble the drive shaft and clutch group as follows:

   Important:

   a. If the center support bearing (10) is being replaced, install it on the drive shaft (15) as specified in *REPAIR PROCEDURES*, step 2, before proceeding with assembly.

Install or Connect:

1. The drive shaft support (17) to the drive shaft (15), seating the bearing (10) in the support.
2. The clutch drive assembly (2) to the drive shaft (15).
3. A new pinion stop (12) onto the drive shaft (15), the end with the recess for the stop rings (35) up.
   a. Install the stop rings (35) in the groove in the drive shaft (15).
   b. Pick up and support the assembly under the pinion stop (12). A metal block, with a U-shaped cutout that will slide over the shaft between the pinion gear and the stop, can be clamped in a vise to provide support (see Figure 12).
   c. Make sure the stop rings (35) (in the drive shaft groove) are fully seated in the pinion stop recess and stake the upper edge of the pinion stop (12) over the stop ring (35) at four places, equally spaced. Do not allow staked metal to contact the drive shaft (15).

Assembly of Gear Reduction and Drive Group (Figure 6)

Important:

If the D.E. bushing (6) and plug (34) are being replaced, install them in the drive housing (18) as specified in *REPAIR PROCEDURES*, step 3, before proceeding with assembly.

1. Lubricate the D.E. housing bushing, shift lever, and drive shaft as described under *LUBRICATION DURING ASSEMBLY*.

Install or Connect:

2. The arms on the shift lever (11) with the shift collar on the drive shaft and clutch group (C).
3. The assembled shift lever (11) and the drive shaft and clutch group (C) into the drive housing (18), aligning the holes in the drive shaft support (17, Figure 7) with those in the drive housing.
   a. Make sure that the drive shaft support is fully seated in the drive housing and that the drive shaft bearing (10, Figure 7) remains fully seated in the drive shaft support.
4. Shift lever screw (21), washer (22) and nut (23).

Tighten:

   a. Nut to 4.5 Nm (40 lb-in.).

5. The plate (26), if used, and the drive housing plug (27) to the drive housing (18).
6. Washers (30 through 32) in the same number and positions as noted at disassembly.
7. The armature support bracket (16) to the drive housing (18), aligning the mark made prior to disassembly with that on the drive housing.
8. Drive housing bolts (36 and 37).

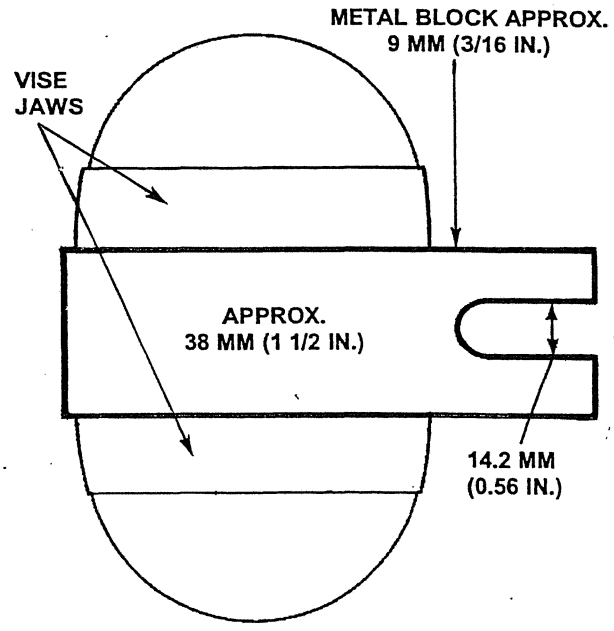


FIGURE 12. PINION STOP SUPPORT BLOCK

Assembly of Frame, Field and Brush Holder Group (Figures 5, 13 and 14)

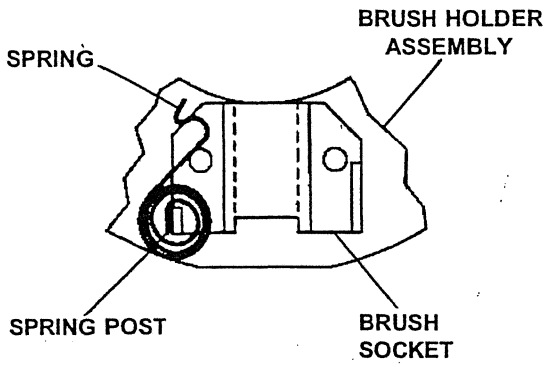


FIGURE 13. BRUSH SPRING ON POST

Install or Connect:

1. Brush springs (7), if removed.
   a. Start each brush spring onto the post on the brush holder assembly (3) as shown in Figure 13, just enough to hold the inside end of the spring from turning.
   b. Grasp the free end of the spring with needle nose pliers and twist clockwise over the top of the brush socket.
   c. Push the spring fully onto the post and release the free end to engage the notch in the brush socket.

NOTE: *The brush leads may be damaged by excessive handling. Do not over-flex the leads near the clip welds or the clips may break off.*

2. Brushes (4 and 5), if removed.
   a. See Figure 14 for the proper installed position of all brushes. Make sure the insulated brushes (5) go into the brush sockets of the brush holder assembly (3) that are mounted on the insulation.
   b. To install each brush, grasp the free end of the brush spring with needle nose pliers, twist clockwise to clear the brush socket and insert the brush partly into the brush socket.
   c. Gradually release the spring so that its end contacts the side (not end) of the brush (see Figure 13). This will hold the brushes retracted until after the brush holder is installed over the armature commutator.
3. Grounded brush screws (39).
   a. Position the terminals of the grounded brush leads behind the terminal tabs on the brush holder (3) (see Figure 13).
   b. Insert the brush screws (39) through the terminal tabs on the brush holder and thread them into the brush lead terminals.

Tighten:

   c. Grounded brush screws to 1.5 Nm (13 lb-in.).

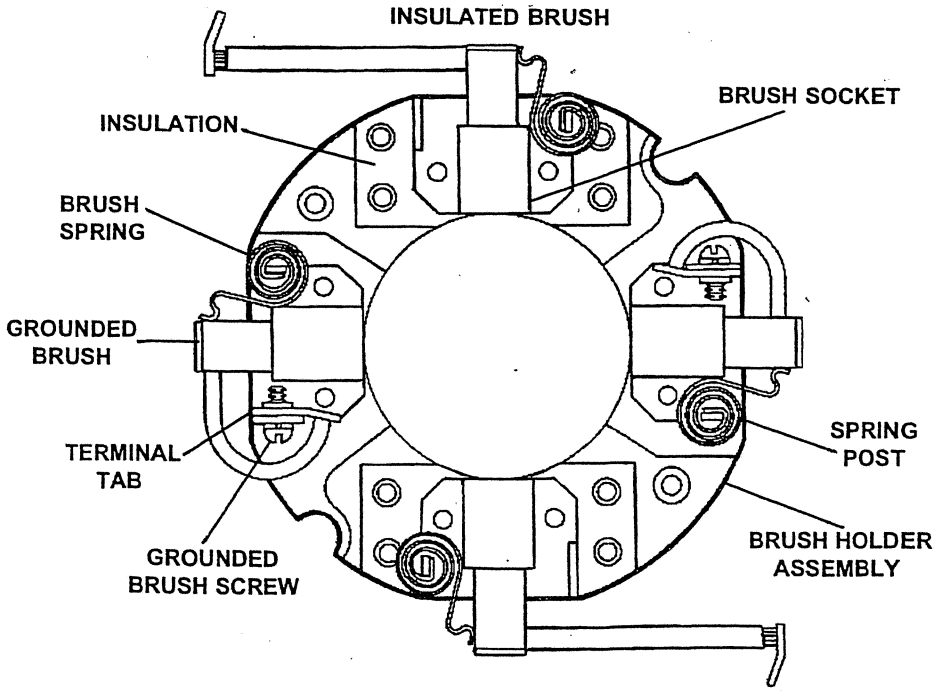


FIGURE 14. SPRINGS AND BRUSHES ON BRUSH HOLDER

4. The frame and field assembly (19) to the brush holder assembly.
   a. Position the brush holder assembly (3) (with installed brushes) over the terminal end of the frame and field assembly (19).
   b. Attach the terminals of the insulated brush leads to the conductors in the frame and field assembly with the insulated brush screws (29).

Tighten:

   c. The insulated brush screws to 1.5 Nm (13 lb-in.).

Starter Assembly (Figures 4 and 15)

Support the gear reduction and drive group (B) with the pinion gear end down and proceed as follows:

Important:

If the armature bearings (8 and 9) are being replaced, install them on the armature (13) as specified in REPAIR PROCEDURES, step 1 before proceeding with assembly.

Install or Connect:

1. Solenoid assembly (1).
   a. Pivot the plunger of the solenoid assembly into engagement with the shift lever in the gear reduction and drive group (B).
   b. Position the solenoid assembly mounting flange and install the solenoid mounting screws (25).

Tighten:

   c. Solenoid screws to 2.8 Nm (25 lb-in.).

2. Frame seal (33).
3. The armature assembly (13) with bearings (8 and 9) into the gear reduction and drive group (B).
   a. Make sure the gear teeth are aligned, then seat the bearing (8) on the armature shaft fully into the housing recess.
4. Frame, field and brush holder group (A).
   a. Place the dowel pin (28) in the hole in the armature support bracket of the gear reduction and drive group (B).
   b. Position the frame, field and brush holder group over the armature assembly (13), align the hole for the dowel pin (28) and the marks made prior to disassembly, and seat in the gear reduction and drive group (B).
   c. Twist the brush springs (7, Figure 5) away from the brushes (4 and 5, Figure 5), slide the brushes in to contact the commutator on the armature (13), and release the brush springs to contact the ends of the brushes.
5. O-ring (20).

Important:

   a. The O-ring can easily be damaged during installation of the C.E. frame (14). To prevent such damage, install the O-ring as described in the following steps.
   b. Install the O-ring on the frame, field and brush holder group (A) so that it is against the shoulder on the field frame that will abut the C.E. frame when installed. This is the normal installed position for the O-ring.
   c. Carefully roll the O-ring out of its normal installed position up onto the major O.D. of the field frame. Allow the O-ring to remain in this position until the C.E. frame is partially installed.

6. C.E. frame (14)
   a. Align the marks on the C.E. frame and frame and field assembly (19, Figure 5) made prior to disassembly.
   b. Start the C.E. frame onto the frame and field assembly, leaving a gap just slightly larger than the thickness of the O-ring (20).
7. Brush plate screw (42).
   a. Use a scribe or similar tool to align the tapped holes in the brush holder assembly (3, Figure 5) with the screw holes in the C.E. frame (14).

Tighten:

   b. Brush plate screws to 2.8 Nm (25 lb-in.).

8. Thru bolts (41).
   a. Install the thru bolts and tighten them by hand but do not close the gap between the C.E. frame and the frame and field assembly where the O-ring (20) goes.
   b. Roll the O-ring (20) back down into its installed position between the C.E. frame and the frame and field assembly.
   c. Align the timing ribs on the edge of the C.E. frame (14) with the timing spots on the frame and field assembly (A) to assure proper brush alignment. Refer to Figure 15. Marks are located in 2 places on the motor but will only match one way.

Tighten:

   d. Thru bolts (41) to 8.5 Nm (75 lb-in.).

9. The motor lead on the frame and field assembly (19, Figure 5).
   a. Remove the nut from the terminal on the solenoid, install the motor lead terminal and reinstall the nut.

Tighten:

   b. The nut on the terminal of the solenoid assembly to 11 Nm (100 lb-in.).

STARTER INSTALLATION

Testing After Repair or Overhaul

After repair or overhaul, the starter can be tested as specified in the Starter No-Load Test found in the *TROUBLESHOOTING* section.

After repair, overhaul, testing or replacement of the starter, reinstall it using the following torques when making the electrical connections to the starter.

> **⚠ CAUTION:** ***Make sure the negative battery cable is disconnected at the battery when making the electrical connections to the starter. Otherwise, injury may result. If a tool is shorted at the solenoid battery terminal, the tool will heat enough to cause a skin burn.***

Tighten:

a. Solenoid battery (B) terminal nut to 18 Nm (13 lb-ft.).

b. Solenoid switch (S) terminal nut to 1.8 Nm (16 lb-in.).

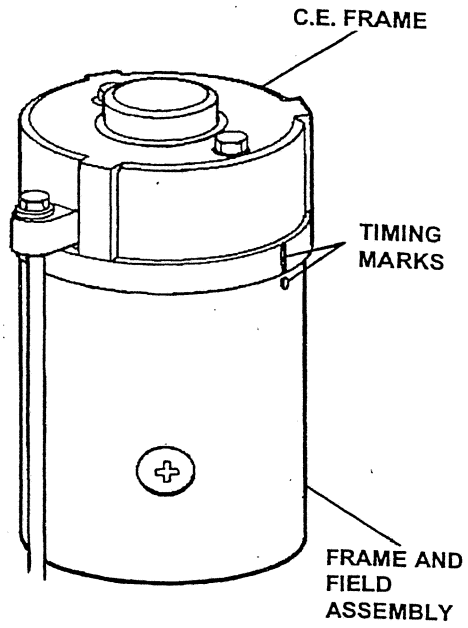


FIGURE 15. ALIGNING TIMING MARKS

STARTER SPECIFICATIONS

All 12 Volt models have these No-Load Test Specifications:

VOLTS	AMPS		RPM	
	Minimum	Maximum	Minimum	Maximum
10	125	190	3000	5600

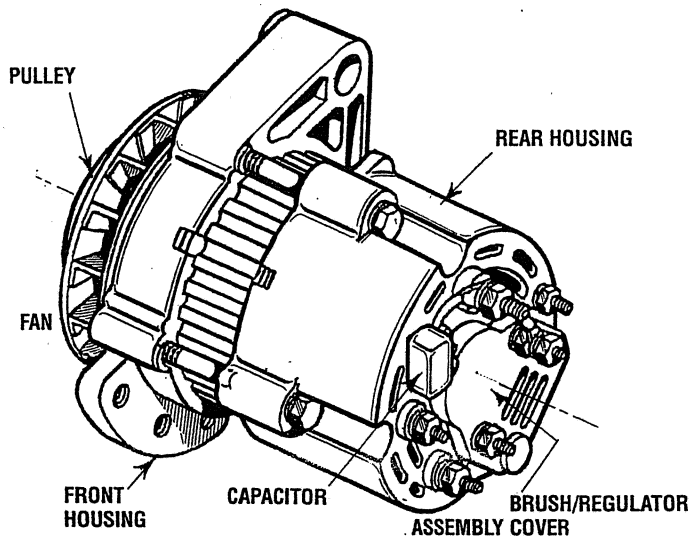
All 24 Volt models have these No-Load Test Specifications:

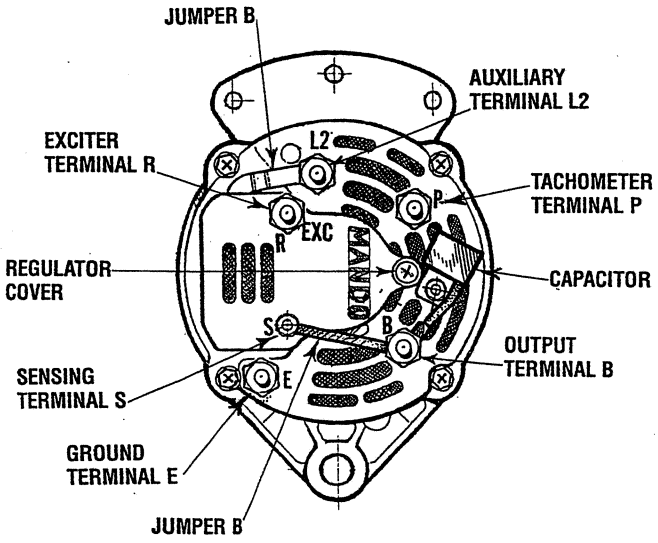
VOLTS	AMPS		RPM	
	Minimum	Maximum	Minimum	Maximum
20	75	90	3600	5400

Starter Solenoid current consumption:

RATED VOLTAGE	PULL IN WINDING			HOLD IN WINDING		
	AMPS	VOLTS	OHMS	AMPS	VOLTS	OHMS
12	52 – 59	10	0.17 – 0.19	12 – 14	10	0.76 – 0.81
24	100 – 125	20	0.16 – 0.20	12 – 14	20	1.15 – 1.65

WESTERBEKE 51A MANDO ALTERNATOR
DISASSEMBLY AND TESTING

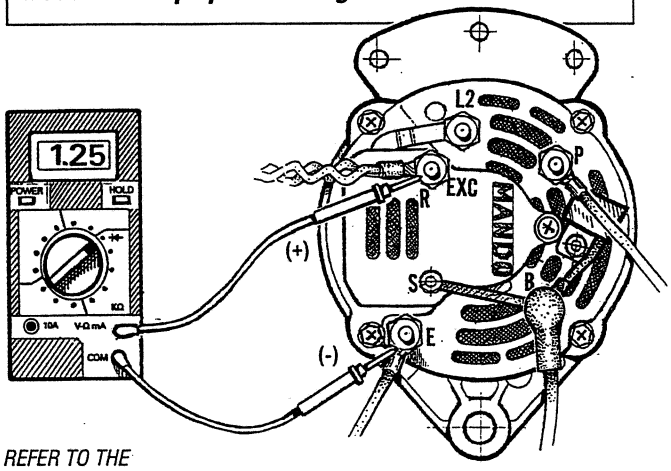




⚠ WARNING: ***A failed alternator can become very hot. Do not touch until the alternator has cooled down.***

⚠ WARNING ***Before starting the engine, make certain that everyone is clear of moving parts! Keep away from sheaves and belts during test procedures.***

⚠ WARNING ***Multimeters and DC Circuits***
DC and AC circuits are ofter mixed together in marine applications. Always disconnect shore power cords, isolate DC and AC converters and shut down generators before performing DC testing. No AC tests should be made without proper knowledge of AC circuits.



REFER TO THE WIRING DIAGRAMS FOR THE ABOVE WIRING HARNESS CONNECTIONS

TESTING THE OUTPUT CIRCUIT

1. Connect the positive voltmeter lead to the output terminal B and connect the negative lead to the ground terminal E on the alternator.
2. Wiggle the engine wiring harness while observing the voltmeter. The meter should indicate the approximate battery voltage, and should not vary. If no reading is obtained, or if the reading varies, check the alternator output circuit for loose or dirty connections or damaged wiring.

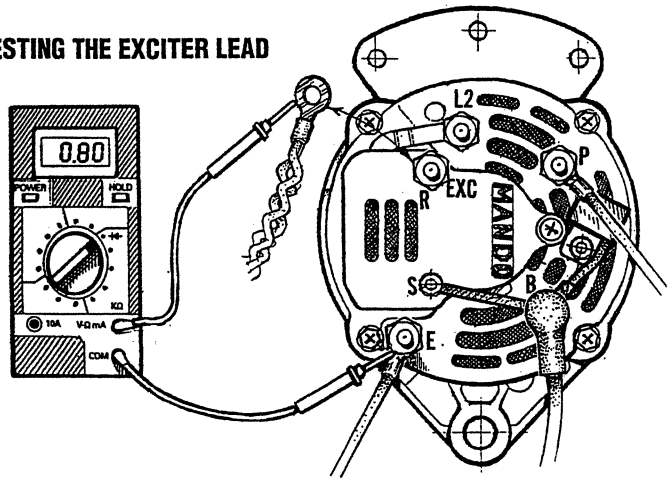
NOTE: *Prior to any alternator testing, inspect the entire alternator system wiring for defects. Check all connections for tightness and cleanliness, particularly battery cable clamps and battery terminals. Inspect the alternator drive belt for excessive wear and replace if necessary. Also adjust for proper belt tension.*

TESTING THE EXCITATION CIRCUIT

1. Connect the positive (+) voltmeter lead to the excitation terminal R on the alternator and the negative (–) lead to the ground terminal E on the alternator.
2. Turn the ignition switch to the on position and note the voltmeter reading. The reading should be 1.3 to 2.5 volts (see illustration).
3. **If the reading is between .75 and 1.1 volts,** the rotor field circuit probably is shorted or grounded. Disassemble the alternator and test the rotor as described under *CLEAN AND TEST ALTERNATOR COMPONENTS* in this section.
4. **If the reading is between 6.0 and 7.0 volts,** the rotor field circuit probably is open. Remove the regulator and inspect it for worn brushes or dirty slip rings. Replace the brushes if they are less than 1/4in. (6 mm) long. If the brushes and slip rings are in good condition, disassemble the alternator and test the rotor, as outlined under *CLEAN AND TEST ALTERNATOR COMPONENTS* in this section.

