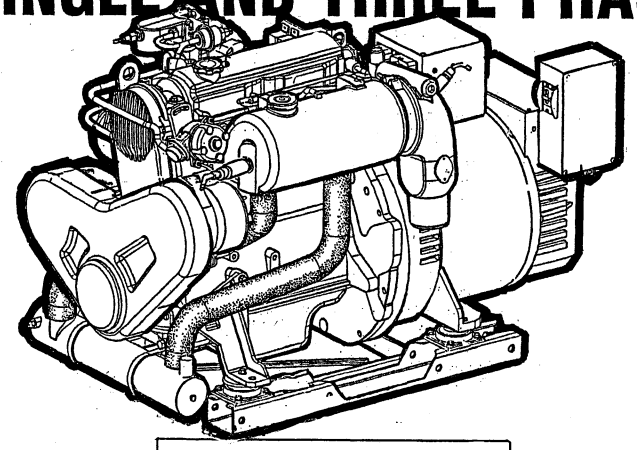
SERVICE MANUAL

20.0 SBEG and SBEGA - 60 HZ
16.0 SBEG and SBEGA - 50 HZ

22.5 SBEG and SBEGA - 60 HZ
18.0 SBEG and SBEGA - 50 HZ

MARINE GASOLINE GENERATORS

SINGLE AND THREE PHASE



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Ultra-Low Carbon Monoxide Emissions

WESTERBEKE™ GENERATORS

EFI Low-CO

⚠ 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.

WESTERBEKE

SAFETY INSTRUCTIONS

INTRODUCTION

Read this safety manual carefully. Most accidents are caused by failure to follow fundamental rules and precautions. Know when dangerous conditions exist and take the necessary precautions to protect yourself, your personnel, and your machinery.
The following safety instructions are in compliance with the American Boat and Yacht Council (ABYC) standards.

PREVENT ELECTRIC SHOCK

> ⚠ **WARNING:** ***Do not touch AC electrical connections while engine is running. Lethal voltage is present at these connections!***

- Do not operate this machinery without electrical enclosures and covers in place.
- Shut off electrical power before accessing electrical equipment.
- Use insulated mats whenever working on electrical equipment.
- Make sure your clothing and skin are dry, not damp (particularly shoes) when handling electrical equipment.
- Remove wristwatch and all jewelry when working on electrical equipment.

PREVENT BURNS — HOT ENGINE

> ⚠ **WARNING:** ***Do not touch hot engine parts or exhaust system components. A running engine gets very hot!***

- Monitor engine antifreeze coolant level at the plastic coolant recovery tank and periodicaly at the filler cap location on the water jacketed exhaust manifold, but only when the engine is COLD.

> ⚠ **WARNING:** ***Steam can cause injury or death!***

- In case of an engine overheat, allow the engine to cool before touching the engine or checking the coolant.

PREVENT BURNS — FIRE

> ⚠ **WARNING:** ***Fire can cause injury or death!***

- Prevent flash fires. Do not smoke or permit flames or sparks to occur near the carburetor, fuel line, filter, fuel pump, or other potential sources of spilled fuel or fuel vapors. Use a suitable container to catch all fuel when removing the fuel line, fuel filters. or other fuel system components.
- Do not operate with the air cleaner/silencer or flame arrester screen removed. Backfire can cause severe injury or death.
- Do not smoke or permit flames or sparks to occur near the fuel system. Keep the compartment and the engine/generator clean and free of debris to minimize the chances of fire. Wipe up all spilled fuel and engine oil.

PREVENT BURNS — EXPLOSION

> ⚠ **WARNING:** ***Explosions from fuel vapors can cause injury or death!***

- Follow re-fueling safety instructions. Keep the vessel's hatches closed when fueling. Open and ventilate cabin after fueling. Check below for fumes/vapor before running the blower. Run the engine compartment blower prior to starting, follow the recommendation of the vessel builder.
- All fuel vapors are highly explosive. Use extreme care when handling and storing fuels. Store fuel in a well-ventilated area away from spark-producing equipment and out of the reach of children.
- Do not fill the fuel tank(s) while the engine is running.
- Shut off the fuel service valve at the engine when servicing the fuel system. Take care in catching any fuel that might spill. DO NOT allow any smoking, open flames, or other sources of fire near the fuel system or engine when servicing. Ensure proper ventilation exists when servicing the fuel system.
- Do not alter or modify the fuel system.
- Be sure all fuel supplies have a positive shutoff valve.
- Be certain fuel line fittings are adequately tightened and free of leaks.
- Make sure a fire extinguisher is installed nearby and is properly maintained. Be familiar with its proper use. Extinguishers rated ABC by the NFPA are appropriate for all applications encountered in this environment.

SAFETY INSTRUCTIONS

ACCIDENTAL STARTING

⚠ WARNING: ***Accidental starting can cause injury or death!***

- Turn OFF the DC breaker on the control panel or turn the unit's battery selector switch to OFF before servicing the engine.
- Make certain all personnel are clear of the engine before starting.
- Make certain all covers, guards, and hatches are re-installed before starting the engine.

BATTERY EXPLOSION

⚠ WARNING: ***Battery explosion can cause injury or death!***

- Do not smoke or allow an open flame near the battery being serviced. Lead acid batteries emit hydrogen, a highly explosive gas, which can be ignited by electrical arcing or by lit tobacco products. Shut off all electrical equipment in the vicinity to prevent electrical arcing during servicing.
- Never connect the negative (–) battery cable to the positive (+) connection terminal of the starter solenoid. Do not test the battery condition by shorting the terminals together. Sparks could ignite battery gases or fuel vapors. Ventilate any compartment containing batteries to prevent accumulation of explosive gases. To avoid sparks, do not disturb the battery charger connections while the battery is being charged.
- Avoid contacting the terminals with tools, etc., to prevent burns or sparks that could cause an explosion. Remove wristwatch, rings, and any other jewelry before handling the battery.
- Always turn the battery charger off before disconnecting the battery connections. Remove the negative lead first and reconnect it last when servicing the battery.

BATTERY ACID

⚠ WARNING: ***Sulfuric acid in batteries can cause severe injury or death!***

- When servicing the battery or checking the electrolyte level, wear rubber gloves, a rubber apron, and eye protection. Batteries contain sulfuric acid which is destructive. If it comes in contact with your skin, wash it off at once with water. Acid may splash on the skin or into the eyes inadvertently when removing electrolyte caps.

TOXIC EXHAUST GASES

⚠ WARNING: ***Carbon monoxide (CO) is a deadly gas!***

- Ensure that the exhaust system is adequate to expel gases discharged from the engine. Check the exhaust system regularly for leaks and make sure the exhaust manifold/water-injected elbow is securely attached.
- Be sure the unit and its surroundings are well ventilated. Run blowers when running the generator set or engine.
- Do not run the generator set or engine unless the boat is equipped with a functioning marine carbon monoxide detector that complies with ABYC A-24. Consult your boat builder or dealer for installation of approved detectors.
- For additional information, refer to ABYC TH-22 (educational information on Carbon Monoxide).

⚠ WARNING: ***Carbon monoxide (CO) is an invisible odorless gas. Inhalation produces flu-like symptoms, nausea or death!***

- Do not use copper tubing in diesel exhaust systems. Diesel fumes can rapidly destroy copper tubing in exhaust systems. Exhaust sulfur causes rapid deterioration of copper tubing resulting in exhaust/water leakage.
- Do not install exhaust outlet where exhaust can be drawn through portholes, vents, or air conditioners. If the engine exhaust discharge outlet is near the waterline, water could enter the exhaust discharge outlet and close or restrict the flow of exhaust. Avoid overloading the craft.
- Although diesel engine exhaust gases are not as toxic as exhaust fumes from gasoline engines, carbon monoxide gas is present in diesel exhaust fumes. Some of the symptoms or signs of carbon monoxide inhalation or poisoning are:

Vomiting	Inability to think coherently
Dizziness	Throbbing in temples
Headache	Muscular twitching
Nausea	Weakness and sleepiness

AVOID MOVING PARTS

⚠ WARNING: ***Rotating parts can cause injury or death!***

- Do not service the engine while it is running. If a situation arises in which it is absolutely necessary to make operating adjustments, use extreme care to avoid touching moving parts and hot exhaust system components.

SAFETY INSTRUCTIONS

- Do not wear loose clothing or jewelry when servicing equipment; tie back long hair and avoid wearing loose jackets, shirts, sleeves, rings, necklaces or bracelets that could be caught in moving parts.
- Make sure all attaching hardware is properly tightened. Keep protective shields and guards in their respective places at all times.
- Do not check fluid levels or the drive belt's tension while the engine is operating.
- Do not allow any swimming or activity around or near the exhaust discharge opening for the generator while the generator is operating. Carbon Monoxide poisoning or death can occur.

HAZARDOUS NOISE

⚠ WARNING: ***High noise levels can cause hearing loss!***

- Never operate an engine without its muffler installed.
- Do not run the engine with the air intake (silencer) or flame arrester removed.
- Do not run engines for long periods with their enclosures open (when installed).

⚠ WARNING: ***Do not work on machinery when you are mentally or physically incapacitated by fatigue!***

OPERATORS MANUAL

Many of the preceding safety tips and warnings are repeated in your Operators Manual along with other cautions and notes to highlight critical information. Read your manual carefully, maintain your equipment, and follow all safety procedures.

GASOLINE ENGINE AND GENERATOR INSTALLATIONS

Preparations to install a gasoline engine or generator should begin with a thorough examination of the American Boat and Yacht Council's (ABYC) standards. These standards are from a combination of sources including the USCG and the NFPA.

Sections of the ABYC standards of particular interest are:

H-2 Ventilation for Boats using Gasoline
H-24 Gasoline Fuel Systems
P-1 Installation of Exhaust Systems
for Propulsion and Auxiliary Engines
P-4 Marine Inboard Engines and Transmissions
E-11 AC and DC Electrical Systems on Boats

All installations must comply with the Federal Code of Regulations (FCR).

www.abycinc.org

ABYC, NFPA AND USCG PUBLICATIONS FOR INSTALLING ENGINES AND GENERATORS

Read the following ABYC, NFPA and USCG publications for safety codes and standards. Follow their recommendations when installing your engine.

ABYC (American Boat and Yacht Council)
"Standards and Technical Information Reports for Small Craft"

Order from:

ABYC
613 Third Street, Suite 10
Annapolis, MD 21403

www.abycinc.org

NFPA - No.302 (National Fire Protection Association)
"Pleasure and Commercial Motor Craft"

Order from:

National Fire Protection Association
Battery March Park
Quincy, MA 02269

USCG (United States Coast Guard)
"regulatedions are under titles CFR33 and CFR46 of the Code of Regulations"

Order from:

U.S. Government Printing Office
Washington, D.C. 20404

INSTALLATION

When installing WESTERBEKE engines and generators it is important that strict attention be paid to the following information:

CODES AND REGULATIONS

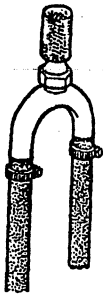
Strict federal regulations, ABYC guidelines, and safety codes must be complied with when installing engines and generators in a marine environment.

SIPHON-BREAK

For installations where the exhaust manifold/water injected exhaust elbow is close to or will be below the vessel's waterline, provisions must be made to install a siphon-break in the raw water supply hose to the exhaust elbow. This hose must be looped a minimum of 20" above the vessel's waterline. ***Failure to use a siphon-break when the exhaust manifold injection port is at or below the load waterline will result in raw water damage to the engine and possible flooding of the boat.***

If you have any doubt about the position of the water-injected exhaust elbow relative to the vessel's waterline under the vessel's various operating conditions, ***install a siphon-break.***

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



AVAILABLE FROM YOUR WESTERBEKE DEALER

SIPHON-BREAK WITH STAINLESS LOOP

EXHAUST SYSTEM

The exhaust system's hose MUST be certified for marine use. Corrugated Marine Exhaust Hose is recommended. The use of this type of hose allows for extreme bends and turns without the need of additional fitting and clamps to accomplish these bends and turns. In this regard, a single length of corrugated exhaust hose can be used. The system MUST be designed to prevent the entry of water into the exhaust system under any sea conditions and at any angle of vessels heel.

A detailed Marine Installation Manual covering gasoline and diesel, engines and generators, is supplied with each unit. A pdf is available to download from our website at www.westerbeke.com.

INSTALLATION

EMISSION-RELATED INSTALLATION INSTRUCTIONS

"Failing to follow these instructions when installing a certified engine in a piece of nonroad equipment violates federal law (40 CFR 1068.105(b)), subject to fines or other penalties as described in the Clean Air Act."

If your product is equipped with OBD (on board diagnostics) go to www.WESTERBEKE.COM and follow the free interface software download instructions specific to your engine to obtain and install the appropriate diagnostic software. The following is a list of OBD compliant products:

20.0 SBEGA
22.5 SBEGA REFER TO THE DATA LOGGING PAGES IN THIS MANUAL.

To sample exhaust emissions on installed OBD compliant generators, gain access to the exhaust stream by removing the test port plug on the exhaust elbow. Be sure to reinstall the plug securely when testing is complete.

The Westerbeke generator that you purchased is certified for constant-speed operation only. The use of any Westerbeke product in any manner inconsistent with its intended use could be a violation of Federal Law.

"If you install the engine in a way that makes the engine's emission control information label hard to read during normal engine maintenance, you must place a duplicate label on the equipment, as described in 40 CFR 1068.105". Contact the factory for an additional engine emission control information label if needed to comply with this rule.

To comply with 40 CFR 1048.105 (a) "*Fuel line permeation.* For nonmetallic fuel lines, you must specify and use products that meet the Category 1 specifications for permeation in SAE J2260 (incorporated by reference in §1048.810)."

To comply with 40 CFR 1048.105 (c) "*Diurnal emissions.* Evaporative hydrocarbon emissions may not exceed 0.2 grams per gallon of fuel tank capacity when measured using the test procedures specified in §1048.501. Diurnal emission controls must continue to function during engine operation."

To comply with 40 CFR 1048.105 (d) "*Running loss.* Liquid fuel in the fuel tank may not reach boiling during continuous engine operation in the final installation at an ambient temperature of 30 °C. Note that gasoline with a Reid vapor pressure of 62 kPa (9 psi) begins to boil at about 53 °C at atmospheric pressure, and at about 60 °C for fuel tanks that hold pressure as described in §1048.245(e)(1)(i)".

To comply with 40 CFR 1048.245 (1) (i) "Use a tethered or self-closing gas cap on a fuel tank that stays sealed up to a positive pressure of 24.5 kPa (3.5 psi); however, they may contain air inlets that open when there is a vacuum pressure inside the tank. Nonmetal fuel tanks must also use one of the qualifying designs for controlling permeation emissions specified in 40 CFR 1060.240."

CARBON MONOXIDE "CO"/ LOW-CO GENERATORS
IMPORTANT INFORMATION

DESCRIPTION

Carbon monoxide "CO" is a component of engine exhaust. It is a colorless, tasteless, odorless, lighter than air poisonous gas that can kill you without any warning. CO poisoning is one of the major safety risks associated with boating. It is a threat that must not be underestimated.

Several standards for CO have been published, expressed in parts per million "ppm" and hours of exposure:

Regulator	CO ppm	Exposure Hours
EPA	9	8
ACGIH	25	8
EPA	35	1
NIOSH	35	8
OSHA	50	8
ACGIH	125	0.5
NIOSH	200	0.0
NIOSH (IDLH)	1200	0.0

1200 ppm is the so-called IDLH concentration - IMMEDIATELY DANGEROUS TO LIFE AND HEALTH.

A city in California characterizes the effect of CO concentration this way:

Parts per Million	Responses
25	**Permissible exposure level, no apparent toxic symptoms.**
100	**No poisoning for long period. Allowable for several hours.**
200	**Should not be exposed above this level for any period of time. A possible mild frontal headache in two to three hours.**

Even though Westerbeke generators are designed to reduce normal levels of CO in the engine exhaust by approximately 99%, an exhaust leak of untreated exhaust would be extremely dangerous. For this reason it is extremely important to install a CO detector near the generator and to be sure it is always turned on and functioning properly. If this detector sounds, do not turn it off, assuming it is a false signal. You can not taste, smell, or otherwise detect CO. Leave the detector on, turn off all engines and generators, evacuate the boat leaving ports and hatches open, and seek professional help.

As soon as CO leaves the exhaust outlet, the level is subject to dilution in the open air. The closer a person is to the exhaust outlet, the higher the concentration of CO.

In a closed space, such as the engine compartment or underneath a stern swim platform, concentrations will potentially rise to the undiluted level emanating from the exhaust system due to a lack of fresh air to dilute the exhaust gas. Therefore, one should never rely on dilution of the exhaust to provide a margin of safety.

Westerbeke generators achieve reduction of CO by precise control control of the engine's air/fuel ration coupled with after treatment in a special catalyst. CO emissions are not the same for every model because each engine is different. Also, certain fuel system components are commonized across several engine models being adequate for some and extra-adequate for others, thus producing different CO levels for different models.

The fuel system which accomplishes the required precise air/fuel ratio control is comprised of many different components: purchased sub-assemblies, machined castings, sensors, electronics and others. Because of the extreme level of CO reduction, any variability in the functioning of any these components can and will cause variability of the CO output.

CO concentration also varies with load. Usually, but not always, the worst case CO concentration occurs at maximum load.

CARBON MONOXIDE "CO"/ LOW-CO GENERATORS
IMPORTANT INFORMATION

Catalyst performance will degrade over time. As the generator accumulates operating hours, CO concentrations will increase. **The catalyst must be replaced every 2,000 hours of engine operation.**

Verification of satisfactory CO levels must be done seasonally or each 1,000 hours (which ever occurs first). Verification involves actual sampling of exhaust gas with an appropriate CO analyzer.

There are two locations where exhaust gas can be sampled. Dry, but hot, exhaust can be sampled at the plugged tapped hole in the exhaust elbow intended for back pressure measurements. Measurements at this location may not be practical in all instances due to the high exhaust temperature, temperature limits of the analyzer, safety concerns over temperatures involved or the possibility of high levels of CO. The other location is the boat's exhaust outlet, which contains entrained cooling water (except dry stack exhaust systems). Only analyzers with probes should be used at this location and it is critical that the probe not ingest water. Probe-type analyzers have an air pump drawing a gas sample through the probe. As a result, they tend to ingest water when it is present. Be sure to aim the probe downwards with the opening pointed in the direction of the water flow and just out of the flow. Position the analyzer as high as possible with the tubing leading to the probe running continuously downhill. Observe the usually translucent tubing between the probe and the analyzer and be sure no water is being ingested. If any water is ingested into the analyzer, it must be repaired or replaced and recalibrated.

When measuring CO at the exhaust outlet be aware of the ambient CO level by also measuring CO away from and upwind of the exhaust outlet, especially in marinas. the CO level at the exhaust will be influenced upwards by the ambient level..

Whenever taking the time to verify proper CO concentration from the exhaust with a CO analyzer, always take the opportunity to use the analyzer to "sniff" around the engine looking for CO from exhaust leaks. Pay close attention to the connection of the cylinder head to the exhaust manifold, the exhaust manifold to the water injected exhaust elbow, and all subsequent downstream exhaust components and hoses. Remember, exhaust gas that has not yet passed through the catalyst is raw, untreated exhaust and is very high in CO content.

Analyzers usually require periodic calibration. Follow the instructions that come with the analyzer very carefully regarding calibration.

The following are manufacturers that offer CO analyzers: Extech, TIF, Testo, TSI, Bacharach, Fluke, Monoxor, Fyrite, Zellwgwer Analytics, Industrial Scientific Corp, GFG, TPI, Teledyne and others. Westerbeke recommends analyzers with a probe connected to the analyzer by a length of transparent tubing. They are slightly more expensive than those with the sensor built into one end of the analyzer, but they allow you to sample the exhaust coming out of the boat's exhaust outlet.

☐ *Refer to MEASURING BACK PRESSURE, CO SENSORS ,and EXHAUST SYSTEM MAINTAINANCE., in the back pages of this manual.*

EMISSIONS

This genset meets the requirements of California's Exhaust Emissions Standards as stated on the nameplate.

California users of this genset should be aware that unauthorized modifications or replacement of fuel, exhaust, air intake, or speed control system components that affect engine emissions are prohibited. Unauthorized modification, removal or replacement of the engine label is prohibited.

Federal Emissions Compliance Period: The Federal Emissions Compliance Period referred to on the nameplate indicates the number of operating hours for which the engine has been shown to meet Federal Emissions requirements.

Catagory C= 250 hrs, B=500 hrs,m A=1000.hrs.

You should carefully review the Operators Manual and Installation Manual and any other information you receive with your genset. If you are unsure that the installation, use, maintenance, or service of your genset is authorized, you should seek approval from your WESTERBEKE dealer.

California genset users may use the table below as an aid in locating information related to the California Air Resources Board requirements for emissions control.

EMISSIONS CONTROL INFORMATION TABLE

Emissions Warranty Information	The California emissions control warranty statement is located in the same packet, if information as this manual when the genset is shipped from the factory.
Engine Fuel Requirements	The engine is certified to operate on unleaded gasoline. See *FUEL RECOMMENDATIONS.*
Engine Valve Adjustment	See *MAINTENANCE SCHEDULE.*
Engine Ignition Timing	See *MAINTENANCE SCHEDULE.*
Engine Lubricating Oil Requirements	See *ENGINE OIL RECOMMENDATIONS.*
Engine Adjustments	ECU.
Engine Emission Contol System	The engine emission control system consists of engine design and precision manufacture.
Catalyst	See *MAINTENANCE SCHEDULE.*
Oxygen Sensor	See *MAINTENANCE SCHEDULE.*
Back Pressure	See *MAINTENANCE SCHEDULE.*

TABLE OF CONTENTS

NOTE: *THE FOLLOWING PAGES 10 THRU 34 ARE DETAILED INSTRUCTIONS ON THE DISASSEMBLY, INSPECTION, AND ASSEMBLY OF THE INTERIOR COMPONENTS OF THE MAIN ENGINE.*

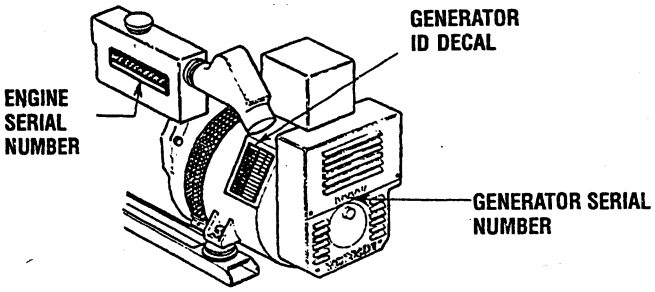
INTRODUCTION

ENGINE IDENTIFICATION PLATE

SERIAL NUMBER LOCATION

The engine's model number and engine serial number are found on an I.D. plate affixed to the engine's rocker cover and on I.D. stickers attached to either side of the AC generators housing.

SPECIFICATION	50 HZ.	60 HZ.
MODEL		
RPM		
KW		
KVA		
VOLTS		
AMPS		
ENG. HP		
ENG. SER. NO.		
GEN. SER. NO.		
PF/PHASE	/	
WIRES		
RATING		
INSUL. CLASS		
TEMP. RISE		
BATTERY		
C.I.D.		



ORDERING PARTS

Whenever replacement parts are needed, always provide the generator and engine model and serial numbers. In addition, include a complete part description and part number for each part needed . Also insist upon WESTERBEKE packaged parts because *will fit* or generic parts are frequently not made to the same specifications as original equipment.

DIAGNOSTIC SOFTWARE

Diagnostic software is available free of charge for all Low-CO generator sets. This is "read only" software. It does not allow the user to change any of the factory programmed settings in the ECU (Electronic Control Unit). The software can be obtained from your area's Westerbeke Distributor. There are two diagnostic software programs - OBD1 and EC10. The OBD1 is for the models 20.0/16.0 SBEGA and 22.5/18.7 SBEGA ONLY.

A Software Diagnostic Kit (#055410) is available from your Westerbeke Distributor/Dealer. The kit contains the OBD1 and EC10 programs for the models in this manual.

The kit also contains an interface communications cable to connect between the ECU and your laptop. This cable has a USB port to plug into your laptop and a 10 pin plug to plug into the communications pins of the ECU. Instructions for installing and programming the software are included in the kit in the **Readme.pdf** file. Be sure to read this file and follow the instructions carefully.

ENGINE OVERHAUL

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

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

TESTING FOR OVERHAUL

HOW TO DETERMINE ENGINE OVERHAUL PERIOD

Cause of Low Compression

Generally, the time at which an engine should be overhauled is determined by various conditions such as lowered engine power output, decreased compression pressure, and increased fuel and oil consumption. The lowered engine power output is not necessarily due to trouble with the engine itself, but is sometimes caused by worn plugs or low octane fuel. 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 eviden, and compression valves are at a minimum or below.

Engine standard compression is 163.5 psi (11.5 kg/cm^2) at 270 rpm.
Minimum compression is 115 psi (8.1 kg/cm^2) at 270 rpm.
Difference between cylinder 28.0 psi (2.0 kg/cm^2) or less.

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 musfire, 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.

COMPRESSION TEST PROCEDURES

NOTE: *The activation of the starter motor is a function of the ECU (Electronic Control Unit). To by-pass the ECU, a simple electrical jumper arrangement can be fabricated to connect between the battery B+ cable connection on the starter solenoid and the spade type activation connection and activate the starter solenoid.*

1. Start the engine and allow it to warm up to its normal operating temperature Then shut it down.
2. Open the DC breaker on the unit's control box to disable the ECU. Connect the jumper arrangement on the starter solenoid connections.
3. Close the unit's raw water thru hull opening. This is to prevent the raw water pump from pumping water into the unit's exhaust system during the test as no or very little exhaust pressure will be present during the test to help expel water from the unit's exhaust system during engine cranking.
4. Remove the high tension leds from the spark plugs and remove all the spark plugs.
5. Thread the compression gauge adapter into the spark plug opening of cylinder #1. Connect the compression gauge to the adapter.
6. Activate the starter motor using the push button on the electrical jumper arrangement for the starter. Allow the engine to crank observing the compression gauge. Allow the engine to crank until the gauge reaches a maximum reading where further cranking does not produce a higher reading on the compression gauge. Stop cranking and record the pressure.
7. Remove the compression gauge and adapter from the #1 spark plug. Open and install it in the #2 cylinber spark plug opening and repeat step #6.
8. Proceed to the next cylinder and repeat step #6 until all the cylinders have been tested and their pressures recorded.

NOTE: *A wet test can be performed on cylinders with low compression figures. This will help determine if the low pressure is the result of worn cylinders/rings or worn valve seats/valves or both. Place a few squires of oil into the cylinder and then perform the compression test on that cylinder.*

a. A dramatic rise in the recorded compression valve would indicate a worn cylinder/rings.

b. A minimal rise in the recorded compression valve would indicate both cylinder/ring and valve wear.

c. No appreciable rise in the recorded compression valve would indicate valve/valve seat wear.

TROUBLESHOOTING ANALYSIS

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

NOTE: **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.*

DIFFICULTY STARTING

Malfunction of Engine-Related Components

1. Burned valve.
2. Worn piston, piston ring, or cylinder.
3. Burned cylinder head gasket.

Malfunction of Fuel System

Malfunction of Electrical System

INSUFFICIENT POWER

Insufficient Compression

1. Compression leakage from valve seat.
2. Seized valve stem.
3. Weak or broken valve spring.
4. Burned cylinder head gasket.
5. Cracked or distorted cylinder head.
6. Sticking, damaged or worn piston ring.
7. Cracked or worn piston.

Malfunction of Fuel System

1. Poor quality/Low Octane Fuel.

Malfunction of Ignition System

EXCESSIVE OIL CONSUMPTION

Oil Working Up

1. Worn or sticking piston ring or piston ring groove.
2. Worn piston or cylinder.

Oil Working Down

1. Bad valve seat.
2. Worn valve stem or guide.

Oil Leakage

ABNORMAL COMBUSTION

Malfunction of Engine-Related Components

1. Sticking or burned valve.
2. Weak or broken valve spring.
3. Carbon accumulated in combustion chamber.

Malfunction of Fuel System

Malfunction of Ignition System

ENGINE NOISE

Crankshaft or Bearing Related Parts

1. Excessive main bearing oil clearance.
2. Main bearing seized or heat damaged.
3. Excessive crankshaft end play.
4. Excessive connecting rod bearing oil clearance.
5. Connecting rod bearing seized or heat damaged.

Piston Related Parts

1. Worn cylinder.
2. Worn piston or piston ring.
3. Seized piston.
4. Damaged piston ring.
5. Bent connecting rod.

Malfunction of Ignition System

Valve or Timing Related Parts

1. Malfunction of HLA*
2. Broken valve spring
3. Excessive clearance between valve stem and guide.
4. Insufficient lubrication of rocker arm.

Others

1. Malfunction of water pump bearing.
2. Malfunction of alternator bearing.
3. Malfunction of timing belt tensioner.

ENGINE HUNTS

1. Low battery voltage.
2. Generator is overloaded.
3. Cracked distributor cap.
4. Faulty high tension wires.
5. Faulty fuel pump.
6. High exhaust back-pressure.
7. Valves are out of adjustment.
8. Dirty fuel filters.

ENGINE BACKFIRES

1. Spark plug wires connected wrong.
2. Incorrect timing.
3. Dirty flame arrester.
4. Cracked distributor cap.
5. High exhaust back-pressure.

POOR IDLING AND ENGINE PERFORMANCE

Malfunction of Engine-Related Components

1. Poor valve-to-valve seat contact.
2. Failure of cylinder head gasket.

Malfunction of Fuel System

Malfunction of Ignition System

Engine Misfires

1. Poor quality fuel.
2. Incorrect timing.
3. Dirty flame arrester.
4. Cracked distributor cap.
5. Faulty ignition wires.
6. Spark plugs are worn.
7. High exhaust back-pressure.
8. Valve clearances are incorrect.

Blue Exhaust Smoke Discharge from the Engine

1. Lube oil is diluted.
2. High lube oil level.
3. Crankcase breather hose is clogged.
4. Valves are worn or adjusted incorrectly.
5. Piston rings are worn or unseated.

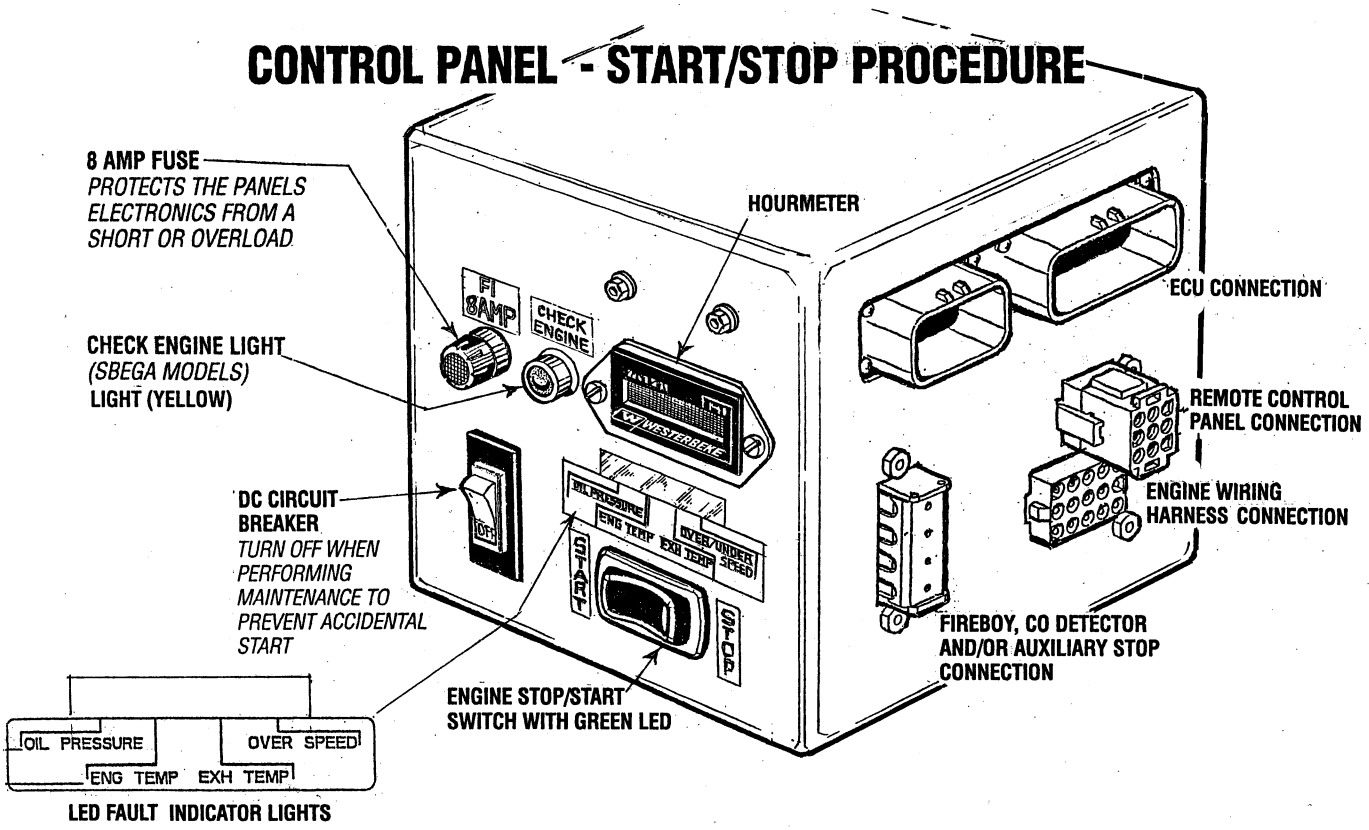
Black Exhaust Smoke

1. Dirty flame arrester.
2. Amperage overload.
3. Faulty injector.

NOTE:

FOR ADDITIONAL ENGINE TROUBLESHOOTING CHARTS, ELECTRICAL TROUBLESHOOTING AND DATA LOGGING TROUBLESHOOTING (USING PC INTERFACE) REFER ***TO THE TABLE OF CONTENTS.***

CONTROL PANEL - START/STOP PROCEDURE



GENERATOR CONTROL PANEL

The start/stop rocker switch is the only functional component on the generator control panel used to start and stop the generator.

The start/stop rocker switch is a three position switch with momentary contacts in the (**START**) and (**STOP**) position and a stationary contact function in the center (**NORMAL**). This position allows the generator to run once started and also enables the remote start/stop panel(s) to control the start/stop functions of the generator.

The (**START**) position starts the generator and once released reverts to the center position. The (**STOP**) position stops the engine in normal operation as well as in an emergency situation. This position opens the K2 run relay which de-energizes the engine's run circuit and shuts down the engine.

To Start: Press the rocker switch to the start position and release. (The switch will revert to its center position). The engine will crank and start electronically. A **green LED** on the switch will indicate the engine is running.

NOTE: *There is a few second delay while the ECU self-tests before the start button responds.*

Apply a light load to the generator and allow the engine to warm up to operating temperature before applying heavy loads.

To Stop: Press the rocker switch to stop and release. The ECU will receive the signal to shut the engine down. The green LED will go off indicating the unit has shut-down.

NOTE: *This green LED may illuminate dimley when the engine is not running. This is part of the self diagnostic circuit and is normal.*

Failure to Start

The start cycle will automatically terminate if the unit fails to start after 12-14 seconds of cranking. **Wait 20 seconds**, then repeat the start.

The ECU will allow 3 crank cycles before the LED Under Speed fault illuminates. This will terminate further crank cycles and require investigation as to the cause of no start.

> ⚠ **CAUTION:** ***Repeated crank cycles without a start can result in the engine's exhaust sytem filling with raw water. If after three crank cycles the unit does not start, drain the system's muffler and investigate and correct the cause of no start.***

The LED fault shut down display board has four separate LED lights to display to the operator the cause of the generators automatic shut down. The four LED displays are: low oil pressure, high engine operating temperature, high exhaust temperature and engine over-speed/under-speed (flashes).

Should the generator shut down from one of these faults, the fault LED will remain illuminated. To reset the LED, the DC breaker on the control box **must** be turned **OFF** and then back **ON**.

NOTE: *The CHECK ENGINE LED indicates a possible emissions control issue. Immediate action should be taken to troubleshoot and correct this problem.*

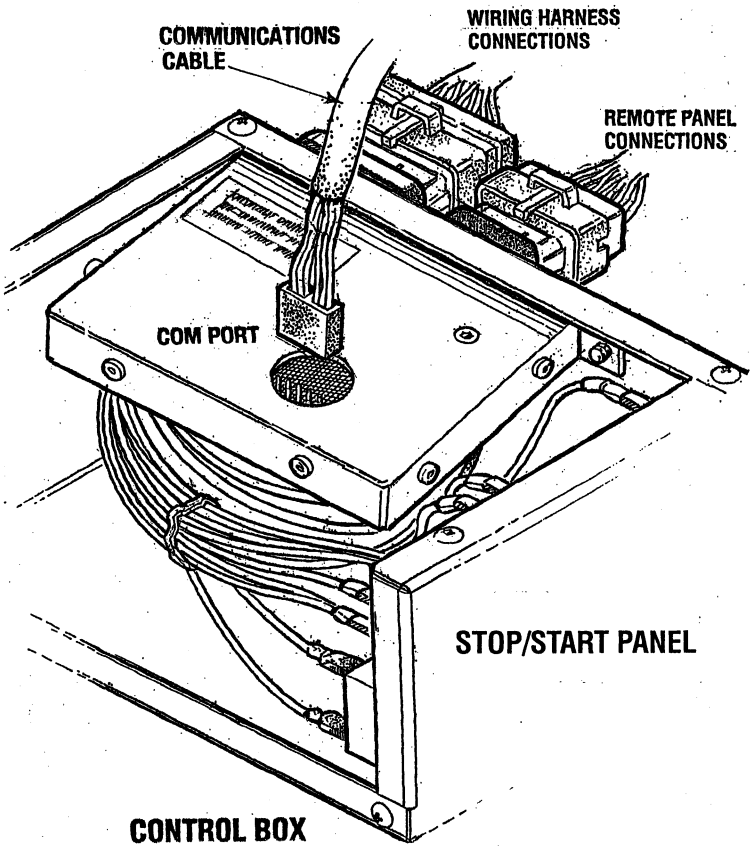
ELECTRONIC CONTROL UNIT (ECU)
CURRENT MODELS

DESCRIPTION

The ECU (Electronic Control Unit) is factory programmed and requires no adjustment. No adjustments in the field can be made to the programming other than engine speed for 50 or 60 hertz operation. The ECU controls starting, engine operation, safety shutdown features and stopping the engine.

The 10 pin communications port is used by the factory to input the operating program into the ECU. This connection can be used with available software Diagnostic Software Kit (#055410) to monitor the operation of the Low CO system and also with the same software to change engine speed for 50 or 60 hertz operation.

The ECU is normally programmed for 60 hertz operation unless specified otherwise. If it is necessary to change the hertz setting of the ECU, the available software has to be used to change this program setting in the ECU. It can not be done any other way.