MANDO ALTERNATOR SERVICE

TESTING THE EXCITER LEAD



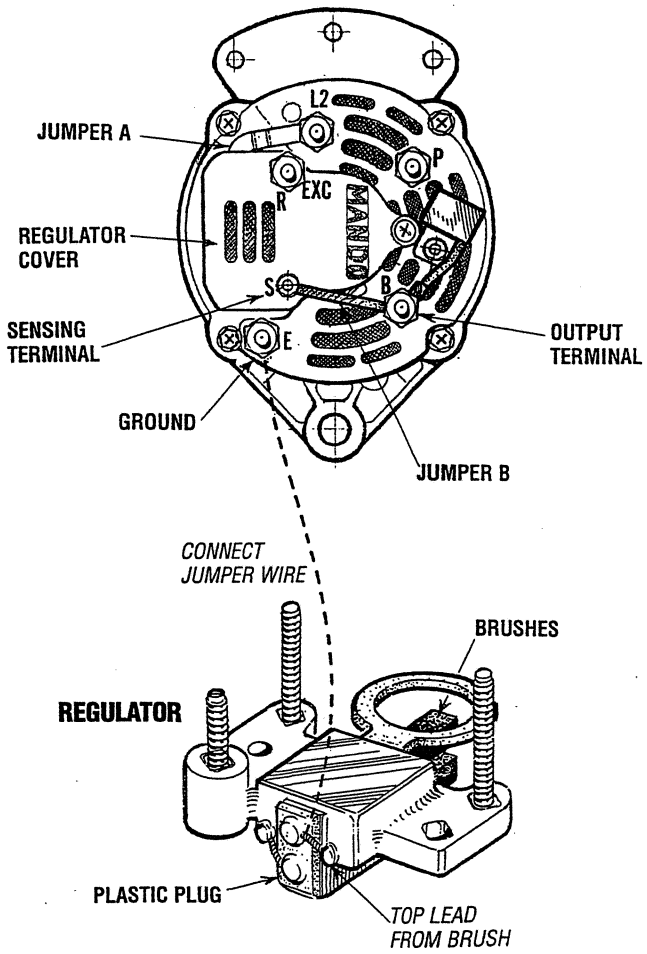
5. **If no reading is obtained,** an open exists in the alternator-excitation lead or in the excitation circuit of the regulator. Disconnect the lead from exc terminal R. Connect the positive voltmeter lead to the excitation lead and the negative voltmeter lead to ground terminal E. If the voltmeter now indicates an approximate battery voltage, the voltage regulator is defective and must be replaced. If no voltage is indicated, check the excitation circuit for loose or dirty connections or damaged wiring.

TEST VOLTAGE REGULATOR

Perform this test to determine if the voltage regulator is operating correctly, using a 0 – 20 volt DC voltmeter.

NOTE: *The battery **must** be fully charged to obtain a proper voltage reading in this test. If necessary, charge the battery with a battery chargeror allow the engine to run a sufficient length of time to fully charge the battery before taking a reading.*

1. Connect the positive (+) voltmeter lead to the positive battery terminal and the negative (–) voltmeter lead to the negative terminal.
2. Start the engine and run it at fast idle until the engine reaches its normal operating temperature. Adjust the engine speed to 1500 – 2000 rpm and observe the voltmeter for the highest reading. The reading should be between 13.7 and 14.7 volts.
3. If the reading is high, check for a loose or dirty alternator ground lead connection. If the connection is good, the voltage regulator is faulty and must be replaced. Be sure to disconnect the battery cables before attempting to remove the alternator.
4. If the reading is low:
   a. Stop the engine and remove the alternator wiring connections.
   b. Remove the Phillips cover screw from the regulator cover (see illustration).
   c. Remove the nut from the output terminal and the nut from the sensing terminal, and remove Jumper (A).
   d. Remove another nut from the sensing terminal, and the nut from the excitation terminal.
   e. Remove the regulator cover.
   f. Temporarily re-install Jumper (A) and all associated nuts. Leave Jumper (B) installed.
   g. Remove the plastic plug from the side of the regulator.
   h. Connect a jumper between the top brush lead and the ground.



   i. Repeat steps 1 and 2.

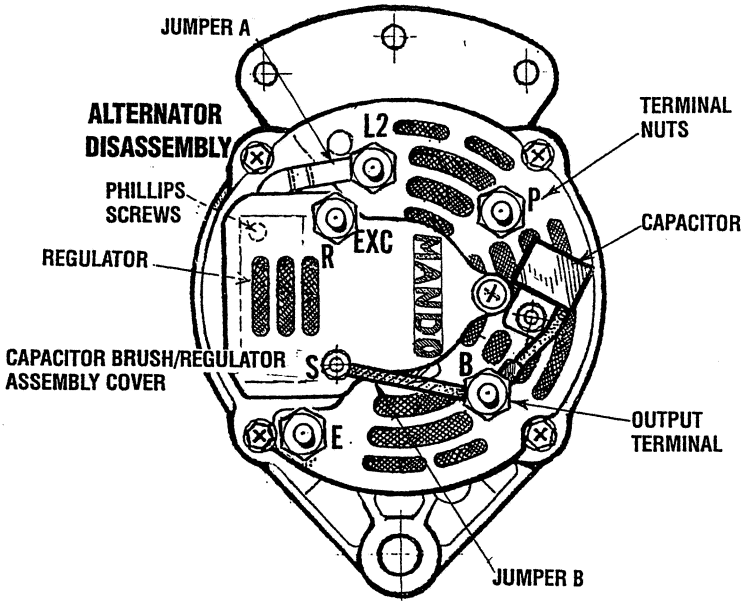
NOTE: *Do not let the voltage exceed 16 volts.*

   j. If a voltmeter reading of 14.5 volts or above is now obtained, the voltage regulator is faulty and must be replaced. If the voltmeter reading is below 14.5 volts, inspect the brushes and slip rings for wear, dirt or damage. If the brushes and slip rings are good, the alternator is fault internally. Disassemble the alternator and test the components, as outlined in this section.

MANDO ALTERNATOR SERVICE

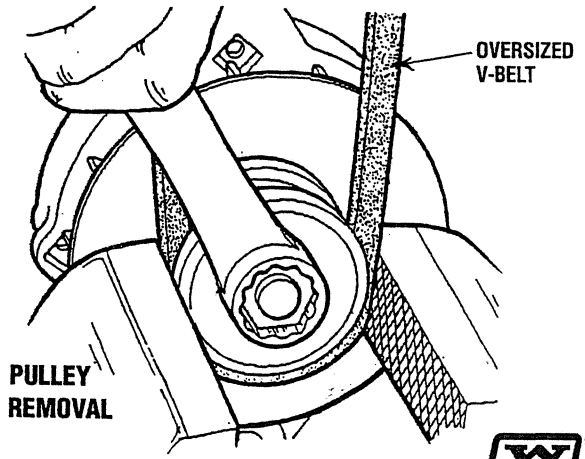
REMOVE ALTERNATOR

1. Disconnect the negative (–) battery ground cable.
2. Disconnect the wiring leads.
3. Loosen the screws. Holding the alternator, rotate it toward the engine and lift the belt off the pulley.
4. Remove the screws and washers and remove the alternator.

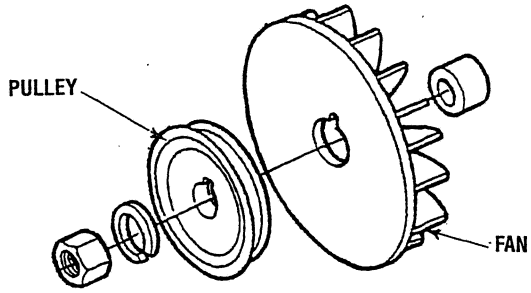


DISASSEMBLE ALTERNATOR

1. Remove the terminal nuts to remove the jumper (see illustration).
2. Remove the remaining terminal nuts.
3. Remove the capacitor.
4. Remove the Phillips screw from the regulator cover.
5. Remove the brush/regulator-assembly cover.
6. Remove the nut from the terminal.
7. Remove the jumper.
8. Remove the terminal insulators.
9. Remove the two Phillips screws and remove the brush/regulator assembly.



10. Place an oversized V-belt around the pulley and fasten the pulley in a vise.
11. Use a 7/8 in. box wrench to loosen and remove the pulley nut.
12. Remove the pulley nut, lockwasher, pulley, fan, and spacer.

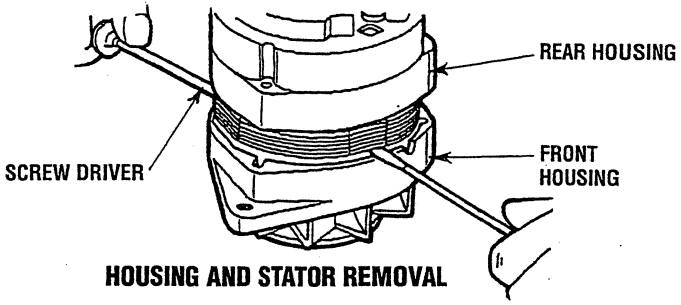


PULLEY AND FAN COMPONENTS

> **⚠ CAUTION:** ***DO NOT insert screwdriver blades more than 1/16 in. (1.6 mm). Damage to the stator winding could result from deeper penetration.***

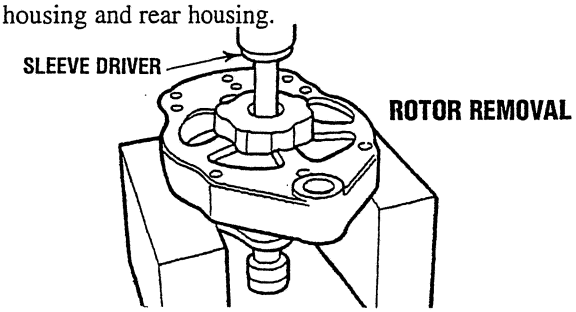
NOTE: *Score the stator, and the front and rear housings so the unit may be reassembled correctly.*

13. Remove the four through-bolts and carefully pry the front housing away from the rear housing using two screwdrivers.



HOUSING AND STATOR REMOVAL

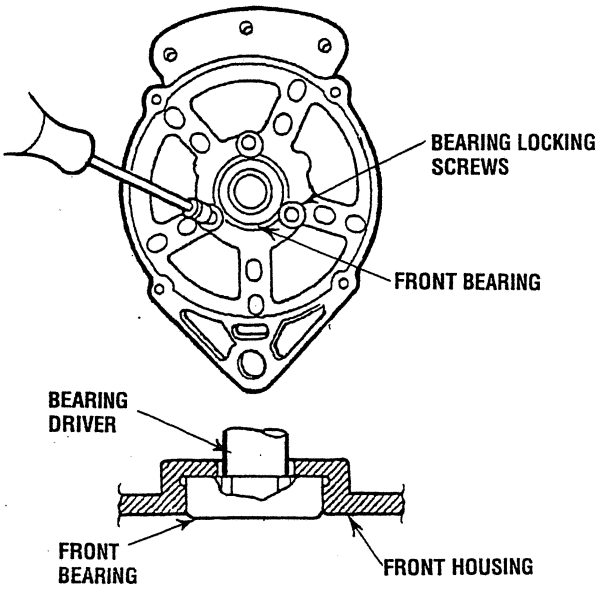
14. Carefully push the rotor assembly out of the front housing and rear housing.



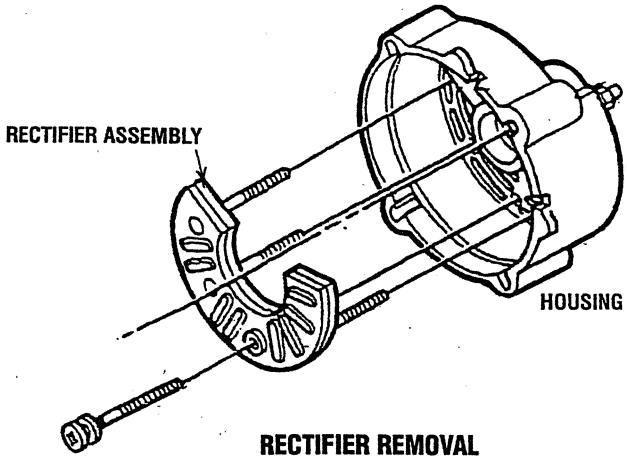
ROTOR REMOVAL

NOTE: *If the bearing is removed from the housing, a new bearing must be installed.*

15. After removing the three bearing locking screws, care fully press the front bearing out of the housing. Press against the inner race of the bearing.



16. Remove the rectifier assembly by removing the Phillips screw and lifting out the assembly.

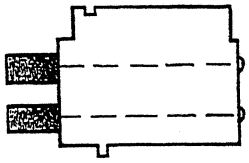


RECTIFIER REMOVAL

CLEAN AND TEST ALTERNATOR COMPONENTS

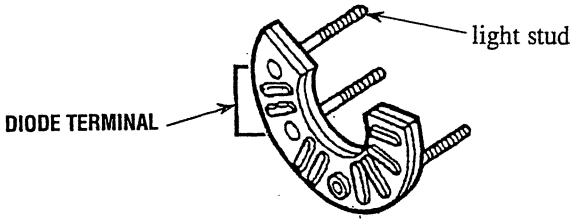
1. Inspect and test the brush/regulator assembly. The brush set may be reused if the brushes are 1/4 in. (6 mm) or longer. The brushes must not be oil soaked, cracked or grooved.

   Test for continuity between 1 and 2, and 3 and 4 using a test lamp or an ohmmeter. These checks will indicate a good brush/regulator assembly; replace the complete assembly, if necessary.



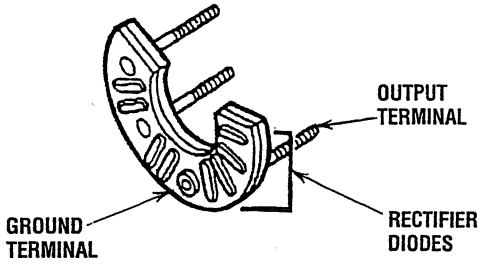
TESTING BRUSH ASSEMBLY

2. Inspect and test the diode-trio assembly:
   a. Using a commercial diode tester, a 12-volt DC test lamp or an ohmmeter, check the resistance between each of the three diode terminals and the indicator light stud.



DIODE TRIO ASSEMBLY

   b. Reverse the tester leads and repeat the resistance checks.
   c. A very low resistance should be indicated in one direction and a very high resistance should be indicated in the other direction if the diodes are normal.
   d. If any diode appears to be defective, replace the complete assembly. Do not attempt to replace an individual diode.
3. Test the diode-rectifier bridge as follows:
   a. Using a commercial diode tester, check for continuity from each of three terminals to the ouput terminal.



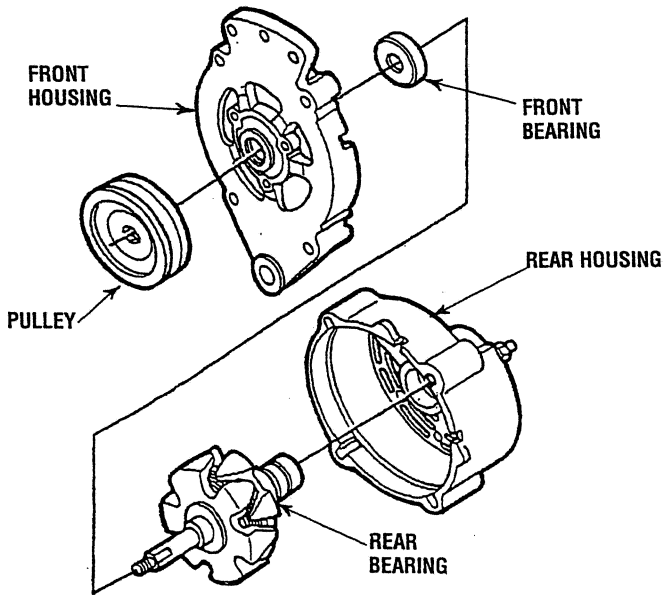
   b. Reverse the tester leads and repeat Step a.
   c. Continuity should exist in only one direction and all diodes should check alike.
   d. Perform the same continuity checks between the three terminals and strap ground terminal. This should show continuity in only one direction through the diodes and all diodes should check alike.
   e. If any diode appears to be defective, replace the rectifier assembly.

MANDO ALTERNATOR SERVICE

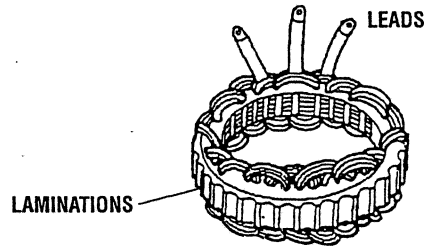
4. Clean and inspect the front and rear housings:
   a. Inspect the rear housing for cracks or breaks in the casting, stripped threads or a damaged bearing bore. Replace the housing if any of these conditions exist.
   b. Inspect the front housing for cracks, stripped or damaged threads in the adjusting ear, or an out-of-round bore in the mounting foot. If possible, correct slightly damaged threads using a tap. Replace the housing, if necessary.
   c. If the housings are to be reused, clean them in solvent and dry with compressed air.
5. Clean and inspect the rotor shaft bearings:

   NOTE: *Do not use a solvent on the rear rotor bearing since it is serviced as a unit with the rotor.*
   a. The bearings should be wiped clean with a lint-free cloth containing a moderate amount of commercial solvent. Do not immerse a bearing in solvent, or use pressurized solvent or air.
   b. Check the bearings for obvious damage, looseness or rough rotation. Replace a bearing if any doubt exists as to its condition.

   NOTE: *If the rear rotor bearing needs replacement, replace the entire rotor.*
6. Inspect the belt pulley for rough or badly worn belt grooves or keyway, and for cracks or breaks. Remove minor burrs and correct minor surface damage; replace a badly worn or damaged pulley.

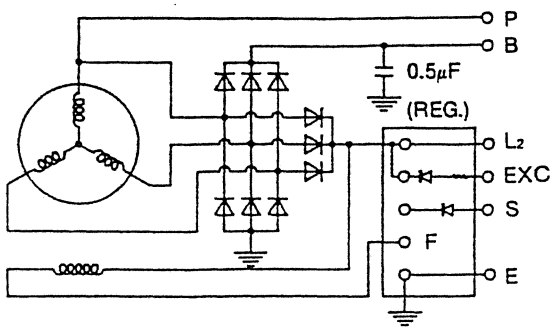


7. Test the stator windings as follows:
   a. Using an ohmmeter or test lamp, check for continuity between all three leads (1, 2, and 3). A low ohm reading or lit test lamp should be observed.



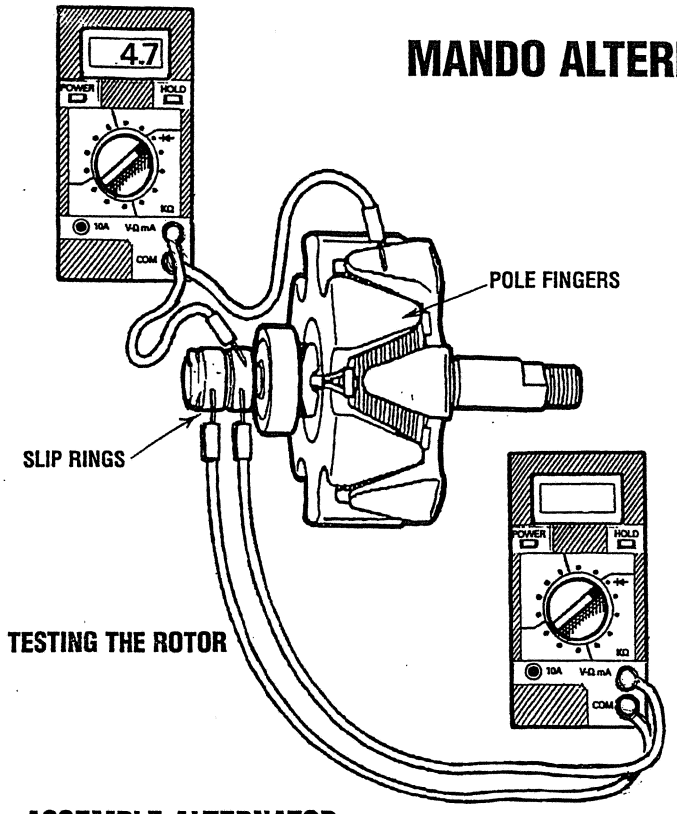
   b. Check the resistance from each lead (1, 2, and 3) to the laminations (4). There should be no continuity if the insulation is good.
   c. Inspect the stator windings for signs of discoloration. A discolored winding should be replaced.
   d. If a winding shows a high resistance or an open circuit between any two of the three winding terminals or indicates poor insulation between the windings and the laminations, the stator must be replaced.
8. Check the rotor assembly as follows:

   NOTE: *If slip rings need to be replaced, you must replace the entire rotor.*
   a. Visually inspect for physical defects such as damaged shaft threads, worn or damaged bearing areas, burned or pitted slip rings or scuffed pole fingers.
   b. Measure the winding resistance across the slip rings (A). Place the ohmmeter leads on the edges of the slip rings, not on the brush contact surfaces. The correct winding resistance at 70 – 80° F (21 – 27° C) is 4.1 to 4.7 ohms.
   c. Minor burning or pitting of the slip ring surfaces can be removed using a crocus cloth. Thoroughly wipe the slip rings clean after polishing, removing all grit and dust.
   d. Check for a grounded slip ring or rotor winding by measuring the resistance from each slip ring to the rotor body or pole finger (B). An open circuit should be indicated in both cases for a good rotor.
   e. If the windings are defective or physical damage cannot be corrected, replace the rotor assembly.
9. Use a commercial capacitor checker to test the capacitor for capacity, shorts, leakage, and series resistance.



INTERNAL CIRCUIT WIRING

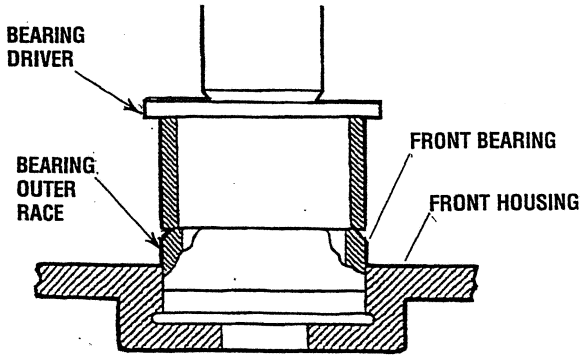
MANDO ALTERNATOR SERVICE



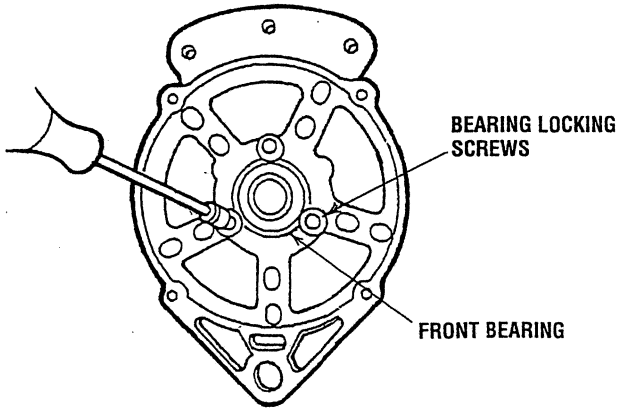
TESTING THE ROTOR

ASSEMBLE ALTERNATOR

1. Carefully press the front bearing into the front housing, pushing against the bearing's outer race using a bearing driver. Lock the bearing in place with screws.
   TORQUE: 25 - 35 lb-in (2.8 - 4.0 Nm)

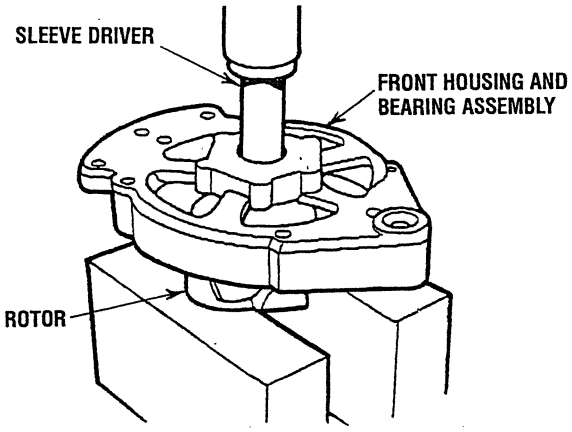


FRONT BEARING ASSEMBLY



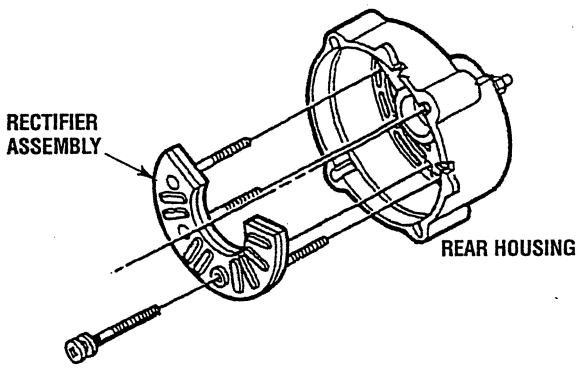
ASSEMBLING THE BEARINGS

2. Place the rotor (pulley end up) on the bed of an arbor press, on two steel blocks.
3. Press the front housing and bearing assembly down onto the rotor shaft. Press against the bearing's inner race only, using a sleeve driver. Take care to insure that the rotor leads clear the steel blocks.



INSTALLING THE FRONT HOUSING ON THE ROTOR ASSEMBLY

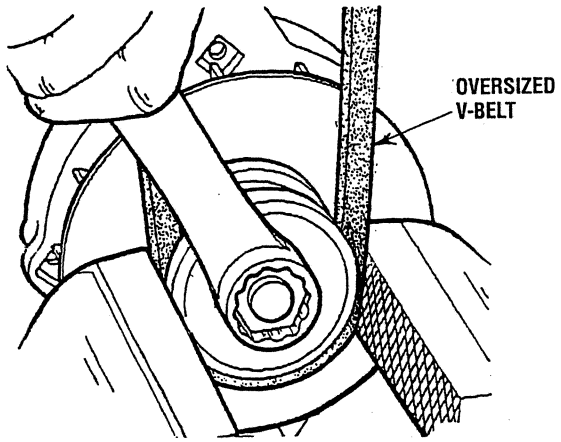
4. Install the rectifier assembly into the rear housing.
5. Insert the Phillips screw and tighten it.



6. Assemble the front and rear housings as follows:
   a. Put the stator winding in the front housing with the stator leads away from the front housing and the notches in the stator laminations aligned with the four through-bolt holes in the housing.
   b. Align the scribe marks you made in the stator, and front and rear housings during disassembly.
   c. Slip the rear housing into place over the rotor shaft. Align the mounting holes and put the stator leads through the holes at the top of the rear housing.
   d. Install the four bolts and tighten them.
      TORQUE: 35 - 65 lb-ft (4.0 - 7.3 Nm)

      NOTE: *If the front housing is new, the through-bolt will not be tapped.*

7. Install the spacer and the fan. Then push the pulley, lockwasher and nut onto the shaft. Turn the nut a few turns.
8. Place an oversized V-belt around the pulley and fasten the pulley in a vise.



INSTALLING THE PULLEY AND THE FAN NUT

9. Use a torque wrench to the tighten the nut.
   TORQUE: 35 - 50 lb-ft (4.7 - 6.8 Nm)
10. Carefully install the brush/regulator assembly on the rear housing with the two mounting screws.
11. Install the small terminal insulators.
12. Install the large terminal insulator.
13. Install the jumper.
14. Install the nut on the terminal.
15. Install the brush/regulator assembly cover.
16. Install the Phillips screw for the brush/regulator assembly cover.
    TORQUE: 25 - 35 lb-ft (2.8 - 5.1 Nm)
17. Install the capacitor.
18. Install the terminal nuts.
19. Install the jumper.
20. Install the last terminal nut.

INSTALL ALTERNATOR

1. Install the alternator, screws and washers.
2. Connect the wiring leads.
3. Put the belt on the alternator, crankshaft and coolant pump pulleys.
4. Adjust the alternator belt's tension (see *DRIVE BELT ADJUSTMENT* under *ENGINE ADJUSTMENTS*).

MANDO ALTERNATOR SPECIFICATIONS

Battery Voltage	12 Volt
Maximum Speed	13500 RPM
Cut in Speed	Max. 2000 RPM (at exc.) Max. 1500 RPM (at L2)
Reg. Set Voltage	14.7 Volts
Ambient Temp.	-20°C - 100°C
Ground	Negative

THE BE GENERATOR
SINGLE AND THREE PHASE

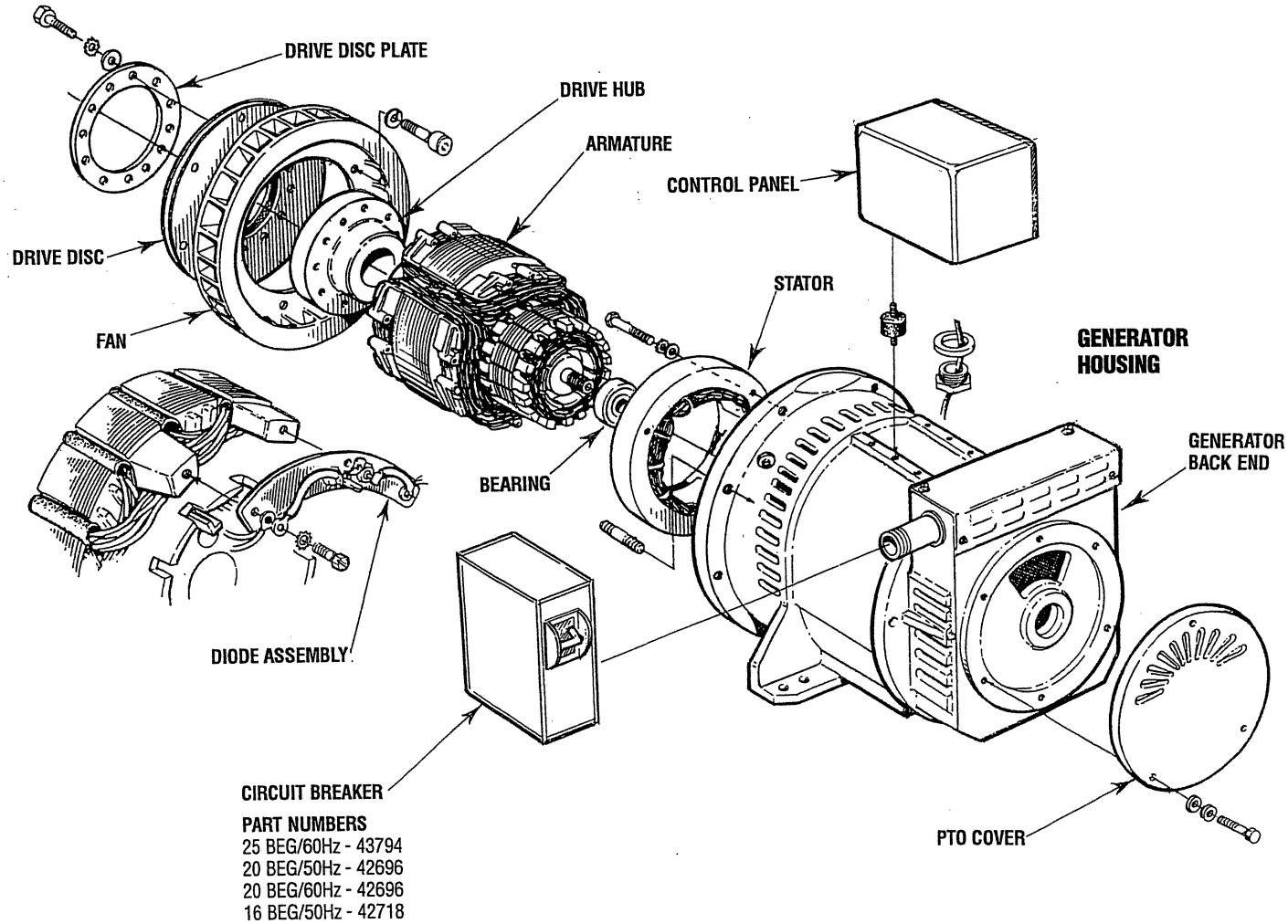
DESCRIPTION

This 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. An AC voltage is produced in the auxiliary windings of the main stator and is, in turn, supplied to a voltage regulator. The regulator produces a DC voltage to further excite the exciter stator windings, enabling the generator to produce a rated AC output. The voltage regulator senses AC voltage output and adjusts DC excitation to the exciter stator winding according to amperage load the generator is furnishing to mainatin a constant voltage output.

CIRCUIT BREAKER

A circuit breaker is installed on all WESTERBEKE generators. This circuit breaker will automatically disconnect generator power in case of an electrical overload. The circuit breaker can be manually shut off when servicing the generator to ensure no power is coming into the boat.

NOTE: *This circuit breaker is available as a WESTERBEKE add-on kit for earlier model generations; contact your WESTERBEKE dealer.*

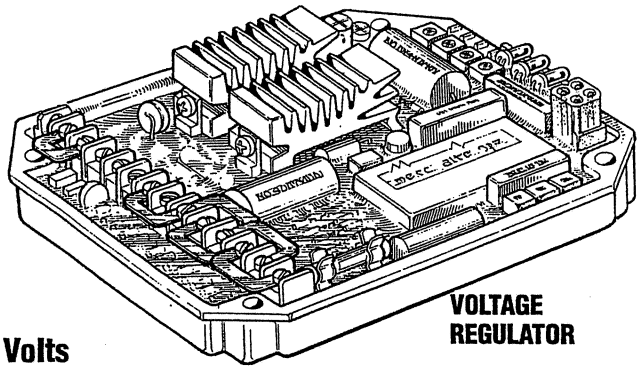


PART NUMBERS
25 BEG/60Hz - 43794
20 BEG/50Hz - 42696
20 BEG/60Hz - 42696
16 BEG/50Hz - 42718

VOLTAGE REGULATOR ADJUSTMENTS

Description

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



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.

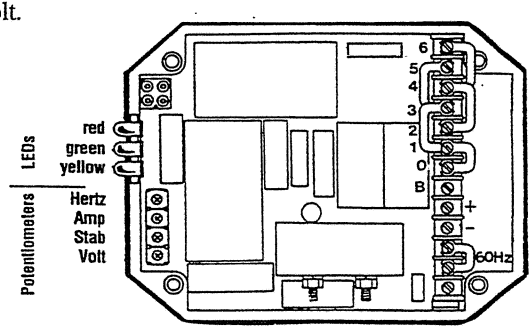
With the alternator running at no-load, at normal speed, and with VOLT adjust at minimum, it is possible that output voltage will oscillate. Slowly rotate the VOLT adjust clockwise. The voltage output of the alternator will increase and stabilize. Increase the voltage to the desired value. In this situation, 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 alternator 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 a 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 alternator must be loaded to its full output rating.

1. Load the alternator 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 alternator 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 alternator 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

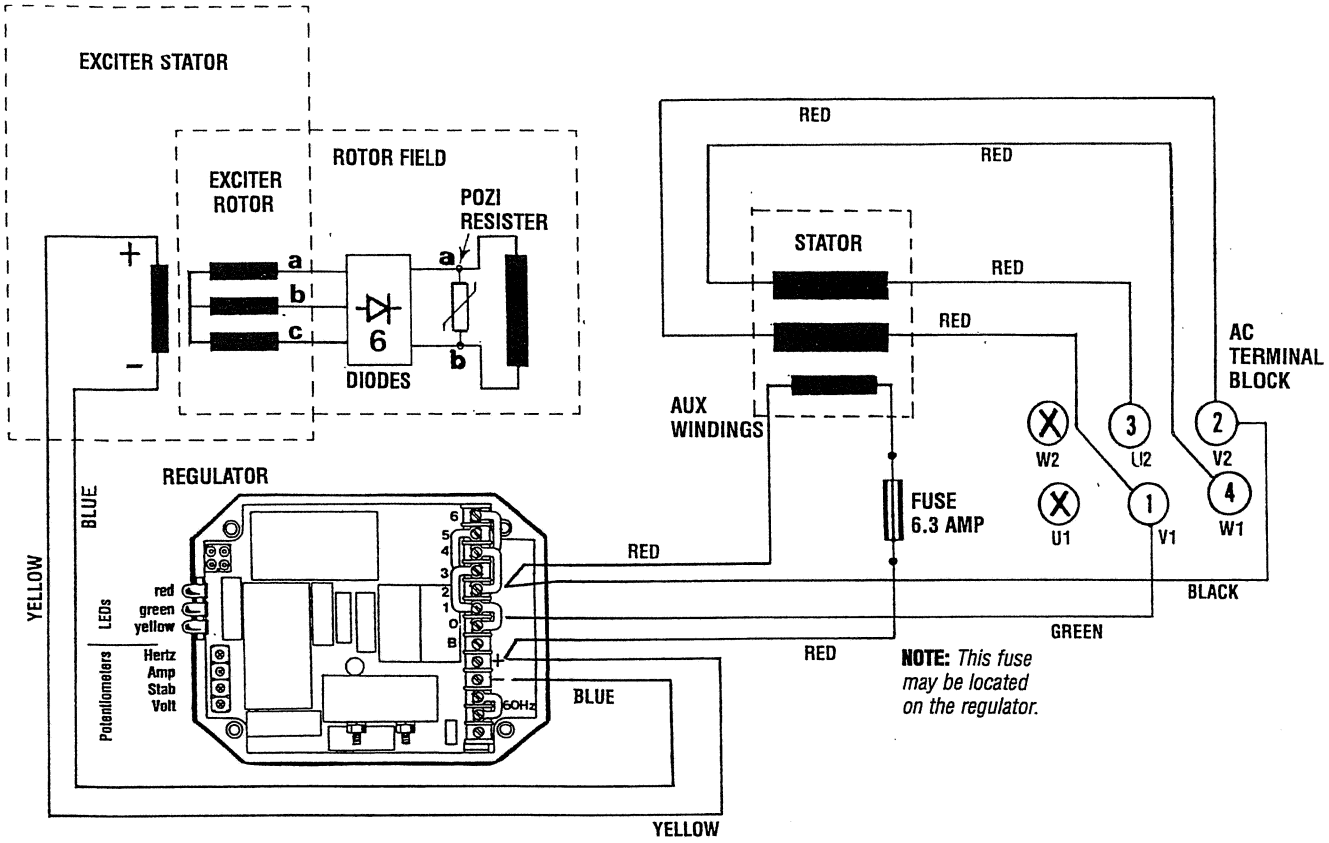
NOTE: *If the unit is operating at 60 Hertz ensure that the jumper strap is in place on the regulator board between the two 60 Hertz terminals. In order to adjust the underspeed setting, the alternator should be running at no-load.*

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 alternator'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.