Setting/Changing Engine Speed

The engine speed can be set for generator operation at either 60Hz (1800 rpm) or 50Hz (1500 rpm). Once the AC voltage output for the generator has been reconfigured as described in the BE Generator section of this manual, proceed as follows:

1. Open the control box on the generator. Shut OFF the DC breaker on the control.
2. Access the opening on the ECU by removing the plug. Connect your laptop (with the software installed) using the communications cable included in the kit to the ECU and turn the laptop ON.

   NOTE: *The arrow on the communications cable connecting plug for the ECU* ***must*** *face the harness connections for the ECU.*
3. Turn the DC breaker to the ON position.
4. Using the EC11 software, start communications. Follow the HELP menu instructions for HELP US using the PC Interface. Program the ECU for the hertz that the generator is being converted to.

   NOTE: *The PC Interface can be left conected to confirm proper rpm during testing. Always stop the generator and turn OFF the DC breaker before disconnecting the communications cable from the ECU.*
5. Along with a hertz change/engine speed, the AC output configuration of the generator will need to be changed to correspond to the new hertz the generator will now be programmed for. AC configurations are illustrated in this manual for both single and three phase models.
6. Along with the reconfiguring of the generators AC output, the generator's AC circuit breaker will need to be changed to correspond to the new amperage rating of the generator. Single phase AC breakers are listed in this manual.

   NOTE: *AC circuit breakers are not supplied with the 3 phase model.*

ELECTRONIC FUEL INJECTION
EARLIER MODELS

DESCRIPTION

The ECU (Electronic Control Unit) is factory programmed and requires no adjustments by the generator operator. It controls all starting, operating and safety shutdown features on the engine. The Gain Pot is set at #50 midpoint for optimum system response.

Dipswitch #1 is used to charge the generator frequency. ON is for 50 hertz and OFF is for 60 hertz operation. The remaining switches #2, #3 and #4 service no function.

The vacant program connector is used by the factory to input the operating program into the ECU. This connector can be used with software to monitor the operation of the Low CO system. Contact your MD to obtain the software kit.

The electrical connections from the engine electrical harness are made to the ECU through two plug connections, one 23 pin and one 35 pin and may therefore vary in number according to the generator model. For further details, consult the engine circuit wiring diagram in this manual.

The ECU is normally set for operation at 60 Hz unless specified otherwise, and is internally configured for a 4 pole generator. If it is necessary to replace the ECU, make sure it is configured by label for the generator in use.

ECU ADJUSTMENTS

Stability Trim (Gain)

When changing engine speed, or if an engine hunting condition should occur, the gain pot may require adjustment. There is no specific set point for this adjustment and it is normally set to the middle of its range or to a point in its range which obtains optimal engine speed response without any tendency of hunting.

NOTE: *The Electrical Control Unit (ECU) for current generators is shown on the following page. Adjustments on this page are for earlier model generators.*

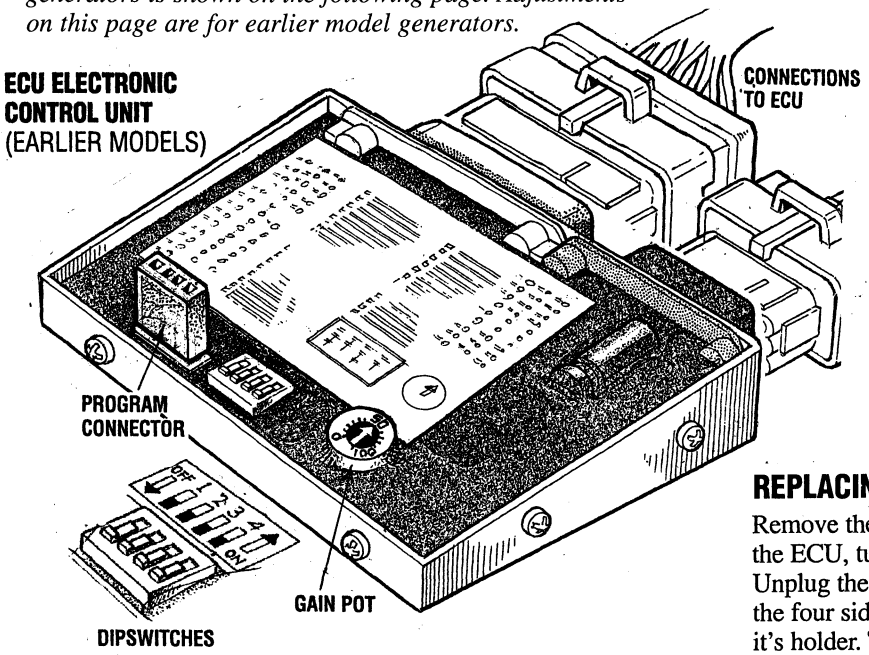
Setting/Changing Engine Speed

The engine speed can be set for operation at either 60Hz (1800 rpm) or 50Hz (1500 rpm) to correspond to the engine speeds for a 4 pole AC generator. :

1. Turn OFF the Control Box DC breaker and move the #1 dipswitch on the ECU of the OFF position for 60 hertz and ON for 50 hertz operation.
2. When changing the engine speed/generator hertz, a corresponding change is made to the AC voltage output configuration of the generator. The AC voltage output configurations are illustrated in this manual for both single and three phase models.
3. The AC breaker in the control box will also need to be changed to correspond to the amperage rating change of the generator that this Hertz/AC voltage output configuration change will produce. The AC breakers are listed in this manual.
4. Once all of the above has been accomplished, the generators AC breaker should be turned OFF and the unit test run. Hertz and AC output should be monitored. The AC voltage (if needed) can be adjusted using the voltage pot on the regulator.
5. There is a GAIN adjustment on the ECU that usually gives the best system reaction to amperage load changes when set between #40-#60.

   NOTE: *A higher GAIN adjustment can induce unstable engine operation. In such cases, lessen the GAIN adjustment.*

With the test run performed and adjustments are made as needed, turn ON the AC breaker and load test the generator.



REPLACING THE ECU

Remove the control box cover. Before attempting to remove the ECU, turn OFF the 20 amp DC control panel breaker. Unplug the two engine harness connections. Then unscrew the four side screws securing the ECU and remove it from it's holder. To install a new ECU, reverse the procedure.

FUEL SYSTEM

BLEEDING THE FUEL SYSTEM

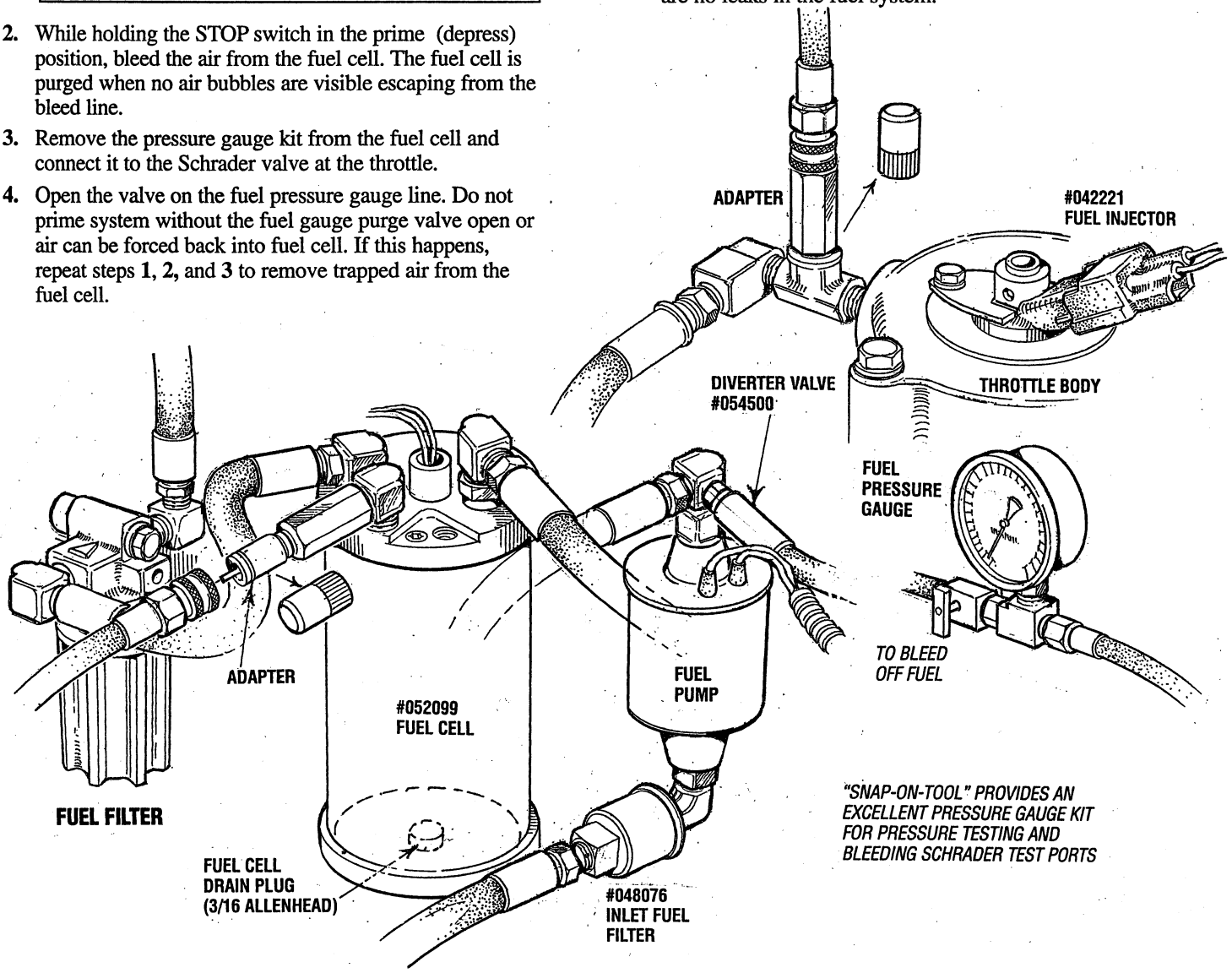
If the engine cranks but fails to start or starts and then shuts down, there may be air in the fuel system. Use the following procedure to purge air from the fuel system.

1. Connect a fuel pressure gauge kit (Snap-On MT 3378) or equivalent to the Schrader port on the fuel cell.

> ⚠ **CAUTION:** ***Follow the manufacturers instructions for the safe use of the pressure gauge kit when purging high pressure fuel systems.***

2. While holding the STOP switch in the prime (depress) position, bleed the air from the fuel cell. The fuel cell is purged when no air bubbles are visible escaping from the bleed line.
3. Remove the pressure gauge kit from the fuel cell and connect it to the Schrader valve at the throttle.
4. Open the valve on the fuel pressure gauge line. Do not prime system without the fuel gauge purge valve open or air can be forced back into fuel cell. If this happens, repeat steps **1**, **2**, and **3** to remove trapped air from the fuel cell.
5. Repeat step **2**, this time purging the air completely from the throttle body. The pressure should be 40psi in the throttle body after purging the system.

   NOTE: *The system can develop 40psi without being fully purged. The system is only fully purged when no bubbles are visible in the purge line.*
6. Remove the pressure gauge set, and cap all Schrader valves.
7. Insure that all wire connections are secure and that there are no leaks in the fuel system.



BLEEDING THE FUEL SYSTEM

DISASSEMBLY OF FUEL SYSTEM COMPONENTS

REMOVING THE ENGINE'S WIRING HARNESS

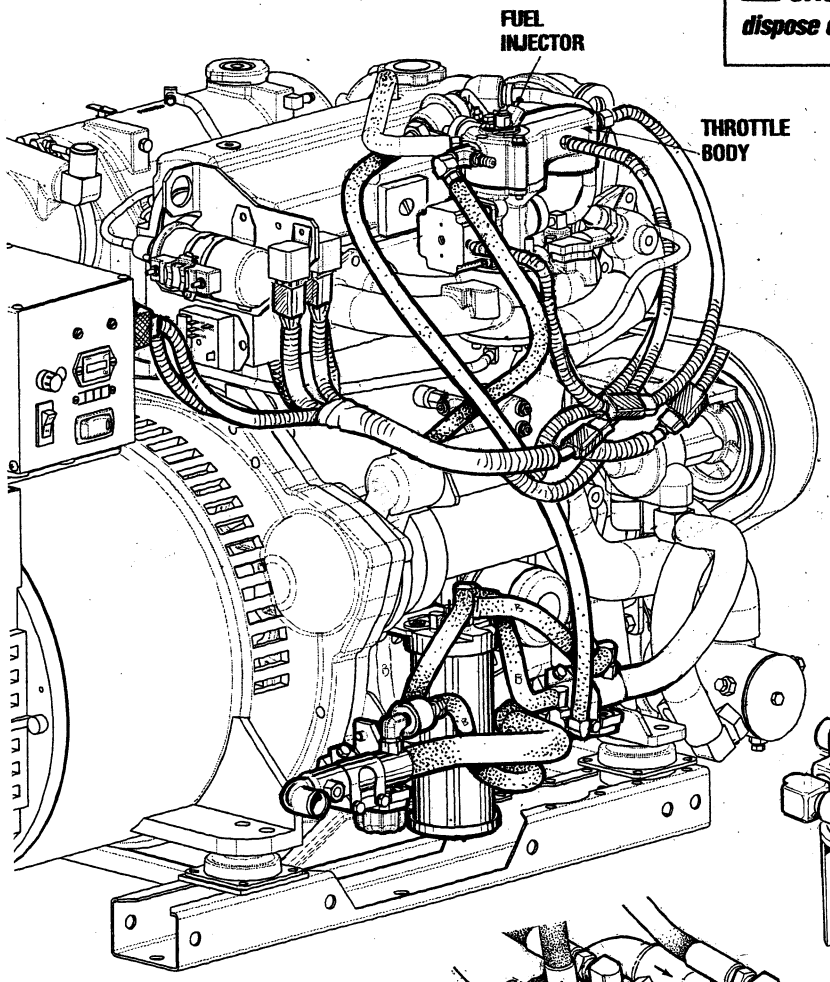
Un plug the wiring connections from the control panel and disconnect the wiring connections to separate the harness from the fuel injector and throttle body. Remove the harness carefully, marking where the assemblies re-connect.

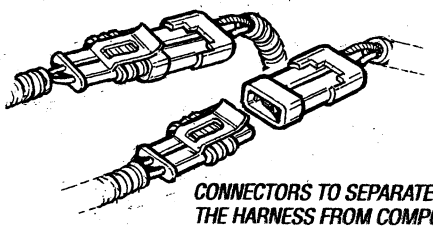
NOTE: *Coolant hoses and fuel lines may need to be drained off as they are disconnected.*

REMOVING THE FUEL SYSTEM COMPONENTS

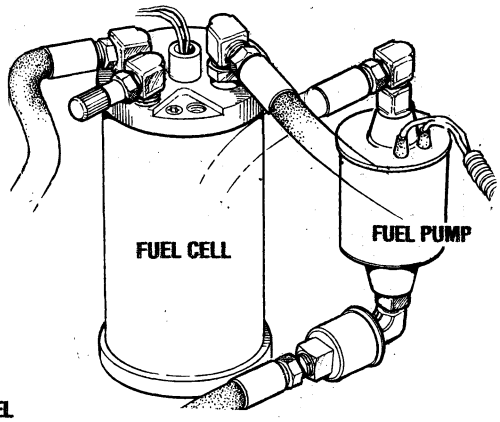
The fuel system components can be removed as assemblies by unbolting their brackets from the engine.When disconnecting the fuel lines (blue), be careful to drain off any fuel that may have accumulated in the lines. Also be aware that the coolant lines (black) may contain coolant.

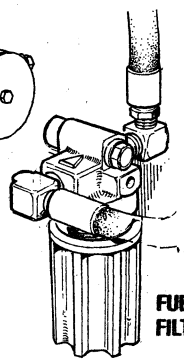
⚠ CAUTION: ***Clean up spilled fuel immediately and dispose of rags properly.***



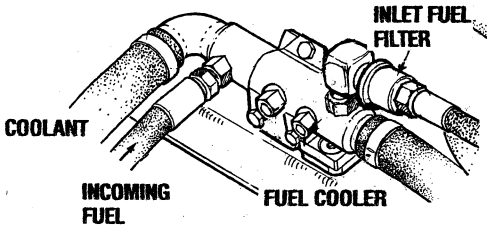


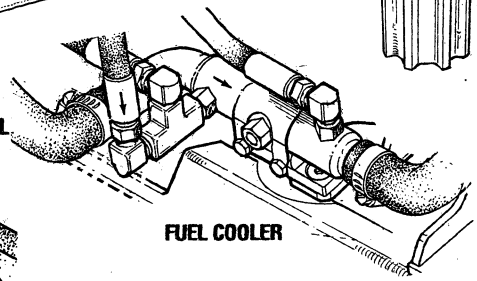
CONNECTORS TO SEPARATE THE HARNESS FROM COMPONENTS (MARK TO IDENTIFY)

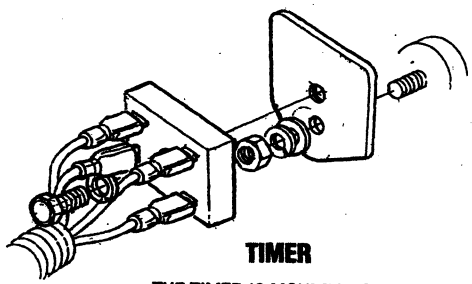




THE FUEL PUMP AND FUEL MODULE CAN BE DISASSEMBLED FROM THE ENGINE AS AN ASSEMBLY BY REMOVING THE BRACKET.







TIMER

THE TIMER IS MOUNTED ON A BRACKET JUST ABOVE THE FUEL CELL. THE TIMER FUNCTION IS TO TERMINATE DC VOLTAGE TO THE FUEL PUMP AT ENGINE SHUTDOWN.

ENGINE/GENERATOR DISASSEMBLY

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.

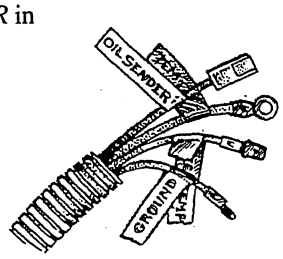
NOTE: *Label any lines, hoses or cables as you separate them.*

Drain the engine oil and the coolant from the engine.

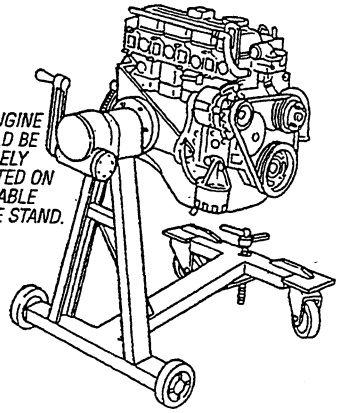
Carefully support and then unbolt the generator backend from the engine. See *SPECIAL TOOLS - GENERATOR* in this manual.

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

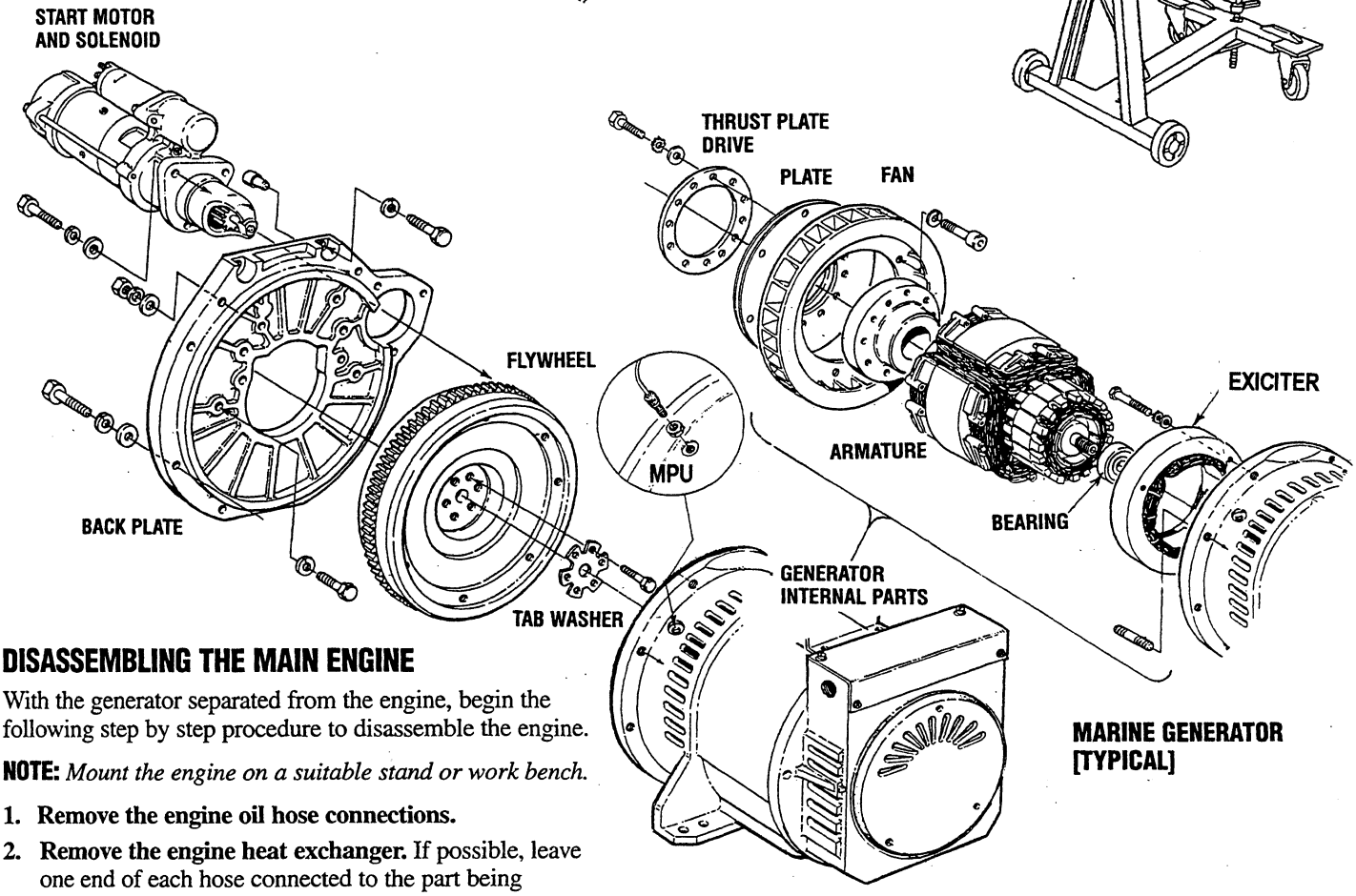
5. **Remove the engine mounted raw water pump, adapter mounting plate, and drive from the front cover.** The drive is removed by turning in a counter clockwise direction. See *RAW WATER PUMP* for parts breakdown.
6. **Remove the coolant recirculating pump.** See *COOLANT RECIRCULATING PUMP* for parts breakdown.
7. **Remove the air intake silencer and the intake manifold.**



LABEL THE TERMINAL CONNECTIONS AS YOU DISCONNECT THE WIRING HARNESS.



THE ENGINE SHOULD BE SECURELY MOUNTED ON A SUITABLE ENGINE STAND.



MARINE GENERATOR [TYPICAL]

DISASSEMBLING THE MAIN ENGINE

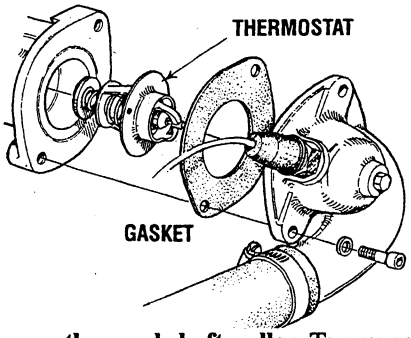
With the generator separated from the engine, begin the following step by step procedure to disassemble the engine.

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.

NOTE: *REMOVE THE MPU BEFORE DISASSEMBLING THE GENERATOR TO PREVENT DAMAGE.*

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

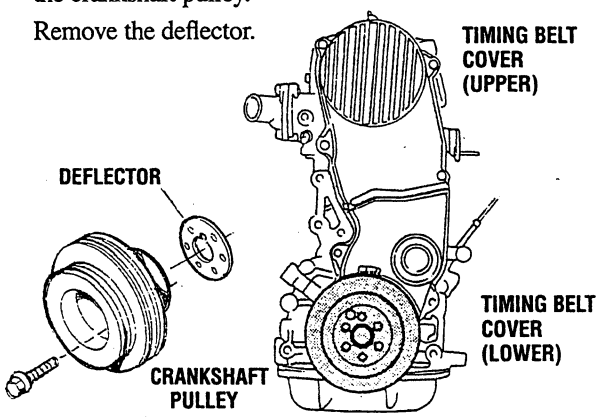


9. **Remove the crankshaft pulley.** To prevent the crankshaft pulley from rotating, insert two bolts into the gap at the rear end of the crankshaft.

   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

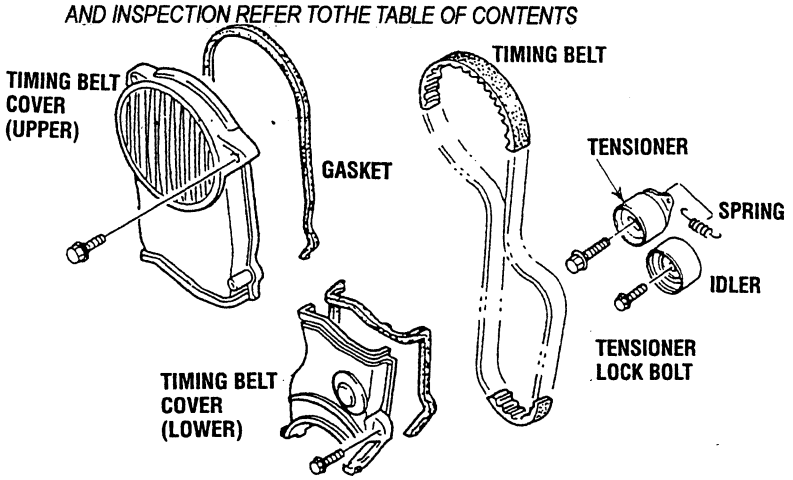
    The exhaust manifold

    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

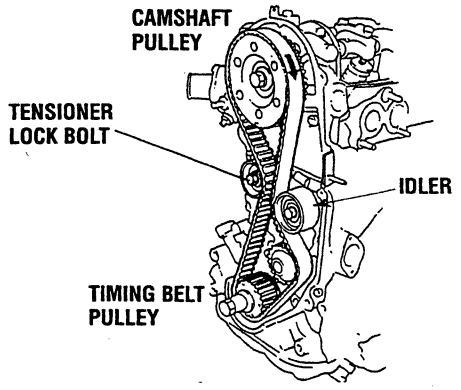
NOTE; *FOR MORE DETAILED BELT DISASSEMBLY AND INSPECTION REFER TOTHE TABLE OF CONTENTS*



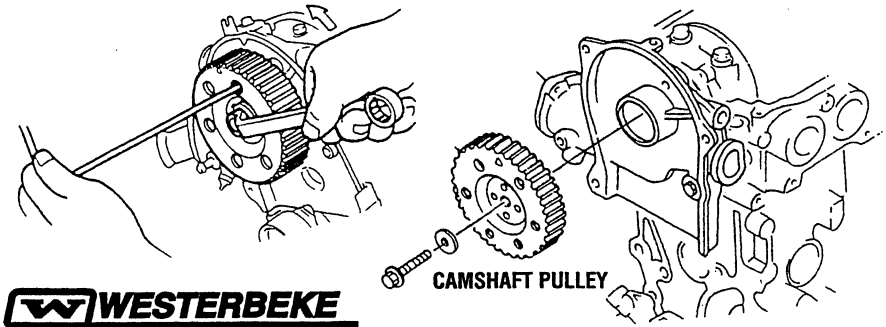
11. **Remove the timing belt covers, upper and lower.**
12. **Loosen the timing belt tensioner lock belt and remove the spring.**
13. **Remove the bolts to remove the timing belt tensioner and remove the timing belt.**

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

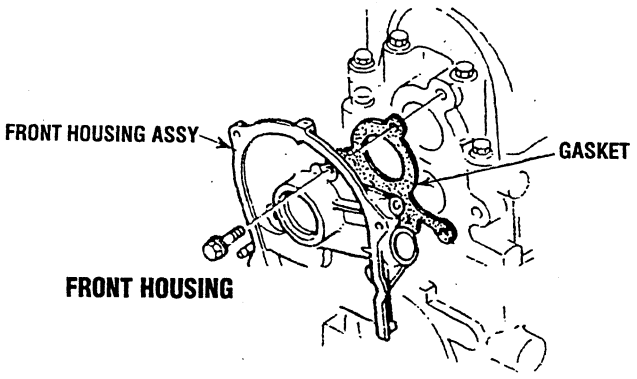
For *INSPECTION* and *ASSEMBLY,* refer to *TIMING BELT* in this manual.



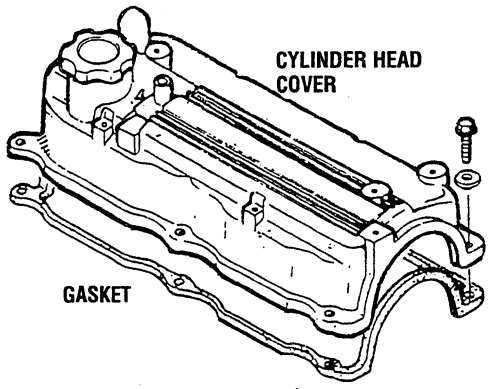
14. **Remove the camshaft pulley.** Remove the pulley by inserting a T-wrench or similar tool to prevent it from turning.



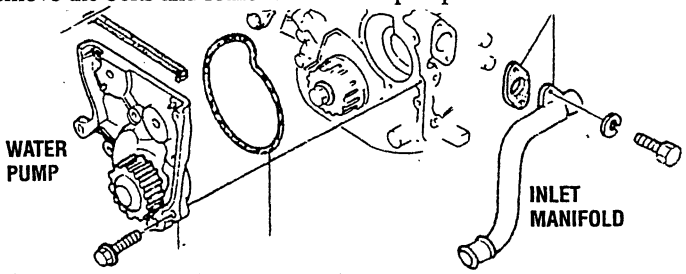
ENGINE DISASSEMBLY/INSPECTION



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



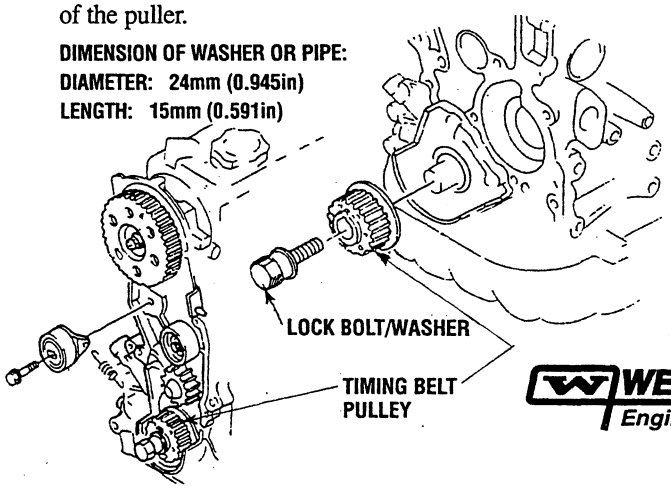
4. Remove the bolts and remove the water pump as a unit.



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)

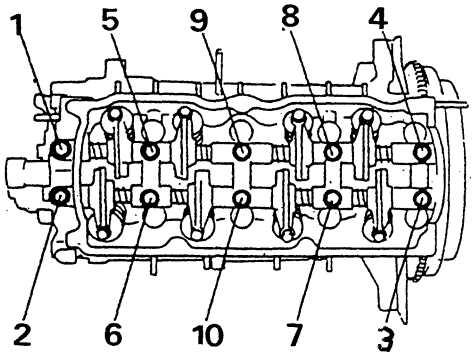


4. Screw in the pulley puller, and remove the spacer and taper ring together.

   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 knock pin.
7. Disassemble the spacer from the pulley puller.

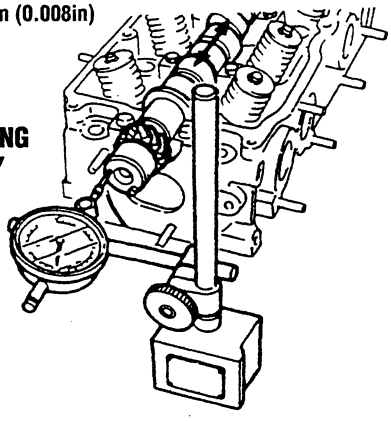
REMOVE THE ROCKER SHAFT ASSEMBLY

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



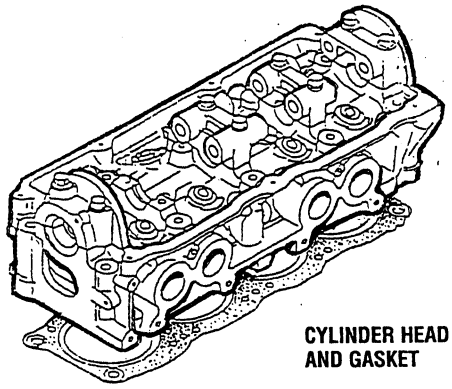
2. Inspect the end play by moving the camshaft forward and backward using a magnet base and dial gauge.

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

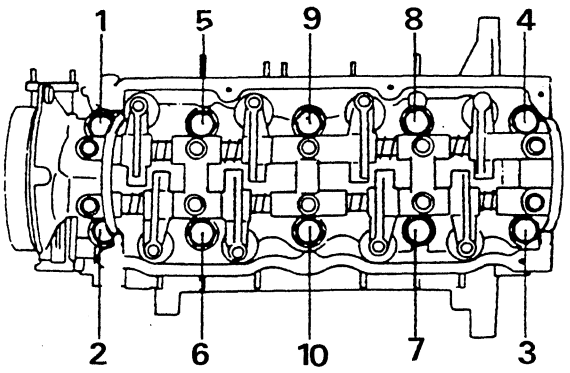


NOTE: *If the end play exceeds specifications, replace the camshaft and/or cylinder head.*

REMOVE THE CYLINDER HEAD ASSEMBLY AS A UNIT



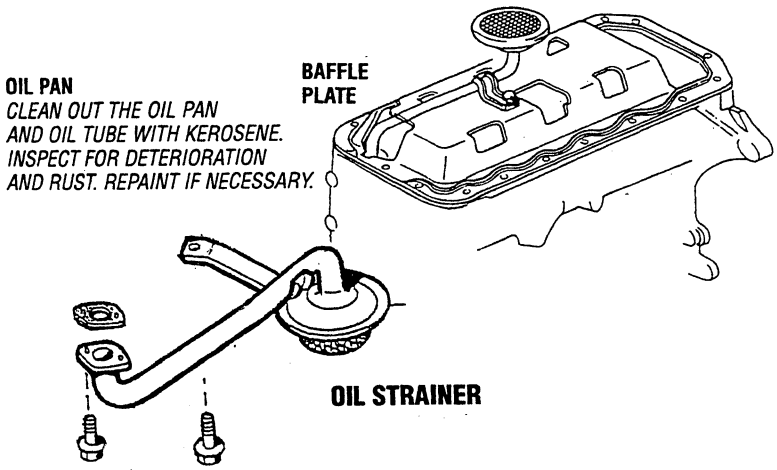
ENGINE DISASSEMBLY/INSPECTION



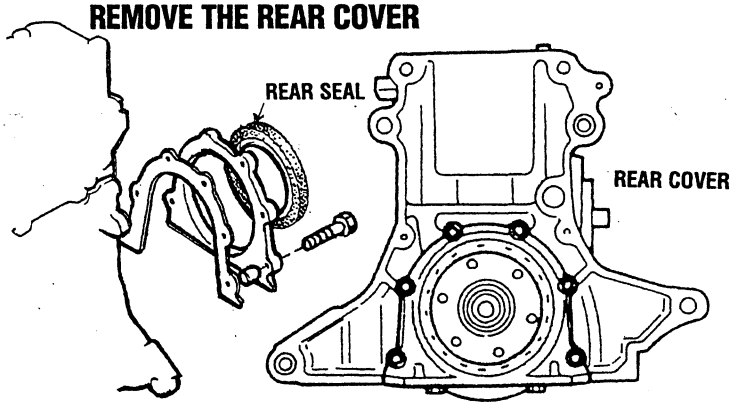
1. Loosen the cylinder head bolts in several increments to remove, following the numerical sequence indicated above.

REMOVE THE OIL PAN, GASKET AND BAFFLE PLATE

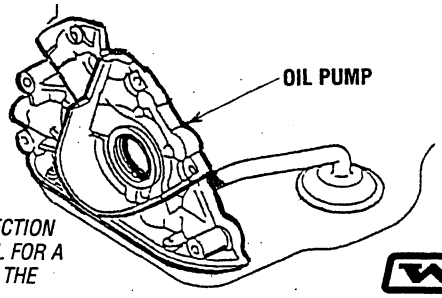
1. Remove the bolts and remove the oil strainer.



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

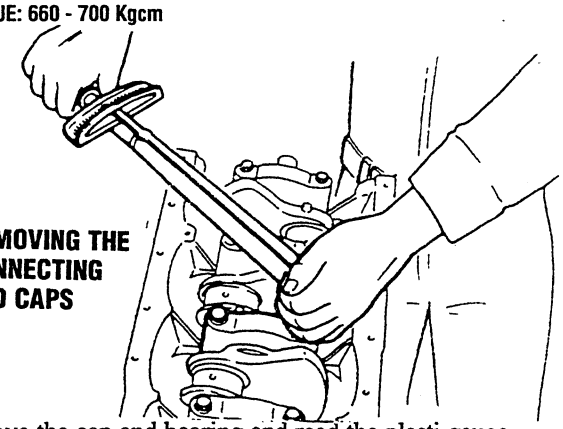
1. Use a magnet base and a dial indicator.

   STANDARD: 0.08 - 0.18 mm (0.003 - 0.007 in)
   LIMIT: 0.30 mm (0.012 in)

   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

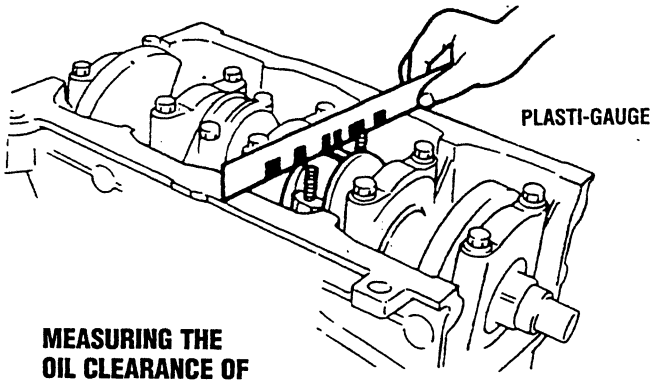


REMOVING THE CONNECTING ROD CAPS

   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: 0.027 - 0.067 mm (0.0011 - 0.0026 in)
   MAXIMUM LIMIT: 0.10 mm (0.004 in)

   f. Remove the plasti-gauge.



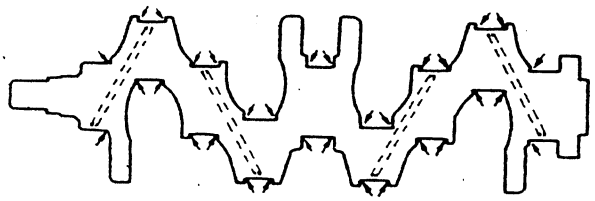
MEASURING THE OIL CLEARANCE OF THE LARGE END BEARING

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)

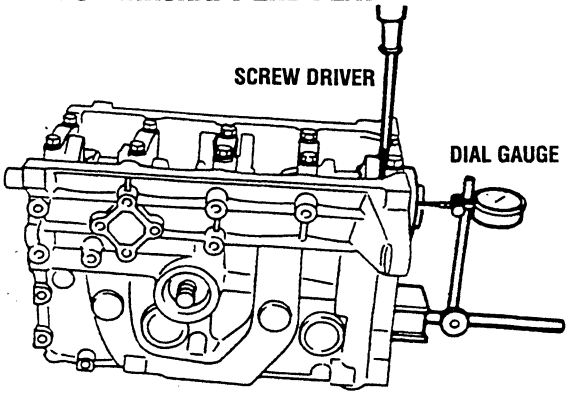


R DIMENSION: 3mm R

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

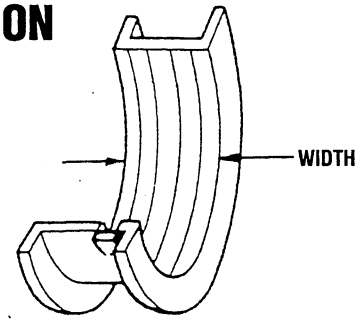


1. Check the end play by moving the crankshaft forward and backward as shown using a magnetic base and dial gauge to measure the amount.

STANDARD: 0.08 - 0.18 mm (0.003 - 0.007 in)
LIMIT: 0.30 mm (0.012 in)

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

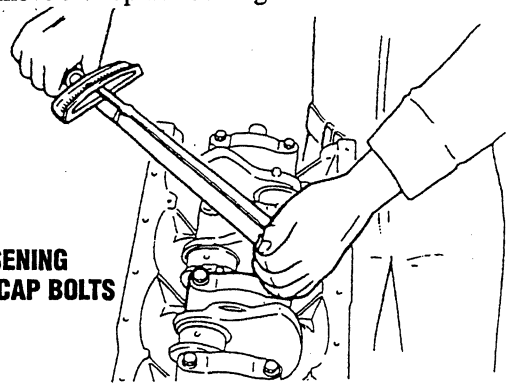
NOTE: *The undersize center main bearings are classified into the following three types. The center main bearings vary in width as shown in the table.*



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 - 27.00mm (1.1008 - 1.103in)

INSPECT THE CRANKSHAFT

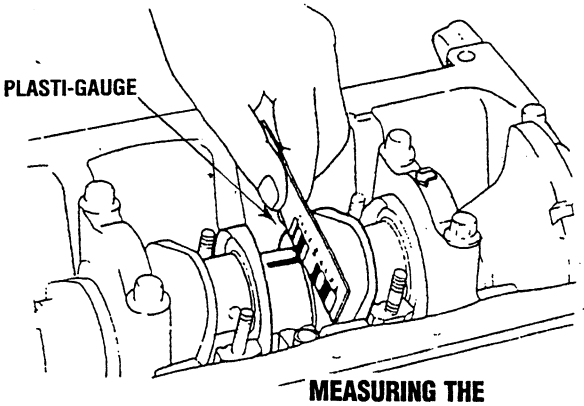
3. Inspect the bearing oil clearance of the crankshaft journal.
   a. Loosen the main bearing cap bolts, alternating between the two bolts of one cap, turning each bolt a few turns at a time.
   b. Remove the cap and bearing to remove the crankshaft.



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.

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

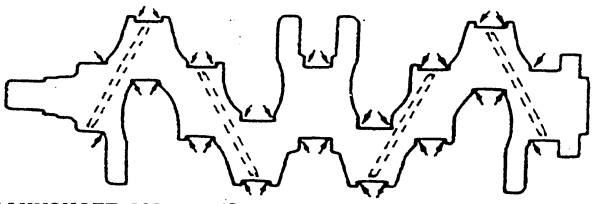
If the oil clearance provided by the replaced bearing set exceeds the limit, grind the crank journal and use the undersize bearing to obtain the oil clearance required.

CLEARANCE BETWEEN JOURNALS AND MAIN BEARINGS

(NO. 1,2,4, AND 5) ..... 0.025 to 0.043mm (0.00099 to 0.00169 in)

(NO. 3) .....0.031 TO 0.049mm (0.00123 TO 0.00192 in.)

SERVICE LIMIT .....0.08mm (0.003 in.)

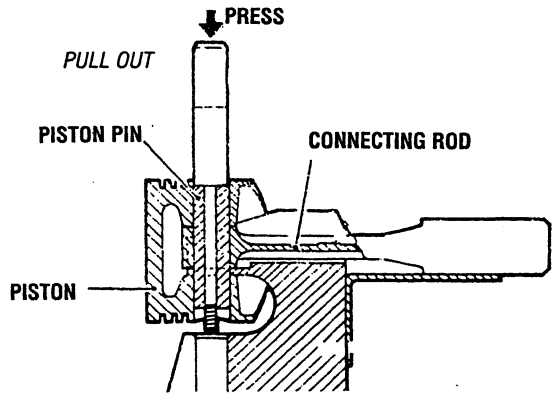


CRANKSHAFT JOURNALS

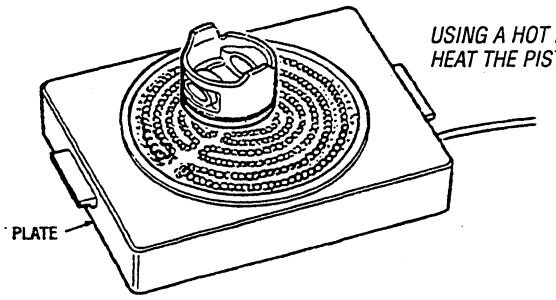
R DIMENSION: 3mm R

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.

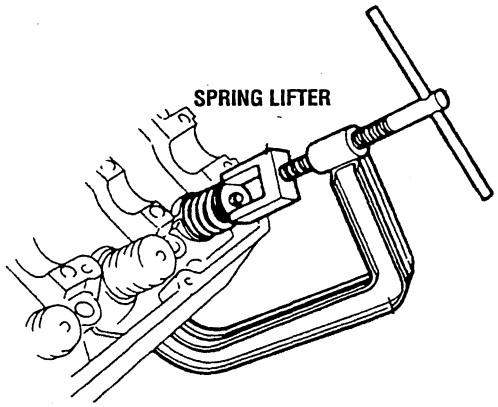


Heat the piston to 122° – 158° F (50° – 70° C).



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.



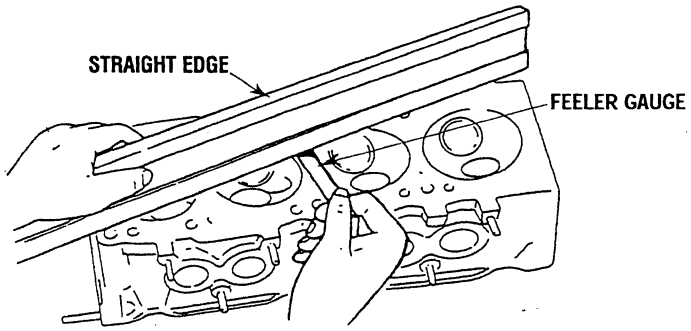
   b. Remove the valve spring and upper and lower valve spring seats by loosening the valve spring compression.
   c. Remove the valve from the valve guide.
   d. Remove the valve seal.
   e. Remove the remaining valve assemblies by repeating the above procedure.

CYLINDER HEAD / VALVES
INSPECTION / REPAIR

INSPECTION

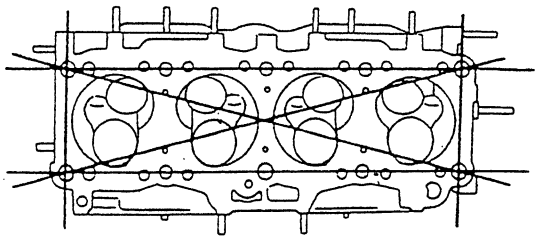
Clean off the cylinder head and remove any gasket fragments.

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

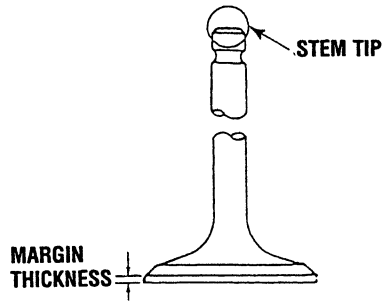
Use the same inspection procedure for the manifold mounting surface, measuring distortion with a gauge and a straightedge in several directions.

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.

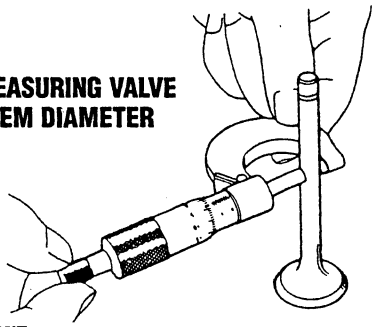
VALVE HEAD MARGIN THICKNESS
IN: 0.5 mm (0.020in) MIN.
EX: 1.0mm (0.039in) MIN.



3. Measure the valve stem diameter.

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

MEASURING VALVE STEM DIAMETER

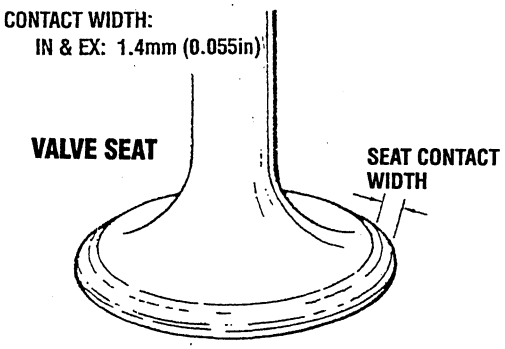


LIMIT:
INTAKE: 7.980 mm (0.3142 in)
EXHAUST: 7.975 mm (0.3140 in)

VALVES SEAT
INSPECTION / REPAIR

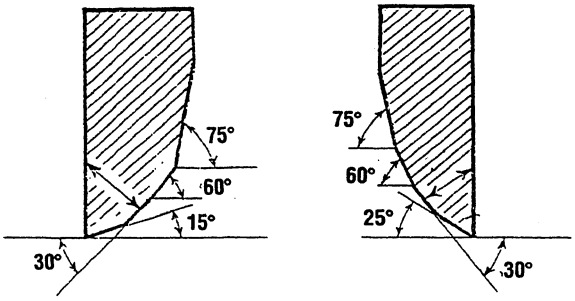
VALVE SEAT

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.



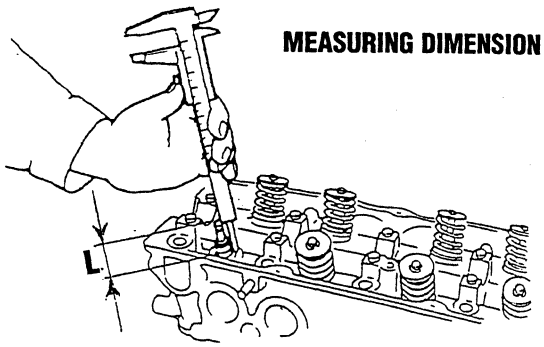
4. Check that the valve seating position is at the center of the valve face.
   (1) If the seating position is too high, correct the valve seat with a 60° cutter and a 30° cutter.
   (2) If the seating position is too low, correct the valve seat with a 25° (IN) cutter and a 15° (EX) cutter.
5. Seat the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

VALVE SEAT ANGLES



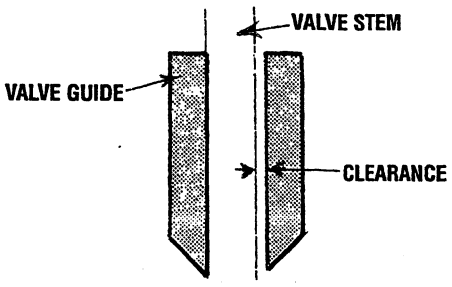
6. Check the sinking of the valve seat.
   Measure protruding length (dimension L) of each valve stem.
   Dimension L: 46.5mm (1.831in)
   (1) If **L** is within **46.5—47.0mm (1.831—1.850in)**, it can be used as is.
   (2) If **L** is within **47.0—48.0mm (1.850—1.890in)**, insert a spacer between the 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**
   Subtract the outer diameter of the valve stem from the inner diameter of the corresponding valve guide.

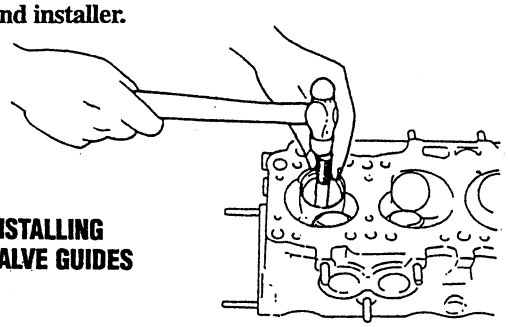
GUIDE/STEM CLEARANCE
STANDARD:
EXHAUST: 0.030 - 0.065 mm (0.0012 - 0.0026 in)
INTAKE: 0.025 - 0.060 mm (0.0010 - 0.0024 in)
LIMIT: (INTAKE AND EXHAUST) 0.10mm (0.004in)



VALVES / VALVE GUIDE / VALVE SPRING
INSPECTION / REPAIR

REPLACEMENT OF THE VALVE GUIDE

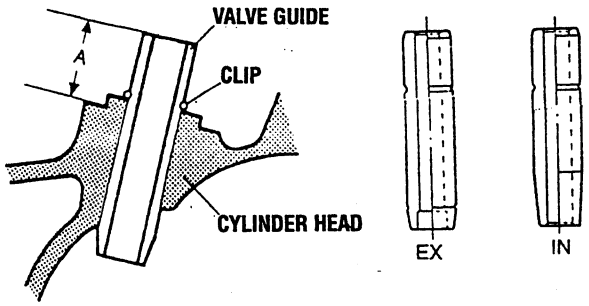
1. Pull the valve seal off the valve guide using pliers.
2. Remove the valve guide toward the side opposite the combustion chamber by using the **valve guide remover and installer.**



INSTALLING VALVE GUIDES

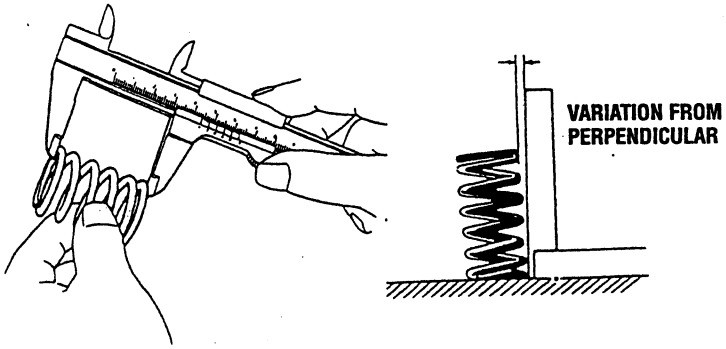
3. Fit the clip onto the valve guide. Use the **valve guide remover and installer** to tap the valve guide in from the side opposite the combustion chamber until the clip just contacts the cylinder head. The height of the valve guide must be **19.1—19.6mm (0.752—0.772in)** from the valve spring seat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

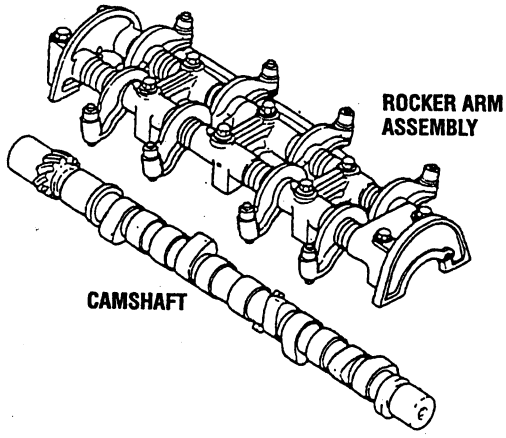
1. Inspect each valve spring for cracks or damage.
2. Check the free length and angle. Replace if necessary.



FREE LENGTH
EX: 52.2mm (2.0 in)
IN: 47.7mm (1.88in)
ANGLE
EX & IN: 1.8mm (0.07in) MAX

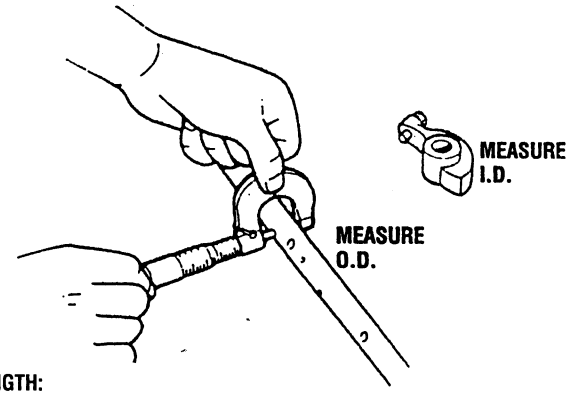
ROCKER ARM AND ROCKER ARM SHAFT

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)



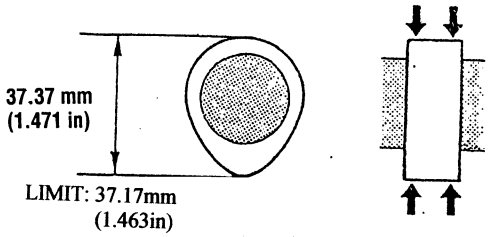
FREE LENGTH:
OUTER SPRING: 52 mm (2.055 in)
LIMIT: 50.6 mm (1.992 in)
INNER SPRING: 47.7 mm (1.878 in)
LIMIT: 46.3 mm (1.823 in)

OUT OF SQUARE
OUTER SPRING: MORE THAN 1.82 mm (0.072 in)
INNER SPRING: MORE THAN 1.66 mm (0.065 in)

CAMSHAFT
INSPECTION / REPAIR

CAMSHAFT

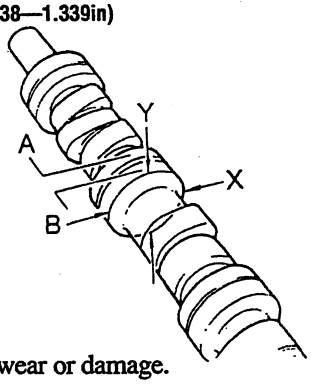
1. Check the cam for wear or damage. Replace if necessary.
2. Check the cam lobe height at the two points as shown.



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

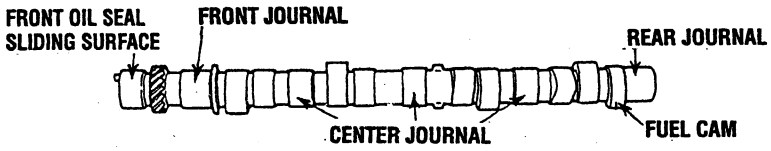
DIAMETER
FRONT AND REAR:
31.940—31.965mm (1.2575—1.2585in)
CENTER THREE JOURNALS:
31.910—31.935mm (1.2563—1.2573in)
FRONT OIL SEAL SLIDING SURFACE:
33.961—34.000mm (1.338—1.339in)

LIMIT: 0.03mm (0.0012in)



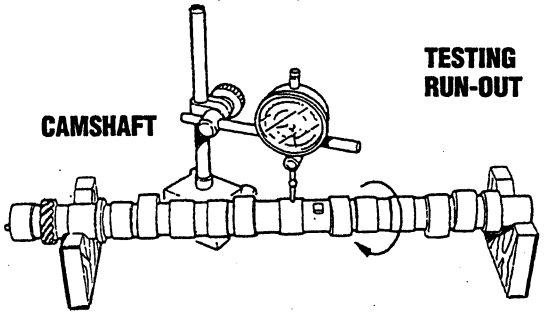
INSPECTING THE CAMSHAFT

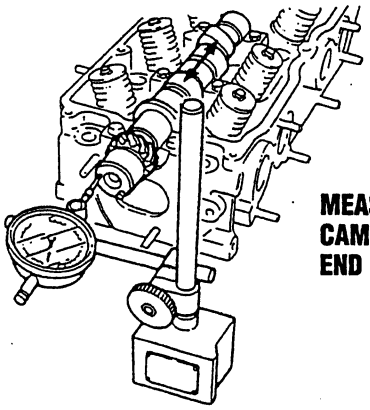
4. Inspect the fuel cam for wear or damage. Replace if necessary.



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)





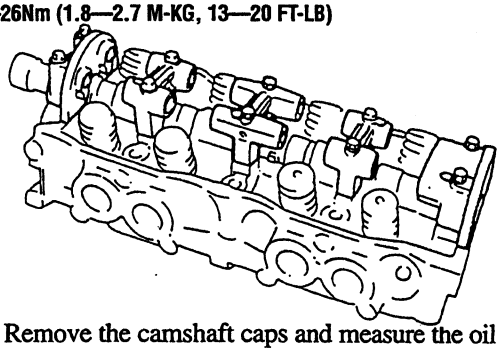
MEASURING CAMSHAFT END PLAY

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)

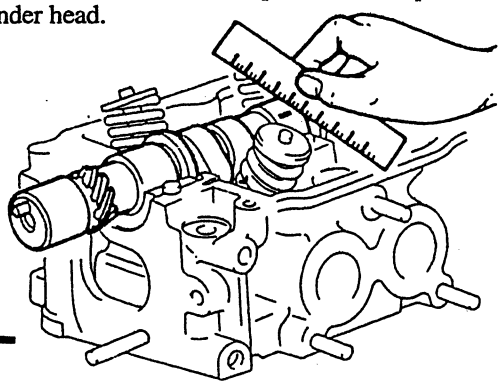


   (5) Remove the camshaft caps and measure the oil clearance at each cap.

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.

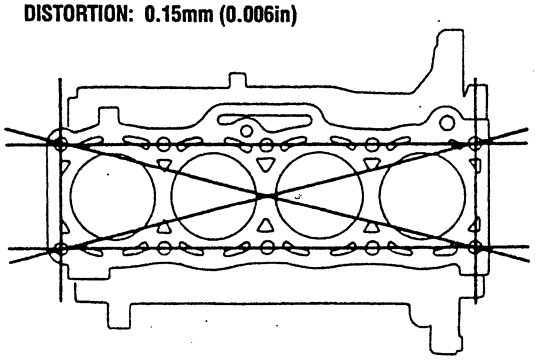
MEASURING WITH PLASTIGAUGE



CYLINDER BLOCK / PISTON
INSPECTION / REPAIR

DESCRIPTION

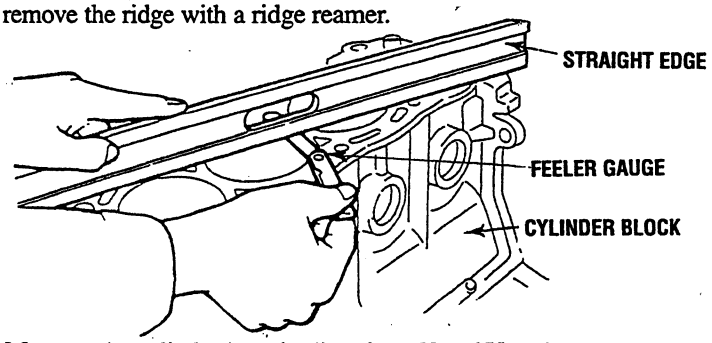
1. Inspect the entire cylinder block for cracks or damage, repair or replace if faulty.
   (1) **Leaking damage**
   (2) **Cracks**
   (3) **Scoring of wall**
2. Measure the distortion of the top surface of the cylinder block in the six directions as shown in the figure.
   DISTORTION: 0.15mm (0.006in)



CYLINDER BLOCK
CHECK FOR WARPAGE ON TOP FACE

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

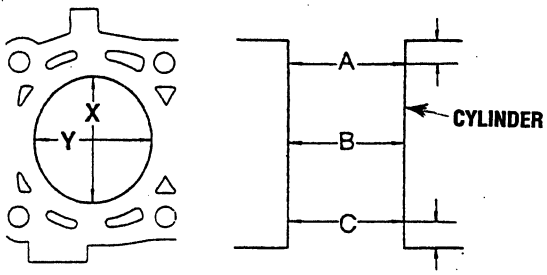
3. If the distortion exceed specification, repair by grinding, or replacing the cylinder block.
   GRINDING LIMIT: 0.20 mm (0.008in)
4. If the upper part of the cylinder wall shows uneven wear, remove the ridge with a ridge reamer.



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

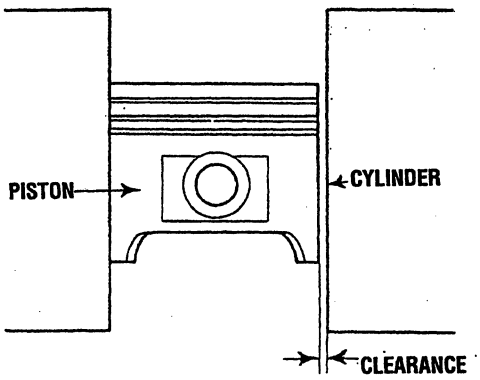
PISTON-PISTON RING
INSPECTION / REPAIR

PISTON

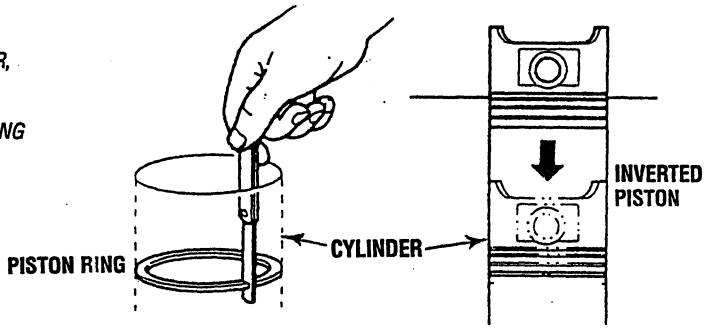
1. Inspect the outer circumferences of all pistons for seizure or scoring. Replace if necessary.
2. Measure the outer diameter of each piston at a right angle (90°) to the piston pin, **18 mm (0.709 in)** below the oil ring land lower edge.
   STANDARD VALUE: 85.944 - 85.964mm (3.3836 - 3.3844in)
   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.*

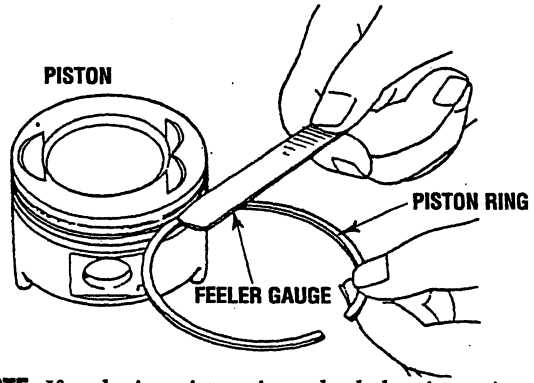


5. inspect the piston rings for damage, abnormal wear, or breakage. Replace if necessary.
6. Insert the piston ring into the cylinder by hand and push it to the bottom of the ring travel by using the piston.
7. Measure the ring end gap.
   END CAP TOP: 0.20 - 0.35 mm (0.008 - 0.014 in)
   SECOND: 0.15 - 0.30 mm (0.006 - 0.012 in)
   OIL RING: 0.20 - 0.70 mm (0.008 - 0.027 in)
   MAXIMUM: 1.0 mm (0.039 in)



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.*

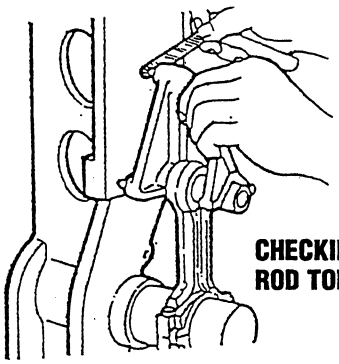
CONNECTING RODS
INSPECTION / REPAIR

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.

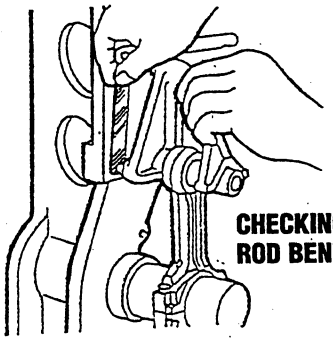
CONNECTING ROD BENDING LIMIT:
0.075 mm (0.003 in) FOR EVERY 50 mm (1.97 in)

CHECK FOR BEND OR TWIST.
CHECK BIG END THRUST CLEARANCE



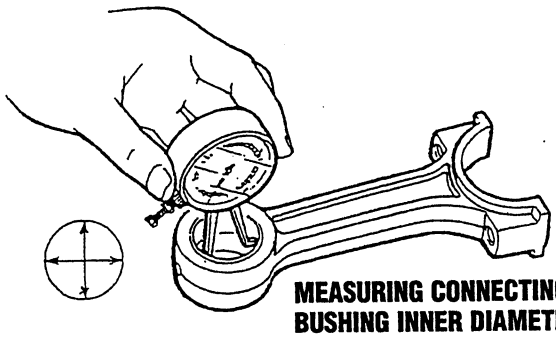
CHECKING CONNECTING ROD TORSION LIMIT

CONNECTING ROD DISTORTION LIMIT:
0.18 mm (0.007 in) FOR EVERY 50 mm (1.97 in)



CHECKING CONNECTING ROD BENDING LIMIT

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



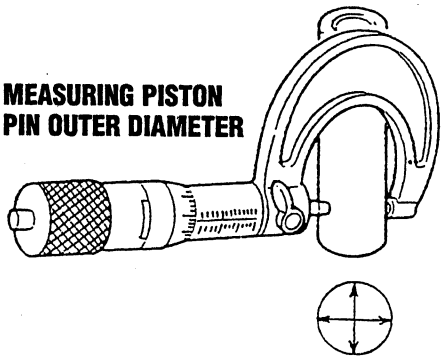
MEASURING CONNECTING ROD BUSHING INNER DIAMETER

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

CLEARANCE BETWEEN SMALL END BORE AND PISTON PIN:
-0.037 - -0.013 mm (-0.0014 - -0.0006 in)

   b. Measure the outer diameter of the piston pins

PISTON PIN BORE: 21.943 - 21.961 mm (0.88639 - 0.8646 in)



MEASURING PISTON PIN OUTER DIAMETER

CONNECTING ROD BENDING LIMIT:
0.075 mm (0.003 in) FOR EVERY 50 mm (1.97 in)

CONNECTING ROD DISTORTION LIMIT:
0.18 mm (0.007 in) FOR EVERY 50 mm (1.97 in)

PISTON PIN BORE:
21.943 - 21.961 mm (0.88639 - 0.8646 in)

CLEARANCE BETWEEN SMALL END BORE AND PISTON PIN:
-0.037 - -0.013 mm (-0.0014 - -0.0006 in)

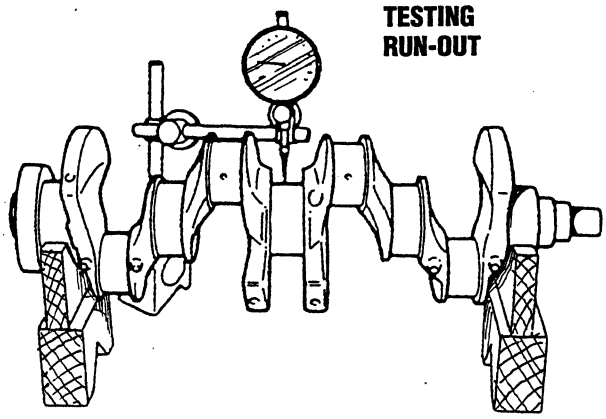
CLEARANCE ROD BEARING AND CRANK JOURNAL:
0.027 - 0.067 mm (0.0011 - 0.0026 in)
LIMIT:0.10 mm (0.004 in)

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.



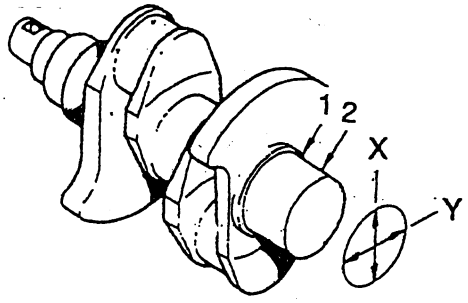
4. Measure each journal diameter in X and Y directions at two points.

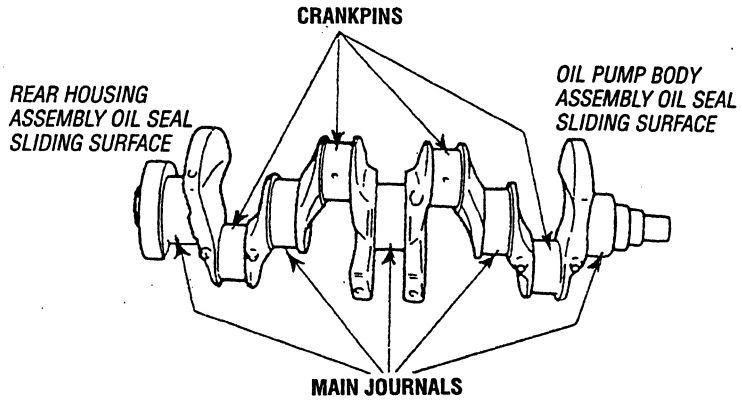
MAIN BEARING JOURNAL DIAMETER:

STANDARD: (No. 1, 2, 3, 4, 5) 59.937 - 59.955 mm (2.3598 - 2.3604 in)
LIMIT: 0.05 mm (0.002 in)
GRINDING LIMIT: 0.75 mm (0.030 in)
CLEARANCE OF JOURNAL TO BEARING:
(No. 1, 2, 4, 5) 0.025 - 0.043 mm (0.00099 - 0.00169 in)

CONNECTING ROD JOURNAL DIAMETER:

STANDARD: 50.940 - 50.955 mm (2.0055 - 2.0061 in)
LIMIT: 0.05 mm (0.002 in)
GRINDING LIMIT: 0.75 mm (0.030 in)
CLEARANCE OF JOURNAL TO BEARING:
0.027 - 0.067 mm (0.001 - 0.0026 in)





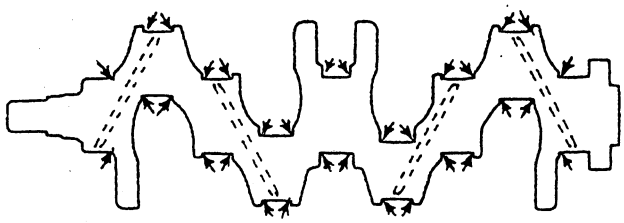
5. If the diameter is less than the minimum, grind the journals to match undersize bearings.

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

MAIN JOURNAL DIAMETER UNDERSIZE	MM (IN)
0.25 UNDERSIZE	59.679 - 59.736 mm (2.3496 - 2.3518 in) 59.673 - 59.730 mm (2.3494 - 2.3515 in)
0.50 UNDERSIZE	59.429 - 59.486 mm (2.3398 - 2.3419 in) 59.423 - 59.480 mm (2.3395 - 2.3417 in)
0.75 UNDERSIZE	59.179 - 59.236 mm (2.3299 - 2.3321 in) 59.173 - 59.230 mm (2.3297 - 2.3318 in)

CONNECTING ROD JOURNAL DIAMETER UNDERSIZE

0.25 UNDERSIZE	50.940 - 50.955 mm (1.9957 - 1.9962 in)
0.50 UNDERSIZE	50.440 - 50.455 mm (1.9859 - 1.9864 in)
0.75 UNDERSIZE	50.190 - 50.205 mm (1.9760 - 1.9765 in)



ALWAYS CHAMFER THE POINTS MARKED WHEN GRINDING THE JOURNALS AND PINS

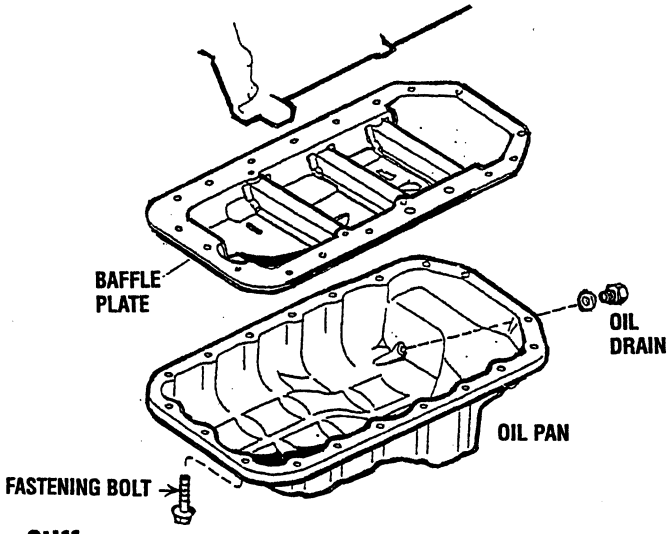
CRANKSHAFT OIL SEAL SURFACE DIAMETER
REAR: 89.946 - 90.000 mm (3.5412 - 3.5433 in)
FRONT: 33.961 - 34.000 mm (1.3371 - 1.3386 in)

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

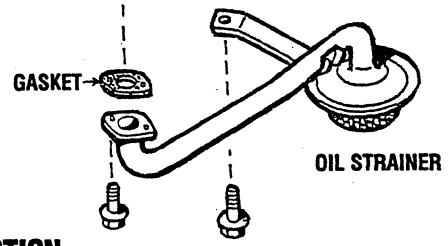
Insert a flat-tipped screwdriver between the oil pan and the baffle plate to separate.



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

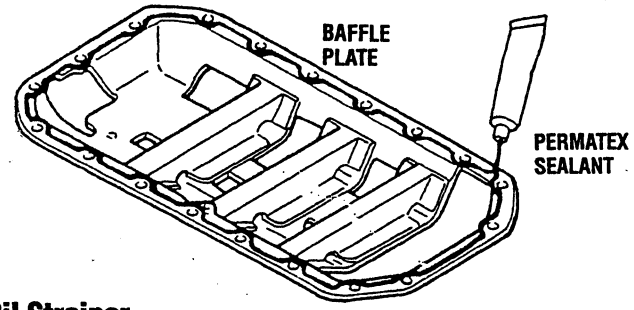
Check for the following problems. Repair or replace if necessary.

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.

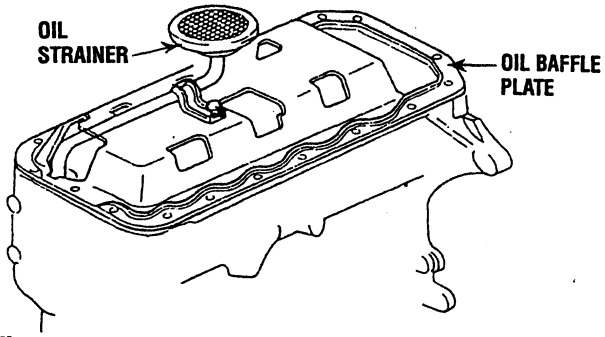
> ⚠ **CAUTION:** ***After the sealant has been applied, the stiffener must be secured within 30 minutes.***



Oil Strainer

Insert the oil strainer with a new gasket.