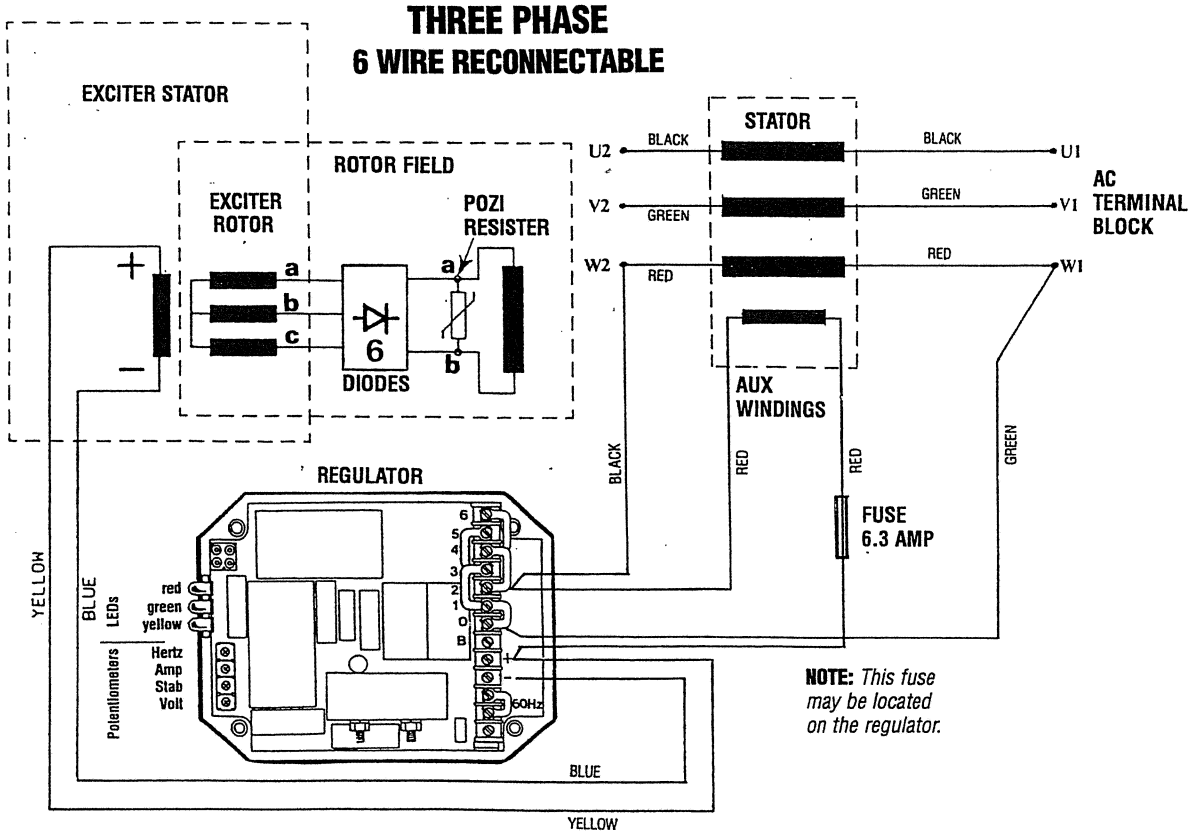
INTERNAL WIRING SCHEMATICS

SINGLE PHASE



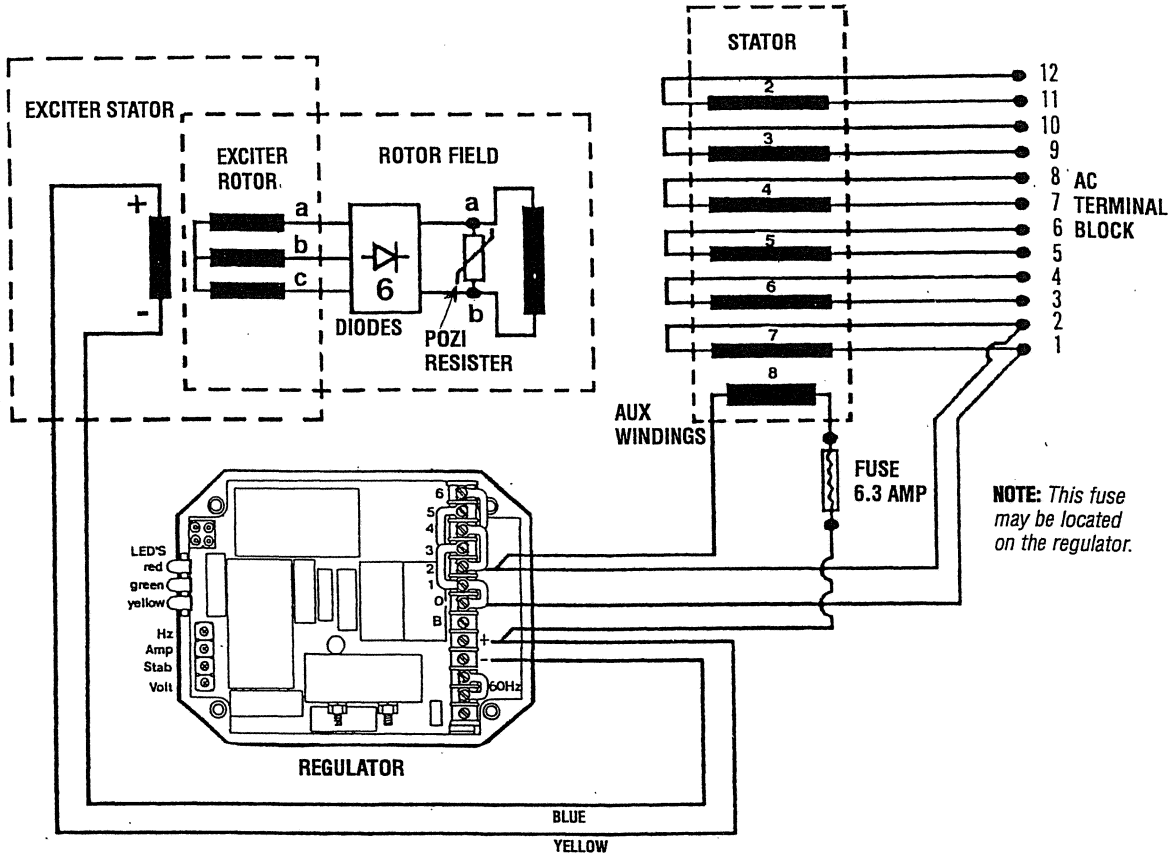
THREE PHASE

6 WIRE RECONNECTABLE



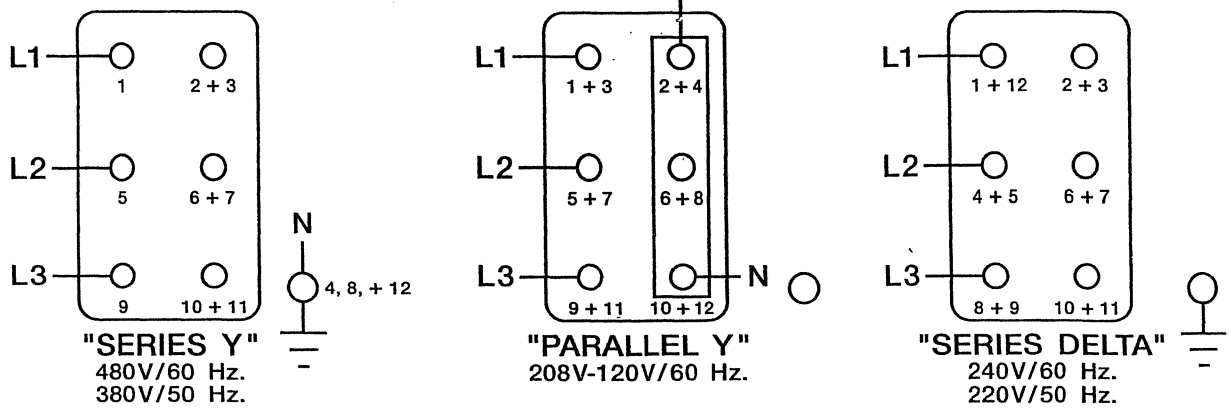
INTERNAL WIRING SCHEMATICS

3 PHASE TWELVE WIRE RECONNECTABLE



AC VOLTAGE CONNECTIONS

NOTE: IF WIRING FOR 50 HZ., THE 60 HZ. JUMPER MUST BE REMOVED FROM THE REGULATOR.



BE TROUBLESHOOTING/3 PHASE

NOTE: *AC GENERATOR TROUBLESHOOTING MUST BE PERFORMED WITH ENGINE OPERATING AT 60 HERTZ.*

PROBLEM	PROBABLE CAUSE	
No AC voltage output at no load.	**1.** Short or open in the main stator winding. **2.** Shorted pozi-resistor on exciter rotor. **3.** Four or more shorted or open diodes on exciter rotor.	**4.** Short or open in exciter stator winding. **5.** Short or open in rotating field winding.
Residual voltage produced at no load 15 - 20 volts AC.	**1.** Blown 6 AMP buse fuse auxiliary circuit feed to 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.** Open or 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.	

BE GENERATOR WINDING RESISTANCE VALUES *(IN OHMS)*

SINGLE PHASE		20 & 25 BE	32 BE
EXCITER STATOR		*18.06*	*18.20*
EXCITER ROTOR	a - b	*0.68*	*0.72*
	b - c	*0.68*	*0.72*
ROTATING FIELD		*1.75*	*2.01*
MAIN STATOR	1 - 2	*0.05*	*0.05*
	3 - 4	*0.05*	*0.05*
AUXILLARY WINDING		*1.19*	*0.98*

THREE PHASE		20, 25, & 32 BE
EXCITER STATOR		*18.20*
EXCITER ROTOR	a - b	*0.7*
	b - c	*0.7*
ROTATING FIELD		*2.01*
MAIN STATOR		*0.06 (each winding)*
AUXILLARY WINDING		*0.98*

GENERATOR AC VOLTAGE CONNECTIONS

AC VOLTAGE CONNECTIONS

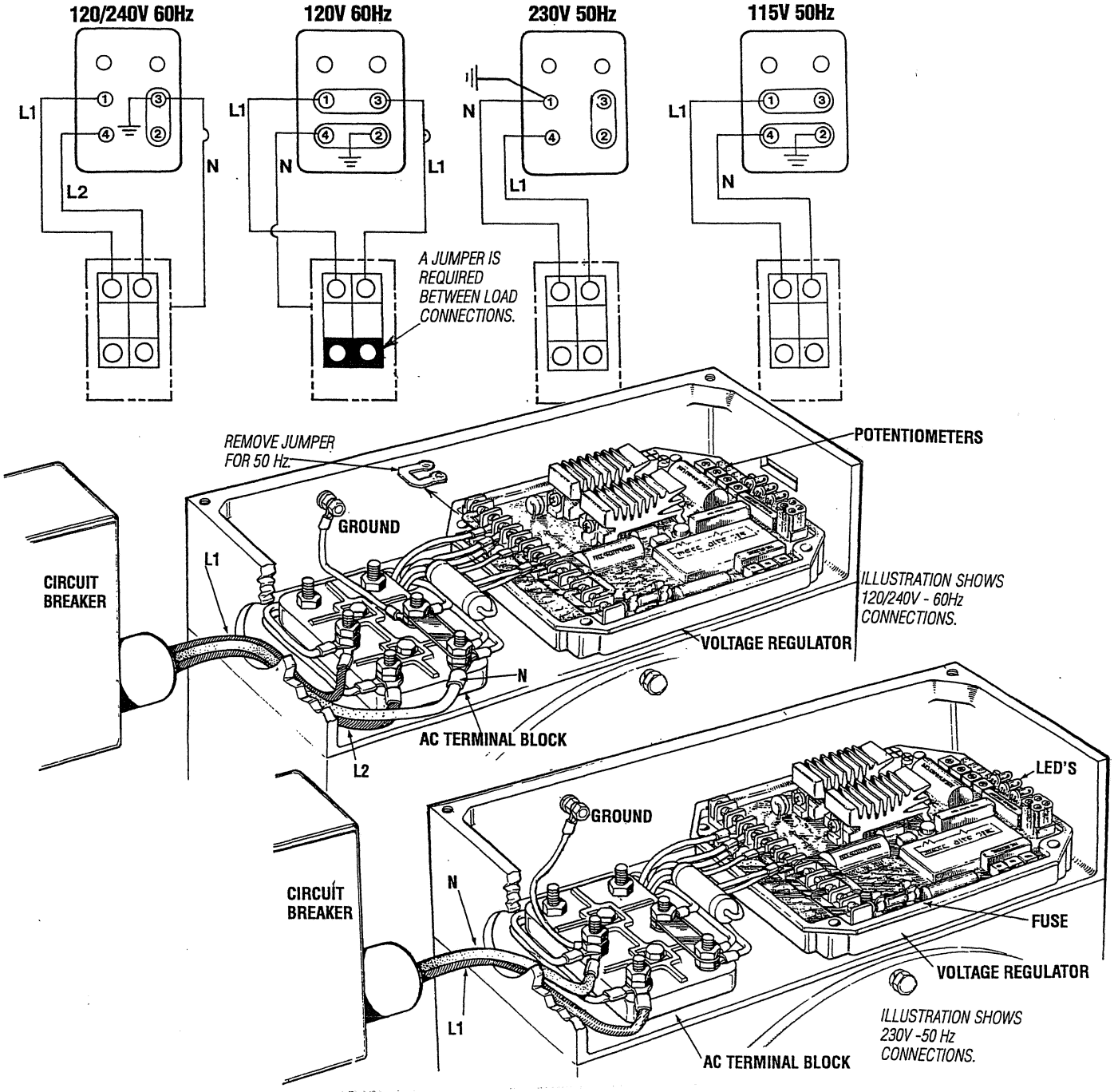
NOTE: The frame ground wire (white/green) must be properly positioned when changing the AC output configuration of the AC terminal block. For making connections to the AC terminal block, use terminal ends for 1/4 inch studs that will accept multi strand copper wire sized for the amperage rating from the hot lead connection. The frame ground wire is white or white with a green strip. It connects between the neutral stud and the generator frame.

Generator Frequency

1. Frequency is a direct result of engine/generator speed: 1800 rpm = 60 hertz; 1500 rmp = 50 hertz.
2. To change generator frequency, follow the steps below:

   Configure the AC terminal block for the desired voltage frequency as shown. Ensure that the case ground wire is connected to the correct terminal block neutral ground stud.

NOTE: *The white/green ground wire may be removed in those installations where the AC circuit has a separate neutral and ground circuit. This will prevent the unit from being a ground source in the vessel.*

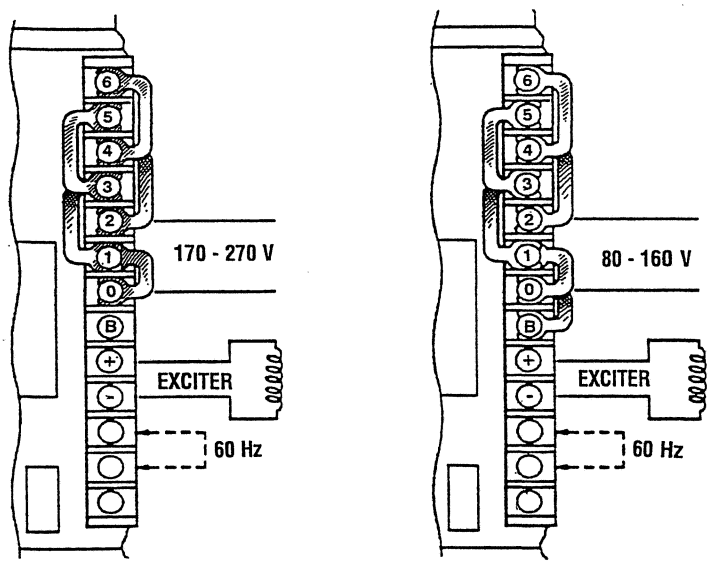


GENERATOR AC VOLTAGE CONNECTIONS

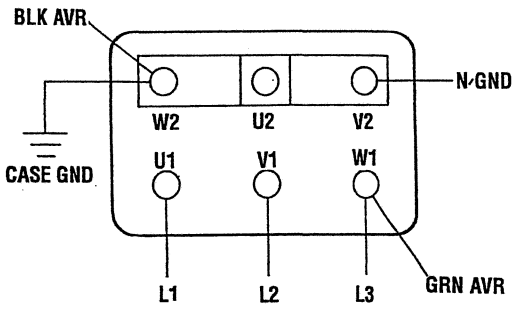
DESCRIPTION

The regulator is equipped with seven numbered terminals (0 to 6) and their related brass jumpers. The illustrations show 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 10.*

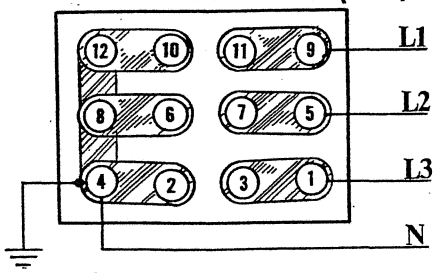


3 PHASE VOLTAGE REGULATOR



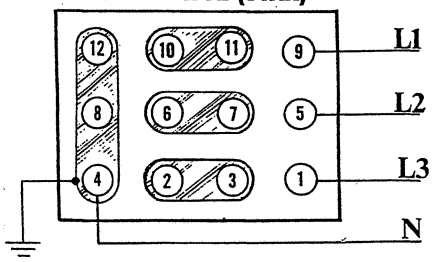
BE THREE PHASE (SIX WIRE)
CONNECTIONS FOR BOTH 60 & 50 HERTZ

PARALLEL WYE (STAR)



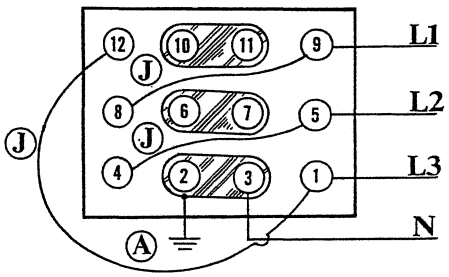
L - L - 208 VAC 3Ø 50 Hz
L - N - 120 VAC 1Ø 60 Hz
L - L - 190 VAC 3Ø 50 Hz
L - N - 110 VAC 1Ø 60 Hz

SERIES WYE (STAR)



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

SERIES DELTA



L - L - 240 VAC 2Ø 60Hz
L2, L3-N - 120 VAC 1Ø 60Hz
L - L - 230 VAC 3Ø 50Hz
L2, L3-N - 110 VAC 1Ø 50Hz

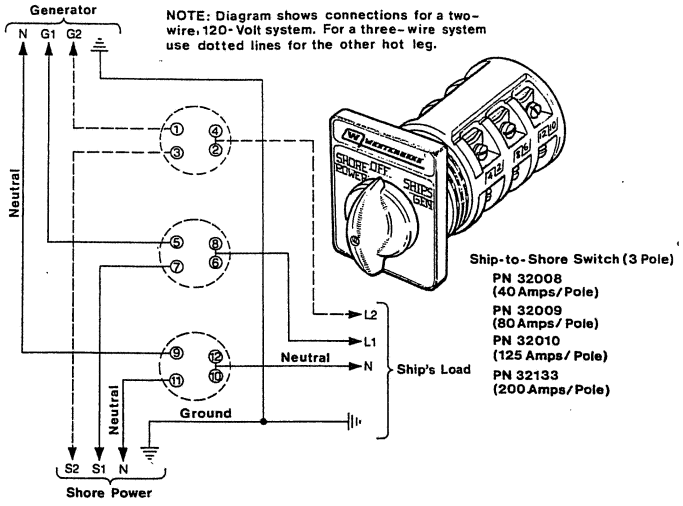
BE THREE PHASE (TWELVE WIRE)

A. SERIES DELTA-Note the repositioning of the ground lead from neutral to generator housing.

J. Jumper using #10 AWG wire.

SHORE POWER TRANSFER SWITCH

SHORE POWER CONNECTIONS (60 HERTZ)

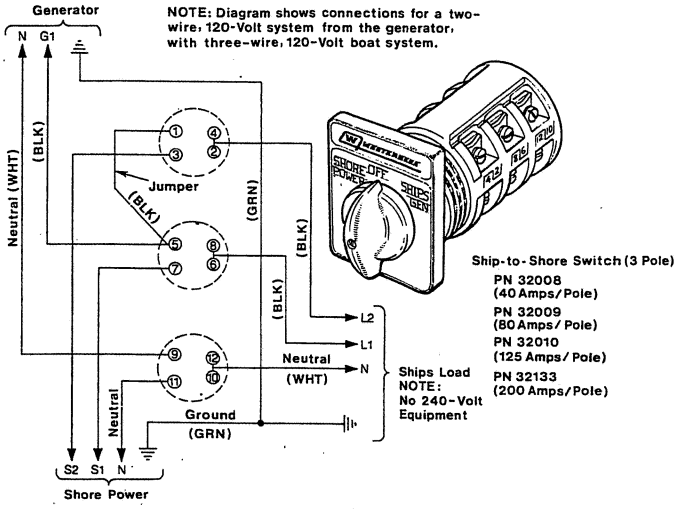


If the installer connects shore power to the vessel's AC circuit, this must be done by means of the Shore Power Transfer Switch. Set the transfer switch shown in the diagrams to the OFF position. This switch prevents simultaneous connection of shore power to generator output.