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

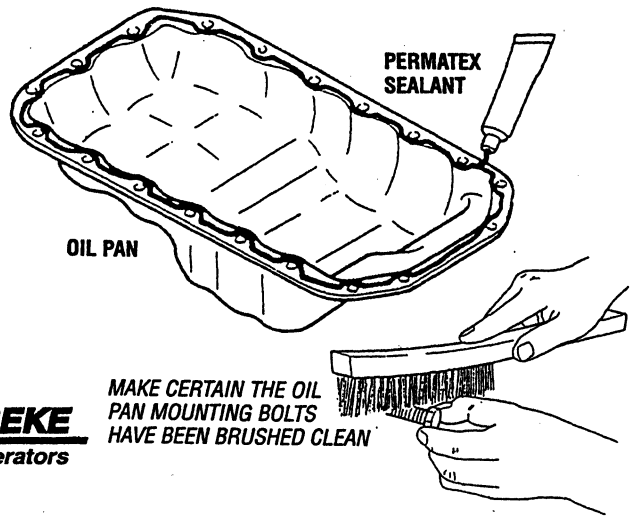


Oil Pan

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)

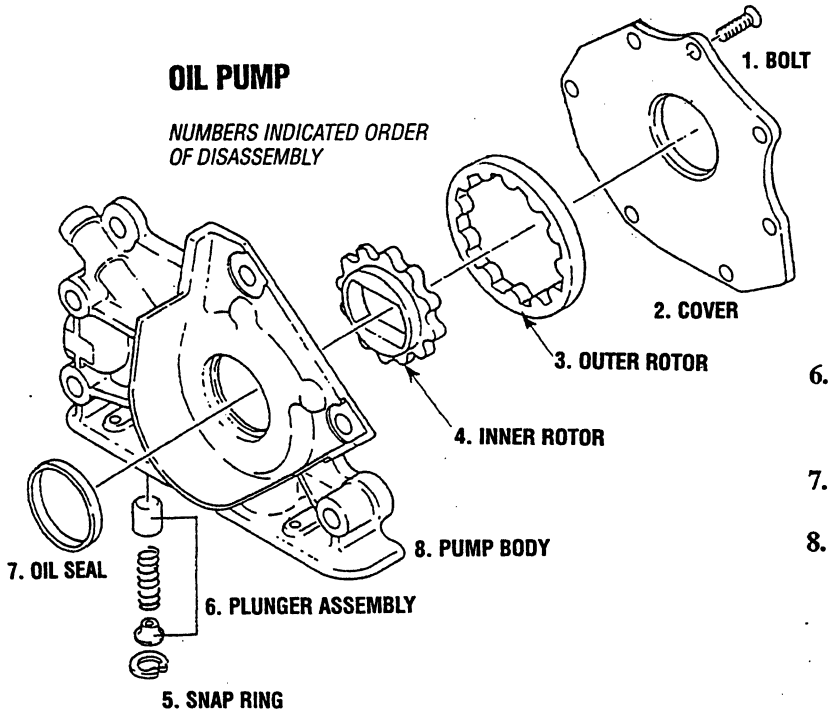
> ⚠ **CAUTION:** ***After the sealant has been applied, the pan must be secured within 30 minutes.***



LUBRICATION SYSTEM

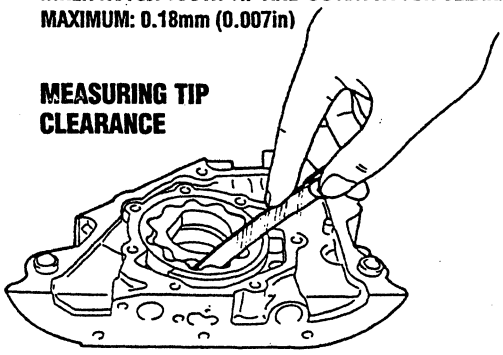
OIL PUMP

NUMBERS INDICATED ORDER OF DISASSEMBLY



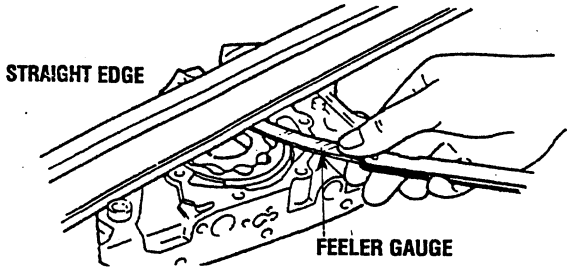
OIL PUMP INSPECTION

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)

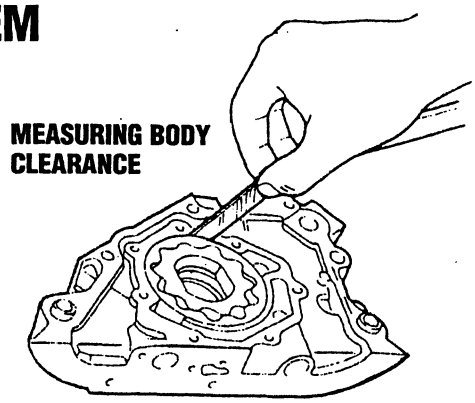


MEASURING TIP CLEARANCE

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



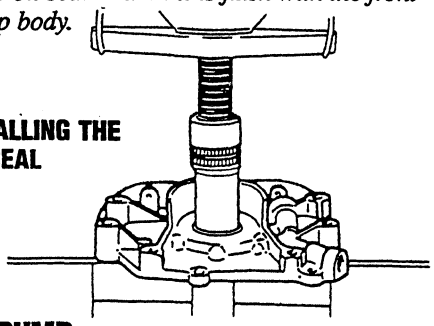
MEASURING SIDE CLEARANCE



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.*

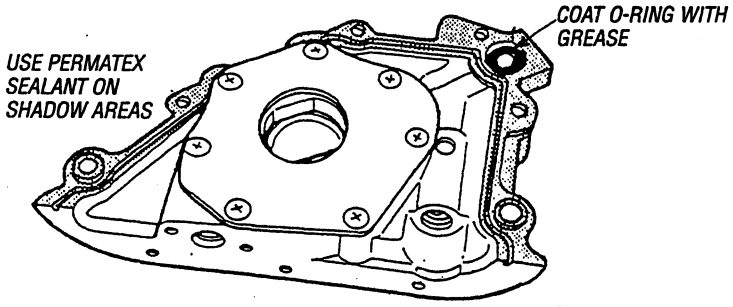


INSTALLING THE OIL SEAL

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.



ENGINE ASSEMBLY

Take the following precautions:

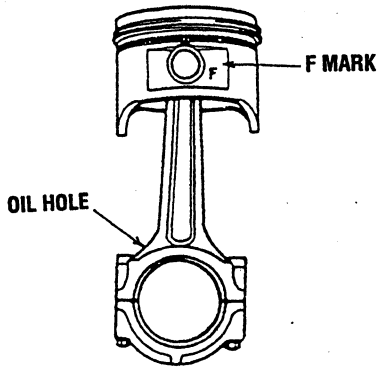
- Be careful not to mix bolts and nuts. Metric and S.A.E. bolts are used on various engine assemblies.
- During assembly, recheck clearances and insure that parts are being assembled in their proper order and facing in the correct direction in relation to the engine block, such as, pistons, piston rings, 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.

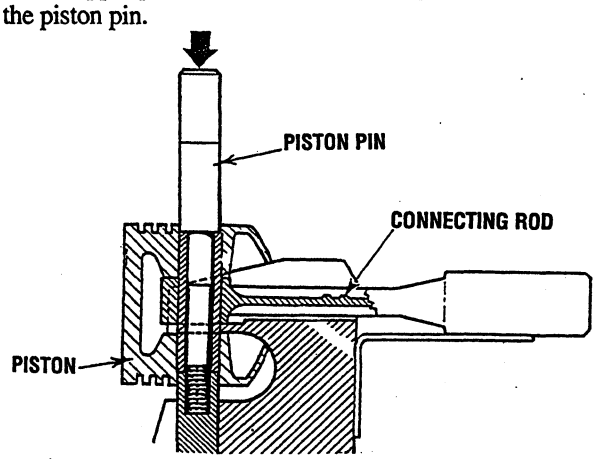
- **Insufficient Lubrication.** Heavily oil sliding and reciprocating parts, lightly oil head bolts and other fasteners, except those that penetrate into the water jacket. These fasteners should be sealed with Permatex No. 2 or the high-tack equivalent.
- **Reversed orientation.** Most gaskets, many 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.

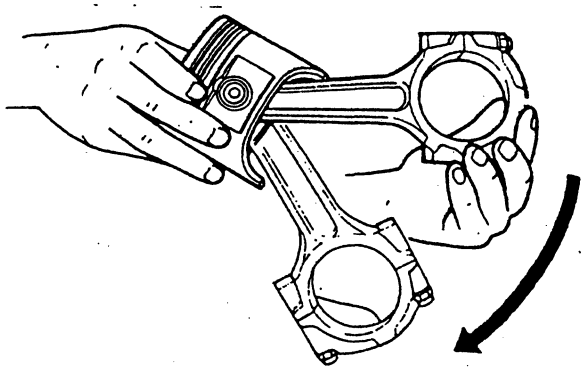


3. Set the piston pin setting tool in position as shown.
4. Press the upper part of the installer with a press to force in the piston pin.



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.



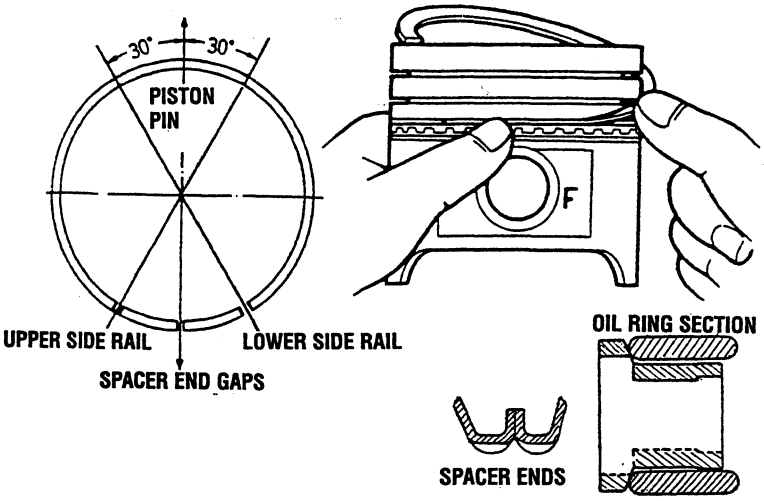
5. After pressing the piston pin in, swing the large end of the connecting rod upward and release it. The connecting rod must swing downward freely.

ENGINE ASSEMBLY

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

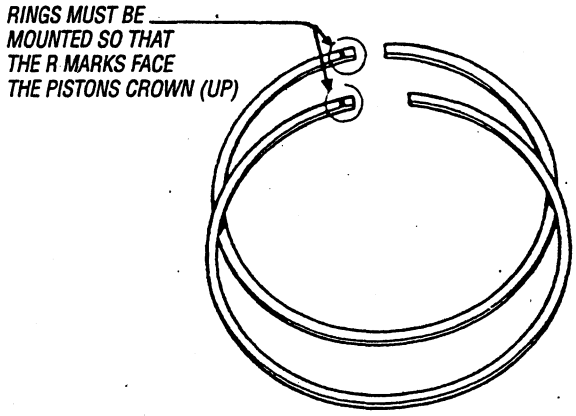
1. Apply a liberal coat of engine oil to the parts during installation.
2. Install the expander.
3. Install the upper rail.
   (a) Insert one edge between the groove and the spacer, applying a firm pressure with one thumb.
   (b) Then press the rail with the other thumb.
4. Install the lower rail in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

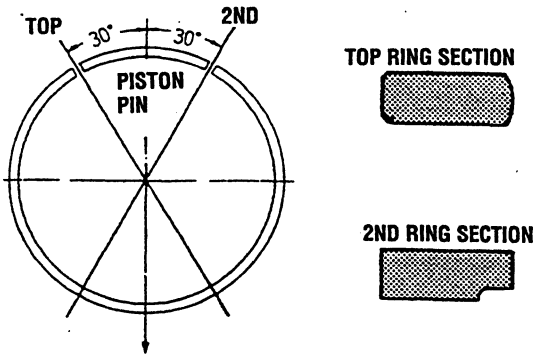
NOTE: *Be careful about the direction of the spacer opening, and after installation of the upper and lower rails, make certain they turn smoothly in both directions.*



Use this method to install the second and top rings.

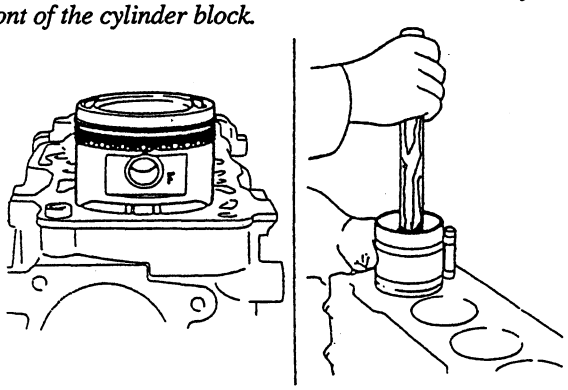
1. install the second ring to the piston first, then the top one, using a piston ring insertion tool (commercially available).
2. Apply a liberal coat of engine oil during installation.
3. Position the opening of each ring as shown.





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.

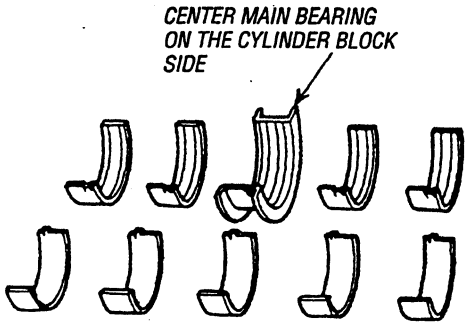
NOTE: *The pistons must be inserted so that the* ***F*** *marks face the front of the cylinder block.*



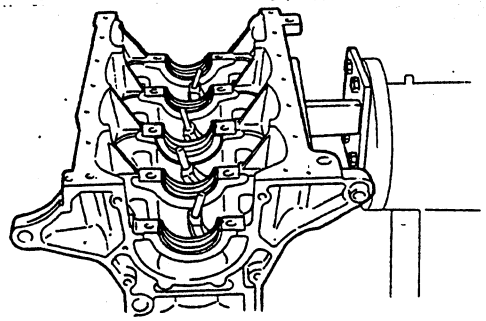
CRANKSHAFT ASSEMBLY

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.*

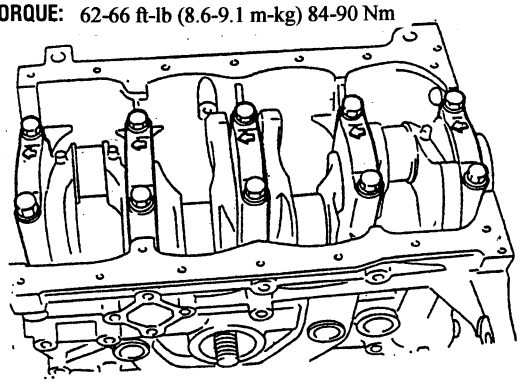


2. Remove any foreign material and oil from the journal and bearing.
3. Coat each bearing surface with clean engine oil. and install the bearings.
4. Gently set the crankshaft in position.



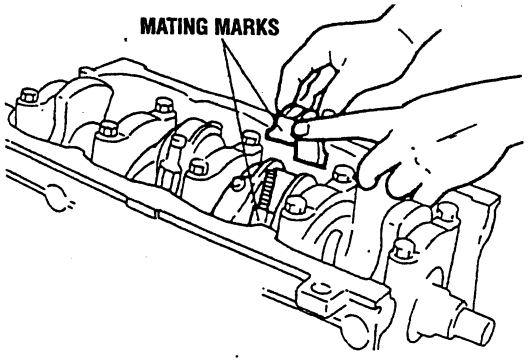
5. Install the main bearing caps in accordance with the numbers and arrows and tighten the bolts to the specified torque.

TORQUE: 62-66 ft-lb (8.6-9.1 m-kg) 84-90 Nm



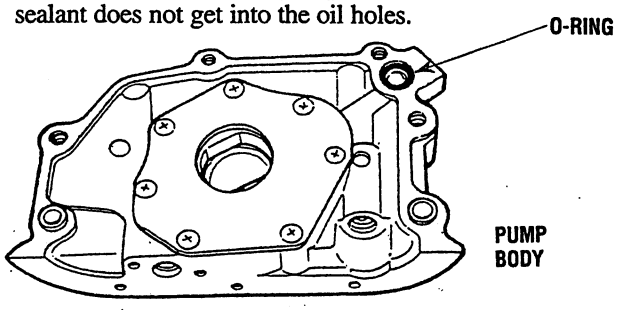
6. Align the connecting rod caps with the match mark.
7. Tighten the connecting rod cap nuts to the specified torque.

TORQUE: 49 - 52 ft-lb (6.7 - 7.2 m-Kg) 66 - 70 Nm



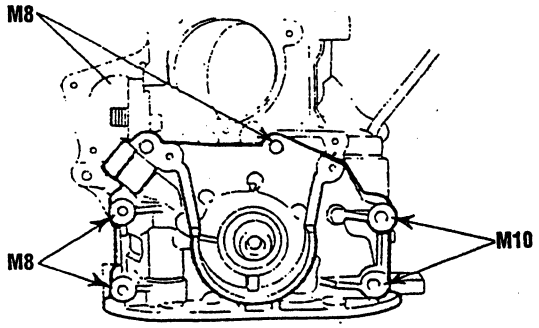
INSTALLING THE OIL PUMP

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.

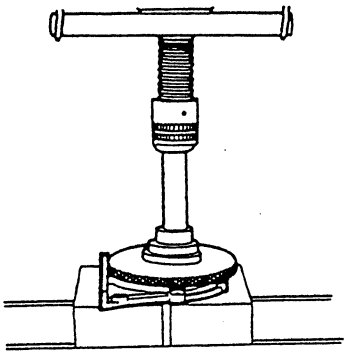
M-10 27-38ft-lb (3.8-5.3m-kg) 52Nm
M-8 14-19ft-lb (1.9-2.6m-kg) 25Nm



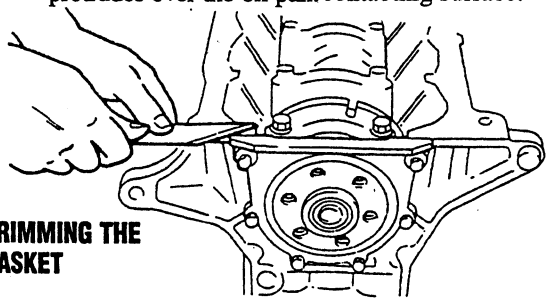
INSTALLING THE REAR COVER

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.*



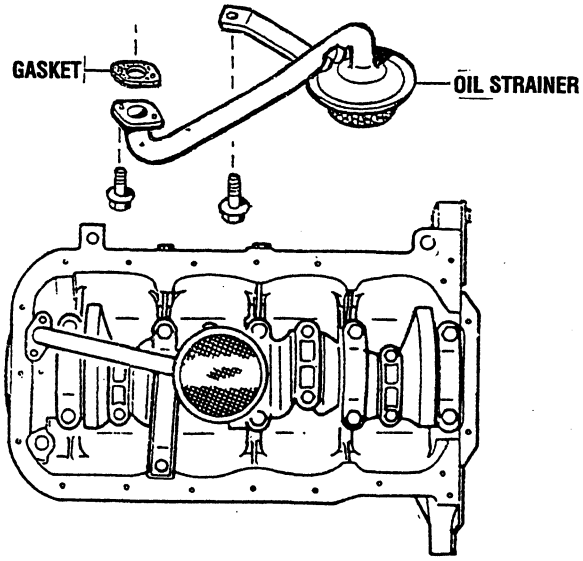
2. Insert the tubular dowel pin on the cylinder block, and install the rear cover
   TORQUE: 70 - 95 in-lbf (8 - 12 Nm)
3. Trim the rear cover gasket to the appropriate size if it protrudes over the oil pan. contacting surface.



TRIMMING THE GASKET

INSTALL THE OIL STRAINER

1. Bolt the oil strainer in place.
   TORQUE: 70 - 95 in-lbf (8 - 12 Nm)



INSTALL THE OIL PAN WITH THE BAFFLE PLATE

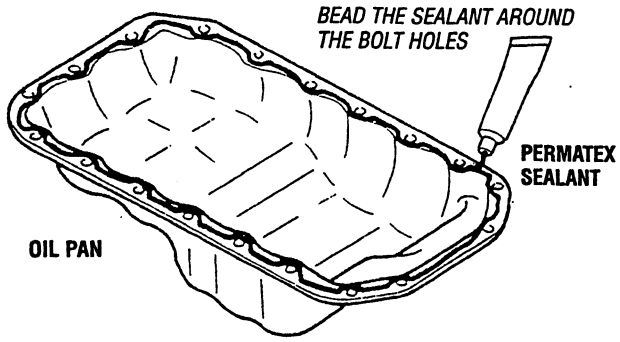
Installation Notes:

- 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.

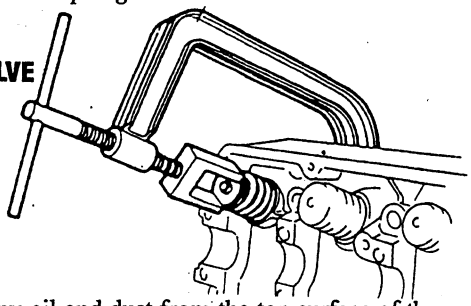
  TORQUE TO: 61-78in-lb (7.0-10.0cm-kg) 7-10Nm



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.*

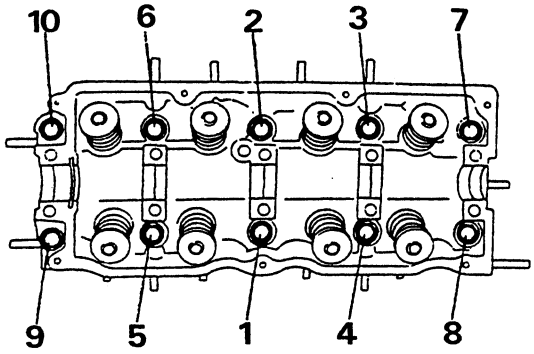


INSTALLING VALVE SPRINGS

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.

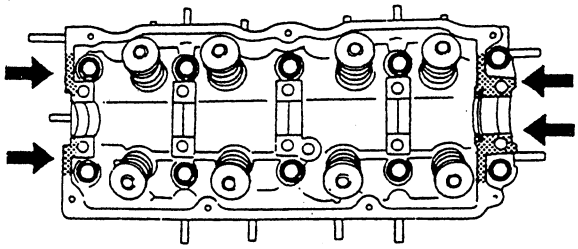
   CYLINDER HEAD BOLTS-COLD TORQUE:
   60 - 65 ft-lb (8.2 - 8.9 m-Kg) 81 - 88 Nm

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



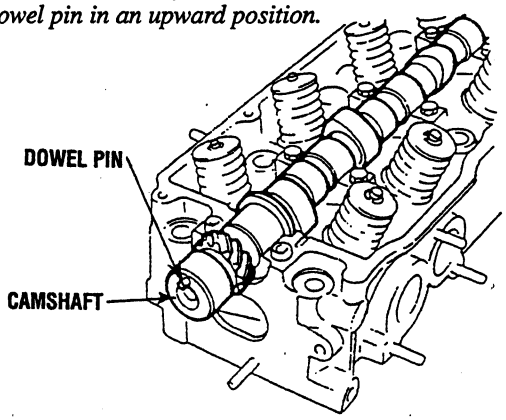
ENGINE ASSEMBLY

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.*

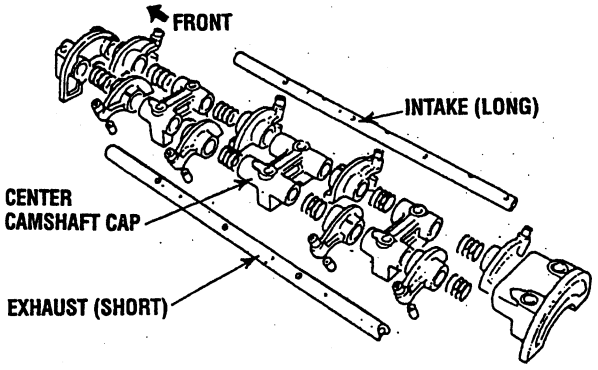


ASSEMBLE THE ROCKER SHAFT

Assemble the rocker arms and camshaft bearing caps as shown.

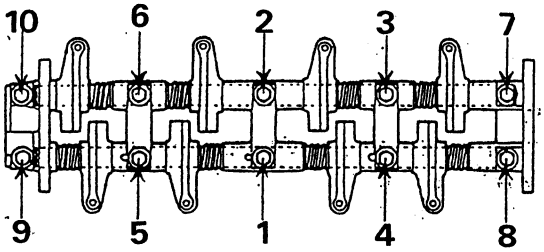
NOTE: *Be sure that the rocker arm shaft oil holes (in the center camshaft cap) face each other.*

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.

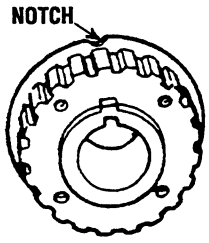
Install the rocker arm and rocker shaft assembly.

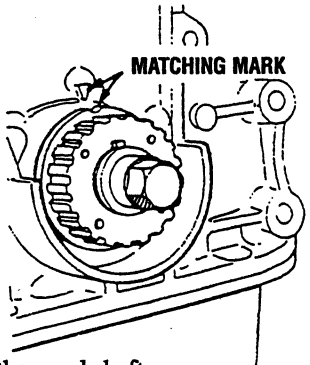
BOLT TORQUE: 13-20ft-lb (1.8-2.7m-kg) 18-26Nm

> **⚠ 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.





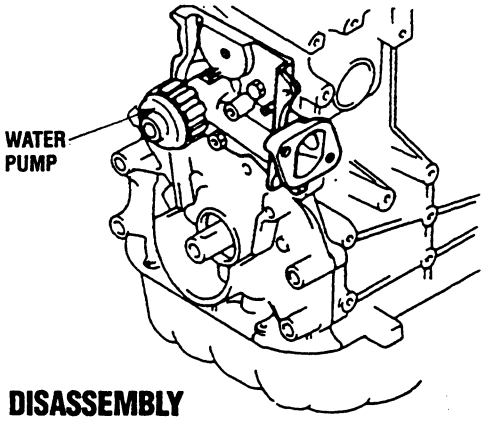
4. Install the dowel pin on the crankshaft.
5. Align the notch of the crankshaft timing belt pulley with the mark on the oil pump body.
6. Install the tapered ring and tighten the lock bolt.

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

COOLING TROUBLESHOOTING

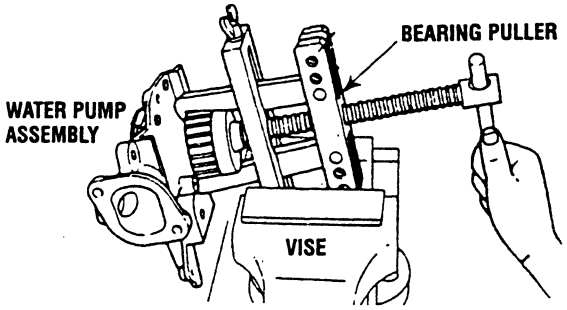
COOLANT LEAKAGE:	Failed Heat Exchanger Leakage from coolant hoses or heater hoses Leakage from water temperature switch Malfunction of water seal (water pump) Damaged or loose thermostat cover or gasket Loose cylinder head bolt Damaged cylinder head gasket Cracked cylinder block
CORROSION	Impurities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

ENGINE WATER COOLANT PUMP

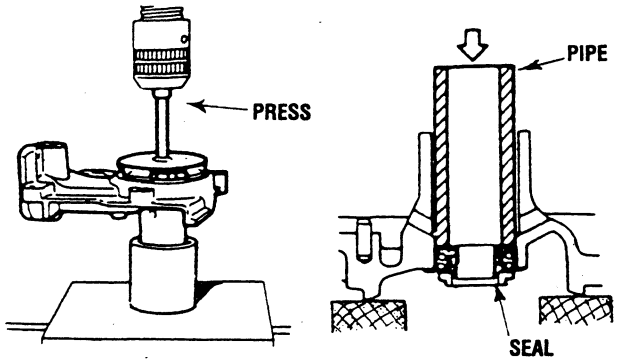


DISASSEMBLY

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.

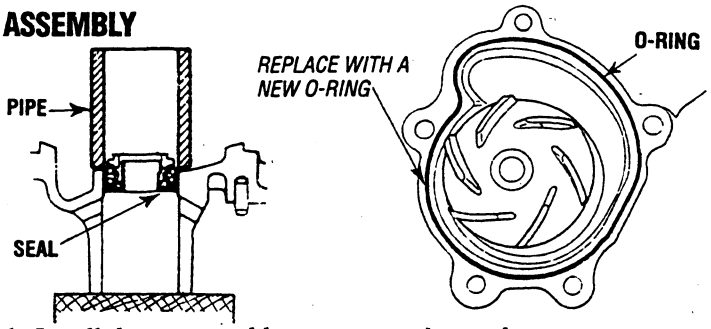


5. Use a pipe to remove the water seal.

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



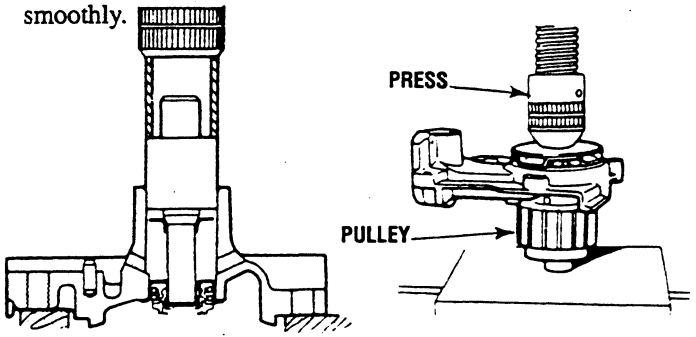
1. Install the water seal by tapping as shown above.

   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.

ENGINE ASSEMBLY

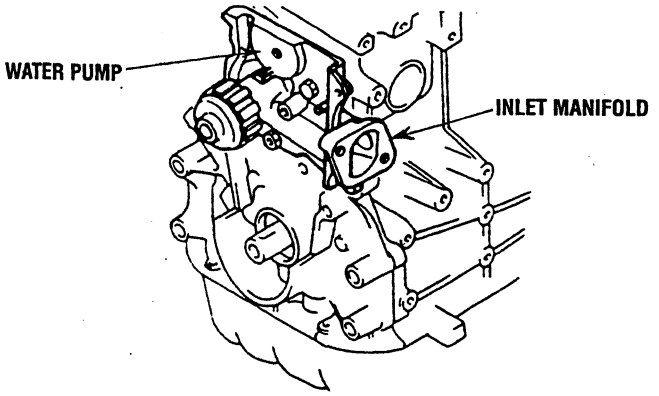
INSTALL THE WATER PUMP

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

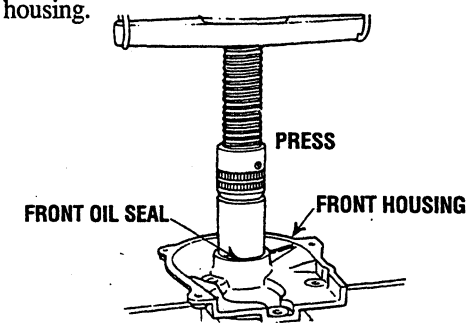
2. Install the inlet manifold.
3. Set the gasket in place and tighten the manifold nuts.

   TORQUE: 14-22ft-lb (1.9-3.1kg-cm) 14-31Nm



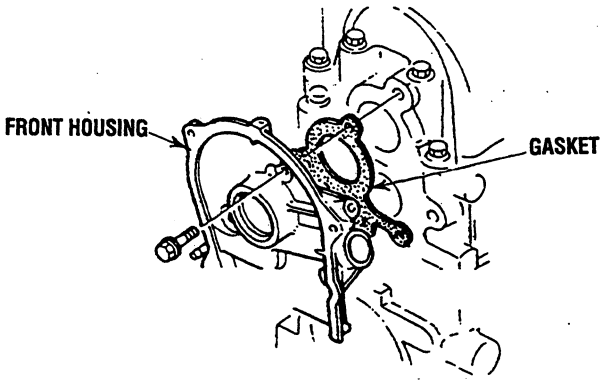
INSTALL THE FRONT HOUSING ASSEMBLY

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.

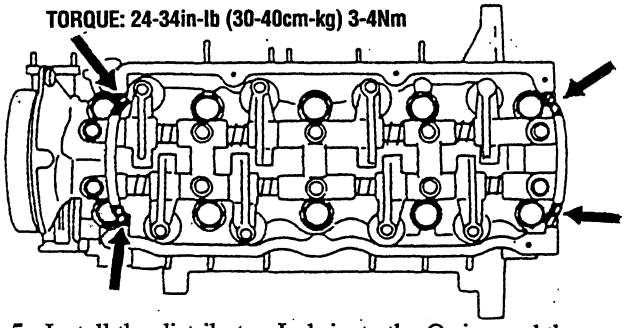
   TORQUE: 14-19ft-lb (1.9-2.6kg-cm) 19-25Nm



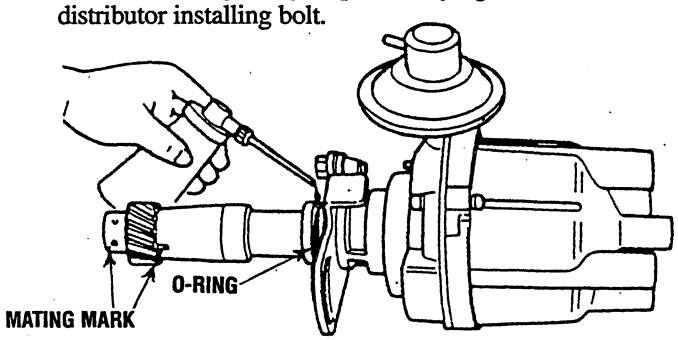
INSTALL THE REMAINING ENGINE COMPONENTS

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 - 17 lb-ft (1.9- 2.4m-Kg) 19 - 31 Nm
   SPARK PLUG GAP: 0.7 - 0.8mm (0.028 - 0.031in)

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: 14 - 18 ft-lb (1.9 - 2.4 m-Kg) 18.9 - 24.4 Nm

8. Install the alternator.

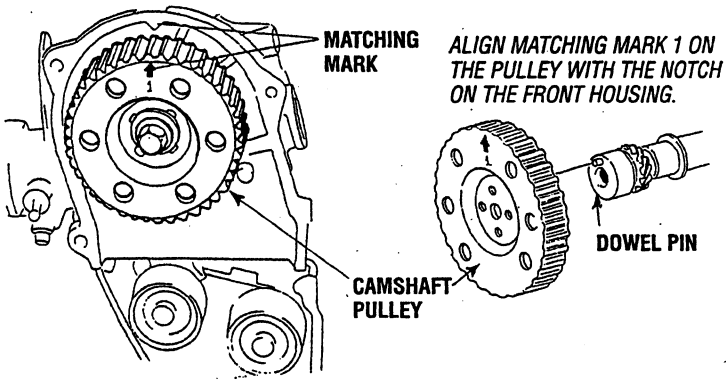
   FLANGE BOLT TORQUE: 14 - 18 ft-lb (1.9 - 2.4 m-Kg) 18.9 - 24.4 Nm

9. Mount the heat exchanger and install the coolant hoses.

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

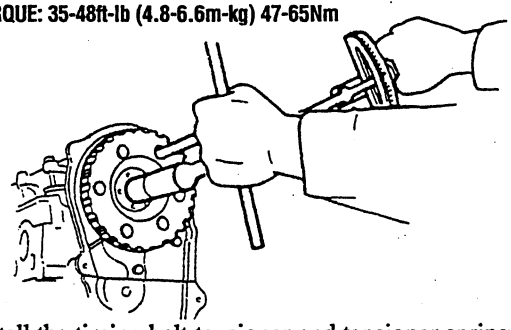
10. Install the starter motor.
11. Install the remaining hoses and carefully attach the wiring harness to the pre-marked terminals.

ENGINE ASSEMBLY



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

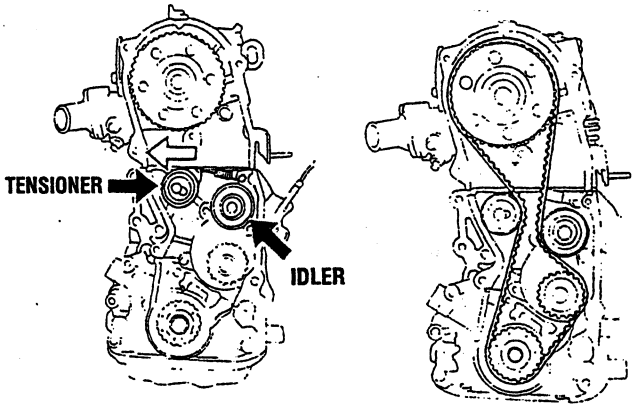
TORQUE: 35-48ft-lb (4.8-6.6m-kg) 47-65Nm



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

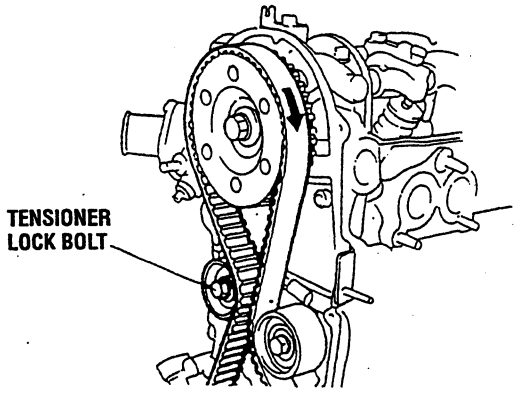
TORQUE: 27-38ft-lb (3.8-5.3m-kg) 37-52Nm

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



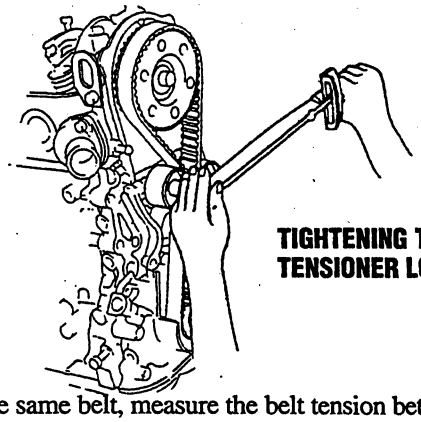
INSTALLING THE TIMING BELT

- *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.*



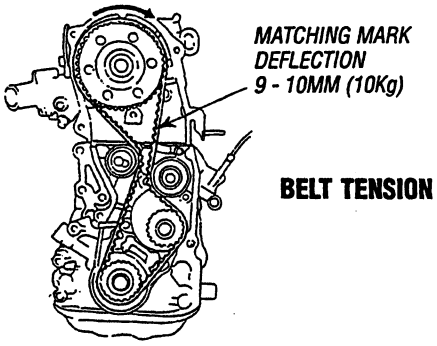
1. Loosen the timing belt tensioner lock bolt and apply spring tension to the belt.
2. Turn the crankshaft timing belt pulley two complete revolutions clockwise and then align the pulley at the **"TOP"** mark and tighten the tensioner lock bolt at the specified torque.

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

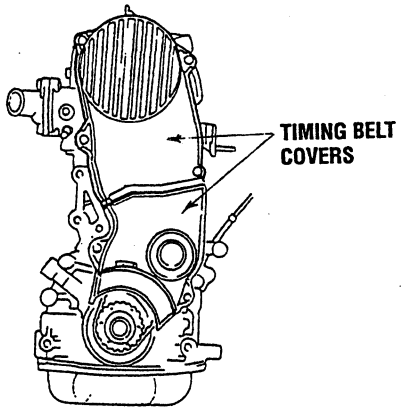
INSTALL THE TIMING BELT COVERS

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.

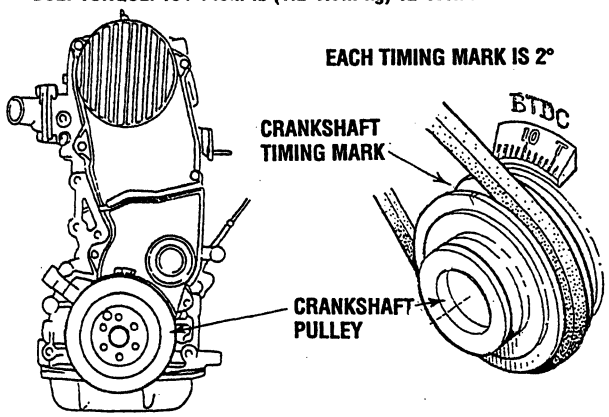
   TORQUE: 61-87in-lb (70-100cm-kg) 7-10Nm



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.

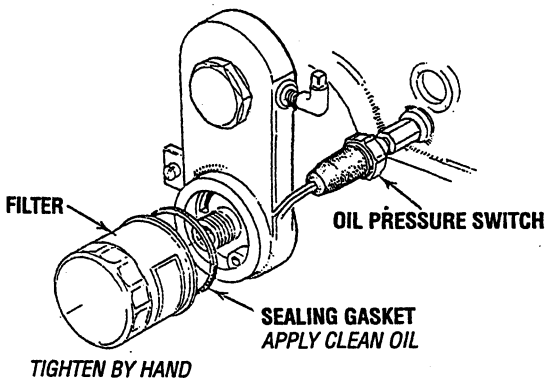
NOTE: *Make certain to use the plain washers to prevent the crankshaft from rotating.*

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

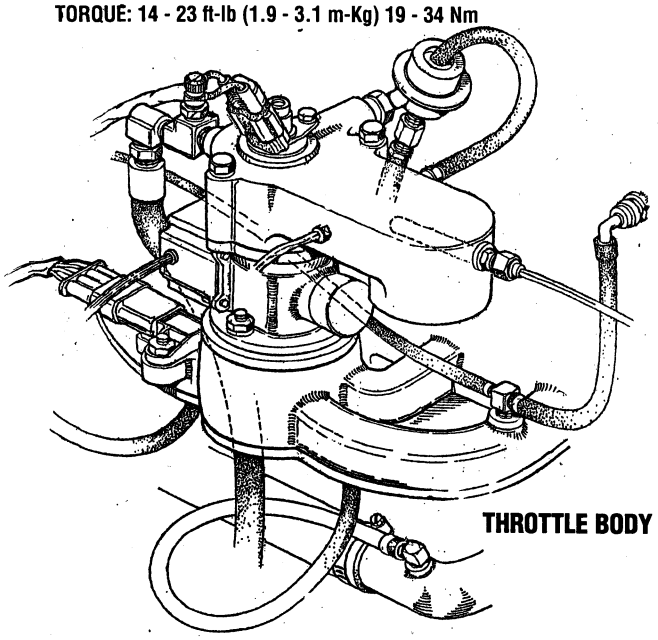


5. Install the oil cooler and oil filter.
6. Install the exhaust manifold, set the new gasket in place and tighten the exhaust manifold to the proper torque.

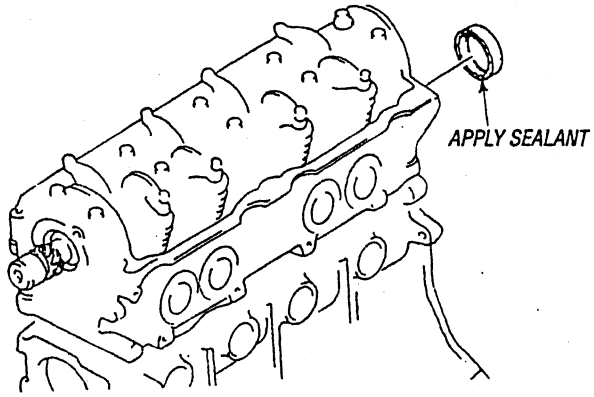
   TORQUE: 16-21ft-lb (2.2-2.9m-kg) 22-28Nm

7. Install the intake manifold and Throttle body.

   TORQUE: 14 - 23 ft-lb (1.9 - 3.1 m-Kg) 19 - 34 Nm



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.



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.

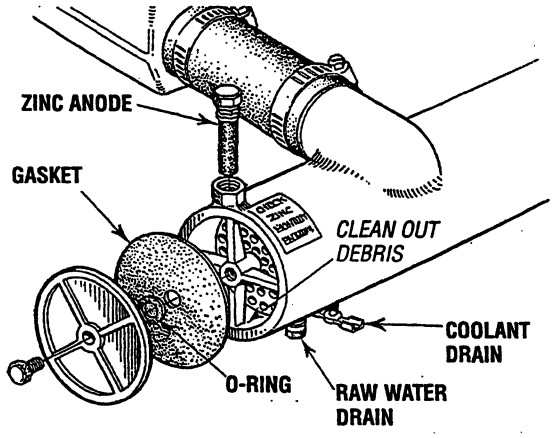
HEAT EXCHANGER

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.

SERVICE DATA - STANDARDS AND LIMITS

ENGINE DATA

Valve Clearance (Cold Engine)
(Intake) ..... 0.15• 0.05 mm
(0.006• 0.002 in.)

Valve Clearance (Cold Engine)
(Exhaust) ..... 0.35• 0.05 mm
(0.014• 0.002 in.)

Compression Pressure ..... 1128 kPa (164 psi) at 270 rpm

– Service Limit ..... 794 kPa (115 psi) at 270 rpm

– Maximum Difference
between Cylinders ..... 196 kPa (28 psi)

Firing Order ..... 1 - 3 - 4 - 2

Compression Ratio ..... 8.6 : 1

THERMOSTAT

Starts to Open ..... 82±1.5°C (180±3°F)

Fully Open ..... 95°C (203°F)

Fully Open Lift ..... 8.5 mm (0.33 in.) min.

CYLINDER HEAD

Height ..... 91.95 to 92.05 mm
(3.621 to 3.624 in.)

Distortion Limit ..... 0.15 mm (0.006 in.)

Grinding Limit ..... 0.20 mm (0.008 in.)

VALVE MECHANISM

Valve Guide
Inside Diameter ..... 8.07 to 8.09 mm
(0.3177 to 0.3185 in.)

Guide Clearance
(Exhaust) ..... 0.030 to 0.065 mm
(0.0012 to 0.0026 in.)

Guide Clearance
(Intake) ..... 0.025 to 0.060 mm
(0.0010 to 0.0024 in.)

– Service Limit
(Intake and Exhaust) ..... 0.10 mm (0.004 in.)

Valve Length
(Intake) ..... 111.49 to 112.29 mm
(4.390 to 4.420 in.)

– Service Limit ..... 111.19 mm (4.378 in.)

Valve Length
(Exhaust) ..... 111.29 to 112.09 mm
(4.382 to 4.412 in.)

– Service Limit ..... 110.99 mm (4.370 in.)

Valve Stem Diameter
(Intake) ..... 8.030 to 8.045 mm
(0.3161 to 0.3167 in.)

– Service Limit ..... 7.980 mm (0.3142 in.)

Valve Stem Diameter
(Exhaust) ..... 8.025 to 8.040 mm
(0.3159 to 0.3165 in.)

– Service Limit ..... 7.975 mm (0.3140 in.)

Valve Head Thickness
(Intake) ..... 0.5 mm (0.020 in.)

Valve Head Thickness
(Exhaust) ..... 1.0 mm (0.040 in.)

Valve Face Angle
(Intake and Exhaust) ..... 30°

Spring Free Length
– Outer ..... 52.2 mm (2.055 in.)
– Service Limit ..... 50.6 mm (1.992 in.)

Spring Free Length
– Inner ..... 47.7 mm (1.878 in.)
– Service Limit ..... 46.3 mm (1.823 in.)

Spring out of Square
– Outer ..... More than 1.82 mm (0.072 in.)
– Inner ..... More than 1.66 mm (0.065 in.)

Rocker Arm Shaft
Diameter ..... 15.966 to 15.984 mm
(0.6286 to 0.6293 in.)

Rocker Arm Bore
Diameter ..... 16.000 to 16.027 mm
(0.6299 to 0.6310 in.)

Clearance Between
Rocker Arm and
Shaft ..... 0.016 to 0.061 mm
(0.0006 to 0.0024 in.)

– Service Limit ..... 0.10 mm (0.004 in.)

(CONTINUED)

SERVICE DATA - STANDARDS AND LIMITS

CAMSHAFT

Runout ..... Less than 0.03 mm (0.0012 in.)

Cam Lobes Height ..... 37.370 mm (1.4713 in.)

Cam Lobes to Service Limit ..... 37.170 mm (1.4634 in.)

Bearing Journals
(No. 1 and 5) ..... 31.940 to 31.965 mm (1.2575 to 1.2585 in.)

Bearing Journals
(No. 2, 3 and 4) ..... 31.910 to 31.935 mm (1.2563 to 1.2573 in.)

Bearing Journal Wear Limit ..... 0.03 mm (0.0012 in.)

Clearance Between Journals and Bore
(No. 1 and 5) ..... 0.035 to 0.085 mm (0.0014 to 0.0033 in.)

Clearance Between Journals and Bore
(No. 2, 3 and 4) ..... 0.065 to 0.115 mm (0.0026 to 0.0045 in.)

– Service Limit ..... 0.15 mm (0.006 in.)

End Clearance ..... 0.08 to 0.16 mm (0.003 to 0.006 in.)

– Service Limit ..... 0.20 mm (0.008 in.)

CRANKSHAFT

Runout ..... Less than 0.03 mm (0.0012 in.)

Main Bearing Journal Diameter
– Standard
(No. 1, 2, 4 and 5) ..... 59.937 to 59.955 mm (2.3598 to 2.3604 in.)
(No. 3) ..... 59.937 to 59.955 mm (2.3598 to 2.3604 in.)
– 0.25 mm (0.01 in.) Undersize
(No. 1, 2, 4 and 5) ..... 59.679 to 59.736 mm (2.3496 to 2.3518 in.)
(No. 3) ..... 59.673 to 59.730 mm (2.3494 to 2.3515 in.)

– 0.50 mm (0.02 in.) Undersize
(No. 1, 2, 4 and 5) ..... 59.429 to 59.486 mm (2.3398 to 2.3419 in.)
(No. 3) ..... 59.423 to 59.480 mm (2.3395 to 2.3417 in.)

– 0.75 mm (0.03 in.) Undersize
(No. 1, 2, 4 and 5) ..... 59.179 to 59.236 mm (2.3299 to 2.3321 in.)
(No. 3) ..... 59.173 to 59.230 mm (2.3297 to 2.3318 in.)

– Service Limit ..... 0.05 mm (0.002 in.)

– Grinding Limit ..... 0.75 mm (0.03 in.)

Clearance Between Journals and Main Bearings
(No. 1, 2, 4 and 5) ..... 0.025 to 0.043 mm (0.00099 to 0.00169 in.)
(No. 3) ..... 0.031 to 0.049 mm (0.00123 to 0.00192 in.)

– Service Limit ..... 0.08 mm (0.003 in.)

Connecting Rod Journal Diameter
– Standard ..... 50.940 to 50.955 mm (2.0055 to 2.0061 in.)
– 0.25 mm (0.01 in.) Undersize ..... 50.690 to 50.705 mm (1.9957 to 1.9962 in.)
– 0.50 mm (0.02 in.) Undersize ..... 50.440 to 50.455 mm (1.9859 to 1.9864 in.)
– 0.75 mm (0.03 in.) Undersize ..... 50.190 to 50.205 mm (1.9760 to 1.9765 in.)

– Service Limit ..... 0.05 mm (0.002 in.)

– Grinding Limit ..... 0.75 mm (0.03 in.)

Thrust Bearing Clearance ..... 0.08 to 0.18 mm (0.003 to 0.007 in.)

– Service Limit ..... 0.30 mm (0.012 in.)

Thrust Bearing Thickness
– Standard ..... 27.94 to 27.99 mm (1.1000 to 1.1019 in.)

– 0.25 mm (0.01 in.) Undersize ..... 28.04 to 28.09 mm (1.1040 to 1.1060 in.)
– 0.50 mm (0.02 in.) Undersize ..... 28.12 to 28.17 mm (1.1071 to 1.1090 in.)
– 0.75 mm (0.03 in.) Undersize ..... 28.20 to 28.25 mm (1.1103 to 1.1122 in.)

(CONTINUED)

SERVICE DATA - STANDARDS AND LIMITS

PISTONS

Diameter
Standard ..... 85.943 to 85.965 mm (3.3836 to 3.3844 in.)
0.25 mm (0.01 in.)
Oversize ..... 86.193 to 86.215 mm (3.3934 to 3.3943 in.)
0.50 mm (0.02 in.)
Oversize ..... 86.443 to 86.465 mm (3.4033 to 3.4041 in.)

Clearance Between
Piston and Bore ..... 0.035 to 0.076 mm (0.0014 to 0.0030 in.)

– Service Limit ..... 0.15 mm (0.0059 in.)

Piston Pin Diameter ..... 21.988 to 21.998 mm (0.8657 to 0.8660 in.)

Piston Rings Groove Width :
Top and Second ..... 1.520 to 1.540 mm (0.0598 to 0.0606 in.)

Groove Width :
Oil Ring ..... 4.020 to 4.040 mm (0.1583 to 0.1591 in.)

Piston Ring Groove Clearance
(Top and Second Ring) ..... 0.03 to 0.07 mm (0.0012 to 0.0028 in.)

– Service Limit ..... 0.15 mm (0.0059 in.)

Piston Ring End Clearance:
– Top Ring ..... 0.20 to 0.35 mm (0.008 to 0.014 in.)
– Second Ring ..... 0.15 to 0.30 mm (0.006 to 0.012 in.)
– Oil Control Ring ..... 0.20 to 0.70 mm (0.008 to 0.027 in.)

– Service Limit
(All Rings) ..... 1.0 mm (0.039 in.)

CYLINDER BLOCK

Top Surface Distortion ..... 0.15 mm (0.0059 in.)

Grinding Limit ..... 0.20 mm (0.008 in.)

Bore Diameter ..... 86.000 to 86.019 mm (3.3858 to 3.3866 in.)

– Wear Limit ..... 0.15 mm (0.0059 in.)

CONNECTING RODS

Distortion Limit ..... 0.18 mm (0.007 in.)/50 mm (1.97 in.)

Bending Limit ..... 0.075 mm (0.003 in.)/50 mm (1.97 in.)

Small End Bore ..... 21.943 to 21.961 mm (0.8639 to 0.8646 in.)

Clearance Between
Piston Pin and
Bore ..... -0.037 to -0.013 mm (-0.0014 to -0.0006 in.)

Clearance Between
Crankshaft Journals
and Rod Bearings ..... 0.027 to 0.067 mm (0.0011 to 0.0026 in.)

– Service Limit ..... 0.10 mm (0.004 in.)

OIL PUMP

Clearance Between
Inner Rotor Tip and Outer Rotor
– Service Limit ..... 0.18 mm (0.007 in.)

Clearance Between
Housing and Outer Rotor ..... 0.090 to 0.176 mm (0.0036 to 0.0069 in.)

– Service Limit ..... 0.20 mm (0.008 in.)

Side Clearance Between
Rotors and Housing ..... 0.03 to 0.09 mm (0.0012 to 0.0035 in.)

– Service Limit ..... 0.10 mm (0.004 in.)

TORQUE SPECIFICATIONS

Air Cleaner Bracket
12.7 - 17.4 ft-lb (16.3 - 23.0 Nm)

Alternator Bracket
25.5 - 35.6 ft-lb (34.6 - 48.2 Nm)

Alternator Flange Bolt
12.7 - 20.8 ft-lb (16.3 - 23.0 Nm)

Alternator Strap
12.7 - 17.4 ft-lb (16.3 - 23.0 Nm)

Camshaft Pulley Lock Bolt
35 - 49 ft-lb (48 - 66 Nm)

Camshaft Cap
13 - 20 ft-lb (18 - 27 Nm)

Coolant Pump Pulley
12 - 17 ft-lb (16.3 - 23.0 Nm)

Coolant Temperature Sendor
9 - 13 ft-lb (12.2 - 17.6 Nm)

Connecting Rod Cap
49 - 52 ft-lb (66 - 70 Nm)

Crankshaft Pulley
9 - 13 ft-lb (12 - 17 Nm)

Cylinder Head
60 - 65 ft-lb (81 - 88 Nm)

Drive Plate
16.1 - 18.1 ft-lb (21.8 -24.5 Nm)

Exhaust Manifold
16 - 21 ft-lb (22 - 29 Nm)

Flywheel Bolt
98 - 105 ft-lb (133.0 - 142.4 Nm)

Front Housing
14 - 19 ft-lb (19 - 26 Nm)

Intake Manifold
12 - 17 ft-lb (16.3 - 23.0 Nm)

Main Bearing Cap
62 - 66 ft-lb (84 - 90 Nm)

Oil Drain Plug (Oil Pan)
22 - 30 ft-lb (30 - 41 Nm)

Oil Pan
70 - 106 in-lb (22 - 29 Nm)

Oil Pressure Sender
9 - 13 ft-lb (12.2 - 17.6 Nm)

Oil Strainer
M6: 5.3 - 8.0 ft-lb (7.18 - 10.8 Nm)
M8: 10.7 - 15.4 ft-lb (16.7 - 20.8 Nm)

Oil Pressure Switch
9 - 13 ft-lb (12 - 17 Nm)

Oil Pump
M8 Capscrews: 14 - 19 ft-lb (19 - 26 Nm)
M10 Capscrews: 28 - 39 ft-lb (38 - 53 Nm)

Rear Cover
70 - 95 in-lb (8 - 12 Nm)

Rocker Cover
52 - 70 in-lb (6 - 8 Nm)

Rocker Shaft Assembly
13 - 20 ft-lb (18 - 27 Nm)

Spark Plugs
11 - 16 ft-lb (15 - 22 Nm)

Thermostat Cover
14 - 19 ft-lb (19 - 26 Nm)

Throttle Body
8 - 11.4 ft-lb (10.8 - 15.4 Nm)

Timing Belt Cover
62 - 89 in-lb (7 - 10 Nm)

Timing Belt Crank Pulley Bolt
120.9 - 134.4 ft-lb (164.0 - 182.3 Nm)

Timing Belt Tension Lock Bolt
28 - 39 ft-lb (38 - 53 Nm)

Timing Pulley Lock Bolt
116 - 123 ft-lb (157 - 167 Nm)

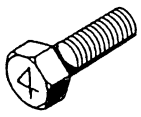
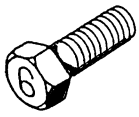
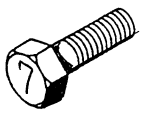
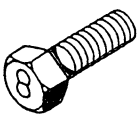
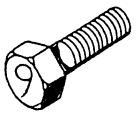
Water Pump
14 - 19 ft-lb (19 - 26 Nm)

Water Temperature Switch
105 - 156 in-lb (11.8 - 17.6 Nm)

STANDARD BOLTS / TIGHTENING TORQUE SPECIFICATIONS

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

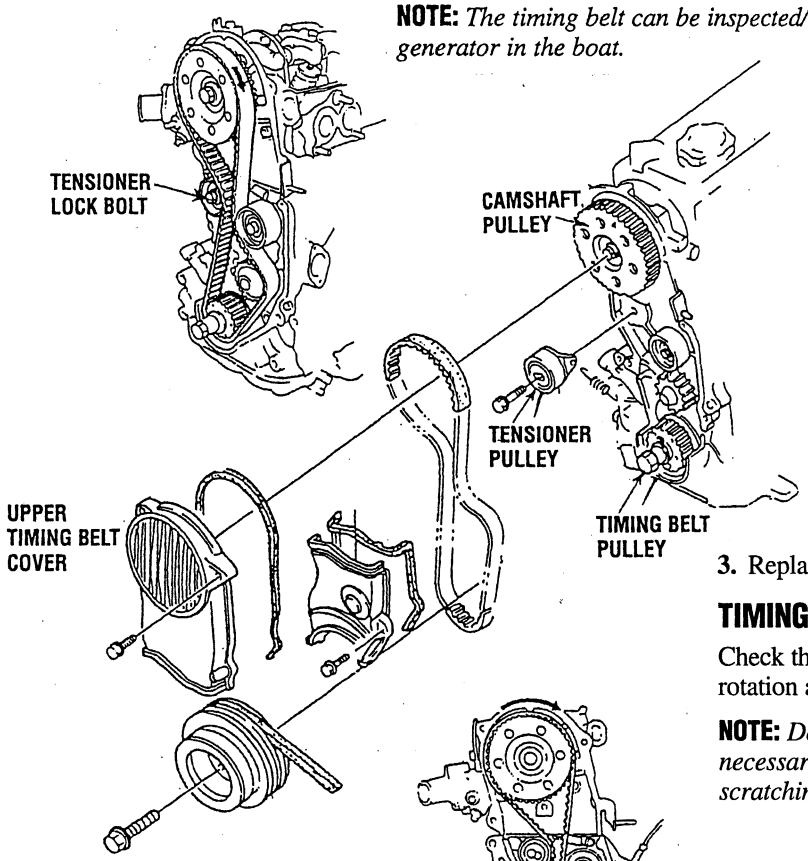
kg-m

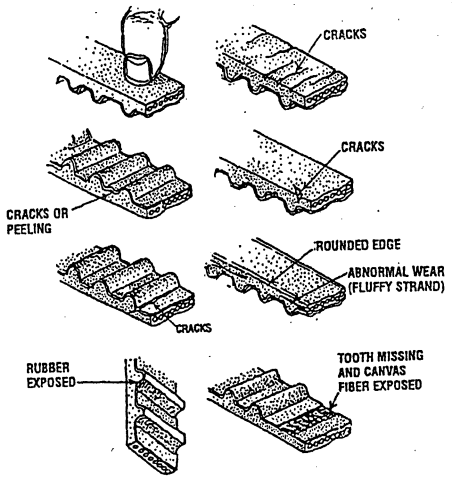
Bolt identification / Bolt diameter × pitch (mm)					
M 6 × 1.0	0.6 ±0.2	0.7 $^{+0.2}_{-0.3}$	0.8 $^{+0.2}_{-0.3}$	0.9 $^{+0.2}_{-0.3}$	———
M 8 × 1.25	1.3 ±0.5	1.6 $^{+0.4}_{-0.6}$	1.8 $^{+0.5}_{-0.6}$	2.1 $^{+0.5}_{-0.7}$	2.4 ±0.7
M10 × 1.25	2.8 ±0.7	3.3 $^{+0.8}_{-0.9}$	3.8 $^{+0.9}_{-1.0}$	4.3 ±0.9	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.*

TIMING BELT
DISASSEMBLY/INSPECTION

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



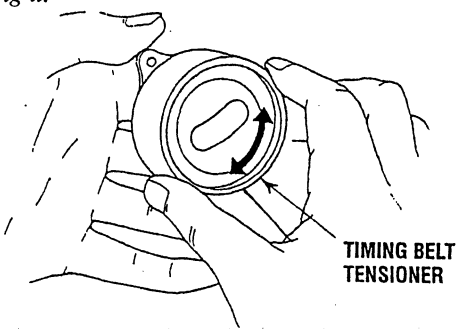


3. Replace the belt if any of the above conditions exist.

TIMING BELT TENSIONER AND IDLER PULLEY

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

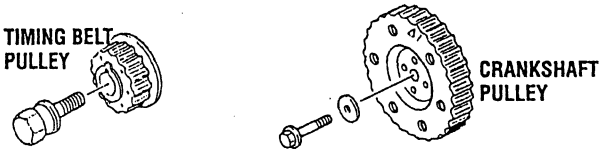
NOTE: *Do not clean the tensioner with cleaning fluids. If necessary, use a soft rag to wipe it clean, and avoid scratching it.*



TIMING BELT PULLEY AND CAMSHAFT PULLEY

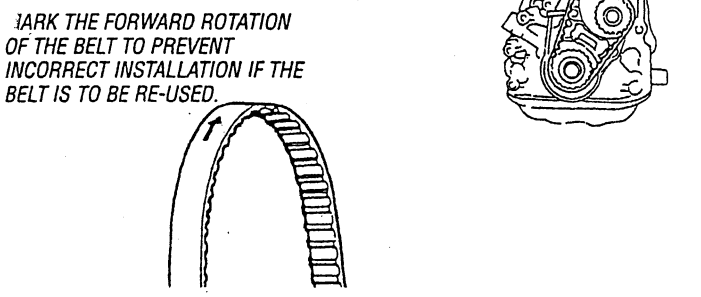
Inspect the pulley teeth for wear, deformation, or other damage. Replace if necessary.

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.



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.*

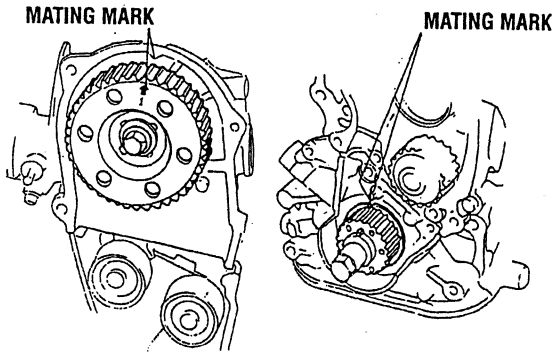
TIMING BELT INSPECTION

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.

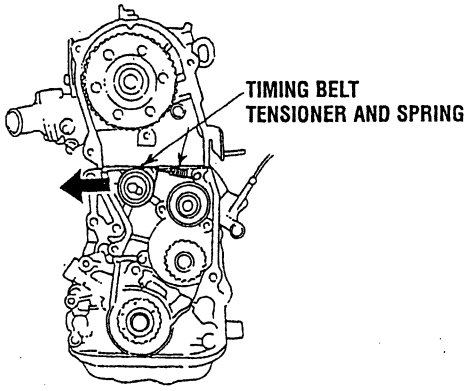
TIMING BELT

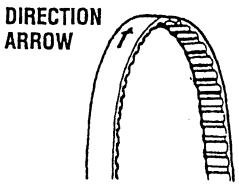
INSTALLATION

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.

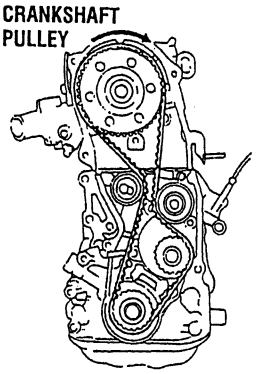


3. Install the timing belt tensioner and spring.
4. Position the timing belt tensioner all the way to the intake side, and temporarily secure it by tightening the lock bolt.

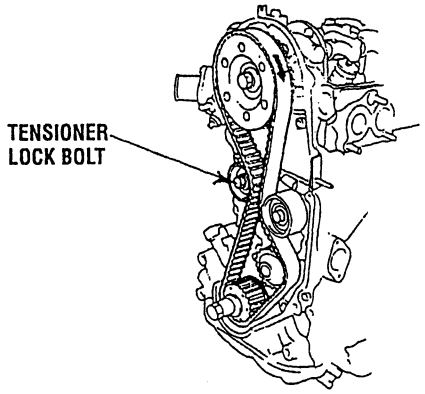




IF RE-USING THE TIMING BELT, INSTALL IT IN THE DIRECTION OF THE APPLIED ARROW - FORWARD ROTATION.

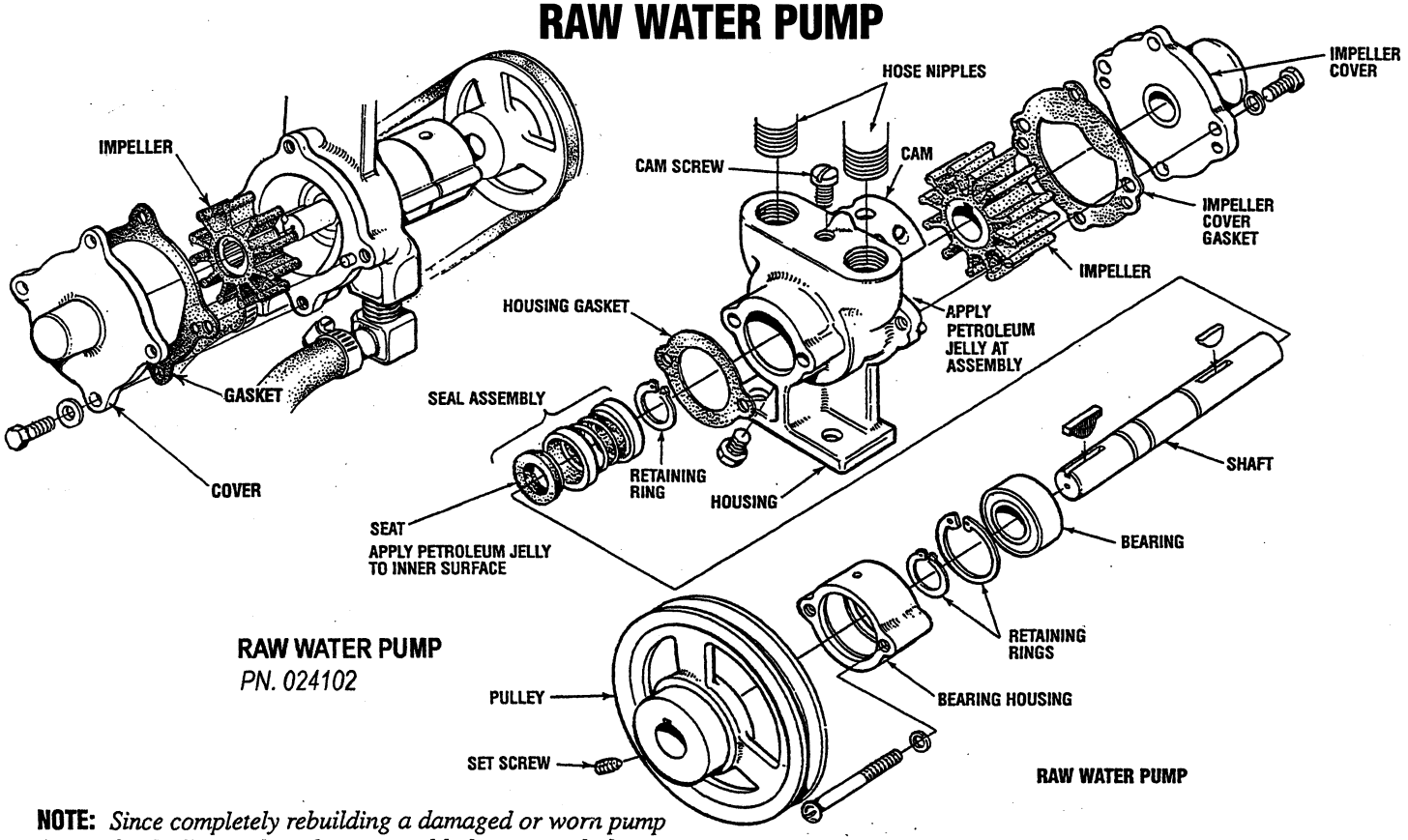


5. Install the timing belt on the crankshaft pulley and the camshaft pulley from the tension side (the right side as viewed from the front of the engine) so that tension is retained.
6. Loosen the tensioner lock bolt so that the tensioner spring applies tension.
7. Turn the crankshaft twice in the direction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



⚠ CAUTION: ***Water or oil on the timing belt severely reduces the service life of the belt. keep the timing belt sproket and tensioner free of oil and grease. These parts should never be cleaned. Replace if seriously contaminated with dirt or oil. If oil is evident on these parts, check the front case, oil pump seals, and camshaft oil seals for a possible leak.***

RAW WATER PUMP



RAW WATER PUMP
PN. 024102

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.

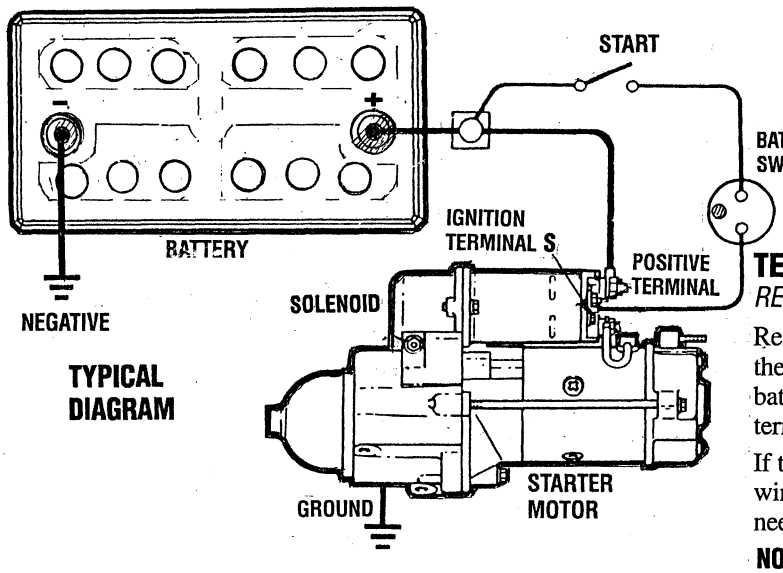
1. Loosen the set screw with an allen wrench and remove the water pump pulley from the shaft, taking care not to lose the key.
2. Remove the four impeller cover screws, the impeller cover and its gasket.

   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.

STARTER MOTOR



STARTER MOTOR
PART NO. 038384

TESTING WITH AN ELECTRICAL JUMPER

REFER TO THE ILLUSTRATION BELOW

Remove the **Terminal S** wire from the ignition and attach the lead from the electrical jumper. Leave the **+ positive** battery attached and clip the jumper aligater fitting to that terminal. The push button should crank the starter.

If the push button fails to crank the starter and the batteries wiring and wired connections have been checked, the starter needs to be removed for service.

NOTE: *This electrical jumper can be **fabricated** using a standard push button and two connecting wires.*

TROUBLESHOOTING/INSPECTION

Prior to testing, make certain the ships batteries are at full charge and that the starting system wiring connections (terminals) are clean and tight. Pay particular attention to the ground wire connections on the engine block.

To check the wiring, try cranking the starter for a few cycles, not more than three crank cycles at a time, then run your hand along the wires and terminals looking for warm spots that indicate resistance. Repair or replace any trouble spots.

Using a multimeter, test the voltage between the positive terminal stud on the start solenoid and the engine block (ground).

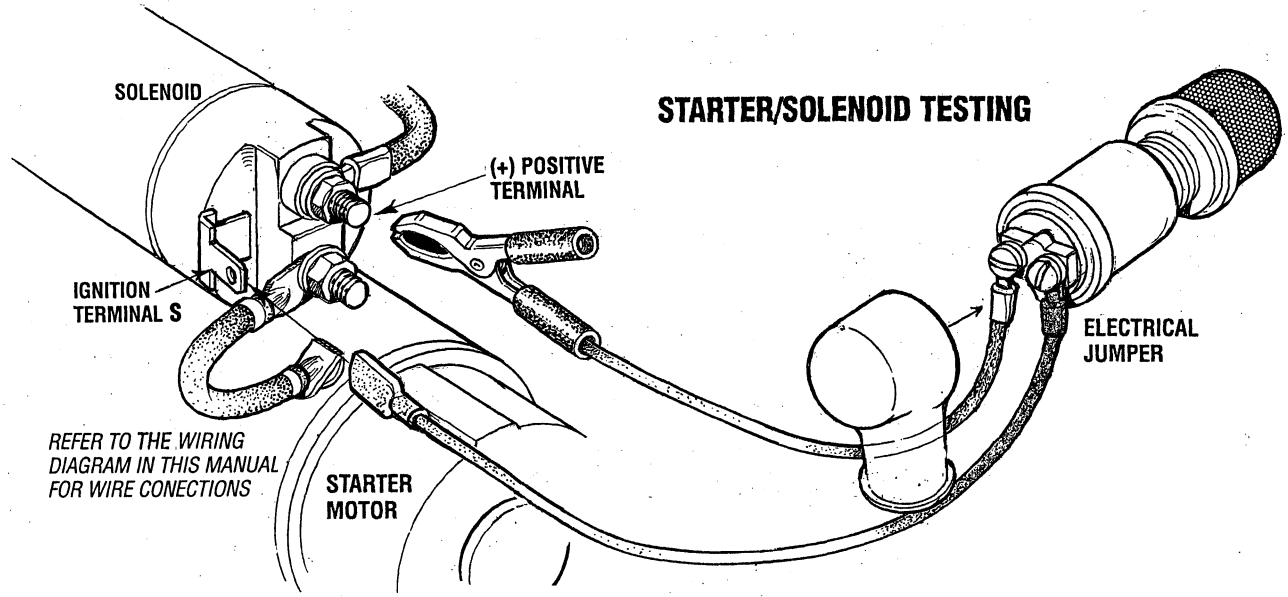
If you read 12 volts, the starter is faulty.

If nothing happens at all, the solenoid is not getting current. Check the battery and inspect the wiring connections. It is also possible that the solenoid is defective.

TO REMOVE FOR SERVICE

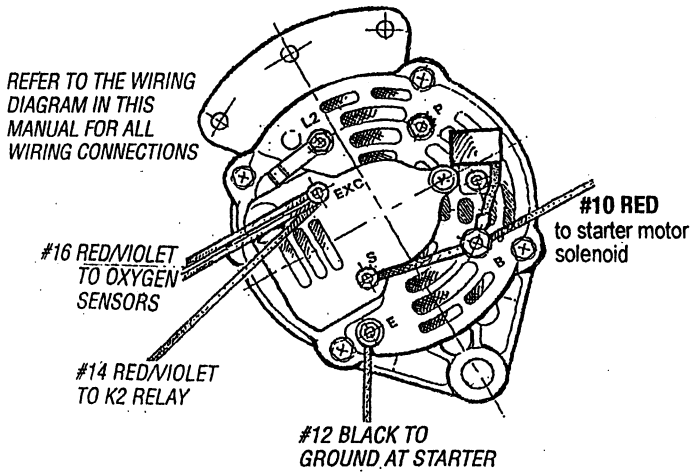
1. Turn off the DC battery switch.
2. If necessary, remove any components to gain full access to the starter motor.
3. Label and disconnect the wiring from the starter. (Do not allow wires to touch, tape over the terminals).
4. Remove the starter mounting bolts.
5. Remove the starter from the engine. In some cases the starter will have to be turned to a different angle to clear obstructions,

NOTE: *WESTERBEKE uses an ignition proof starter approved by the U.S. Coast Guard. If it is necessary to replace the starter, purchase a new starter from a WESTERBELE dealer/distributor.*



STARTER/SOLENOID TESTING

ALTERNATORS TESTING/TROUBLESHOOTING



51 AMP ALTERNATOR

DESCRIPTION

The following information applies to the standard alternators that are supplied with WESTERBEKE'S Engines and Generators.