> **⚠ CAUTION:** ***Damage to the generator can result if utility shore power and generator output are connected at the same time. This type of generator damage is not covered under the warranty; it is the installer's responsibility to make sure all AC connections are correct.***

120 VOLT/60 HZ THREE WIRE CONFIGURATION

Notice the repositioning of the white wire ground load on the terminal block to the generator case.



Switching Shore Power to Generator Power

> **⚠ CAUTION:** ***Heavy motor leads should be shut off before switching shore power to generator power or vice-versa because voltage surges induced by switching with heavy AC loads on the vessel being operated may cause damage to the exciter circuit components in the generator.***

WESTERBEKE 25KW AND 20KW BEG GENERATOR SPECIFICATIONS

ENGINE SPECIFICATIONS

Engine Type	Gasoline, four-cycle, four-cylinder, fresh water-cooled, Vertical, in-line overhead mechanism
Governor	Hoof, flyball type. 5% speed regulation.
Combustion Chamber	Multi-sphere type.
Bore & Stroke	3.38 x 3.70 inches (86.0 x 94.0 mm).
Piston Displacement	133.26 cubic inches (2184 cubic centimeters)
Firing Order	1 - 3 - 4 - 2
Direction of Rotation	Clockwise, when viewed from the front
Compression Ratio	8.6:1
Dimensions	Height: 42.2 inches (1071.9 mm) Width: 22.4 inches (568.9 mm) Length: 28.2 inches (716.3 mm)
Weight **25KW** **20KW**	968 lbs (439.5 kgs) 940 lbs (426.7 kgs)
Inclination	Continuous 26° Temporary 30°

TUNE-UP SPECIFICATIONS

Compression Pressure (Limit of difference between cylinders)	163.5psi (11.5kg/cm²) at 270 rpm 28.0 psi {2.0 kg/cm²}
Valve Timing	Intake Opens 2° BTDC Intake Closes 53° ABDC Exhaust Opens 57° BBDC Exhaust Closes -2° ATDC
Valve Seat Angle	Intake 45° Exhaust 45°
Valve Clearance (engine warm)	Intake 0.012 inches (0.3 mm) Exhaust 0.012 inches (0.3 mm)
Engine Timing **25KW** **20KW**	 20° BTDC at 1800 rpm ± .5° 12° BTDC at 1800 rpm ± .5°

EXHAUST EMISSIONS SYSTEMS

Emission Control Systems	Meets U.S.C.G. Regulation 33 CFR 183

IGNITION SYSTEM

General	Battery ignition 12V negative ground. Distributor with ignition module and ignitor. Ignition coil and spark plugs.
Distributor	Solid state type with signal generator and ignitor.
Spark Plug Thread Size	14mm X 1.25 pitch
Carburetor (STD Type)	Down draft type, single barrel. USCG approved flame arrester
Spark Plug Gap	.030 inches (0.8 mm)
Dwell	63° at 1800 rpm.

FUEL SYSTEM

General	Conventional carburetor type with electric fuel pump.
Fuel	Unleaded gasoline (E10 Maximum). Octane rating of 89 or better.
Fuel Consumption **25KW** **20KW**	 3.0 U.S. GPH (11.3 LPH) at full output 2.5 U.S. GPH (9.4 LPH) at full output
Fuel Lift Pump	Electromagnetic-Lift capacity 6 feet (wet) (1.8 meters)
Fuel Filter (on engine)	Replaceable cartridge-screw on. Replaceable at fuel pump inlet.
Air Cleaner (flame arrester)	Metal screen type - cleanable.
Air Flow (engine combustion)	69.5 cfm (1.9 cmm)

COOLING SYSTEM

General	Fresh water-cooled block, thermostatically-controlled with heat exchanger.
Operating Temperature	130 - 150° F (55 - 66° C)
Fresh Water Pump	Centrifugal type, metal impeller, belt-driven
Raw Water Pump	Positive displacement, rubber impeller, belt driven.
Raw Water Flow, at 1800 rpm	6.7 gpm (25.3 lpm)
System Capacity (coolant)	7.3 qts (6.9 liters)

(continued)

WESTERBEKE 25KW AND 20KW BEG GENERATOR SPECIFICATIONS

LUBRICATION SYSTEM

General	Pressure fed system
Oil Filter	Full flow, paper element, spin-on type
Sump Capacity (not including filter)	4.0 U.S. qts (3.7 liters) plus filter/cooler assembly
Operating Oil Pressure (engine hot)	55-75 psi (3.8 - 5.2 kg/cm²)
Oil Grade	API Category of SJ, SL, SM or better SAE 10W-30 or 15W-40

ELECTRICAL SYSTEM

Starting Battery	12-Volt, (-) negative ground
Battery Capacity	300 - 600 Cold Cranking Amps(CCA)
Starter	12-Volt, reduction-solenoid mounted.
DC Charging	12 VDC belt driven alternator.
DC Charging Cranking Current	175 - 200 amps

AC GENERATOR (SINGLE PHASE)

General-Single Phase	Brushless six pole, revolving field. Sealed lubricated single bearing design. Reconnectable single phase for 120/240 volts with solid state voltage regulator	
Voltage - Single Phase	120 Or 120/240 volts - 60 hertz 230 volts - 50 hertz	
Voltage Regulation	±2% no load to full load.	
Frequency Regulation	±5% no load to full load.	
Rating (Volts AC)		
20KW - 60 Hz	120 volts 120/240 volts	166 amps 166/183 amps
16KW - 50 Hz	230 volts	72.7 amps
22.5KW - 60 Hz	120 volts 120/240 volts	208 amps 1208/104 amps
20KW - 50 Hz	230 volts	91 amps

AC GENERATOR (THREE PHASE)

General-3 Phase	Brushless six pole, revolving field. Sealed lubricated single bearing design. 12 lead reconnectable for low voltage WYE and for Delta. Solid state voltage regulator with protection circuitry.	
Voltage - 3 Phase (60 Hertz)	Low voltage WYE High voltage WYE Delta	208 volts 480 volts 240 volts
Voltage - 3 Phase (50 Hertz)	High voltage WYE Delta	380volts 230 volts
20KW - 60 Hz Amperage 3 Phase	Low voltage WYE High voltage WYE Delta	70 amps 35 amps 60 amps
16KW - 50 Hz Amperage 3 Phase	High voltage WYE Delta	30.4 amps 52.5 amps
25KW - 60 Hz Amperage 3 Phase	Low voltage WYE High voltage WYE Delta	86.7 amps 37.6 amps 75.2 amps
20KW - 50 Hz Amperage 3 Phase	High voltage WYE Delta	38 amps 65.6 amps

GENERATOR COOLING

Air requirements (60 Hz at 1800 rpm)	450 cfm (12.74 cmm)

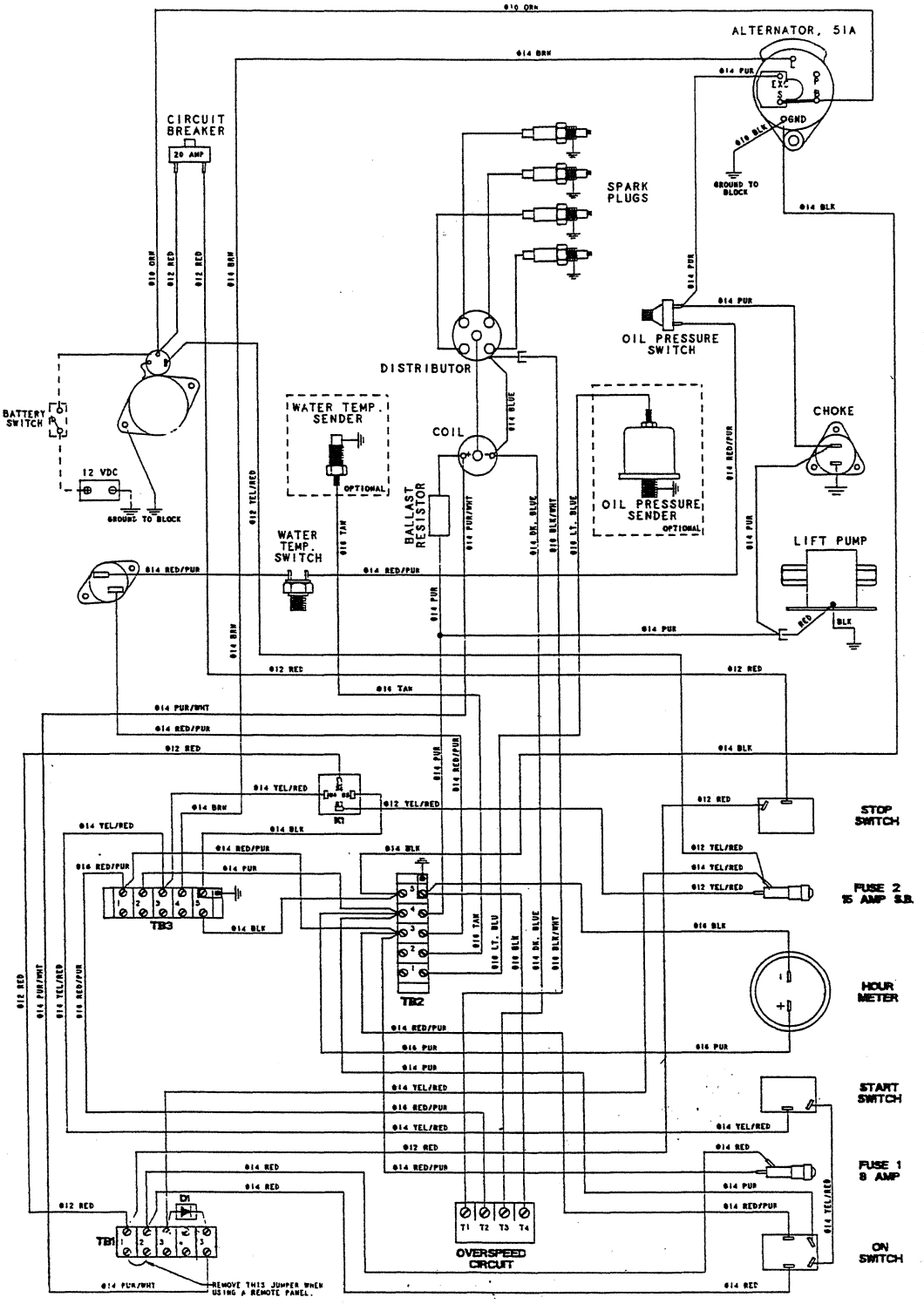
NOTE: *Increase air supply 15% for 50 Hertz operation at 1500 rpm*

Engine Combustion Air Requirements (60 Hz at 1800 rpm)	69.5 cfm (1.9 cmm)
Engine Cooling Air	100 cfm (2.83 cmm)
Generator Compartment Ambient Temperature Recommendations	122°F (50°C) maximum

NOTE: *Forced ventilation should be provided to maintain generator compartment temperatures below maximum.*

25KW AND 20KW BE GENERATOR

WIRING DIAGRAM #040620

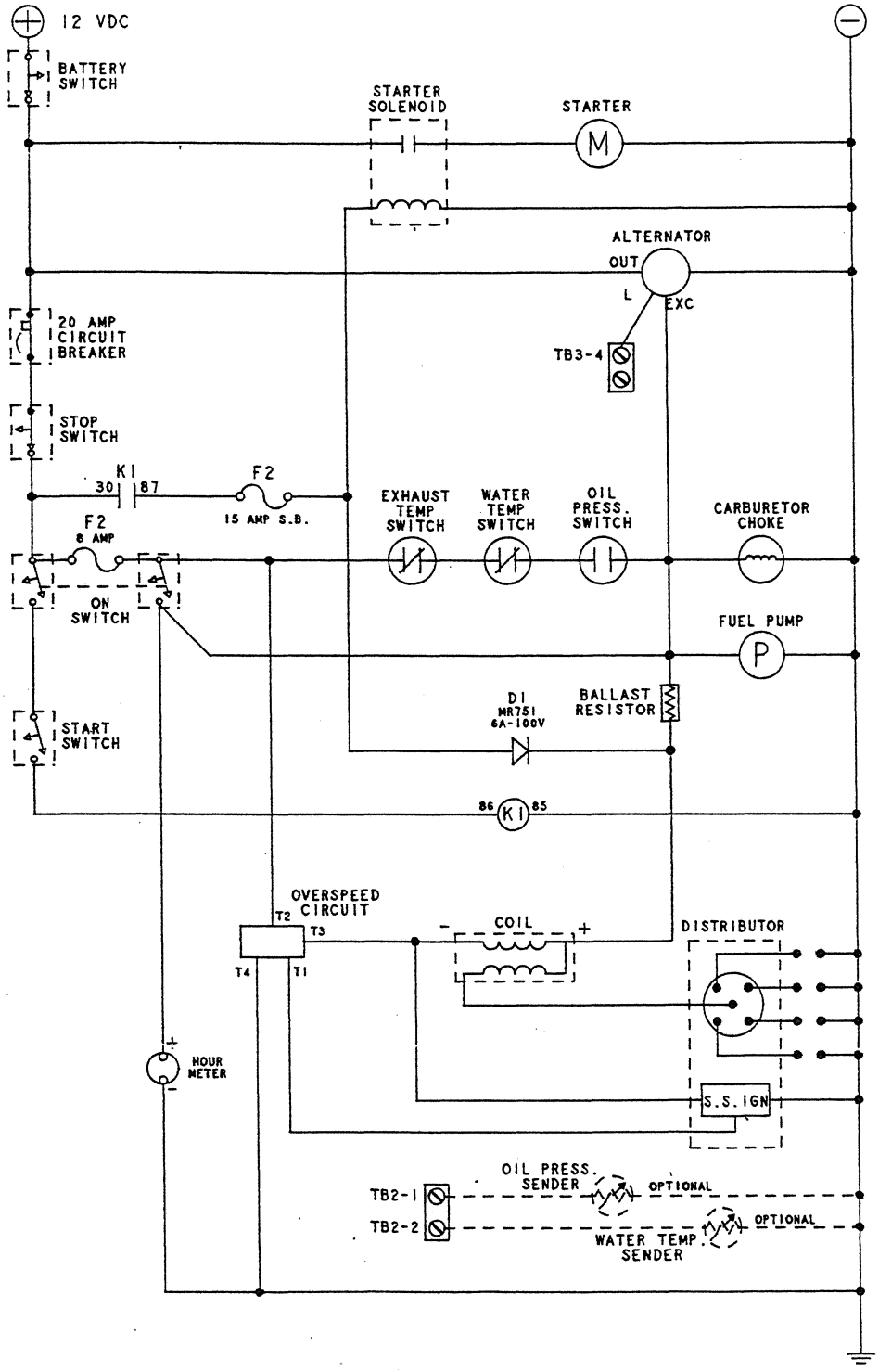


25KW AND 20KW BE GENERATOR

WIRING SCHEMATIC #040620

NOTE:

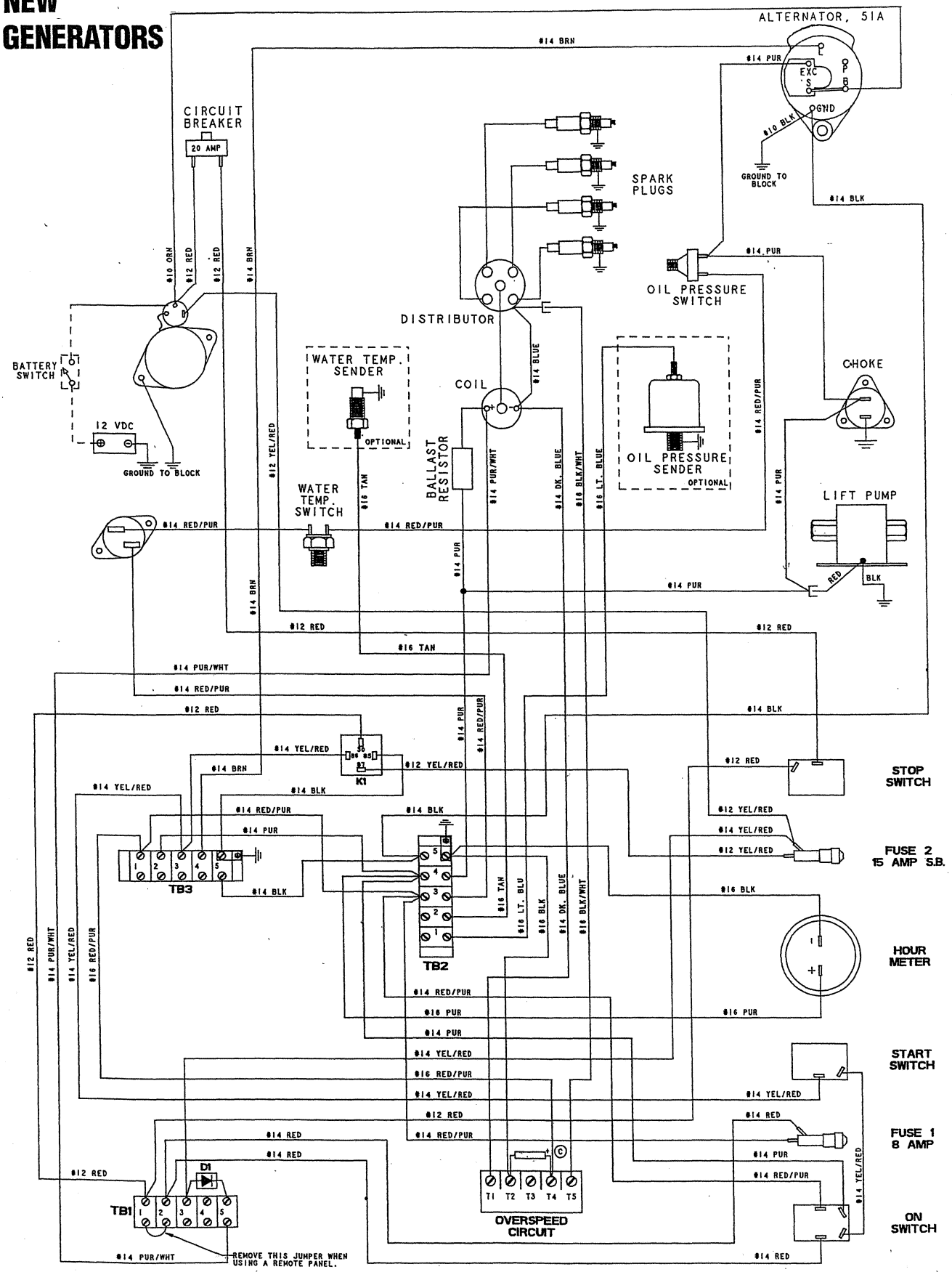
AN ON-OFF SWITCH SHOULD BE INSTALLED BETWEEN THE BATTERY AND STARTER TO DISCONNECT THE BATTERY IN AN EMERGENCY AND WHEN LEAVING THE BOAT. A SWITCH WITH A CONTINUOUS RATING OF 300 AMPS AT 12 VDC WILL SERVE THIS FUNCTION. THIS SWITCH SHOULD NOT BE USED TO MAKE OR BREAK THE CIRCUIT.