ELECTRICAL CHARGING CIRCUIT

The charging system consists of an alternator with a voltage regulator, an engine DC wiring harness, a mounted DC circuit breaker and a battery with connecting cables. Because of the use of integrated circuits (IC's), the electronic voltage regulator is very compact and is mounted internally or on the back of the alternator.

It is desirable to test the charging system (alternator and voltage regulator) using the wiring harness and electrical loads that are a permanent part of the system and will then provide the technician with an operational test of the charging system as well as the major components of the electrical system.

ALTERNATOR DESCRIPTION

The stator is connected to a three-phase, full-wave bridge rectifier package which contains six diodes. The bridge converts the AC generated in the stator to a DC output for battery charging and accessories,

Power to the regulator and the field of the integral regulator alternator is provided by the field diode (or diode trio) package contained in the alternator.

These alternators produce a rated output of 50 or 51 amps. rated output is achieved at approximately 6000 alternator rpm at an ambient temperature of 75°F (23.8°C). The alternators are designed to operate in an ambient temperature range of -40° to 212°F (-40° to 100°C).

VOLTAGE REGULATOR

The integral voltage regulator is an electronic switching device which senses the system voltage level and switches the voltage applied to the field in order to maintain a proper system voltage.

The regulator design utilizes all-silicon semi conductors and thick-film assembly techniques. After the voltage has been adjusted to the proper regulating valve, the entire circuit is encapsulated to protect the circuit and the components from possible damage due to handling or vibration.

ALTERNATOR TROUBLESHOOTING

Use this troubleshooting section to determine if a problem exists with the charging circuit or with the alternator. If it is determined that the alternator or voltage regulator is faulty, have a qualified technician check it.

> ⚠ **WARNING:** ***A working alternator runs hot. A failed alternator can become very hot. Do not touch the alternator until if has cooled.***

continued

Battery Care

Review the manufacturer's recommendations and then establish a systematic maintenance schedule for your engine's starting batteries and house batteries.

- ☐ Monitor your voltmeter for proper charging during engine operation.
- ☐ Check the electrolyte level and specific gravity with a hydrometer.
- ☐ Use only distilled water to bring electrolytes to a proper level.
- ☐ Make certain that battery cable connections are clean and tight to the battery posts (and to your engine).
- ☐ Keep your batteries clean and free of corrosion.

> ⚠ **WARNING:** ***Sulfuric acid in lead batteries can cause severe burns on skin and damage clothing. Wear protective gear.***

BATTERY

The recommended "dedicated" battery used for the engine's starting 12 volt DC control circuit should be 800-1000 Cold Cranking Amps (CCA) rated.

ALTERNATORS TESTING/TROUBLESHOOTING

PRELIMINARY INSPECTION

Before starting the actual alternator and voltage regulator, testing the following checks are recommended.

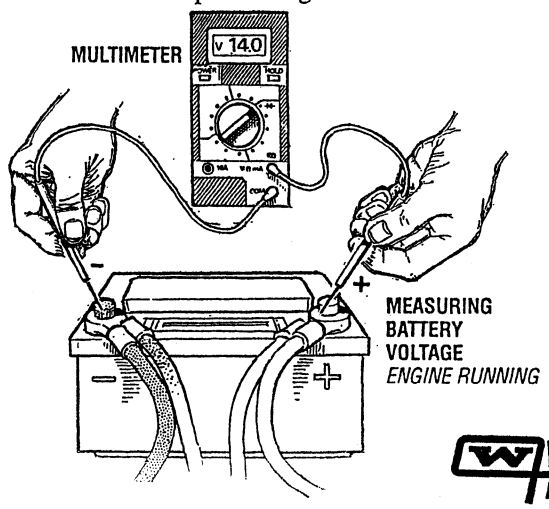
1. Make certain your alternator is securely mounted.
2. Check the drive belt for proper tension. Replace the belt if it is worn or glazed.
3. Check that all terminals, connectors and plugs are clean and tight. loose or corroded connections cause high resistance and this could cause overcharging, undercharging or damage to the charging system. Badly corroded battery cables could prevent the battery from reaching a fully charged condition.
4. Check the condition of the battery and charge if necessary. A low or discharged battery may cause false or misleading readings on the in-vessel tests.

   NOTE: *An isolator with a diode, a solenoid, or a battery selector switch is usually mounted in the circuit to isolate the batteries so the starting battery is not discharged along with the house batteries. If the isolator is charging the starting battery but not the house battery, the alternator is Ok and the problem is in the battery charging circuit.*

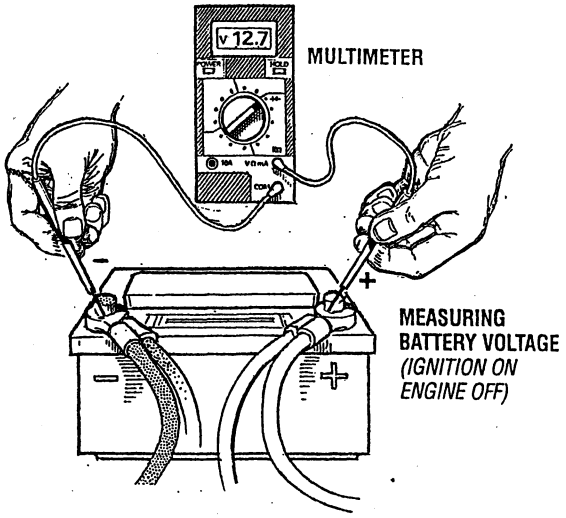
TESTING THE ALTERNATOR

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

1. **Start the engine.**
2. After the engine has run for a few minutes, measure the starting battery voltage at the battery terminals using a multimeter set on DC volts.
   a. If the voltage is increasing toward 14 volts, the alternator is working; omit Steps 3 through 8 and go directly to "Checking the Service Battery".
   b. If the voltage remains around 12 volts, a problem exists with either the alternator or the charging circuit; continue with Steps 3 through 8.



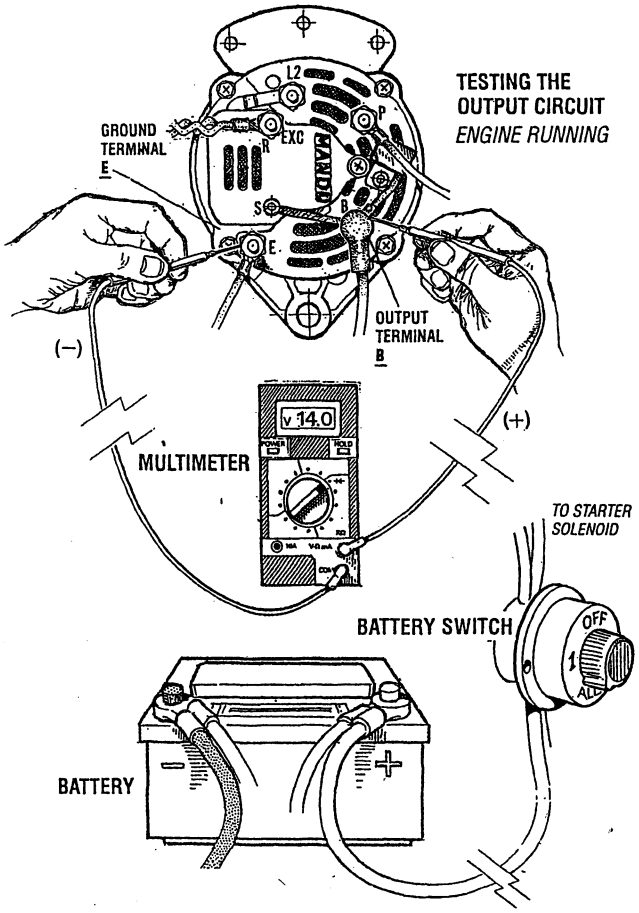
3. **Turn off the engine.** Inspect all wiring and connections. Ensure that the battery terminals and the engine ground connections are tight and clean.
4. If a battery selector switch is in the charging circuit, ensure that it is on the correct setting.
5. **Turn on the ignition switch, but do not start the engine.**
6. Check the battery voltage. If the battery is in good condition, the reading should be 12 to 13 volts.



Testing The Output Circuit

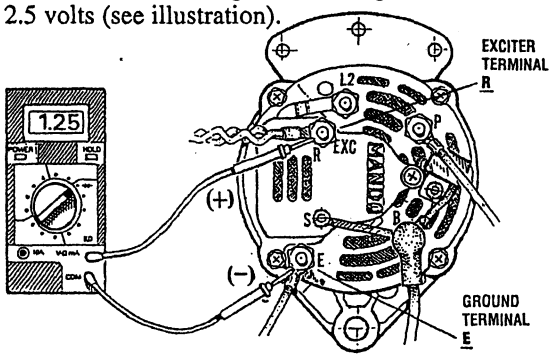
1. Connect the positive probe to the output terminal **B** and connect the negative probe to the ground terminal **E** on the alternator.
2. Wiggle the engine wiring harness while observing the voltmeter. The meter should indicate the approximate battery voltage, and should not vary. If no reading is obtained, or if the reading varies, check the alternator output circuit for loose or dirty connections or damaged wiring.
3. **Start the engine.**
4. Repeat the same measurement, the negative probe to **E**, the positive probe to **B** with the engine running. The voltage reading should be between 13.5 and 14.5 volts. If your alternator is over or under-charging, have it repaired at a reliable service shop.
5. If the previous test reads only battery voltage at terminal **B** use the meter to measure the DC excitation terminal. If 12 volts is not present at exciter terminal **R**, inspect the wiring for breaks and poor connections. Jump 12 volts from a 12 volt source (such as the battery) and operate the alternator. If voltage output is 13-14 volts, then the alternator is OK.

ALTERNATORS TESTING/TROUBLESHOOTING

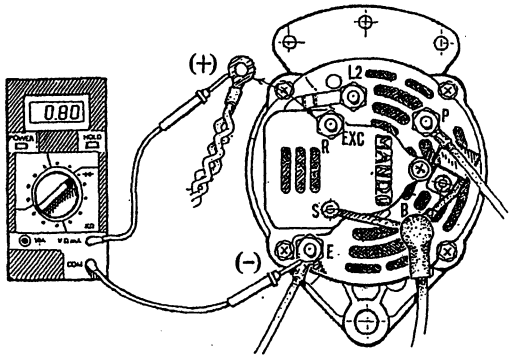


TESTING THE EXCITATION CIRCUIT

1. Connect the positive (+) multimeter probe to the excitation terminal **R** on the alternator and the negative (–) probe to the ground terminal **E** on the alternator.
2. **Turn the ignition switch to the on position** and note the multimeter 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.
4. **If the reading is between 6.0 and 7.0 volts,** the rotor field circuit probably is open.



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 multimeter probe to the excitation lead and the negative multimeter probe to ground terminal **E**. If the multimeter 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.

CHECKING THE SERVICE BATTERY

Check the voltage of the service battery. This battery should have a voltage between 13 and 14 volts when the engine is running. If not, there is a problem in the service battery charging circuit. Troubleshoot the service battery charging circuit by checking the wiring and connections, the solenoid, isolator, battery switch, and the battery itself.

When the problem has been solved and before the alternator is back in operation, take the time to tighten and clean the terminal studs. Also clean the connecting terminals from the wiring harness.,

ALTERNATOR REPAIR

If tests indicate a failed alternator, it will need to be disassembled and repaired. Any good alternator service shop can do the job.

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

If 12 volts is not present at the EXC terminal, trace the wiring and look for breaks and poor connections.

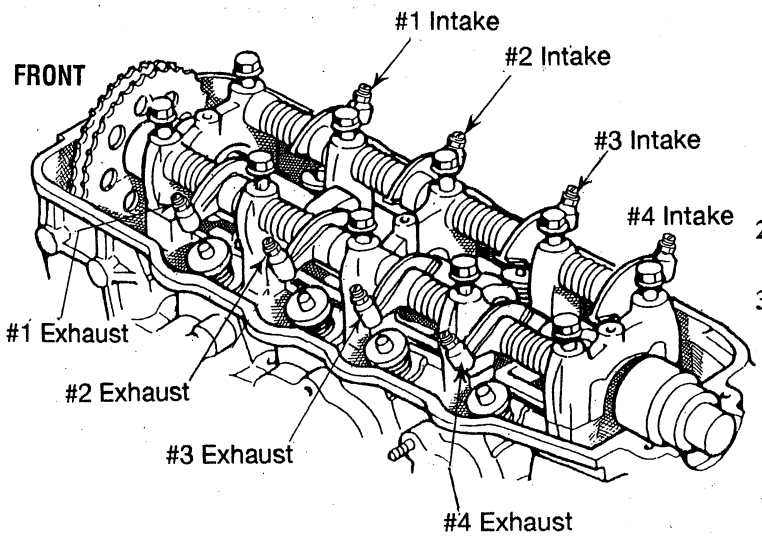
ENGINE ADJUSTMENTS

NOTE: *WESTERBEKE recommends that the following engine adjustments be performed by a competent engine mechanic.*

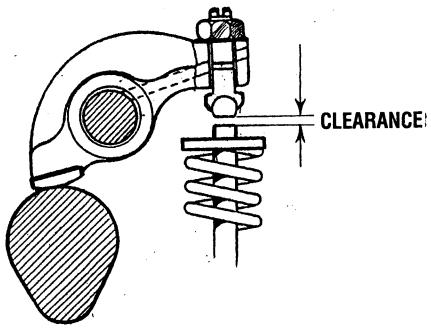
VALVE CLEARANCE ADJUSTMENT

NOTE: *Retorque 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 its 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: 52-70 in-lb(4.3-5.8 ft-lb) 6-8 Nm
4. Adjust all valves with the engine cold.
   INTAKE : 0.006 in (0.15 mm)
   EXHAUST : 0.014 in (0.35 mm)



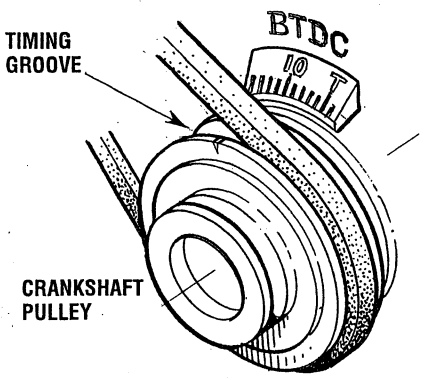
ENGINE COMPRESSION

REFER TO " COMPRESSION TEST PROCEDURES" ON PAGE 3.

IGNITION TIMING

1. Attach a digital 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 digital timing light, check the ignition timing first with the vacuum hose disconnected from the distributor and then with it connected. Compare timing with the specifications below. Adjust the timing as needed.

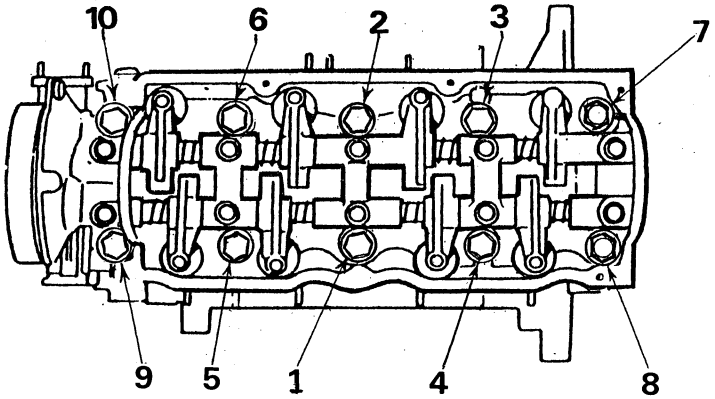
   Timing Specifications: 16° BTDC at 1800 rpm ±1°
   (vacuum advance hose disconnected)
   33° BTDC at 1800 rpm ±1°
   (vacuum advance hose connected)

TORQUING CYLINDER HEAD BOLTS

After the initial break-in period (approximately 50 hours), the cylinder heads 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 60 - 65 lb-ft. (8.2 - 8.9 m-kg). Then proceed to the next head bolt in the sequence. Tighten the RS (rocker cover stud) securely.

CYLINDER BOLT TORQUE: 60 - 65 lb-ft (8.2- 8.9m-Kg)



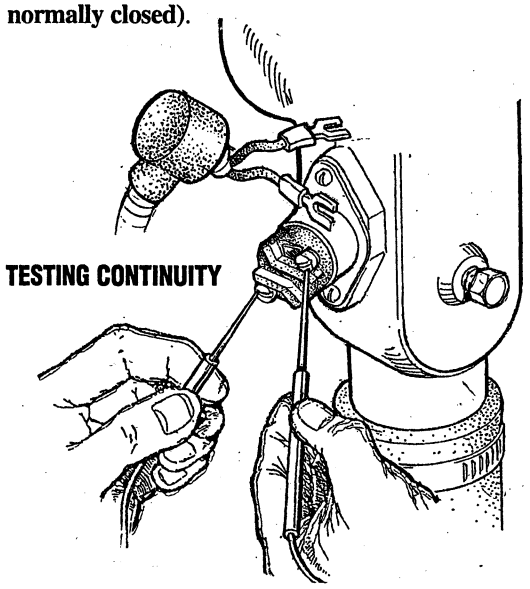
ENGINE ADJUSTMENTS

TESTING THE EXHAUST TEMPERATURE SWITCH

An exhaust temperature switch is located on the water injected exhaust elbow. Normally closed, this switch will open and the ECU will interpret this as a high exhaust temperature and open the K2 run relay stopping the generator. The exhaust temperature LED on the panel will illuminate.

The switch opens at 260 - 270°F (127 - 132°C). This switch resets (contacts close) at approximately 225°F (107°C).

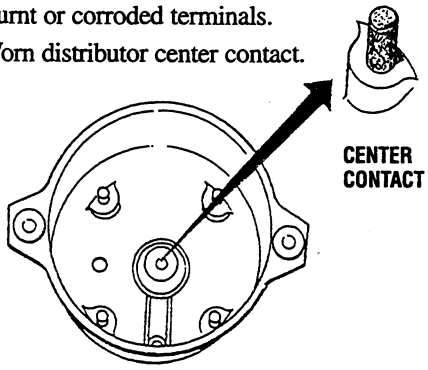
When testing, continuity should be found (switch is normally closed).

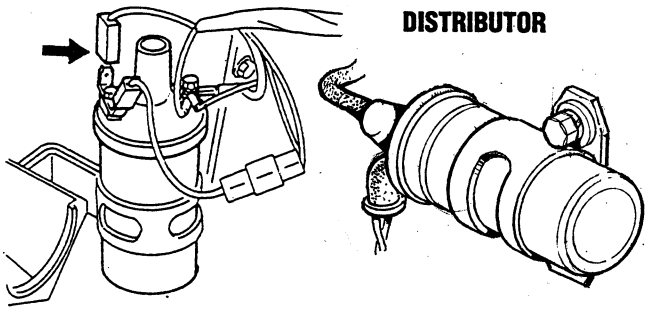


DISTRIBUTOR CAP INSPECTION

Check the following points. Replace if necessary.

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

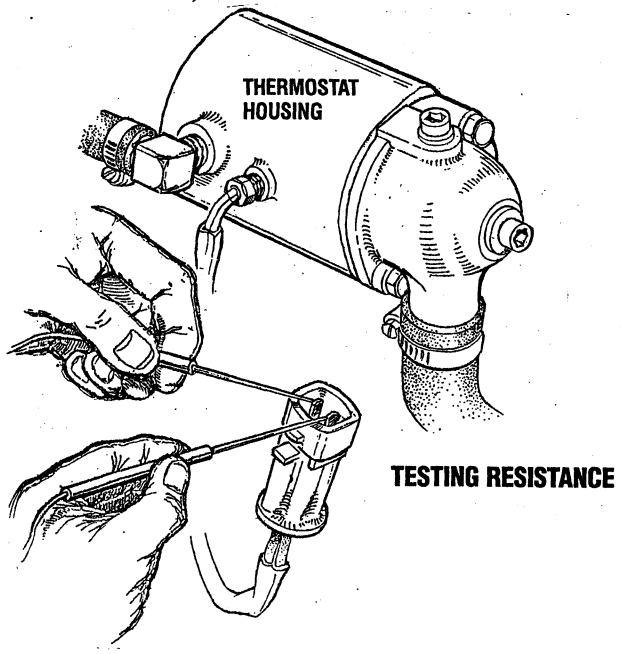




COOLANT (WATER) TEMPERATURE SENSOR

A temperature sensor is located at the thermostat housing. This sensor sends a DC voltage to the ECU that it interprets as engine (antifreeze) coolant temperature. Should this voltage reach a set value, the ECU will interpret this as a high temperature and open the K2 run relay, stopping the generator. The overheat LED on the panel will then illuminate.

Test the sensor as shown. Resistance at room temperature should indicate 10,000 Ohms.



HIGH/LOW RPM SHUTDOWN

The ECU monitors engine speed by the AC voltage produced by the MPU. Should this voltage reach a preset value, the ECU will interpret this as an engine overspeed (2175 rpm approximately) and open the K2 relay, stopping the generator. The panel Overspeed LED will illuminate. Should the MPU produce a low AC voltage that the ECU interprets as an underspeed condition, the ECU will open the K2 relay and stop the generator. The Overspeed LED will then blink.

ENGINE DC CIRCUIT BREAKER

The generator's engine DC circuit is protected by a rocker type DC 20 amp breaker mounted on the control box (this also serves as an Emergency Stop Switch). Excessive DC current draw or DC electrical overload anywhere in the instrument panel wiring or engine wiring will cause the breaker to trip to the OFF position. In this event, the DC power to the ECU will be interrupted, stopping the generator. No panel LED will illuminate. Check and repair the source of the problem. After repairing the fault, reset the breaker and restart the generator.

ENGINE ADJUSTMENTS

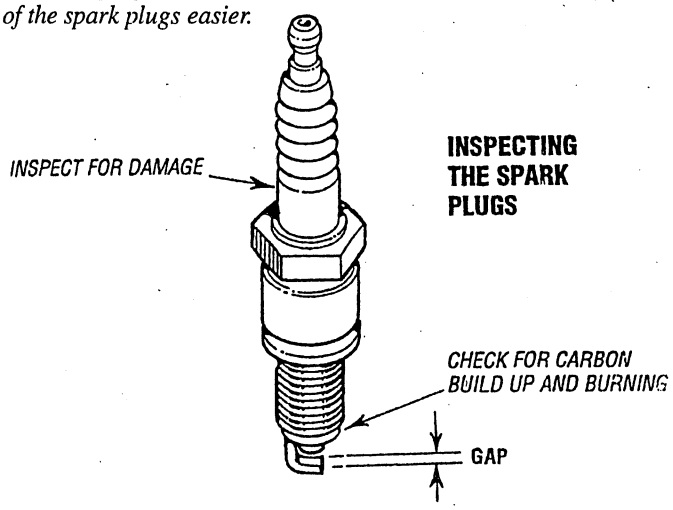
SPARK PLUGS

The spark plugs should be cleaned and re-gapped after the first 50 hours of break-in operation. Then replace the spark plugs every 250 hours of engine operation. Spark plugs play an important part in the LOW CO system operation.

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

SPARK PLUG GAP: 0.28 - 0.31in (0.7 - 0.8mm)
SPARK PLUG TORQUE: 10 - 15 lb-ft (1.5 - 2.31 Kg-m) 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

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 22.5Kw and 20KW generators have two drive belts, one drives the DC alternator and the other drives the raw water pump. The tension adjustment procedure for both belts is as follows:

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

1. Remove the belt guard.
2. To adjust the DC alternator drive belt, loosen the pivot bolt and adjusting arm 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 DC alternator drive belt, slide the alternator in or out as required, then retighten its two 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.

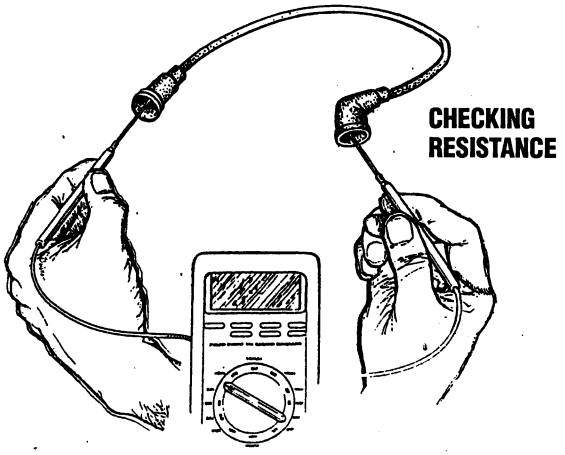
   NOTE: *Maintain a 22 lb pressure to the belt's outer face for proper belt operation. Spare belts should always be carried on board.*
6. Operate the generator for about 5 minutes, then shut down the generator and recheck the belt(s) tension.
7. Replace the belt guard.

INSPECTING IGNITION COMPONENTS

HIGH TENSION CORDS (IGNITION WIRES)

Check all the high tension ignition wires every 500 operating hours and replace after 1,000 hours of engine operation. High engine compression temperatures will lead to the deterioration of the wires.

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



LEAD WIRES (HIGH TENSION LEAD) INSPECTION

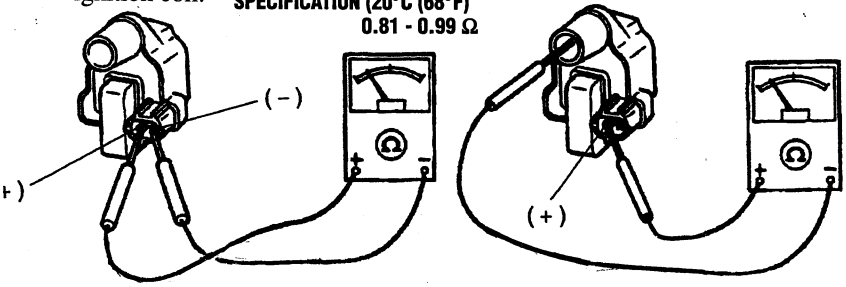
1. Measure the resistance of each lead, using an ohmmeter. If not as specified, replace the high-tension lead.

No.1 lead	2.57- 6.65 kΩ
No.2 lead	3.53- 8.89 kΩ
No.3 lead	4.10-10.23 kΩ
No.4 lead	5.26-12.92 kΩ
Center lead	5.02-12.36 kΩ

IGNITION COIL

Primary Coil Winding: Measure the resistance at the primary coil using an ohmmeter. If not specified, replace the ignition coil.

SPECIFICATION (20°C (68°F)
0.81 - 0.99 Ω

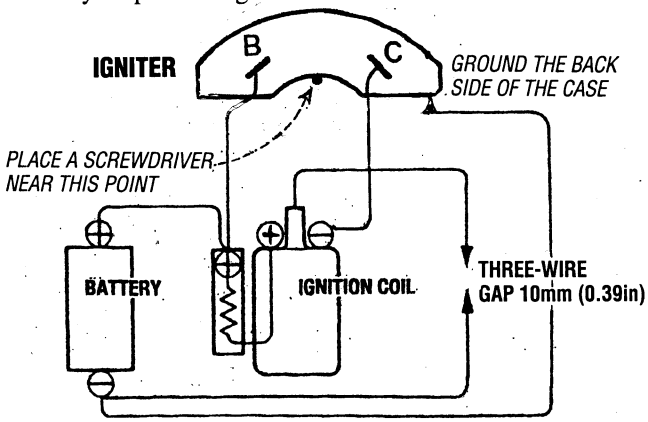


Secondary Coil Winding: Measure the resistance at the secondary coil using an ohmmeter. If not specified, replace the ignition coil.

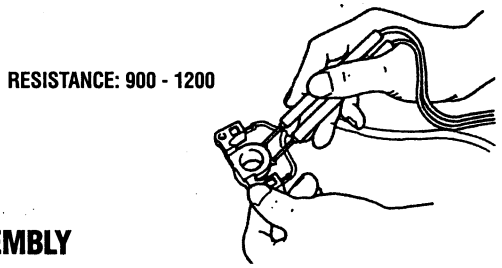
SPECIFICATION (20°C (68°F)
10.4 - 15.6 kΩ

IGNITER

Igniter Integrated with Distributor: Connect the igniter as shown in the illustration below. The will test the electrical current as it floes through the ignition coil. Place a metal instrument, such as a screwdriver, near the middle of the pick-up of the igniter. The electrical current is interrupted and sparks are generated in the three- wire gap. The igniter unit is satisfactory if sparks are generated.



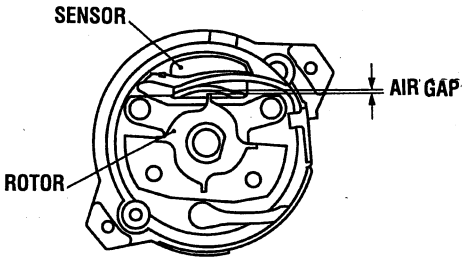
Pick-Up Coil: Measure the resistance using an ohmmeter. If not as specified, replace the pick-up coil.



ASSEMBLY

Assemble the distributor by reversing the disassembly steps and pay attention to the following points.

1. After putting the oil seal into the body, coat the lip of the seal with grease.
2. Adjust the air gap illustrated to 0.8 mm (0.03 in).

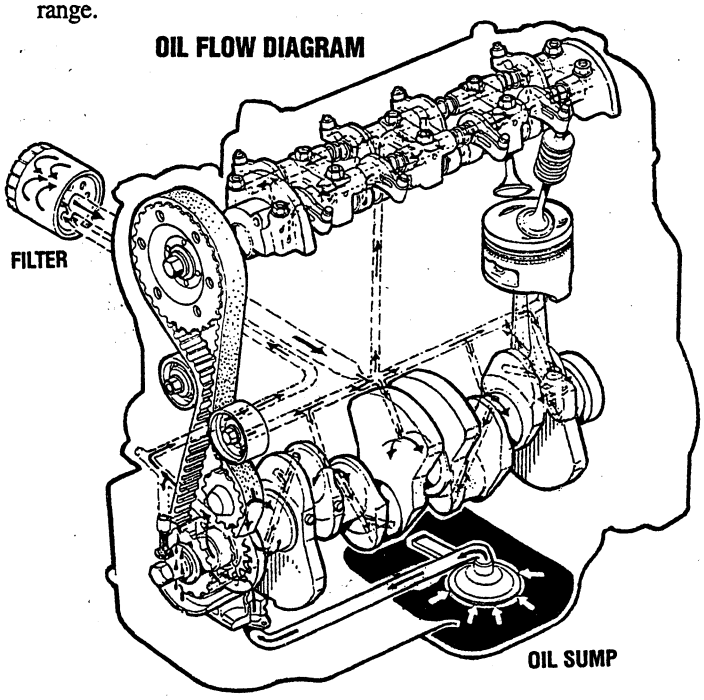


LUBRICATING SYSTEM

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.

OIL FLOW DIAGRAM



LUBRICATION TROUBLESHOOTING

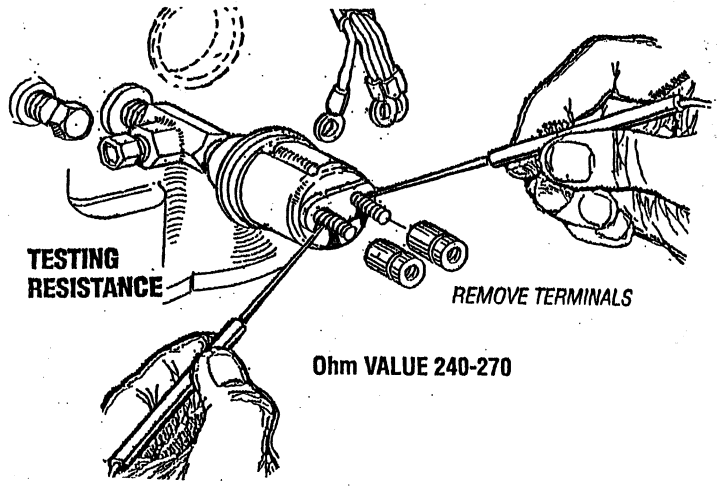
OIL LEAKAGE:	Loose drain plug. Faulty seat at oil pan and cylinder block. Damaged cylinder head cover. Loose oil pump body bolt, cylinder head cover bolt, or oil pan bolt. Damaged front housing gasket or cylinder head gasket. Faulty oil filter. Loose oil filter. Loose or damaged oil pressure switch.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

OIL PRESSURE SENSOR

An oil pressure sender #049197 is fitted to the engine oil gallery. This sends a voltage signal to the control ECU that it interprets as oil pressure. Should this voltage signal fall to a present value, the ECU will shut the unit down and illuminate the oil pressure LED on the control panel.

Test the sensor by checking resistance (at rest):

SENDOR AND SWITCH TORQUE **9 - 13 ft-lb (1.2 - 1.8 m-kg)**



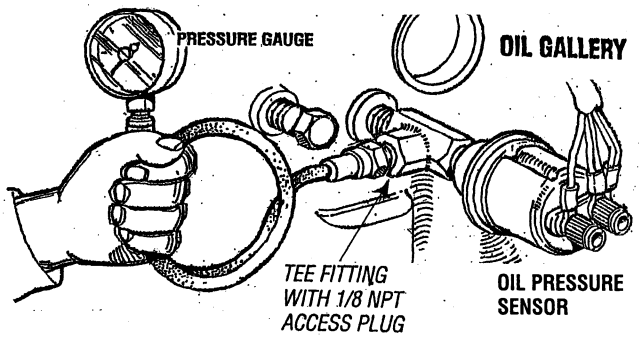
LOW OIL PRESSURE

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.

TESTING OIL PRESSURE

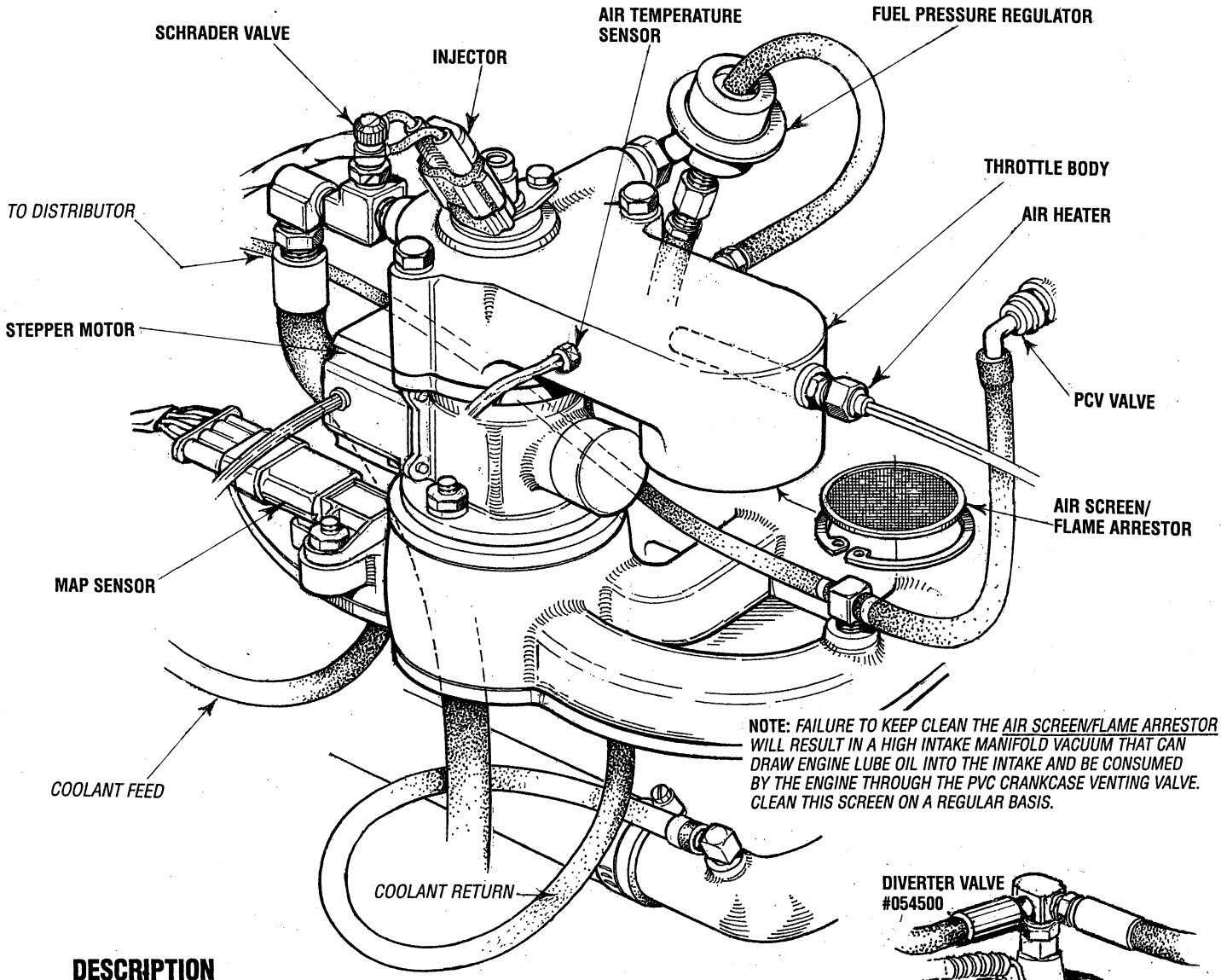
To test the oil pressure, remove the hex plug from the oil manifold and install a mechanical oil pressure gauge in its place. After warming up the engine, set the engine speed at 1800 rpm and read the oil pressure.

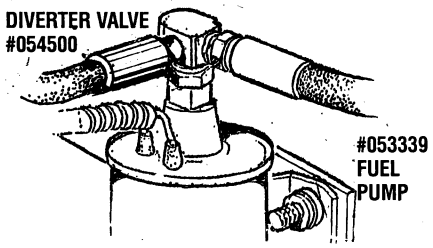
OIL PRESSURE **BETWEEN 50 AND 60 PSI AT 1800 RPM**



TESTING OIL PRESSURE

ELECTRONIC FUEL INJECTION (EFI)





DESCRIPTION

The above illustration shows the throttle body assembly attached to the intake manifold.

An electronic control unit (ECU) controls the fuel injection and throttle actuator.

The ECU is supplied with electrical signals it interprets as engine operating conditions from sensors that monitor intake air temperature, engine coolant temperature, map sensor (intake manifold absolute pressure), engine rpm, battery voltage and distributor cam signal.

The ECU interprets this information to determine the appropriate injector pulse rate and throttle opening position.

A high pressure fuel pump supplies fuel to the area around the injector and regulator maintains the fuel pressure in that area at 35 - 40 PSI.

The injector is a solenoid operated pintle valve that meters fuel into the intake manifold depending on engine operating conditions and generator amperage load as determined by the ECU.

Air flow into the intake manifold is through the flame arrester/air filter and is controlled by the ECU operation of the throttle plate via the stepper motor. Throttle plate positioning for proper air flow into the engine is accomplished through the ECU interpretation of the engine operating conditions. The Schrader valve is used to monitor/check fuel pressure around the fuel injector and to bleed air from that area after fuel system servicing.

DIVERTER VALVE

The diverter valve mounted on the electric fuel pump shown in the illustration must be replaced every 1000 operating hours.

AIR SCREEN / FLAME ARRESTER

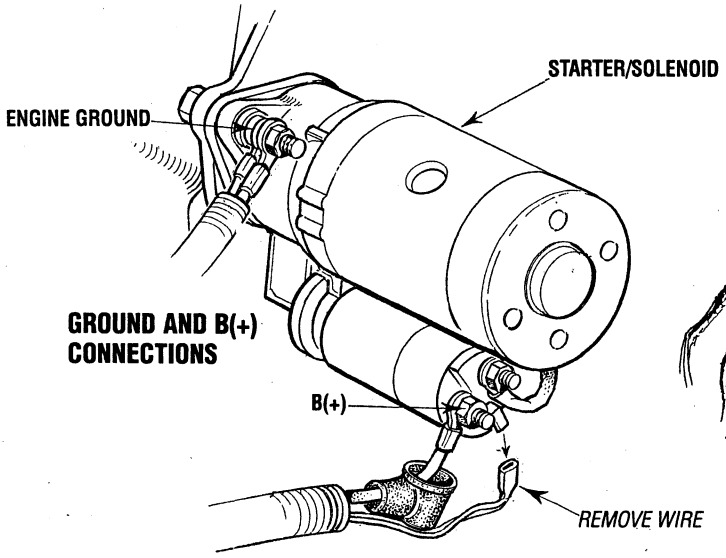
The air screen/ flame arrester should be inspected and cleaned. Inspect the rubber sealing and replace if worn or cracked. Clean the screen in a water soluble cleaner such as gunk.

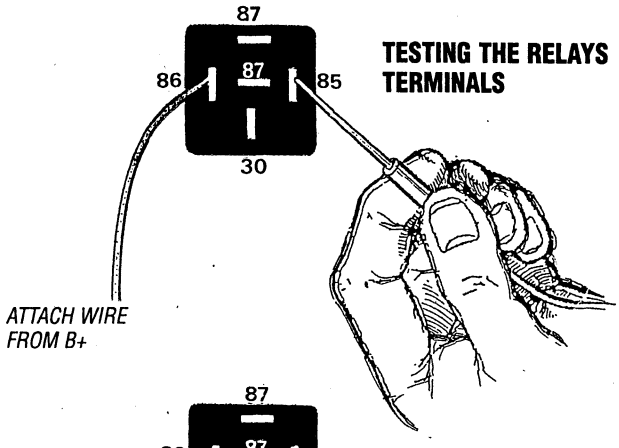
COMPONENT TESTING

GENERAL

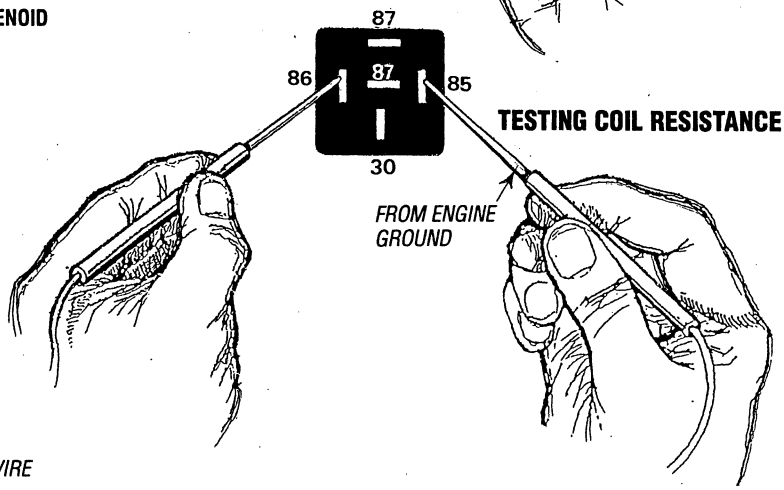
All DC voltage measurements are made to the engine battery negative ground point unless specified otherwise. In making test measurements, make sure that a good ground for the meter is established, preferably the point where the negative battery is connected to the engine. Battery positive voltage is indicated as B+ and should measure no less than 11.5 volts.

AC voltage measurements should be made with a true RMS AC meter to insure accuracy.





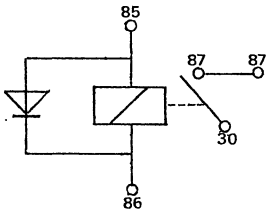
TESTING THE RELAYS TERMINALS



TESTING COIL RESISTANCE

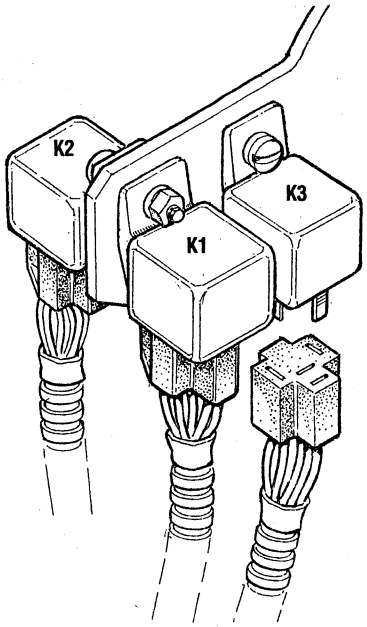
RELAYS

The relays used in the control system have coils which are polarized by the fact that they have internal free wheeling suppression diodes across them. Relay coil terminal 86 must be maintained (+), terminal 85(–). The relay coil is rated 12V DC, and the coil resistance is typically 85 ohms. With B+ on terminal 86, direct grounding of terminal 85 is permissible for testing purposes.



RELAY INTERNAL DIAGRAM

REFER TO THE TROUBLESHOOTING CHART IN THIS MANUAL FOR ADDITIONAL RELAY TESTS



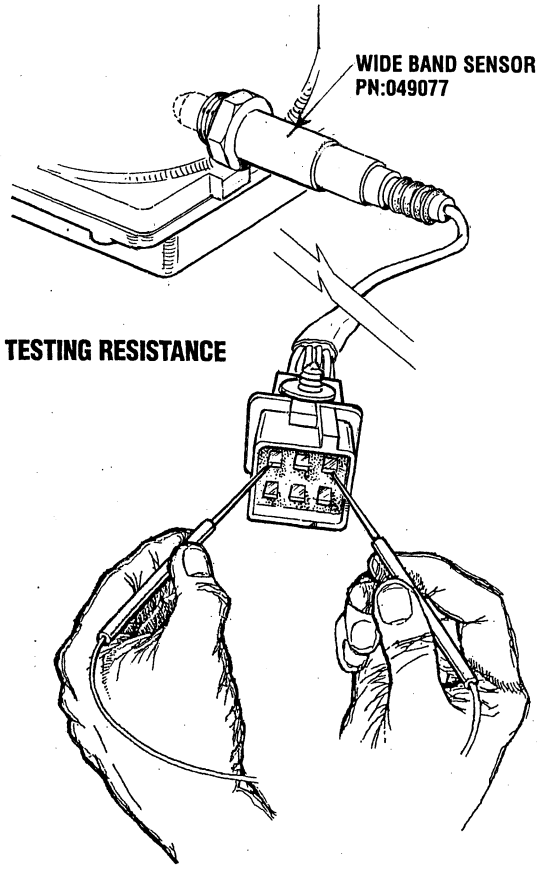
RELAYS

TYPICAL RELAY ARRANGEMENT

COMPONENT TESTING

TESTING OXYGEN SENSORS

Two oxygen sensors are used in the EFI system. A narrow band sensor on the exhaust inlet side of the catalyst and a wide band sensor on the exhaust discharge side of the catalyst. These sensors monitor engine operation that the ECU interprets and adjusts air/fuel ratios accordingly.



TESTING THE OXYGEN SENSORS IN A STATIC MODE

Narrow Band Sensor: Unplug the sensor from the engine harness. Locate the 2 white pin leads, measure across these two pins with an ohm meter.

Resistance Value 2.0 - 4.0 OHM (approximately)

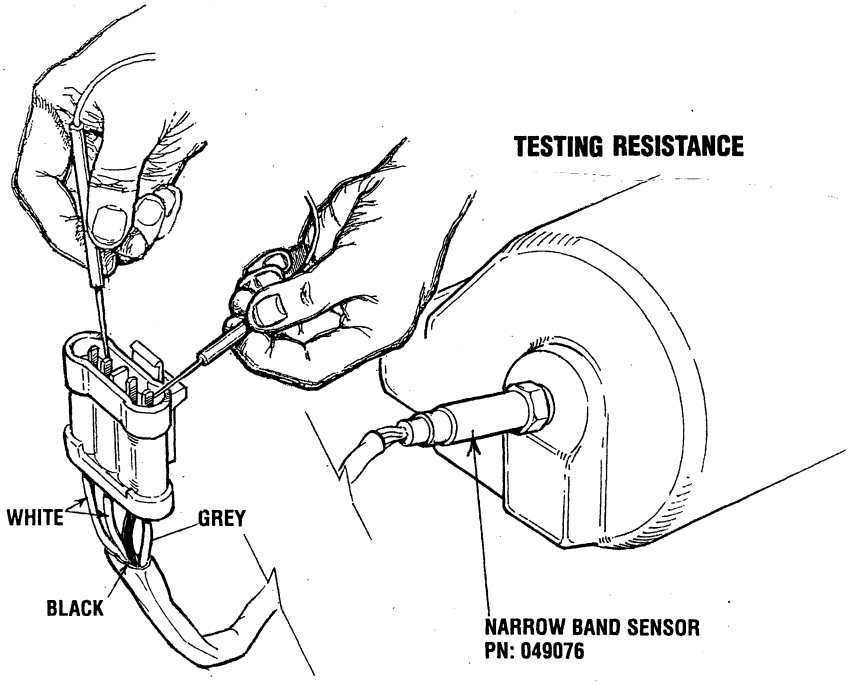
There should be no continuity between either of the two white lead pins and the black or grey lead pins.

Wide Band Sensor: Unplug the sensor from the engine harness. Locate the red pin lead and the vacant black pin lead. Measure across these two pins with an ohm meter.

Resistance Value 110.0 - 130.0 OHM (approximately)

No continuity should be found between these two pins and any of the other four.

Sensors not meeting these tests are presumed faulty. care should be taken when installing a replacement sensor. Do not scratch, damage, or handle the sensor end in any way.

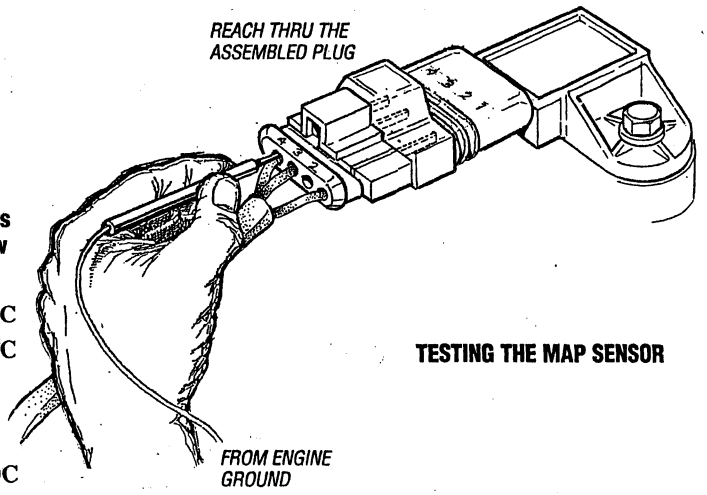


COMPONENT TESTING

MAP SENSOR

The Manifold Absolute Pressure (MAP) sensor is a solid state pressure transducer which measures the intake manifold pressure (vacuum). It derives its operating power (+5V, Pin 4; Gnd, Pin 1) from the ECU and receives power only when the ECU is in an *on* state. Its output (Pin 3) is measured to ground.
Typical output voltages are as follows:

Map Sensor -- Voltages	**EFI Generators 20/22.5Kw**
Pin 4 (sig) to Grnd (at rest)	**0 VDC**
Pin 4 (sig) to Grnd (prime delay in start mode)	**4.058 VDC**
Pin 4 (sig) to Grnd (running 1800 rpm no AC load)	**1.300 VDC (typical)**
Pin 3 (+5V) to Grnd (at rest)	**0 VDC**
Pin 3 (+5V) to Grnd (prime delay in start mode)	**4.999 VDC**
Pin 3 (+5V) to Grnd (running 1800 rpm no AC load)	**5.014 VDC (typical)**



TESTING THE MAP SENSOR

Map Sensor -- Resistances	**EFI Generators All Models**
Pin 1 (grnd) to Pin 2	**1.9Ω**
Pin 1 (grnd) to Pin 3	**5.9Ω**
Pin 1 (grnd) to Pin 4	**5.3Ω**

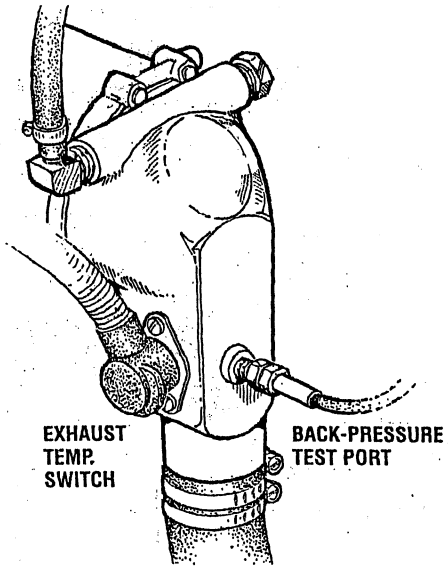
MEASURING EXHAUST BACK PRESSURE

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 the exhaust pressure, connect a PSI tube to the exhaust port on the exhaust elbow and read the gauge.

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) of 1800 rpm (for 60 Hz applications). Back-pressure should not exceed 1.5 psi)o.11 kg/cm²).

NOTE: *High exhaust system back-pressure will affect the operation of the Low CO system.*



COMPONENT TESTING

TESTING THE MAGNETIC PICK UP COIL

Test the magnetic pick-up AC voltage output while cranking. Voltages are listed below.

Test the magnetic pick-up coil winding in a static mode.Resistance values are shown below., If the AC output voltage is not present or lower than listed and the resistance value of the coil winding is correct, debris maybe insulating the MPU tip end. remove the MPU and examine and clean the tip end of debris.

Coil winding resistance being lower or not present would damage the MPU.

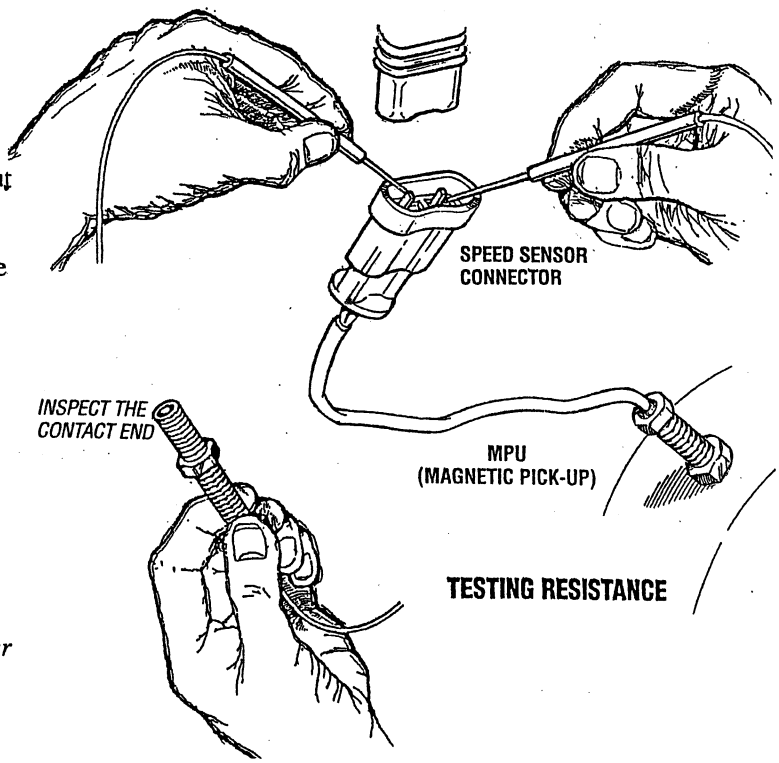
NOTE: *Carefully follow the installation instructions provided with the new MPU.*

Speed Sensor Test Values Voltage (while cranking)

20, 22.5 Kw EFI - 1.26 VAC

Resistance (at rest) - 950-1000Ω (all models)

NOTE: *The AC signal produces by the MPU will be greater the closer the MPU is positioned to the flat of the ring gear tooth and weaker the farther away from the tooth.*



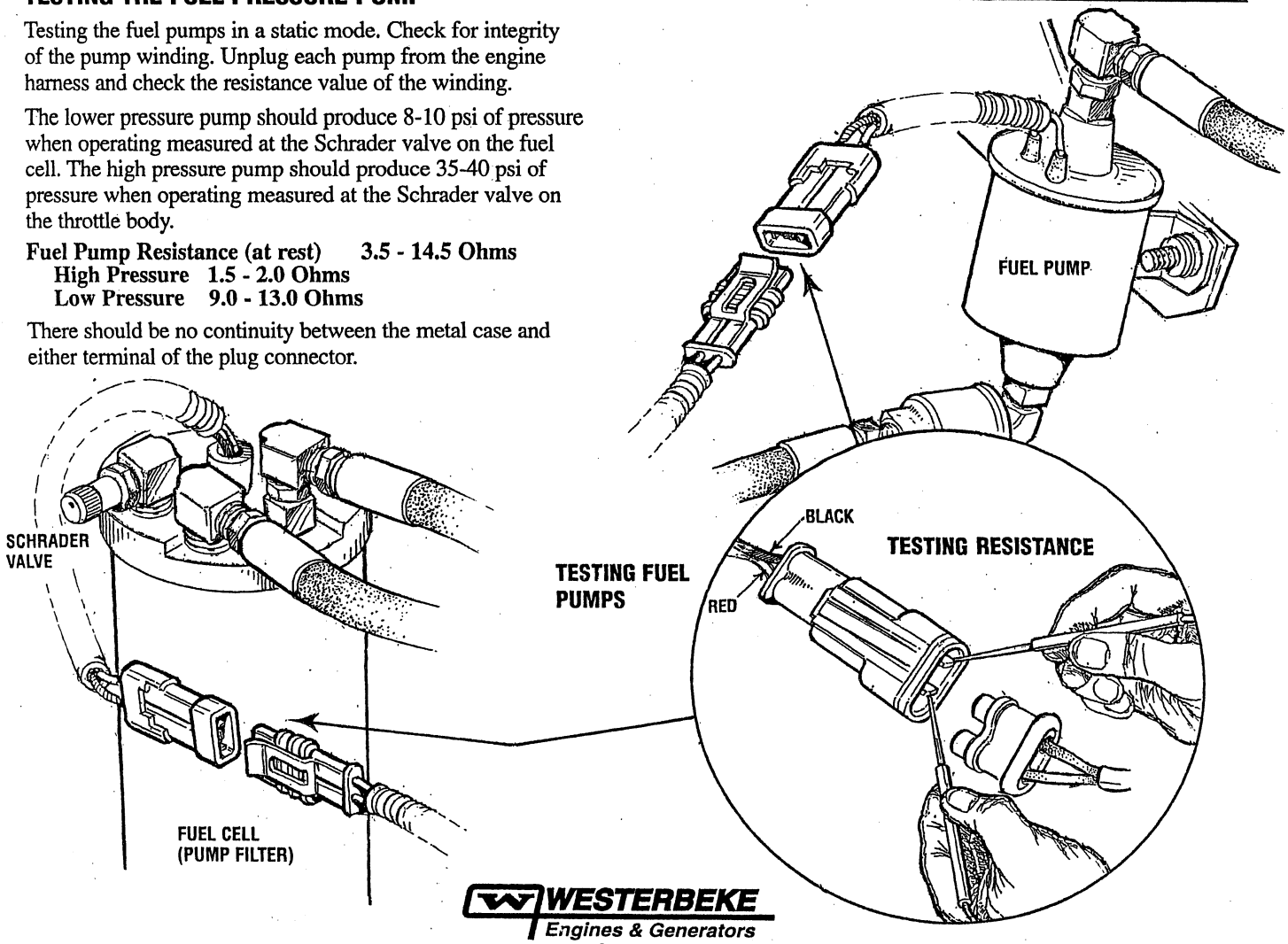
TESTING THE FUEL PRESSURE PUMP

Testing the fuel pumps in a static mode. Check for integrity of the pump winding. Unplug each pump from the engine harness and check the resistance value of the winding.

The lower pressure pump should produce 8-10 psi of pressure when operating measured at the Schrader valve on the fuel cell. The high pressure pump should produce 35-40 psi of pressure when operating measured at the Schrader valve on the throttle body.

Fuel Pump Resistance (at rest) 3.5 - 14.5 Ohms
High Pressure 1.5 - 2.0 Ohms
Low Pressure 9.0 - 13.0 Ohms

There should be no continuity between the metal case and either terminal of the plug connector.



COMPONENT TESTING

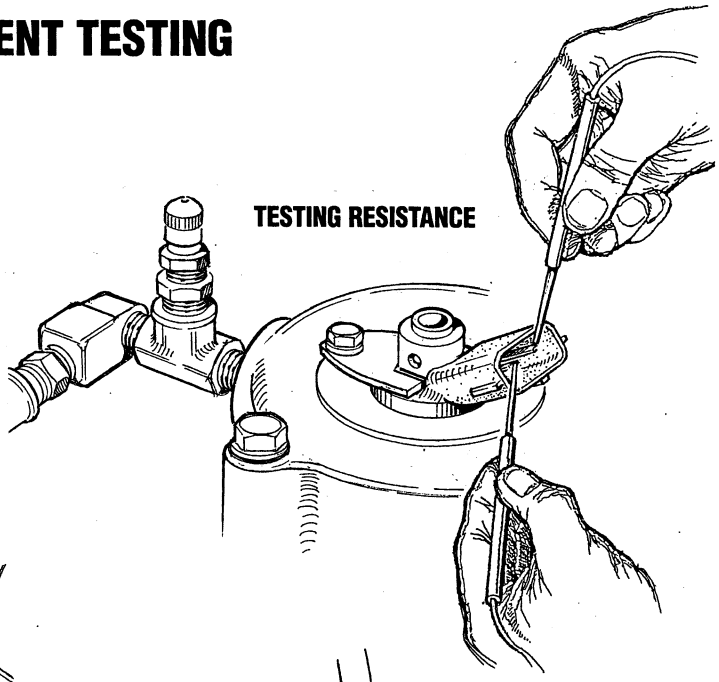
STEPPER MOTOR

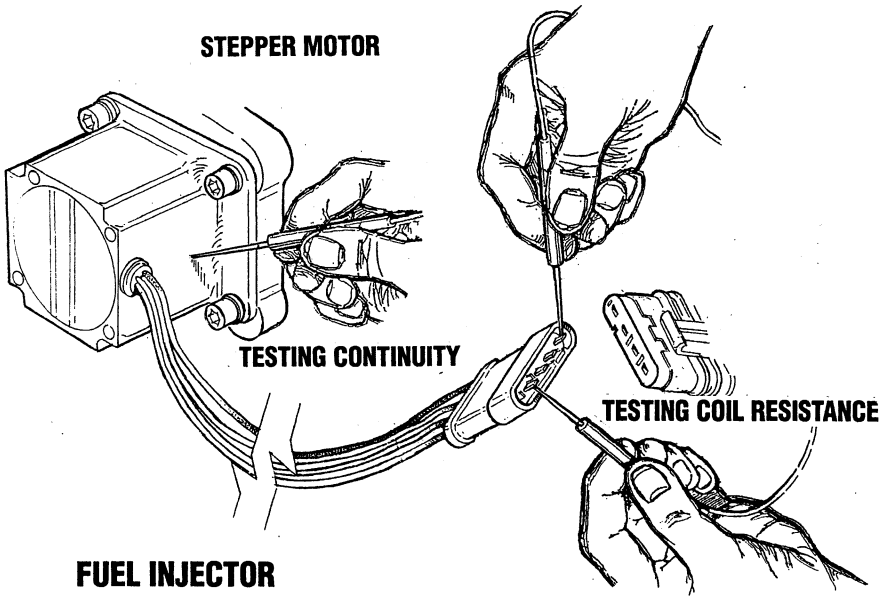
The throttle plate rotary stepper motor operates on a low DC voltage supplied from the ECU. There are two independent operating coils in the stepper motor. Each coil resistance is typically 2.61 ohms.

A resistance value test only should be performed on the stepper motors two coils. Do not apply 12VDC to these coils as it will damage the coils.

Check the resistance value of each coil between coil #1 (blue and red) and coil #2 (black and green).

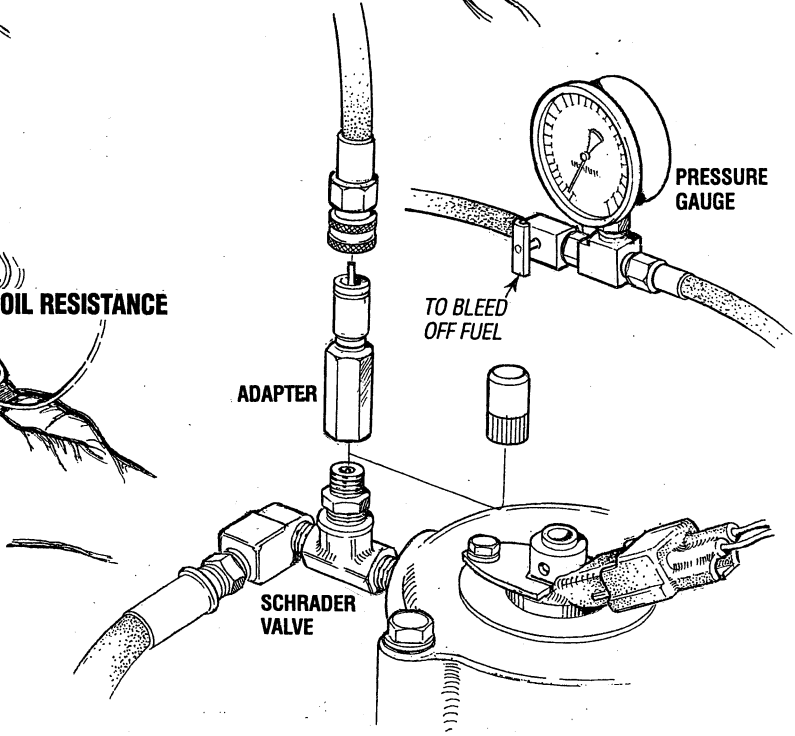
There should be no continuity found between any of the coil connectors and the metal case of the stepper body.





FUEL INJECTOR

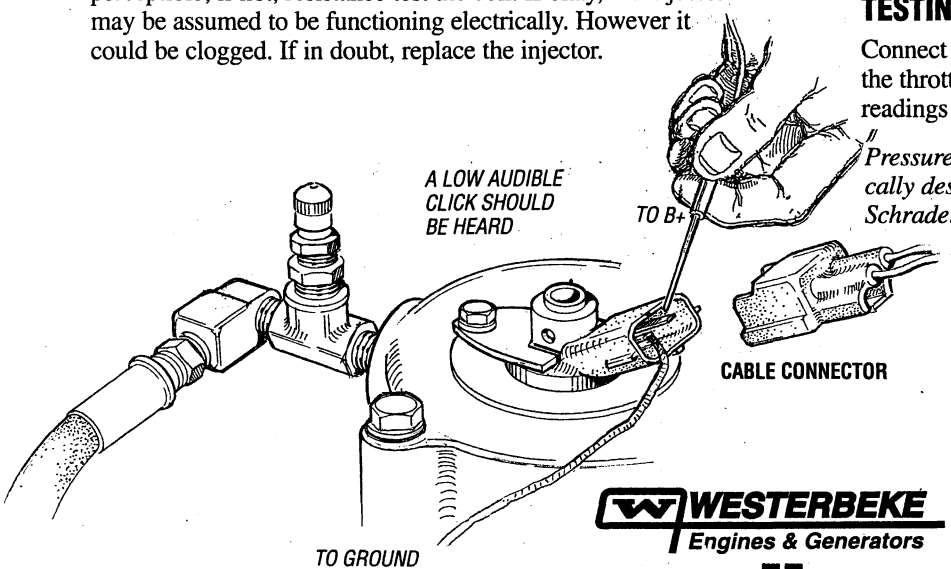
The fuel injector has no polarity and operates on 12 VDC. The coil resistance is typically in the order of 14 to 16 ohms. The positive wire to the injector is supplied power through the contacts of relay K2, which is off when the engine is not running. To test the injector, disconnect its cable connector and connect a ground wire to one of its input pins. Connect a wire from a point of B+ and repeatedly touch the other input pin. When touched, a low audible click should be perceptible; if not, resistance test the coil. If okay, the injector may be assumed to be functioning electrically. However it could be clogged. If in doubt, replace the injector.



TESTING SYSTEM FUEL PRESSURE

Connect a fuel pressure test gauge to the Schrader valve on the throttle body as shown and run the engine. Pressure readings should indicate 35 - 40 psi.

Pressure gauge kit MT 337B "SNAP -ON-TOOL" is specifically designed for fast accurate testing of fuel pressure for Schrader test ports.



COMPONENT TESTING

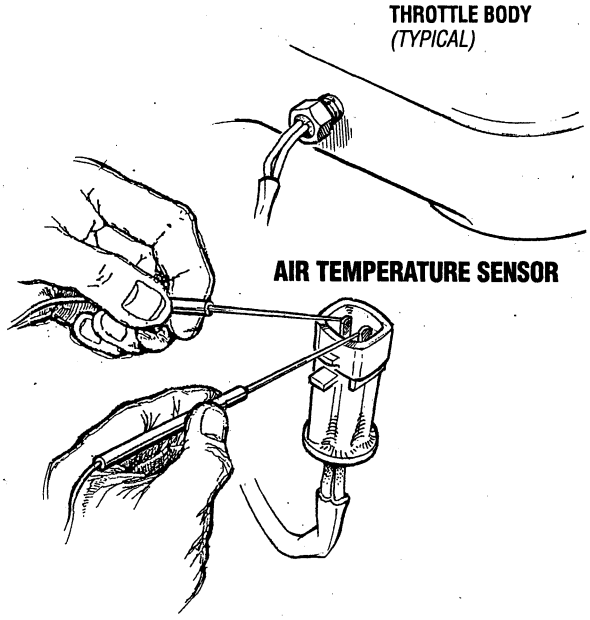
AIR, COOLANT, AND WATER HEATER TEMPERATURE SENSORS

These three sensors contain as their sensing elements identical negative temperature coefficient (NTC) thermistors whose internal resistance inversely changes to a change in temperature (i.e., temperature increase, resistance decrease). The thermistors nominal resistance value at 77° F (25° C) is 10,000 ohms. When the ECU is in an *on* state, the thermistors (–) lead is connected to ground, and its (+) lead is connected to the ECU and then through a fixed series 10,000 ohm resistor to the +5V power source. Therefore, the voltage at the thermistors (+) lead should be approximately +2.5 volts at a temperature of 77° F and decreases to a voltage of approximately +.25V at 220° F. The voltage – temperature relationship however, is not linear over this range and therefore it should only serve as an indicator that the thermistor is functioning.

Resistance Values (at room temperature)

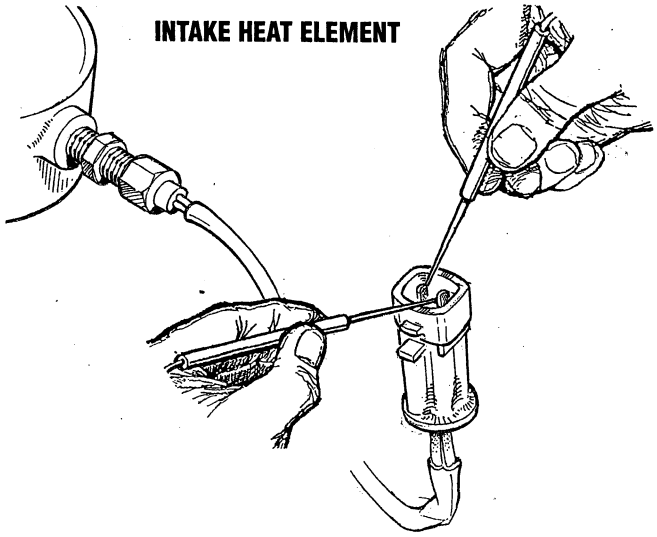
Air Temperature Sensor - 10,000Ω
Coolant Temperature Sensor - 10,000Ω

Generally, the thermistor may be assumed to be good if there is a perceptual resistance change for a corresponding temperature over the indicated range, otherwise replace the sensor.



INTAKE HEATER ELEMENT

An intake heater is located in the air inlet area of the throttle body on all four cylinder models. the heater operates to warm incoming air on a cold engine start and in adverse cold operating conditions.



Testing (static) the Heater Element

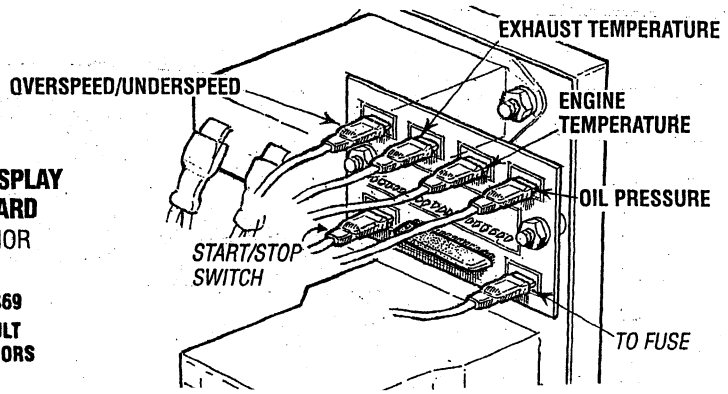
Unplug the heater from the engine harness. Put the ohmmeter probes across the two heater plug pin contacts.

Resistance Value 1.5 - 2.5 OHM (approximately)

There should be no continuity between either of the two pin contacts and the metal case of the element.

Overspeed shutdown

The ECU is monitoring engine rpm from an AC signal sent to it from the MPU (Magnetic Pick-up) positioned over the flywheel ring gear teeth. Should the engine speed cause the MPU to generate an AC voltage indicating an overspeed condition. The ECU will shut the engine down and illuminate the overspeed fault LED on the control panel. Likewise with an under-speed, the ECU will shut the unit down and the LED will flash.