25KW AND 20KW BE GENERATOR

WIRING DIAGRAM #040620

NEW GENERATORS



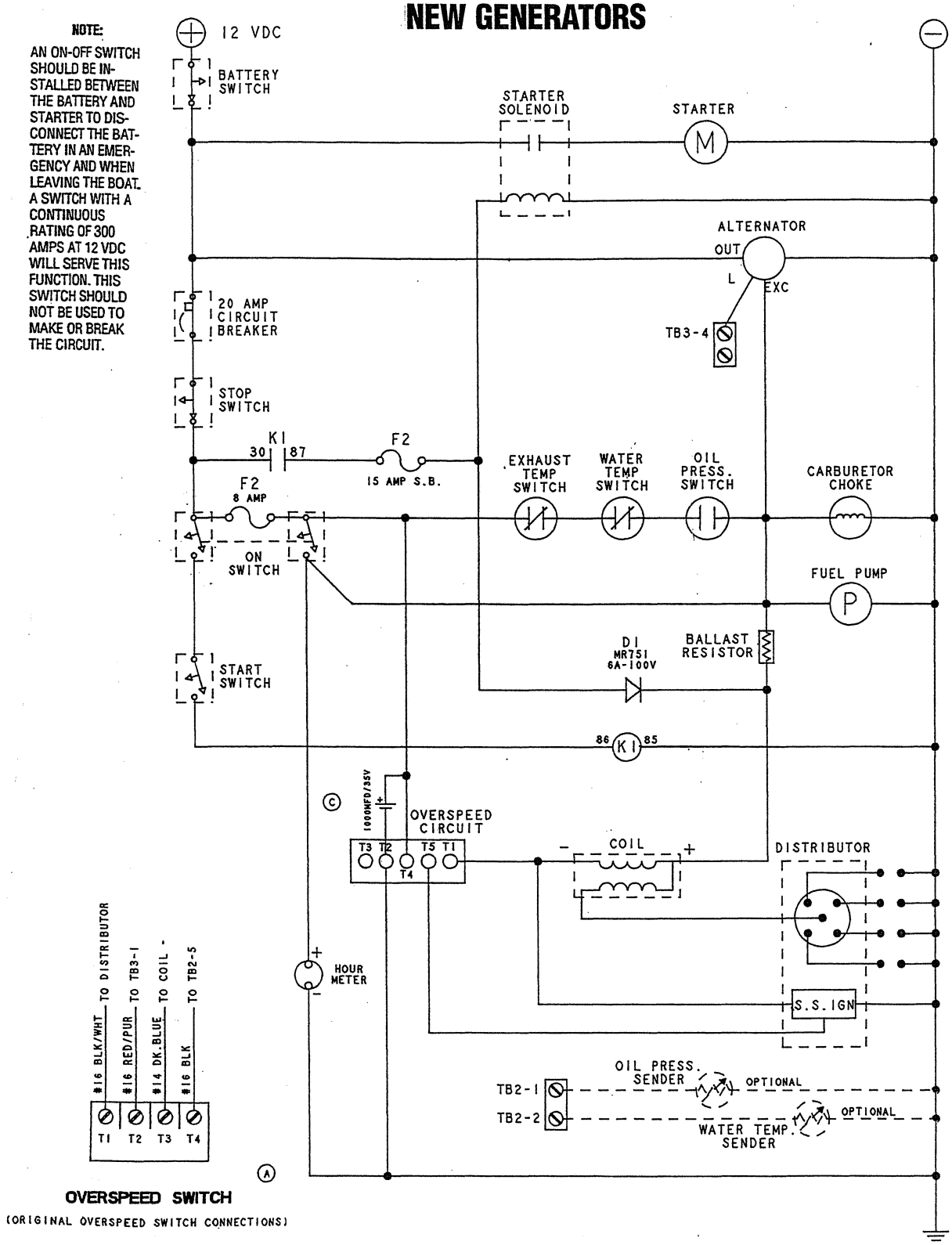
25KW AND 20KW BE GENERATOR

WIRING SCHEMATIC #040620

NEW GENERATORS

NOTE:

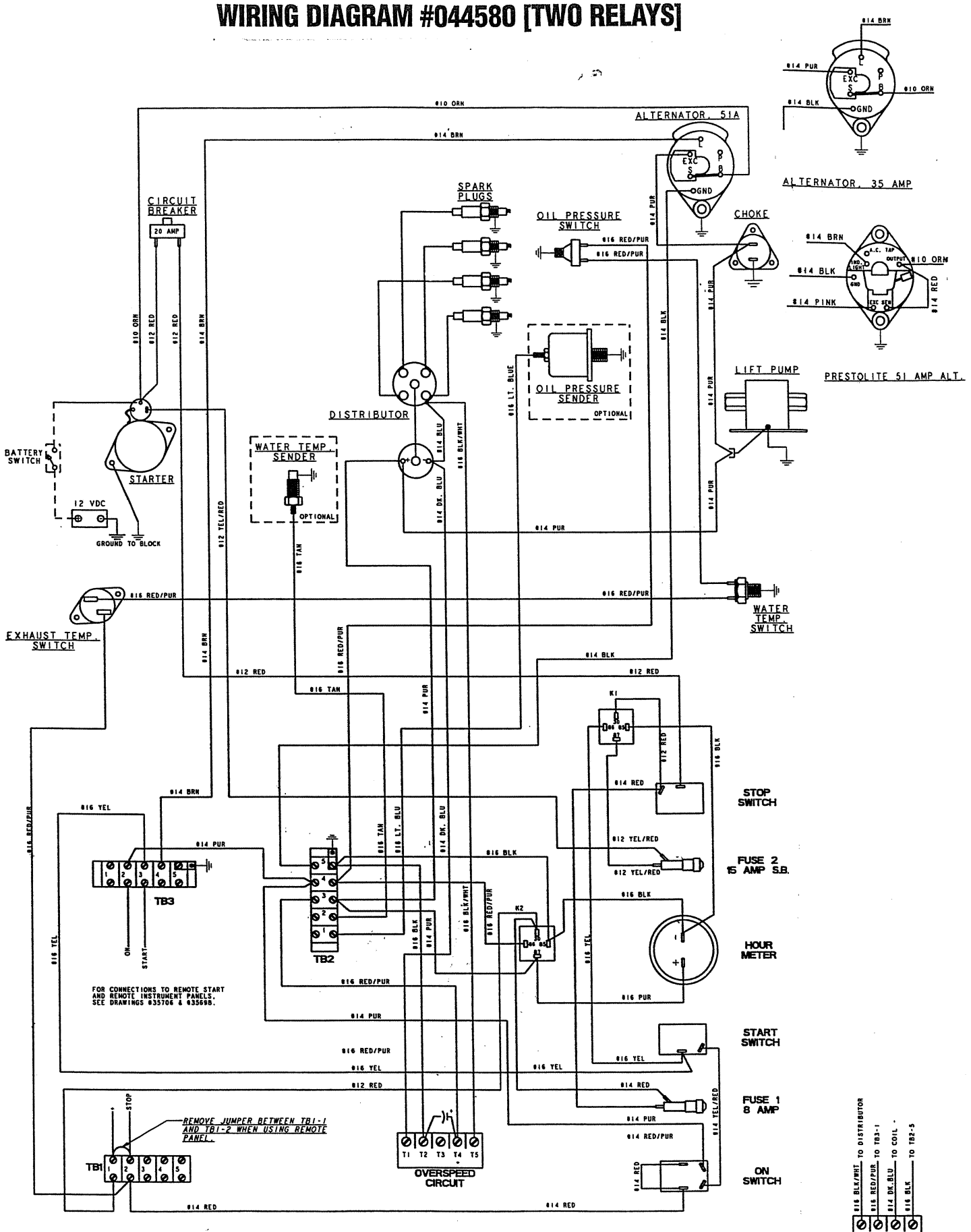
AN ON-OFF SWITCH SHOULD BE INSTALLED BETWEEN THE BATTERY AND STARTER TO DISCONNECT THE BATTERY IN AN EMERGENCY AND WHEN LEAVING THE BOAT. A SWITCH WITH A CONTINUOUS RATING OF 300 AMPS AT 12 VDC WILL SERVE THIS FUNCTION. THIS SWITCH SHOULD NOT BE USED TO MAKE OR BREAK THE CIRCUIT.



OVERSPEED SWITCH

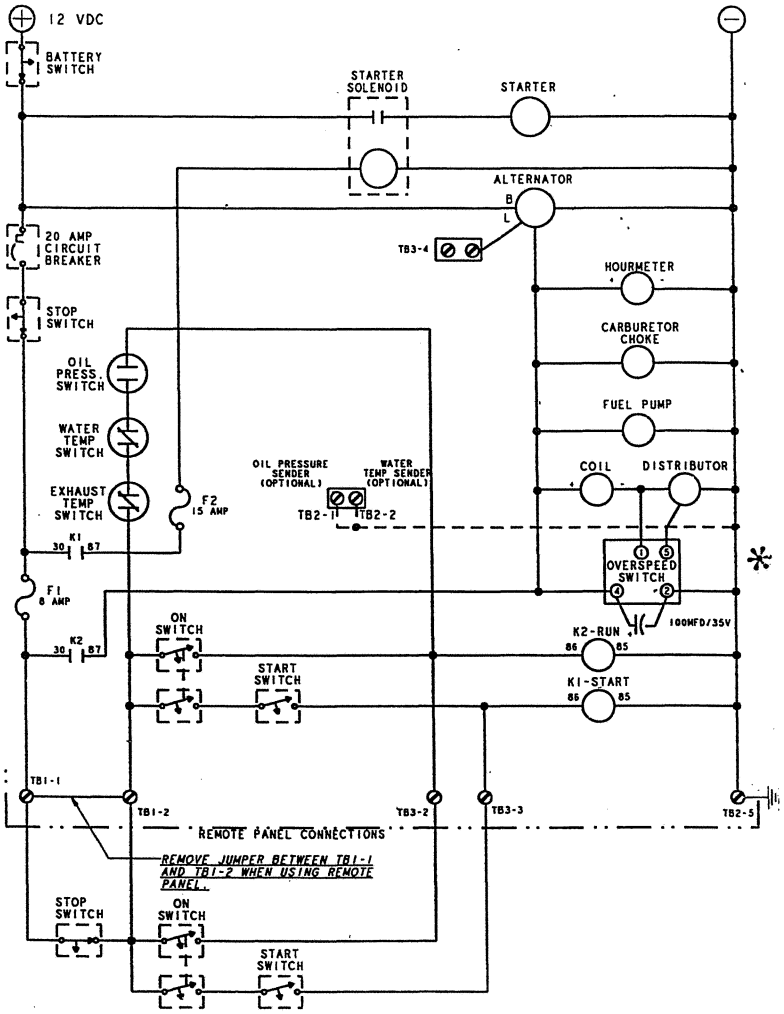
(ORIGINAL OVERSPEED SWITCH CONNECTIONS)

20KW and 25KW BE GENERATOR
WIRING DIAGRAM #044580 [TWO RELAYS]



20KW and 25KW BE GENERATOR
WIRING SCHEMATIC #044580 [TWO RELAYS]

NOTE: *An on-off switch should be installed in this circuit to disconnect the starter from the battery in an emergency and when leaving the boat. Twelve volt engine starters typically draw 200 to 300 amps when cranking. A switch with a continuous rating of 175 amps at 12 VDC will normally serve this function, but a switch must never be used to "make" the starter circuit.*



* TESTING THE OVERSPEED SWITCH

An internal component failure in the OVERSPEED SWITCH can shut the unit down (without an overspeed cause). The switch can be by-passed to determine if an internal component has failed.

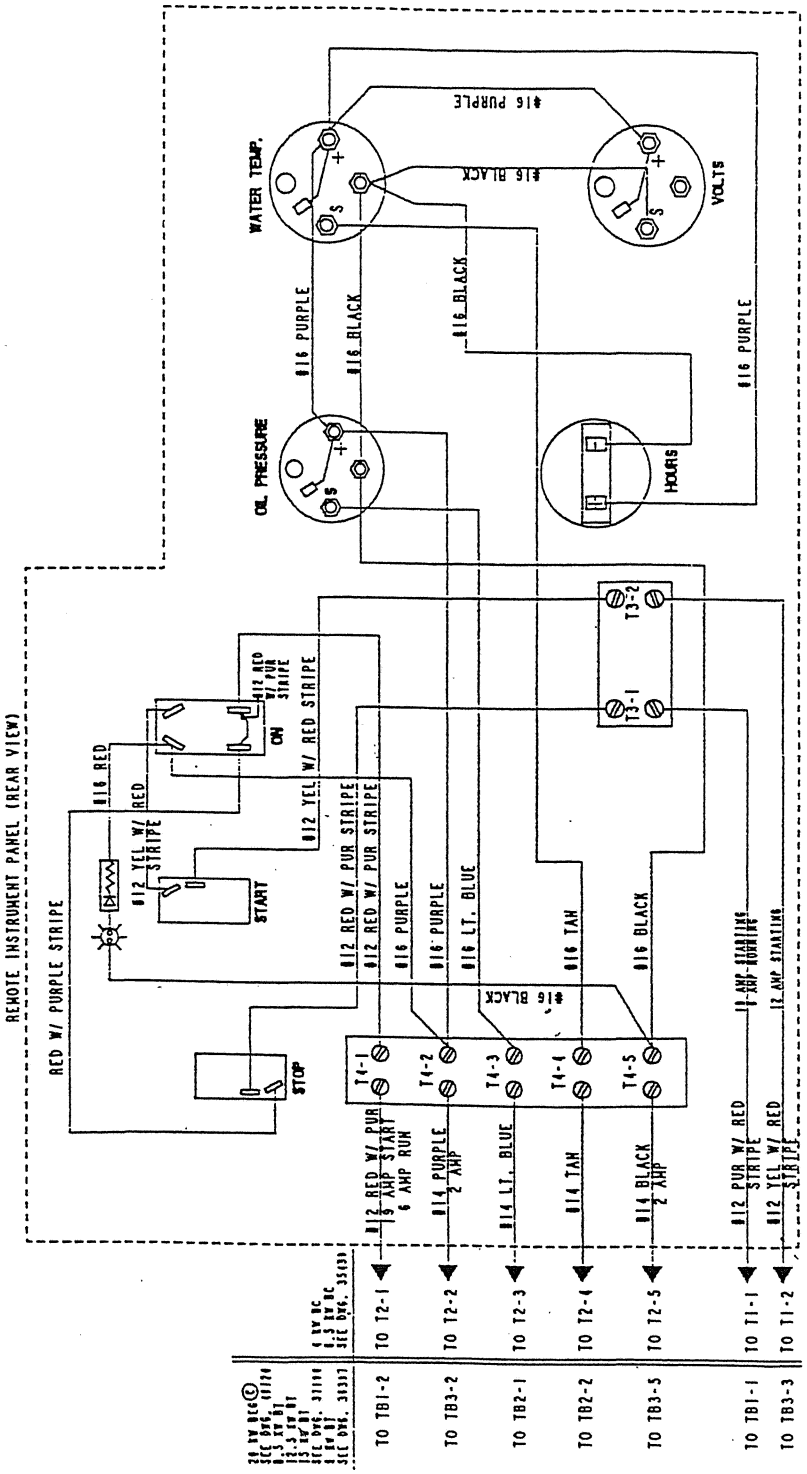
Overspeed Switch with Four T Connections: Lift the T1 connection and connect it on (and with) the T2 connection.

Overspeed Switch with Five T Connections: Lift the T5 connection and connect it on (and with) the T4 connection.

NOTE: *If by-pass testing indicates a defective OVERSPEED SWITCH, do not operate the generator. Replace the faulty switch to maintain the integrity of the engine's Safety Shutdown Circuit.*

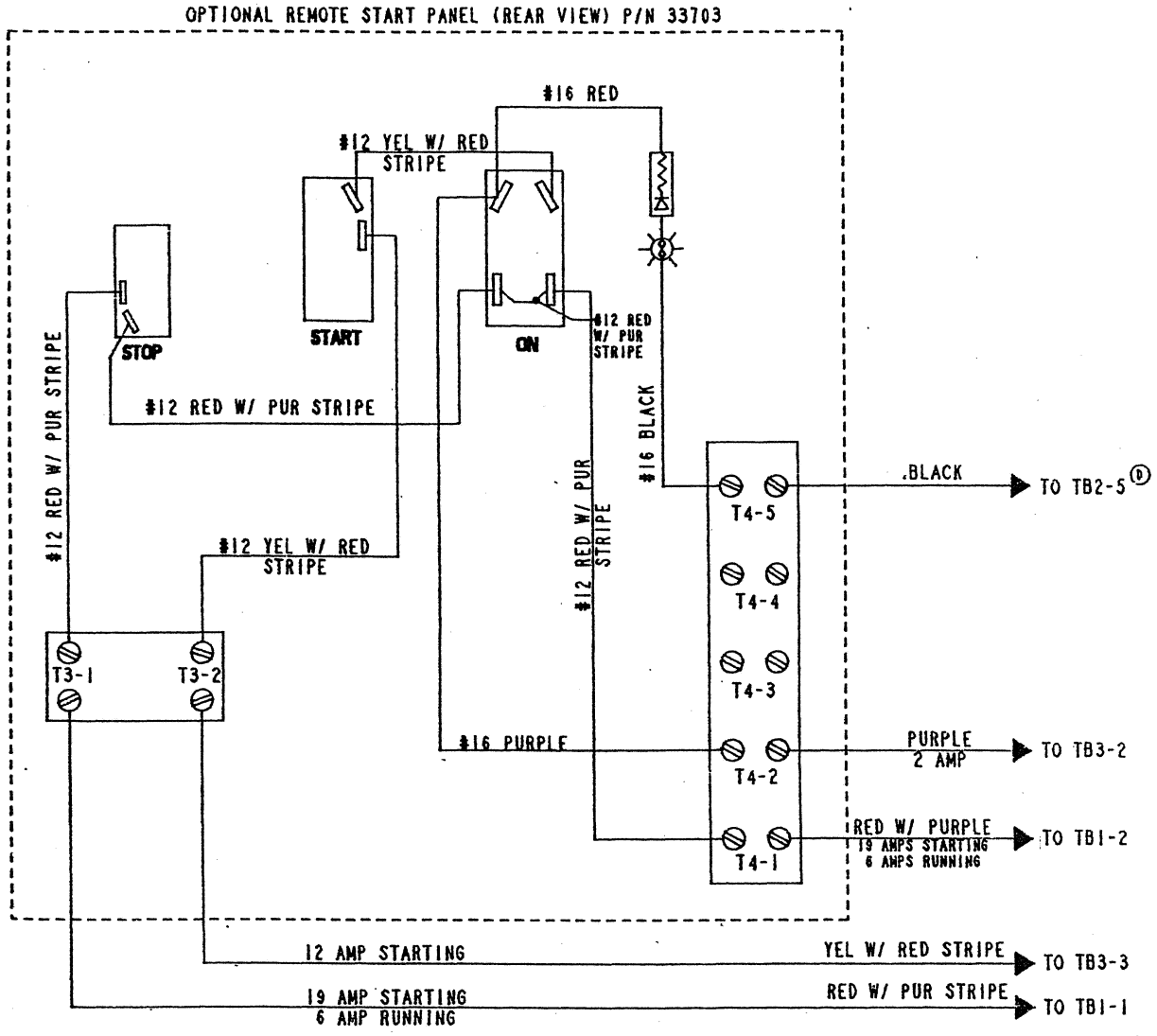
OPTIONAL REMOTE INSTRUMENT PANEL

WIRING DIAGRAM #035698



OPTIONAL REMOTE START PANEL

WIRING DIAGRAM #035706



W-70GA GASOLINE ENGINE

SPECIFICATIONS

Engine Type	Gasoline, four-cycle, four-cylinder, fresh water-cooled, Vertical, in-line overhead valve mechanism 66 hp@3600 rpm
Combustion Chamber	Multi-sphere type
Bore & Stroke	3.38 x 3.70 inches (86.0 x 94.0 mm)
Piston Displacement	133.3 cubic inches (2.2 liters)
Firing Order	1 - 3 - 4 - 2
Direction of Rotation	Clockwise, when viewed from the front
Compression Ratio	8:6:1
Dimensions	Height: 25.0 inches (634 mm) Width: 21.2 inches (538 mm) Length: 35.1 inches (893 mm)
Weight	421 lbs (190.9 kgs)
Maximum angle of Installation	Not to exceed 14°
Maximum angle of Operation	Not to exceed 20°

TUNE-UP SPECIFICATIONS

Compression Pressure (Limit of difference between cylinders)	198.1 psi (14 kg/cm²) at 400 rpm 28.0 psi (2.0 kg/cm²)
Valve Timing	Intake Opens 2° BTDC Intake Closes 53° ABDC Exhaust Opens 57° BBDC Exhaust Closes 2° ATDC
Valve Seat Angle	Intake 45° Exhaust 45°
Valve Clearance (engine warm)	Intake 0.012 inches (0.3 mm) Exhaust 0.012 inches (0.3 mm)
Engine Timing	0° TDC at 625 rpm

EXHAUST EMISSIONS SYSTEMS

Emission Control Systems	Meets U.S.C.G. Regulation 33 CFR 183

IGNITION SYSTEMS

General	Battery ignition 12V negative ground. Distributor with ignitor module and ignitor, ignition coil, and spark plugs.
Distributor	Solid state type with signal generator and ignitor
Spark Plug Thread Size	14mm X 1.25 pitch
Carburetor (STD Type)	Down draft type, single barrel, USCG approved flame arrester
Spark Plug Gap	0.030 inches (0.8mm)

FUEL SYSTEM

General	Conventional carburetor type with electric fuel pump
Fuel	Unleaded gasoline (E10 Maximum). Octane rating of 89 or better.
Fuel Lift Pump	Electromagnetic-Lift capacity 6 feet (wet) (1.8 meters)
Fuel Consumption	6.0 U.S. GPH at 3600 rpm
Fuel Filter (on engine)	Replaceable cartridge-screw on
Air cleaner (Flame Arrester)	Metal screen type-cleanable
Air Flow (engine combustion)	140.0 cfm (3.9 cmm) at 3600 rpm

COOLING SYSTEM

General	Fresh water-cooled block, thermostatically-controlled with heat exchanger
Operating Temperature	130 - 150° F (55 - 66° C)
Fresh Water Pump	Centrifugal type, metal impeller, belt-driven
Raw Water Pump	Positive displacement, rubber impeller, belt driven
System Capacity (coolant)	9.0 qts (8.5 liters)

LUBRICATION SYSTEM

General	Pressure fed system
Oil Filter	Full flow, paper element, spin-on type
Sump Capacity (not including filter)	4.0 U.S. qts (3.7 liters)
Operating Oil Pressure (engine hot)	55-75 psi (3.8 - 5.2 kg/cm²)
Oil Grade	API Specification of SJ,SL or SM

ELECTRICAL SYSTEM

Starting Battery	12-Volt, (-) negative ground
Battery Capacity	300 - 600 Cold Cranking Amps (CCA)
Starter	12-Volt, reduction-solenoid mounted
DC Charging	12 VDC belt driven alternator
DC Amperage Draw Cranking	175-200 amps (cold engine)

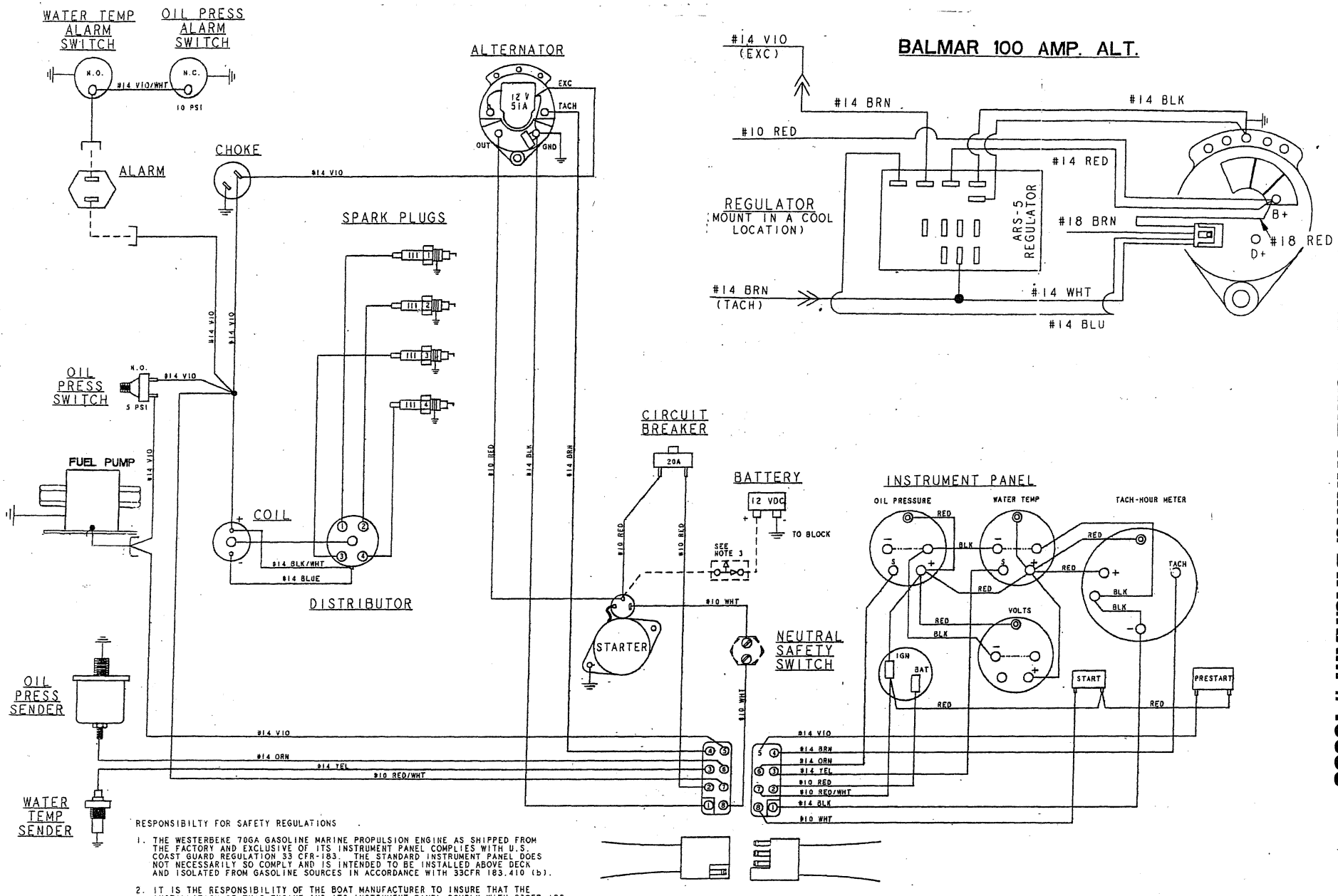
ENGINE COMPARTMENT

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

Forced Ventilation to Maintain below Maximum

NOTE: *Engine Idle Speed must be adjusted with the engine at normal operating temperature. Idle speed should be adjusted in the range specified where it operates the smoothest. Different model transmissions will affect engine idle speeds.*

W70GA MARINE ENGINE WIRING DIAGRAM #48630



RESPONSIBILTY FOR SAFETY REGULATIONS

1. THE WESTERBEKE 70GA GASOLINE MARINE PROPULSION ENGINE AS SHIPPED FROM THE FACTORY AND EXCLUSIVE OF ITS INSTRUMENT PANEL COMPLIES WITH U.S. COAST GUARD REGULATION 33 CFR-183. THE STANDARD INSTRUMENT PANEL DOES NOT NECESSARILY SO COMPLY AND IS INTENDED TO BE INSTALLED ABOVE DECK AND ISOLATED FROM GASOLINE SOURCES IN ACCORDANCE WITH 33CFR 183.410 (b).

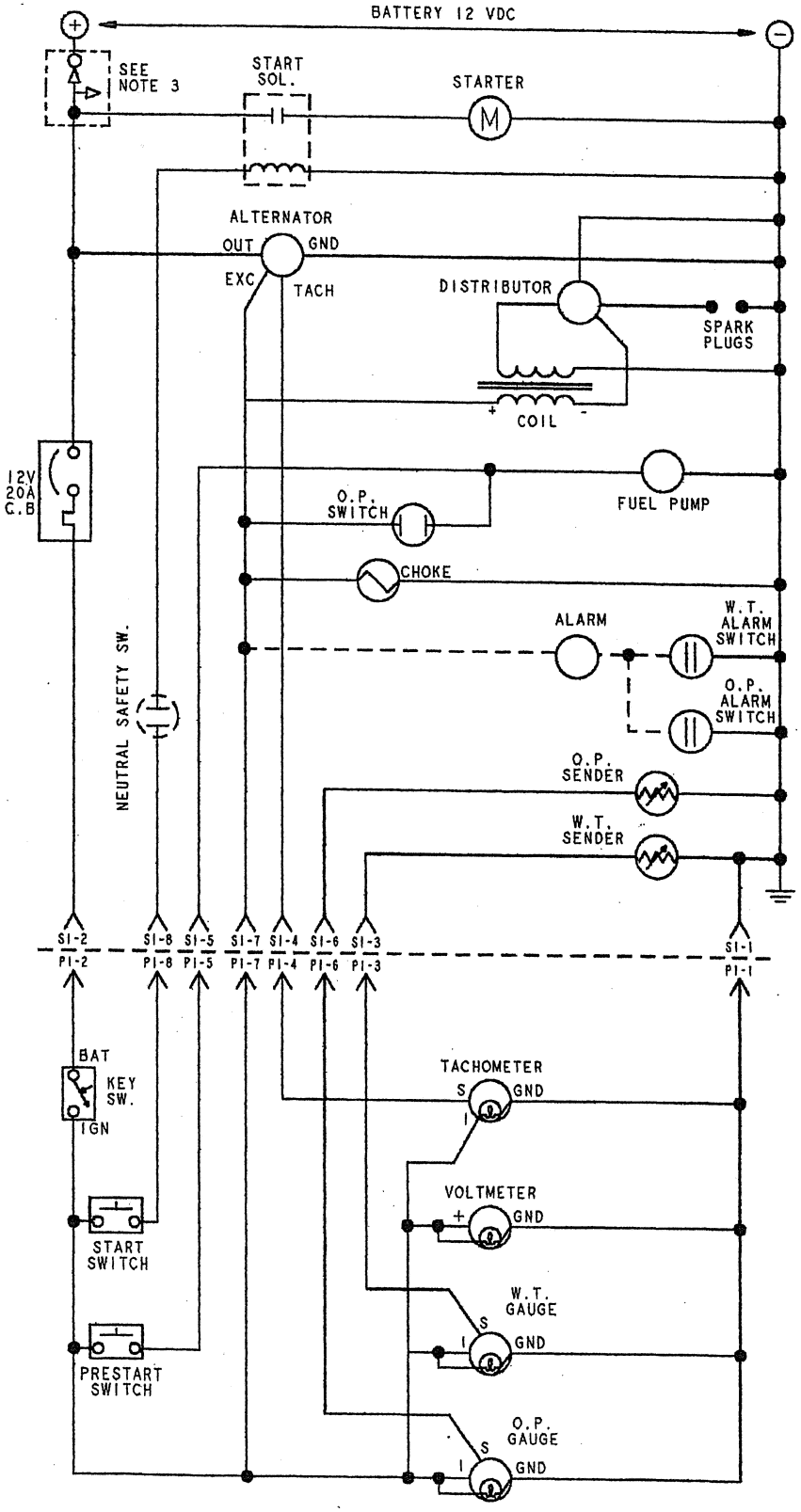
2. IT IS THE RESPONSIBILITY OF THE BOAT MANUFACTURER TO INSURE THAT THE INSTALLATION OF THIS ENGINE AND ITS INSTRUMENT PANEL COMPLY WITH 33CFR-183.

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

4. 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.

W70GA MARINE ENGINE WIRING DIAGRAM #48630

W70GA MARINE ENGINE SCHEMATIC #48630



W70GA TRANSMISSIONS

A variety of transmission makes and models may be found on the W70GA engine depending on the engine's application.

Transmission maintenance and troubleshooting will be found in the unit's Operators Manual Publication #049278.

Should the transmission need an overhaul, contact the transmission manufacturer for the location of their authorized repair facility closest to you.

Westerbeke Corporation recommends the use of manufacturer authorized repair facilities to ensure proper manufacturer overhaul procedures and parts are used.

HURTH/ZF Marine Transmission

ZF Industries Marine US Headquarters
3131 SW 42nd Street
Fort Lauderdale, FL 33312
Tel: 954-581-4040
Website: www.zf-marine.com

BW/JS Marine Transmissions

Westerbeke Corporation
150 John Hancock Road
Taunton, MA 02780
Tel: 508-823-7677
Website: www.westerbeke.com

PRM Marine Transmissions

Newage Transmission Limited
Barlow Road
Coventry CV2 2LD
England
Tel: +44 (0) 24 7661 1845
Website: www.newage-prm.co.uk

NOTE: If the transmission is not being re-built, it should be visually inspected. Flush out and pressure test the oil cooler and replace the coolant hoses. Inspect and lubricate the gear shift linkage and the propeller shaft coupling. Clean and repaint the transmission and change the transmission fluid.

SERVICE DATA - STANDARDS AND LIMITS

Component	Standard mm (inches)	Repair Limit mm (inches)

CAMSHAFT

Journals X and Y Diameter
Front and Rear .....31.940 - 31.965 (1.2575 - 1.2585)

Center Three Journals.....31.910 - 31.935 (1.2563 - 1.2573)

Front Oil Seal Sliding Surface.....33.961 - 34.000 (1.338 - 1.339)

Out-of-Round.....0.05 (0.002)

Fuel Cam
- Height: 37.6 (1.481)
- Minimum.....37.1 (1.452)

Runout.....0.03 (0.0012)

End Play.....0.08 - 0.16 (0.003 - 0.006)
Maximum.....0.20 (0.008)

Oil Clearance Front and Rear .....0.035 - 0.085 (0.0014 - 0.0033)

Center Three Journals.....0.0651 - 0.085 (0.0014 - 0.0033)

Maximum.....0.15 (0.0059)

CONNECTING ROD

End Play	0.110 - 0.262 (0.004 - 0.010)	0.150 (0.012)
Oil Clearance	0.027 (0.001)	0.10 (0.004)

Amount of Undersize
- 0.25 (0.009)
- 0.50 (0.019)
- 0.75 (0.029)

Bending Limit..... .....0.04 (0.0016) for every 100mm

Torsion Limit..... .....0.04 (0.0016) for every 100mm

Clearance between the Small End and the Piston Pin
. . ..0.015 - 0.040 (0.006 - 0.0016)

Piston Pin Diameter .....21.947 - 21.980 (0.864 - 0.866)

CRANKSHAFT

End Play	0.08 - 0.282 (0.003 - 0.011)	0.30 (0.012)

Component	Standard mm (inches)	Repair Limit mm (inches)

CRANKSHAFT

Undersize Parts.....Width
- 0.25 (0.009) .....28.04 - 28.09 (1.106 - 1.107)
- 0.50 (0.019) .....28.12 - 28.17 (1.108 - 1.109)
- 0.75 (0.029) .....28.20 - 27.00 (1.1008 - 1.103)
- Standard.....27.94 - 27.00 (1.1008 - 1.103)

Oil Clearance	0.032 - 0.049 (0.0012 - 0.0019)	0.08 (0.003)

Runout.....0.03 (0.0012)

Main Journal
- Diameter.....59.937 - 59.955 (2.3597 - 2.3604)
- Minimum.....59.89 (2.358)
- Out-of-Round.....0.05 (0.0029

Crank Pin Journal
- Diameter.....50.940 - 50.955 (2.0055 - 2.0061)
- Minimum.....50.89 (2.004)
- Out-of-Round 0.05 (0.0020)

Undersize Bearing 0.25 (0.010)
0.50 (0.020)
0.75 (0.030)

CYLINDER BLOCK/PISTON

Distortion 0.15 (0.006)

Grinding Limit.....0.20 (0.008)

CYLINDER HEAD/VALVES

Distortion 0.15 (0.006)

Height.....	91.95 - 92.05 (3.620 - 3.624)	0.20 (0.008)

Valve Head Margin Thickness
IN: 0.5 (0.20) Min..
EX: 1.0 (0.039) Min..

Valve Stem Diameter
IN: 8.030 - 8.045 (0.3161 - 0.3167)
EX: 8.025 - 8.040 (0.3159 - 0.165)

Manifold
- Distortion Grinding Limit.....0.20 (0.008)

OIL PUMP

Inner Rotor Tooth Tip and Outer Rotor Clearance.....0.18 (0.007)

Side Clearance 0.10 (0.004)

Outer Rotor to Pump Body .....0.20 (0.008) max.

SERVICE DATA - STANDARDS AND LIMITS

Component	Specified Value / Standard mm(inches)	Repair Limit mm(inches)

PISTON/PISTON RING

Outer Diameter.....85.944 - 85.964 (3.3836 - 3.3844)
0.25mm Oversize..86.194 0 86.214 (3.3935 - 3.3942)
0.50mm Oversize..86.444 - 86.464 (3.4033 - 3.4041)

Piston to Cylinder
Clearance.....0.036 - 0.075 (0.0014 - 0.0030)
Maximum.....0.15 (0.0059)

End Gap Top.....0.20 - 0.35 (0.008 - 0.014)
Second.....0.15 - 0.30 (0.006 - 0.012)
Oil Ring.....0.30 - 0.90 (0.012 - 0.035)
Maximum.....1.0 (0.039)

Piston Ring to Ring Clearance.....
Clearance Top.....0.03 - 0.07 (0.001 - 0.003)
Second.....0.03 - 0.07 (0.001 - 0.003)
Maximum.....0.15 (0.006)

ROCKER ARM/ROCKER ARM SHAFT

Oil Clearance.....0.016 - 0.061 .....0.10
.....(0.0006 - 0.0024) .....(0.004)

Rocker Arm
I.D.:.....15.000 - 16.027 (0.630 - 0.631)
O.D.: .....15.966 - 15.984 (0.629 - 0.6297)

TIMING BELT PULLEY

Dimension of Washer or Pipe
Diameter.....24mm (0.945in)
Length 15mm (0.591in)

VALVE SPRING

Free Length	EX: 52.2 (2.0) IN: 47.7 (1.88)	
Angle	EX & IN: 1.8 (0.07)	

VALVE SEAT

Contact Width.....IN & EX 1.4 (0.055)

Dimension L.....46.5 (1.831)

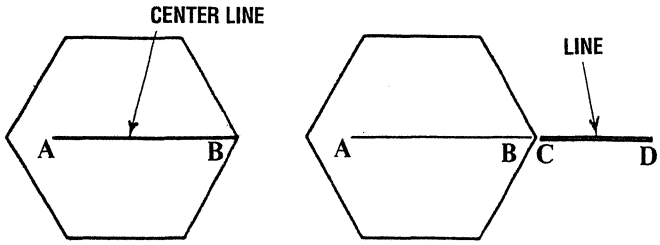
Valve Stem to Valve Guide
Method 1.....IN: 7.980 (0.312)
....IN: 7.975 90.314)

Method 2.....IN & EX: 0.025 - 0.060
.....(0.0010 - 0.0024)
Maximum.....0.20 (0.0079)

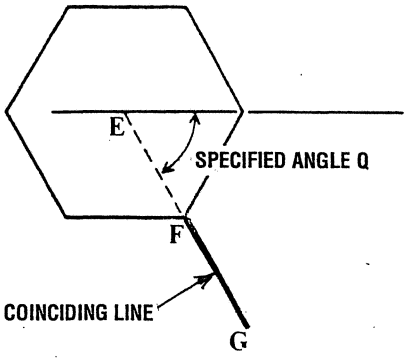
O.D.: .....15.966 - 15.984 (0.629 - 0.6297)

ANGULAR NUT AND BOLT TIGHTENING METHOD

1. Carefully wash the nuts and bolts to remove all oil and grease.
2. Apply a coat of molybdenum disulfide grease to the threads and setting faces of the nuts and bolts.
3. Tighten the nuts and bolts to the specified torque (snug torque) with a torque wrench.



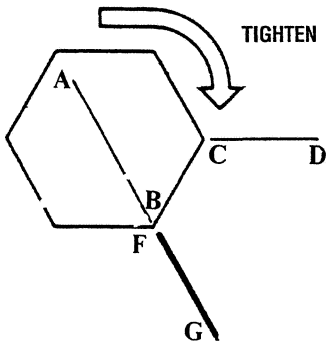
4. Draw a line (A-B) across the center of each bolt.
5. Draw another line (C-D) on the face of each of the parts to be clamped. This line should be an extension of the line (A-B).

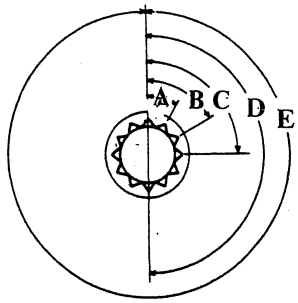


6. Draw another line (F-G) on the face of each of the parts to be clamped. This line will be in the direction of the specified angle (Q) across the center (E) of the nut or bolt.
7. Use a socket wrench to tighten each nut or bolt to the point where the line (A-B) is aligned with the line (F-G).

Example: Specified Angle and Tightening Rotation

A	30°	1/12 of a turn
B	60°	1/6 of a turn
C	90°	1/4 of a turn
D	180°	1/2 of a turn
E	360°	One full turn





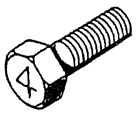
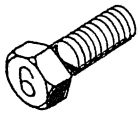
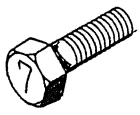
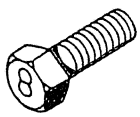
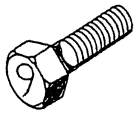
TORQUE SPECIFICATIONS

COMPONENT	ft – lb	(m-kg)	Nm
Bearing Cap	61-65	(8.4 - 9.0)	82.88
Camshaft Caps	13 - 20	(1.8 - 2.7)	18 - 26
Camshaft Pulley	35 - 48	(4.8 - 6.6)	47 - 65
Camshaft Tightening	13 -20	(1.8 - 2.7)	18 - 26
Connecting Rod Cap Nut	48 - 51	(6.6 - 7.0)	65 - 69
Crankshaft Bolt Torque	104 -148	(1.2 - 1.7)	12 - 17
Crankshaft Timing Belt	27 -38	(3.8 - 5.3)	39 - 52
Crankshaft Lock Bolt	116 - 123	(16 - 17)	57 -167
Cylinder Head Bolt (cold)	55 - 59	(8.2 - 8.8)	82 - 88
Cylinder Head Cover	24 - 34	(3.0 -4.0)	3 - 4
Exhaust Manifold	16 - 21	(2.2 - 2.9)	22 - 28
Front Housing	14 -19	(1.9 - 2.6)	19 -25
Inlet Manifold	14 - 22	(1.9 - 3.1)	14 -31
Intake Manifold/Carburetor	14 -19	(1.9 - 2.6)	19 - 25
Main Bearing Cap	61 - 65	(8.4 - 9.0)	82 - 88
Oil Pan	61 - 104	(8.4 - 12.0)	8 -12
Oil Pan Baffle Plate	69 - 100	(8.0 - 11.0)	8 -10
Oil Pan Bolts	61 - 78	(8.4 - 10.0)	7 - 10
Oil Pressure Switch	104 - 156	(1.2 - 1.8)	12 -18
Oil Pump (M-10)	27 - 38	(3.8 - 5.3)	52
Oil Pump (M-8)	14 - 19	(1.9 - 2.6)	25
Oil Strainer	69 - 104	(8.0 - 12.0)	8 - 12
Rocker Arm	13 - 20	(1.8 - 2.7)	18 - 26
Rocker Shaft Assembly	13 - 20	(1.8 - 2.7)	18 - 26
Spark Plug	11 -17	(1.5 - 2.3)	15 - 23
Timing Belt	27 -38	(3.8 - 5.3)	37 - 52
Timing Belt Covers	61 - 87	(8.4 -10.0)	7 -10
Timing Belt Gasket	61 - 87	(8.4 -10.0)	7 -10
Water Pump Bolts	14 -19	(1.9 - 3.1)	19 -25
Flywheel Bolts	85 – 90	(11.7 12. 4)	

STANDARD BOLTS / TIGHTENING TORQUE SPECIFICATIONS

NOTE: *The torque values given in the following table should be applied where a particular torque is not specified.*

kg-m

Bolt identification / Bolt diameter × pitch (mm)					
M 6 × 1.0	0.6 ±0.2	0.7 $^{+0.2}_{-0.3}$	0.8 $^{+0.2}_{-0.3}$	0.9 $^{+0.2}_{-0.3}$	———
M 8 × 1.25	1.3 ±0.5	1.6 $^{+0.4}_{-0.6}$	1.8 $^{+0.5}_{-0.6}$	2.1 $^{+0.5}_{-0.7}$	2.4 ±0.7
M10 × 1.25	2.8 ±0.7	3.3 $^{+0.8}_{-0.9}$	3.8 $^{+0.9}_{-1.0}$	4.3 ±0.9	5.1 ±1.3
***M10 × 1.5**	2.7 ±0.7	3.2 ±0.8	3.7 ±0.9	4.2 ±1.0	4.9 ±1.2
M12 × 1.25	6.2 $^{+1.3}_{-1.2}$	6.7 $^{+1.4}_{-1.3}$	7.7 $^{+1.6}_{-1.5}$	8.8 $^{+1.8}_{-1.7}$	9.7 $^{+1.9}_{-2.0}$
***M12 × 1.75**	5.8 ±1.2	6.3 ±1.2	7.2 ±1.4	8.2 ±1.6	9.1 ±1.8
M14 × 1.5	9.7 $^{+2}_{-1.9}$	10.4 $^{+2}_{-2.1}$	11.9 $^{+2.3}_{-2.4}$	13.6 $^{+2.6}_{-2.8}$	14.5 ±2.9
***M14 × 2.0**	9.1 ±1.8	9.8 ±1.9	11.2 ±2.2	12.8 ±2.5	13.6 ±2.7
M16 × 1.5	13.3 ±2.7	15.1 ±3.1	17.3 ±3.5	19.7 ±4.0	20.4 ±4.1
***M16 × 2.0**	12.7 ±2.5	14.4 ±2.9	16.5 ±3.3	18.8 ±3.8	19.5 ±3.9
M18 × 1.5	19.2 ±3.8	21.7 $^{+4.4}_{-4.3}$	24.9 ±5.0	28.4 ±5.7	29.3 ±5.9
***M18 × 2.5**	19.2 ±3.8	21.8 $^{+4.4}_{-4.3}$	25.0 ±5.0	28.5 ±5.7	29.4 $^{+5.9}_{-5.8}$
M20 × 1.5	26.3 ±5.3	30.0 $^{+6.1}_{-6}$	34.4 ±6.9	39.2 $^{+7.9}_{-7.8}$	40.4 ±8.1
***M20 × 2.5**	24.3 ±4.9	27.8 $^{+5.5}_{-5.6}$	31.8 ±6.4	36.3 $^{+7.2}_{-7.3}$	37.4 ±7.5
M22 × 1.5	32.0 $^{+10.2}_{-6.4}$	40.4 ±8.1	46.3 $^{+9.2}_{-9.3}$	52.8 $^{+10.5}_{-10.6}$	54.1 ±10.8
***M22 × 2.5**	27.8 ±5.6	37.6 ±7.5	43.1 ±8.6	49.1 ±9.8	50.3 ±10.1
M24 × 2.0	45.8 ±9.2	47.9 $^{+15.4}_{-9.6}$	54.9 $^{+17.6}_{-11.0}$	62.6 $^{+20.1}_{-12.6}$	70.6 ±14.1
***M24 × 3.0**	43.1 ±8.6	45.1 ±9.0	51.7 ±10.3	58.9 $^{+11.8}_{-11.7}$	66.4 ±13.3

NOTE: *Bolts marked with an asterisk are used for female threaded parts made of soft materials such as castings.*

STANDARD AND METRIC CONVERSION DATA

LENGTH-DISTANCE

Inches (in) x 25.4 = Millimeters (mm) x .0394 = Inches
Feet (ft) x .305 = Meters (m) x 3.281 = Feet
Miles x 1.609 = Kilometers (km) x .0621 = Miles

DISTANCE EQUIVALENTS

1 Degree of Latitude = 60 Nm = 111.120 km
1 Minute of Latitude = 1 Nm = 1.852 km

VOLUME

Cubic Inches (in^3) x 16.387 = Cubic Centimeters x .061 = in^3
Imperial Pints (IMP pt) x .568 = Liters (L) x 1.76 = IMP pt
Imperial Quarts (IMP qt) x 1.137 = Liters (L) x.88 = IMP qt
Imperial Gallons (IMP gal) x 4.546 = Liters (L) x .22 = IMP gal
Imperial Quarts (IMP qt) x 1.201 = US Quarts (US qt) x .833 = IMP qt
Imperial Gallons (IMP gal) x 1.201 = US Gallons (US gal) x .833 = IMP gal
Fluid Ounces x 29.573 = Milliliters x .034 = Ounces
US Pints (US pt) x .473 = Liters(L) x 2.113 = Pints
US Quarts (US qt) x .946 = Liters (L) x 1.057 = Quarts
US Gallons (US gal) x 3.785 = Liters (L) x .264 = Gallons

MASS-WEIGHT

Ounces (oz) x 28.35 = Grams (g) x .035 = Ounces
Pounds (lb) x .454 = Kilograms (kg) x 2.205 = Pounds

PRESSURE

Pounds Per Sq In (psi) x 6.895 = Kilopascals (kPa) x .145 = psi
Inches of Mercury (Hg) x .4912 = psi x 2.036 = Hg
Inches of Mercury (Hg) x 3.377 = Kilopascals (kPa) x .2961 = Hg
Inches of Water (H_2O) x .07355 = Inches of Mercury x 13.783 = H_2O
Inches of Water (H_2O) x .03613 = psi x 27.684 = H_2O
Inches of Water (H_2O) x .248 = Kilopascals (kPa) x 4.026 = H_2O

TORQUE

Pounds-Force Inches (in-lb) x .113 = Newton Meters (Nm) x 8.85 =in-lb
Pounds-Force Feet (ft-lb) x 1.356 = Newton Meters (Nm) x .738 = ft-lb

VELOCITY

Miles Per Hour (MPH) x 1.609 = Kilometers Per Hour (KPH) x .621 = MPH

POWER

Horsepower (Hp) x .745 = Kilowatts (Kw) x 1.34 = MPH

FUEL CONSUMPTION

Miles Per Hour IMP (MPG) x .354 = Kilometers Per Liter (Km/L)
Kilometers Per Liter (Km/L) x 2.352 = IMP MPG
Miles Per Gallons US (MPG) x .425 = Kilometers Per Liter (Km/L)
Kilometers Per Liter (Km/L) x 2.352 = US MPG

TEMPERATURE

Degree Fahrenheit (°F) = (°C X 1.8) + 32
Degree Celsius (°C) = (°F - 32) x .56

LIQUID WEIGHTS

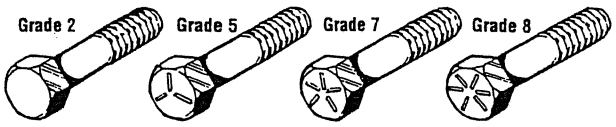
Diesel Oil = 1 US gallon = 7.13 lbs
Fresh Water = 1 US gallon = 8.33 lbs
Gasoline = 1 US gallon = 6.1 lbs
Salt Water = 1 US gallon = 8.56 lbs

STANDARD HARDWARE

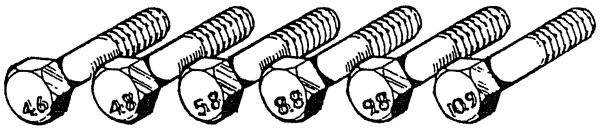
BOLT HEAD MARKINGS

Bolt strength classes are embossed on the head of each bolt.

Customary (inch) bolts are identifed by markings two to grade eight (strongest). The marks correspond to two marks less than the actual grade, i.e.; a grade seven bolt will display five embossed marks.



Metric bolt class numbers identify bolts by their strength with 10.9 the strongest.



NOTES: 1. *Use the torque values listed below when specific torque values are not available.*
2. *These torques are based on clean, dry threads. Reduce torque by 10% when engine oil is used.*
3. *Reduce torques by 30% or more, when threading capscrews into aluminum.*

STANDARD BOLT & NUT TORQUE SPECIFICATIONS

Capsrew Body Size (Inches) - (Thread)	SAE Grade 5 Torque Ft-Lb (Nm)	SAE Grade 6-7 Torque Ft-Lb (Nm)	SAE Grade 8 Torque Ft-Lb (Nm)
1/4 - 20	8 (11)	10 (14)	12 (16)
- 28	10 (14)		14 (19)
5/16 - 18	17 (23)	19 (26)	24 (33)
- 24	19 (26)		27 (37)
3/8 - 16	31 (42)	34 (46)	44 (60)
- 24	35 (47)		49 (66)
7/16 - 14	49 (66)	55 (75)	70 (95)
- 20	55 (75)		78 (106)
1/2 - 13	75 (102)	85 (115)	105 (142)
- 20	85 (115)		120 (163)
9/16 - 12	110 (149)	120 (163)	155 (210)
- 18	120 (163)		170 (231)
5/8 - 11	150 (203)	167 (226)	210 (285)
- 18	170 (231)		240 (325)
3/4 - 10	270 (366)	280 (380)	375 (508)
- 16	295 (400)		420 (569)
7/8 - 9	395 (536)	440 (597)	605 (820)
- 14	435 (590)		675 (915)
1 - 8	590 (800)	660 (895)	910 (1234)
- 14	660 (895)		990 (1342)

METRIC BOLT & NUT TORQUE SPECIFICATIONS

Bolt Dia.	Wrench Size	Grade 4.6 Ft-Lb (Nm)	Grade 4.8 Ft-Lb (Nm)	Grade 8.8 - 9.8 Ft-Lb (Nm)	Grade 10.9 Ft-Lb (Nm)
M3	5.5 mm	0.3 (0.5)	0.5 (0.7)	1 (1.3)	1.5 (2)
M4	7 mm	0.8 (1.1)	1 (1.5)	2 (3)	3 (4.5)
M5	8 mm	1.5 (2.5	2 (3)	4.5 (6)	6.5 (9)
M8	10 mm	3 (4)	4 (5.5)	7.5 (10)	11 (15)
M9	13 mm	7 (9.5)	10 (13)	18 (25)	35 (26)
M10	16 mm	14 (19)	18 (25)	37 (50)	55 (75)
M12	18 mm	26 (35)	33 (45)	63 (85)	97 (130)
M14	21 mm	37 (50)	55 (75)	103 (140)	151 (205)
M16	24 mm	59 (80)	85 (115)	159 (215)	232 (315)
M18	27 mm	81 (110)	118 (160)	225 (305)	321 (435)
M20	30 mm	118 (160)	166 (225)	321 (435)	457 (620)
M22	33 mm	159 (215)	225 (305)	435 (590)	620 (840)
M24	36 mm	203 (275)	288 (390)	553 (750)	789 (1070)
M27	41 mm	295 (400)	417 (565)	811 (1100)	1154 (1565)
M30	46 mm	402 (545)	568 (770)	1103 (1495)	1571 (2130)
M33	51 mm	546 (740)	774 (1050)	1500 (2035)	2139 (2900)
M36	55 mm	700 (950)	992 (1345)	1925 (2610)	2744 (3720)

NOTE: *Formula to convert Ft-Lbs to Nm (Newton Meters) multiply Ft-Lb x 1.356.*

SEALANTS & LUBRICANTS

GASKETS/SEALANTS

Oil based PERMATEX #2 and it's 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.

High-copper ADHESIVE SPRAYS are useful for holding gaskets in position during assembly.

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

Use LIQUID TEFLON for sealing pipe plugs and fillings that connect coolant passages. **Do not use tape sealants!**

BOLTS & FASTENERS/ASSEMBLIES

Lightly oil head bolts and other fasteners as you assemble them. Bolts and 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.

Anti-seize compounds and thread locking adhesives such as LOCTITE protect threaded components yet allows them to came apart when necessary. LOCTITE offers levels of locking according to the job.

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

Heavily oil all sliding and reciprocating components when assembling. **Always use clean engine oil!**

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