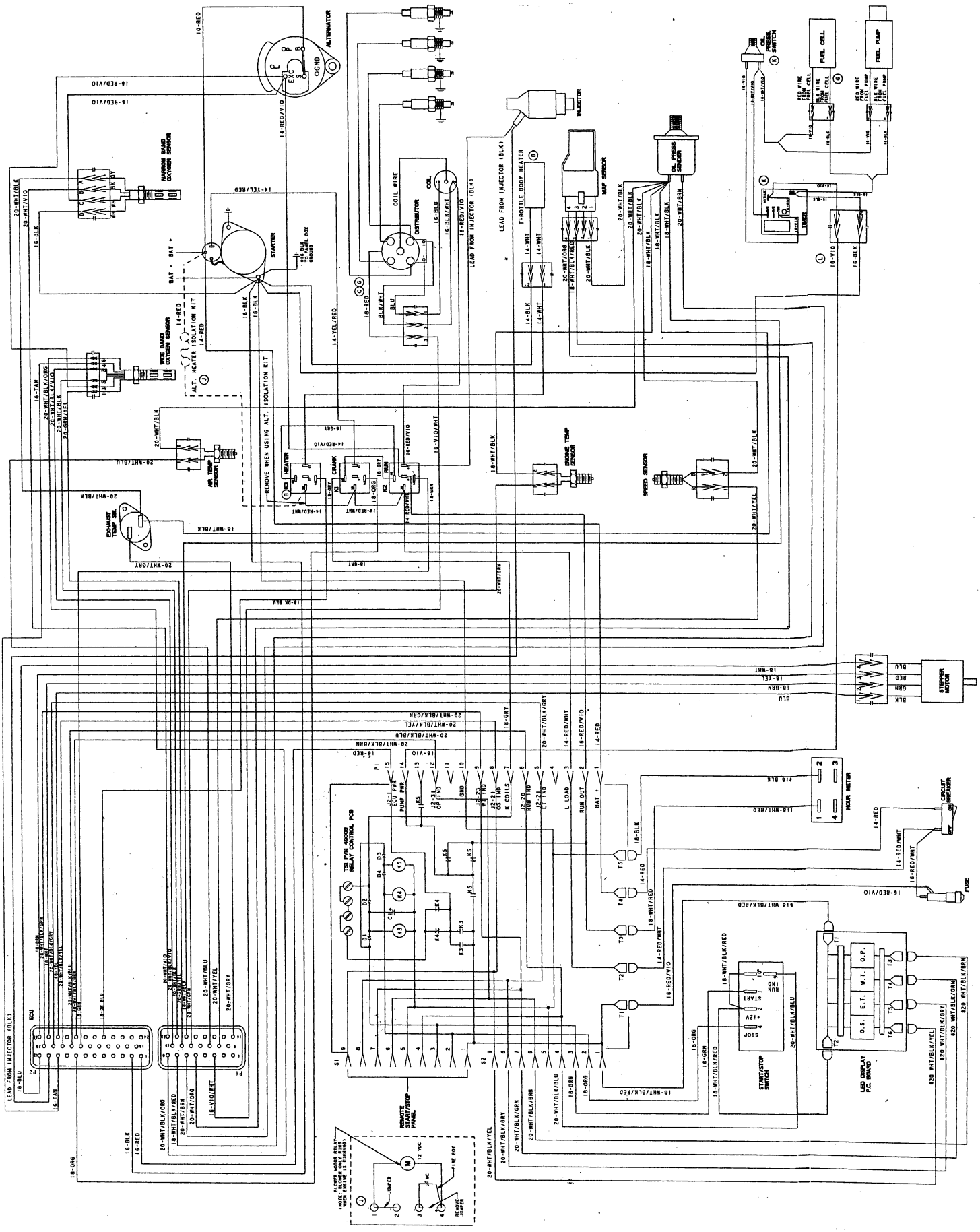
LED DISPLAY PC BOARD
(INTERIOR VIEW)
PN:045369
LED FAULT INDICATORS

EFI GENERATOR ELECTRICAL TESTING VALUES

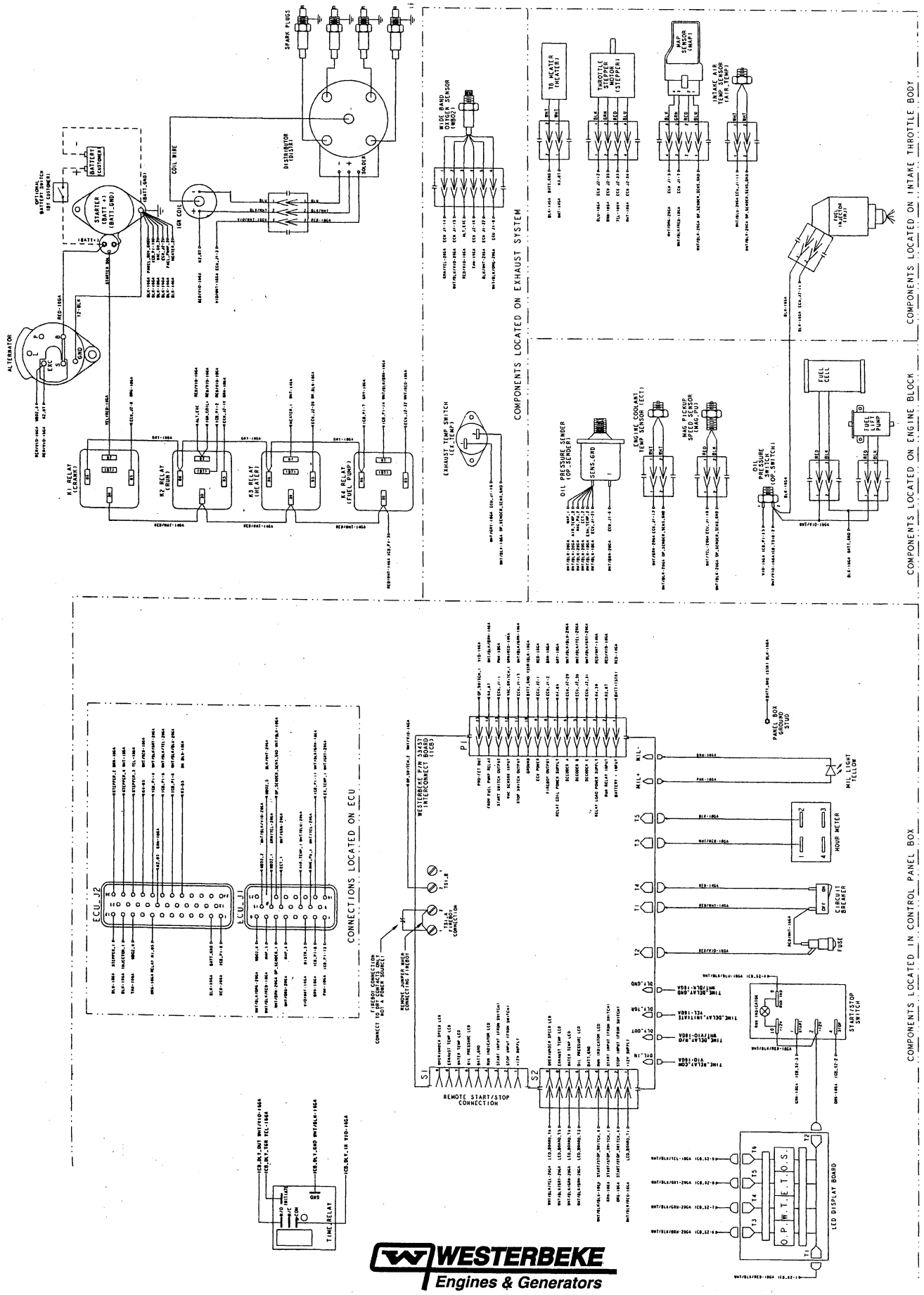
DEVICE AND CONDITION	GENERATOR MODELS			
	All Models	5.0/6.5Kw	8,10,12.5.14Kw	20/22Kw EFI
Speed Sensor-Voltage (while cranking) (AC Volts)		1.33	0.98	1.26
Speed Sensor-Resistance (at rest) (in Ohms)	950-1000Ω			
Distributor-Voltages (in AC volts)				
Red (ECU) and Black/White (+)		0.55	0.447	0.253
Red (ECU) and Blue (-)		0.44	0.44	0.177
Blue (-) and Black/White (+)		0	0	0
Black/White (+) and Engine Ground		0.072	0.011	0
Blue (-) and Engine Ground		0	0	0
Red (ECU) and Engine Ground		0.60	0.45	0.277
Distributor-Resistance (in Ohms)				
Red (ECU) and Black/White (+)	None (open)			
Red (ECU) and Blue (-)	None (open)			
Blue (-) and Black/White (+)	None (open)			
Black/White (+) and Engine Ground	None (open)			
Blue (-) and Engine Ground	None (open)			
Red (ECU) and Engine Ground	None (open)			
Map Sensor-Voltages (in DC Volts)				
Pin 4 (sig) to Ground (at rest)		0	0	0
Pin 4 (sig) to Ground (prime delay in start mode)		4.089	4.05	4.056
Pin 4 (sig) to Ground (running 1800 rpm no AC load)		1.73*	1.25*	1.300*
Pin 3 (+5V) to Ground (at rest)		0	0	0
Pin 3 (+5V) to Ground (prime delay in start mode)		4.997	4.997	4.999
Pin 3 (+5V) to Ground (running 1800 rpm no AC load)		5.005*	5.003*	5.014*
Map Sensor-Resistance (in Ohms)				
Pin 1 (grnd) to Pin 2	1.9Ω			
Pin 1 (grnd) to Pin 3	5.9Ω			
Pin 1 (grnd) to Pin 4	5.3Ω			
Intake Heater Element in Ohms	1.5 - 2.5Ω			
Air Temperature Sensor (room temp.)in Ohms	10,000Ω			
Water Temperature Sensor (room temp.)in Ohms	10,000Ω			
Oil Pressure Sensor (at rest)in Ohms	245Ω			
Stepper Motor (at rest)in Ohms				
Black and Green	2.61Ω			
Red and Blue	2.61Ω			
Stepper Motor-Resistance (in Ohms)				
Purple: Part #42221				14.55Ω
Blue: Part #48921			14.55Ω	
Black: Part #49556		12.50Ω		
K1, 2, or 3 Relay (between terminal 86 and 86)in Ohms			86Ω	86Ω
Mando Alternator-part #39139 (in DC Volts)				
B+ (typical at rest)			12.7	12.7
B+ (typical while running)			14.1	14.5
At Excitation (typical while running)			13.4	13.6
At Excitation (at rest)			0	0
Fuel Pump in Ohms				
Low Pressure	1.5 - 2.0Ω			
High Pressure	9.0 - 13.0Ω			

Note: * Approximate Voltages

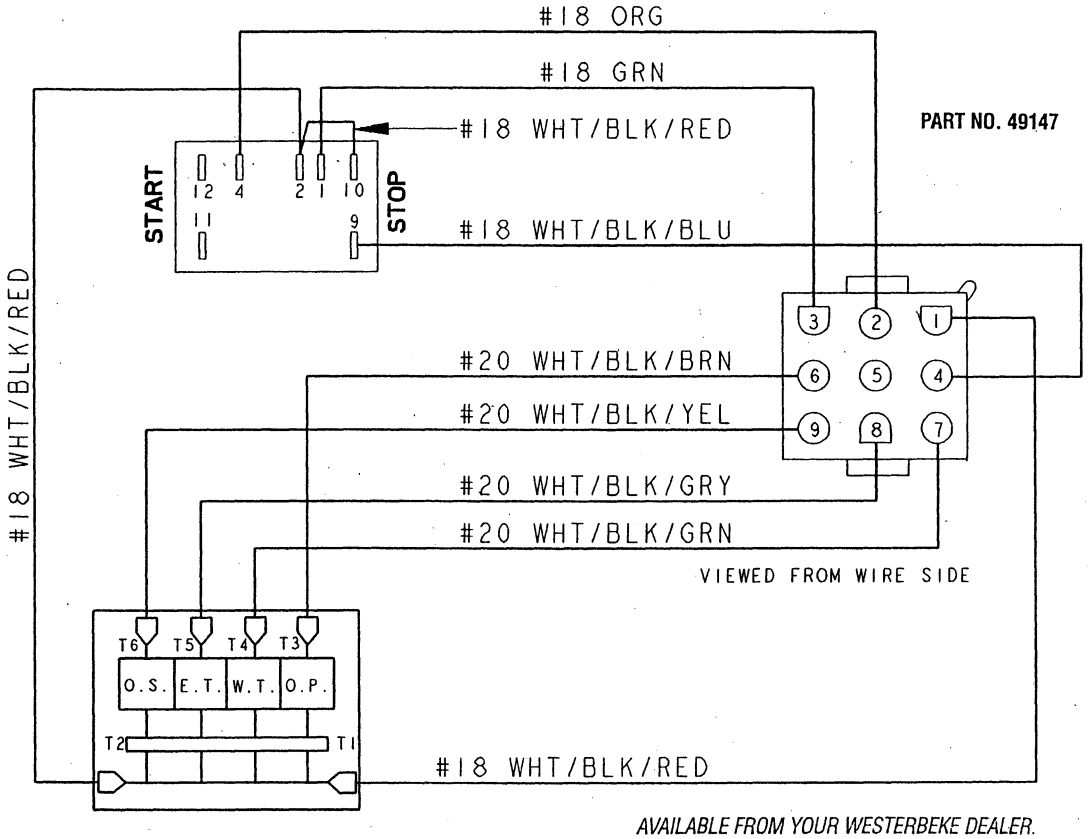
20KW and 22.5KW SBEG GENERATOR
WIRING DIAGRAM #49232



20KW AND 22.5KW SBEGA GENERATOR
WIRING DIAGRAM #53467

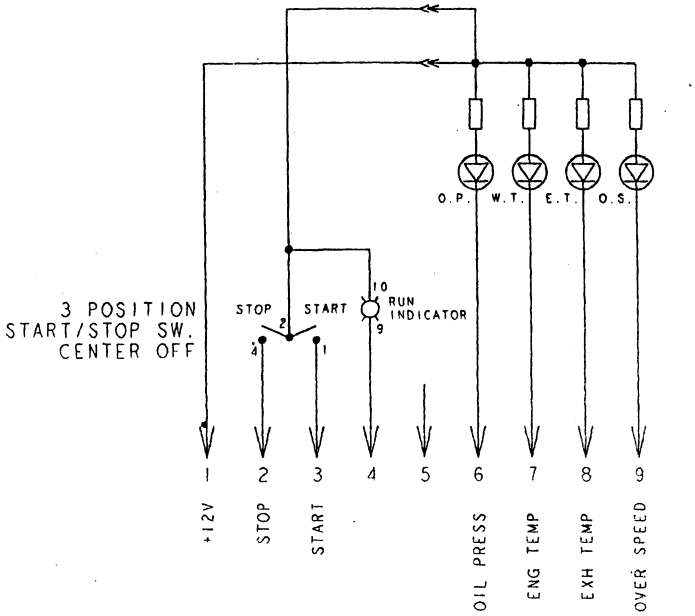


REMOTE START/STOP PANEL WIRING
SCHEMATIC #49209



AVAILABLE FROM YOUR WESTERBEKE DEALER.
WIRING HARNESS EXTENSIONS:

15 FT. PART NO. 49201
30 FT. PART NO. 49211
50 FT. PART NO. 49667
75 FT. PART NO. 49668
100 FT. PART NO. 49669



GENERATOR INFORMATION

USE OF ELECTRIC MOTORS

The power required to start an electric motor is considerably more than is required to keep it running after it is started. Some motors require much more current to start them than others. Split-phase (AC) motors require more current to start, under similar circumstances, than other types. They are commonly used on easy-starting loads, such as washing machines, or where loads are applied after the motor is started, such as small power tools. Because they require 5 to 7 times as much current to start as to run, their use should be avoided, whenever possible, if the electric motor is to be driven by a small generator. Capacitor and repulsion-induction motors require from 2 to 4 times as much current to start as to run. The current required to start any motor varies with the load connected to it. An electric motor connected to an air compressor, for example, will require more current than a motor to which no load is connected.

In general, the current required to start 115-Volt motors connected to medium starting loads will be approximately as follows:

MOTOR SIZE (HP)	AMPS FOR RUNNING (AMPERES)	AMPS FOR STARTING (AMPERES)
1/6	3.2	6.4 to 22.4*
1/4	4.6	9.2 to 32.2*
1/3	5.2	10.4 to 72.8*
1/2	7.2	14.4 to 29.2*
3/4	10.2	20.4 to 40.8*
1	13	26 to 52

***NOTE:** In the above table the maximum Amps for Starting is more for some small motors than for larger ones. The reason for this is that the hardest starting types (split-phase) are not made in larger sizes.*

Because the heavy surge of current needed for starting motors is required for only an instant, the generator will not be damaged if it can bring the motor up to speed in a few seconds. If difficulty is experienced in starting motors, turn off all other electrical loads and, if possible, reduce the load on the electric motor.

REQUIRED OPERATING SPEED

Run the generator first with no load applied, then at half the generator's capacity, and finally loaded to its full capacity as indicted on the generator's data plate. The output voltage should be checked periodically to ensure proper operation of the generating plant and the appliances it supplies. If an AC voltmeter or amp meter is not installed to monitor voltage and load, check it with a portable meter and amp probe.

NOTE: *When the vessel in which the generator is installed contains AC equipment of 120 volts only, it is recommended that the generator's AC terminal block be configured to provide one 120 volt AC hot leg for the vessel's distribution panel. This will ensure good motor starting response from the generator.*

Generator Maintenance

- Maintaining reasonable cleanliness is important. Connections of terminal boards and rectifiers may become corroded, and insulation surfaces may start conducting if salts, dust, engine exhaust, carbon, etc. are allowed to build up. Clogged ventilation openings may cause excessive heating and reduced life of windings.
- For unusually severe conditions, thin rust-inhibiting petroleum-base coatings should be sprayed or brushed over all surfaces to reduce rusting and corrosion.
- In addition to periodic cleaning, the generator should be inspected for tightness of all connections, evidence of overheated terminals and loose or damaged wires.
- The drive discs on single bearing generators should be checked periodically if possible for tightness of screws and for any evidence of incipient cracking failure. Discs should not be allowed to become rusty because rust may accelerate cracking. The bolts which fasten the drive disc to the generator shaft must be hardened steel SAE grade 8, identified by 6 radial marks, one at each of the 6 corners of the head.
- The rear armature bearing is lubricated and sealed; no maintenance is required. However, if the bearing becomes noisy or rough-sounding, have it replaced.
- Examine bearing at periodic intervals. No side movement of shaft should be detected when force is applied. If side motion is detectable, inspect the bearing and shaft for wear. Repair must be made quickly or major components will rub and cause major damage to generator.

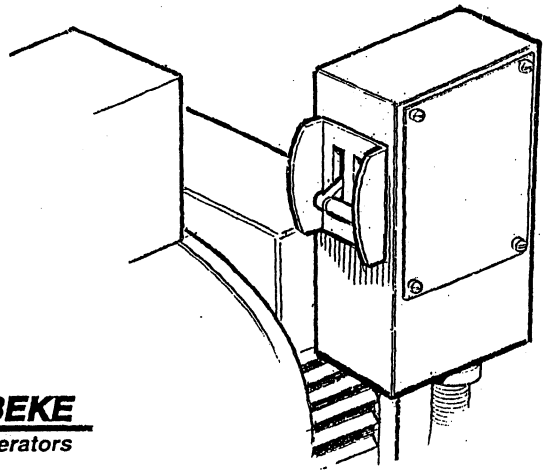
AC CIRCUIT BREAKER

The AC Breaker is mounted on the control box. This is where the AC connections from the ships service connect to the generators AC output. The breaker helps protect the generator from an amperage overload. Should an overload occur, the breaker will trip, disconnecting the AC amperage load from the vessel. The breaker must be manually re-set to re-connect the ships service.

Disconnect this breaker when performing maintenance/repair to the generator.

Breaker Part no.

20Kw.....#042300 *22.5Kw.....#039493*
16Kw.....#042718 *18Kw.....#052606*



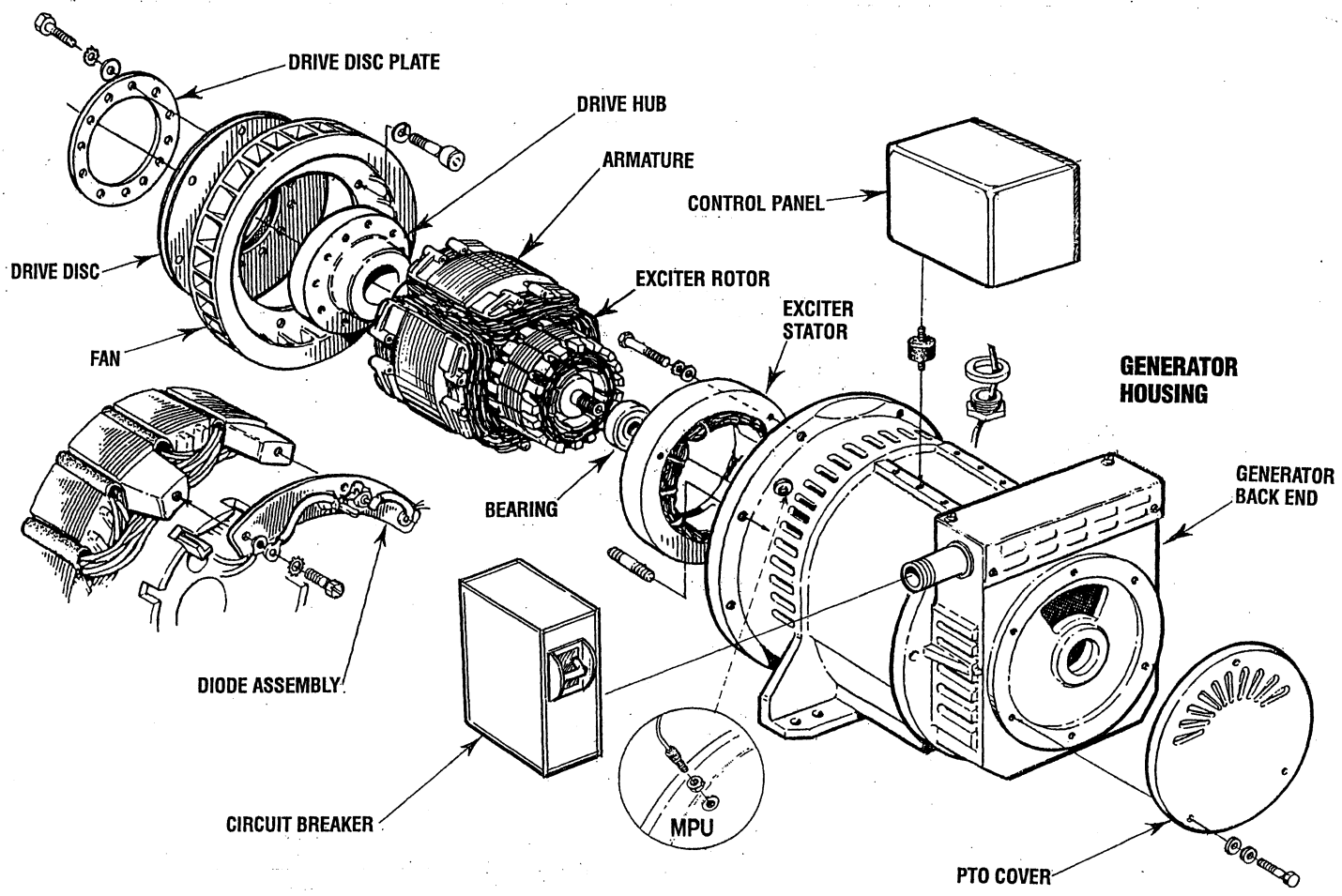
THE SBEG GENERATOR
SINGLE AND THREE PHASE

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 excitor rotor windings during rotation. Diodes located in the exciter rotor rectify this voltage to DÇ 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 maintain a constant voltage output.

CIRCUIT BREAKER

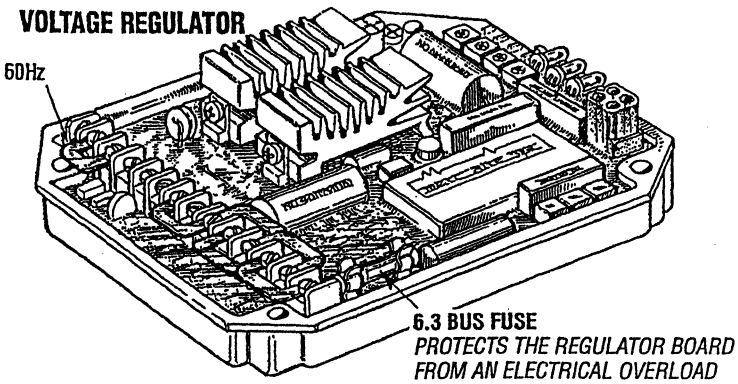
A circuit breaker is installed on all WESTERBEKE generators. This circuit breaker will automatically disconnect generator power in case of an electrical overload. The circuit breaker can be manually shut off when servicing the generator to ensure that no power is coming into the boat.



VOLTAGE REGULATOR ADJUSTMENTS

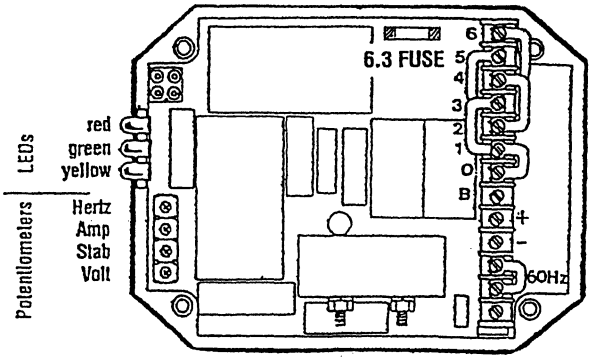
Description

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.



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 screw-driver) fully in a counter clockwise (Minimum) direction until you feel them hit their stops. Turn the AMP and HERTZ trimmers completely clockwise (Maximum) in the same manner. With the generator running at no-load, at normal speed, and with VOLT adjust at minimum, it is possible that output voltage will oscillate. Slowly rotate the VOLT adjust clockwise. The voltage output of the alternator will increase and stabilize. Increase the voltage to the desired value. In this situation, only the green LED will stay lit.



VOLTAGE REGULATOR DIAGRAM

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.

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.

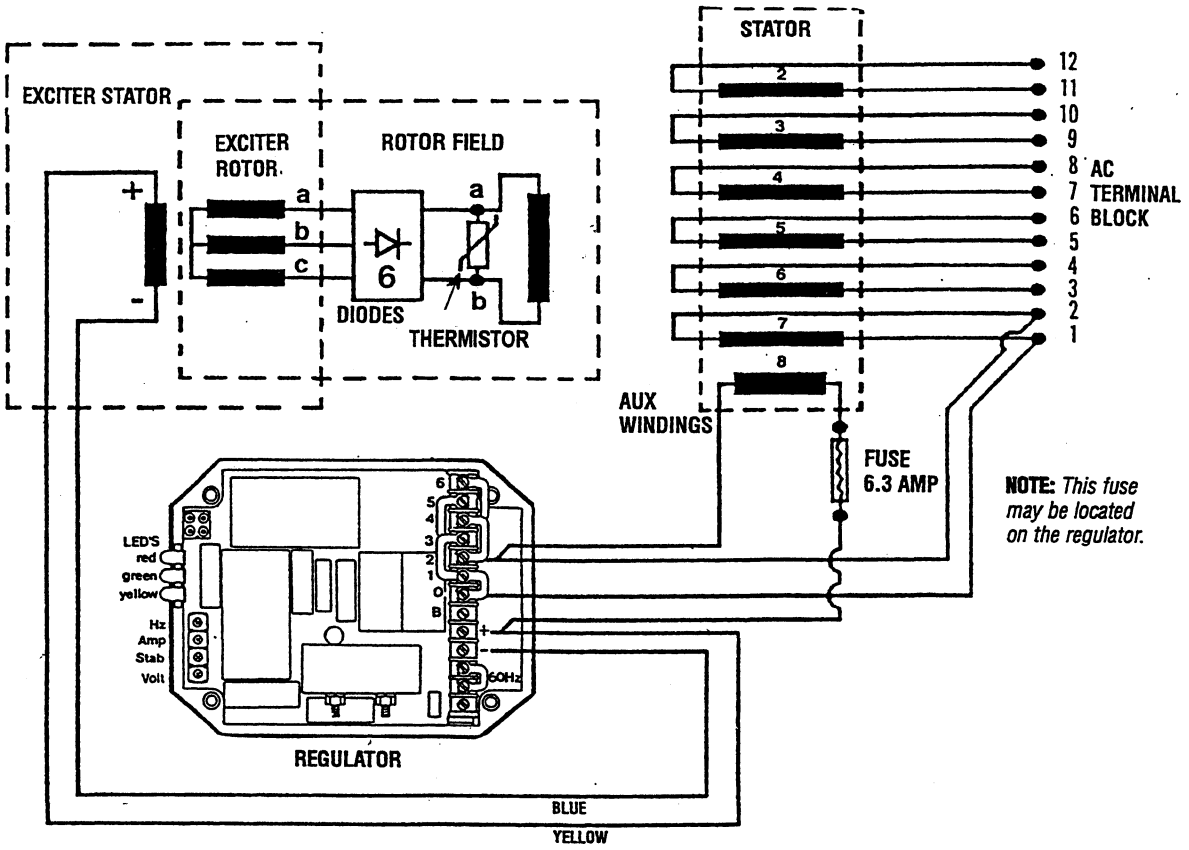
1. Delayed overload protection (yellow LED).
2. Low speed protection (red LED).

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.

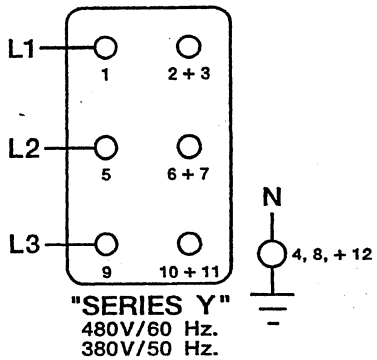
INTERNAL WIRING SCHEMATICS

3 PHASE TWELVE WIRE RECONNECTABLE

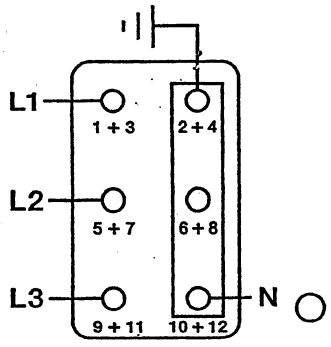


AC VOLTAGE CONNECTIONS

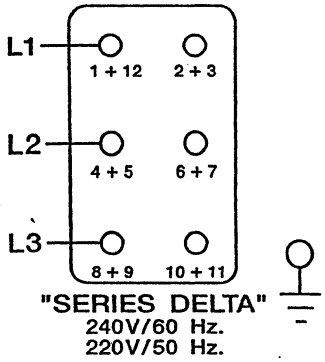
NOTE: IF WIRING FOR 50 HZ., THE 60 HZ. JUMPER MUST BE REMOVED FROM THE REGULATOR.



"SERIES Y"
480V/60 Hz.
380V/50 Hz.

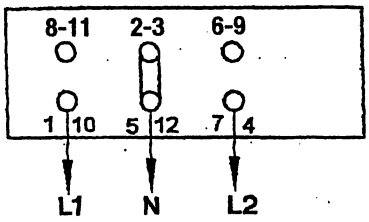


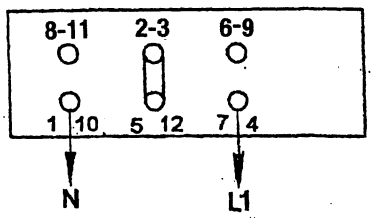
"PARALLEL Y"
208V-120V/60 Hz.



"SERIES DELTA"
240V/60 Hz.
220V/50 Hz.

"DOUBLE DELTA"
3 WIRE
120-240V/60Hz
115-230V/50Hz





"DOUBLE DELTA"
2 WIRE
240V/60Hz
230V/50Hz

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 **Thermistor** 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.	

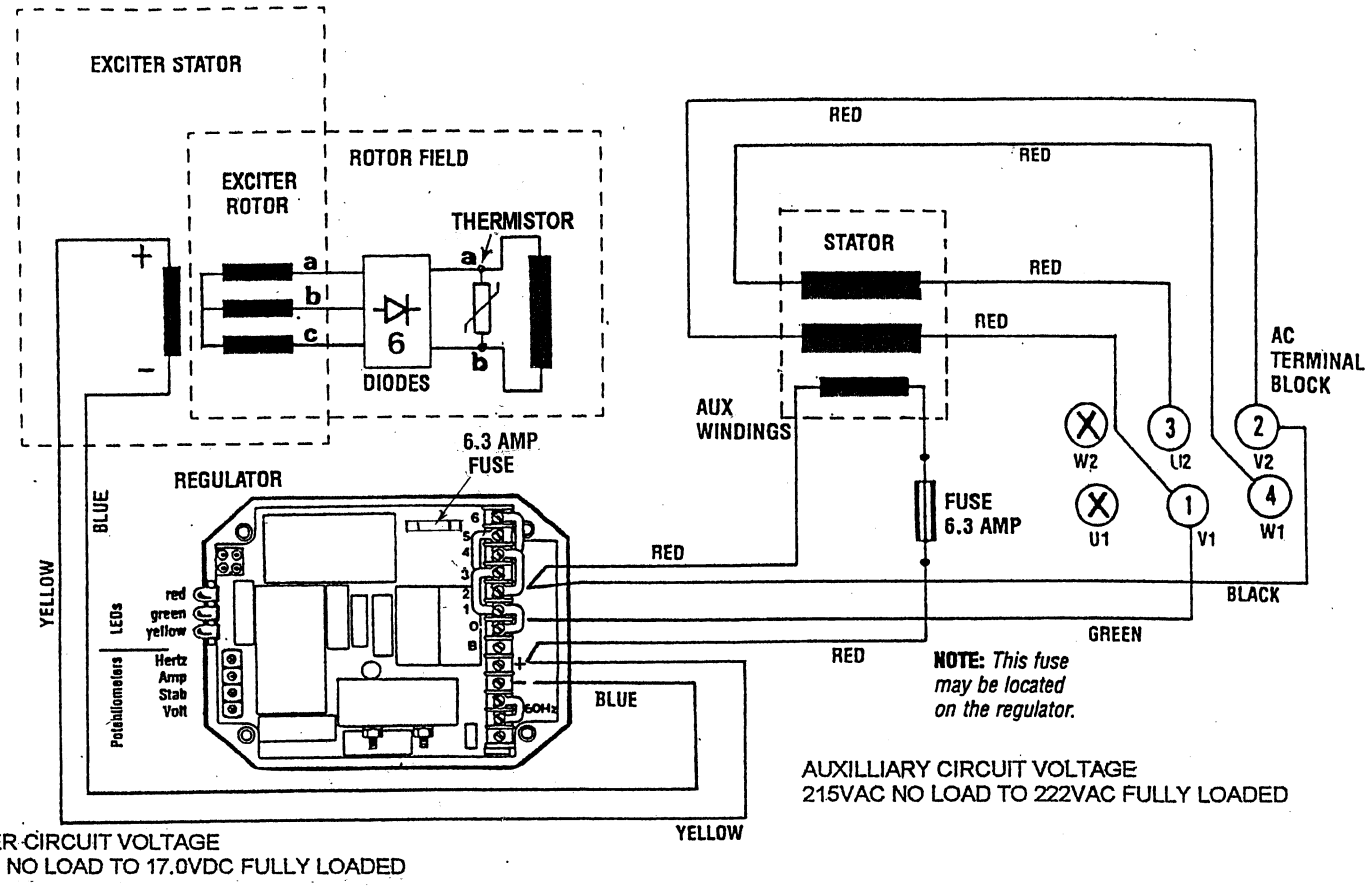
BE GENERATOR WINDING RESISTANCE VALUES *(IN OHMS)*

SINGLE PHASE		20 & 22.5
EXCITER STATOR		*18.06*
EXCITER ROTOR	a - b	*0.68*
	b - c	*0.68*
ROTATING FIELD		*1.75*
MAIN STATOR	1 - 2	*0.05*
	3 - 4	*0.05*
AUXILLARY WINDING		*1.19*

THREE PHASE		20 & 22.5
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*

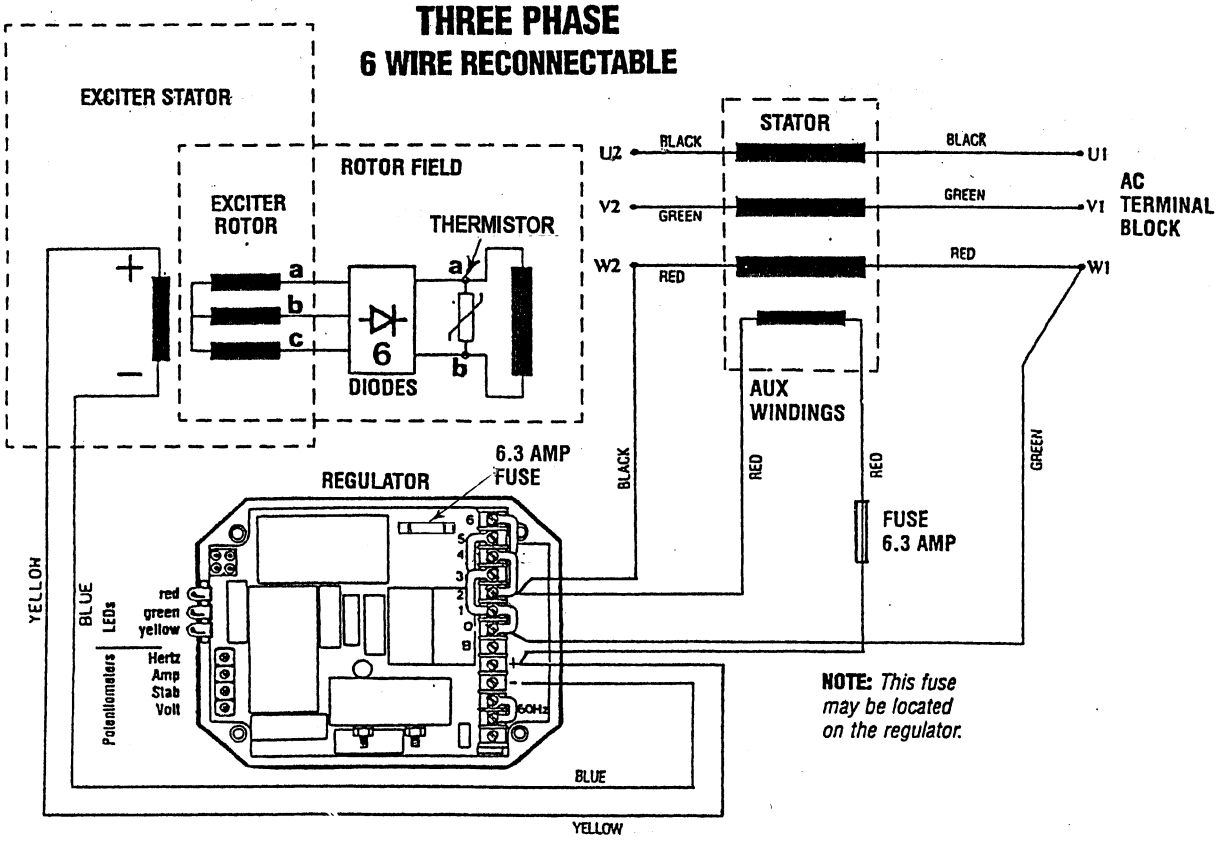
INTERNAL WIRING SCHEMATICS

SINGLE PHASE



THREE PHASE

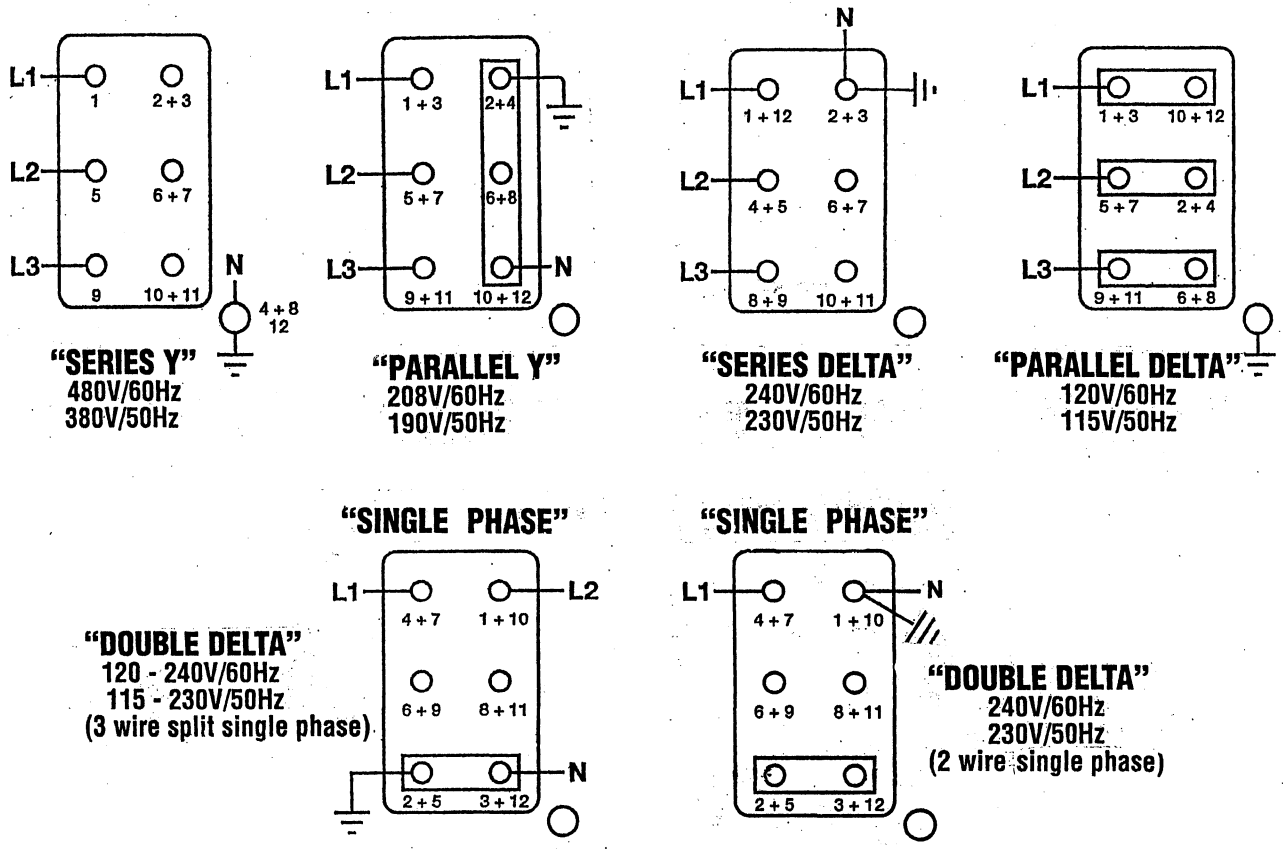
6 WIRE RECONNECTABLE



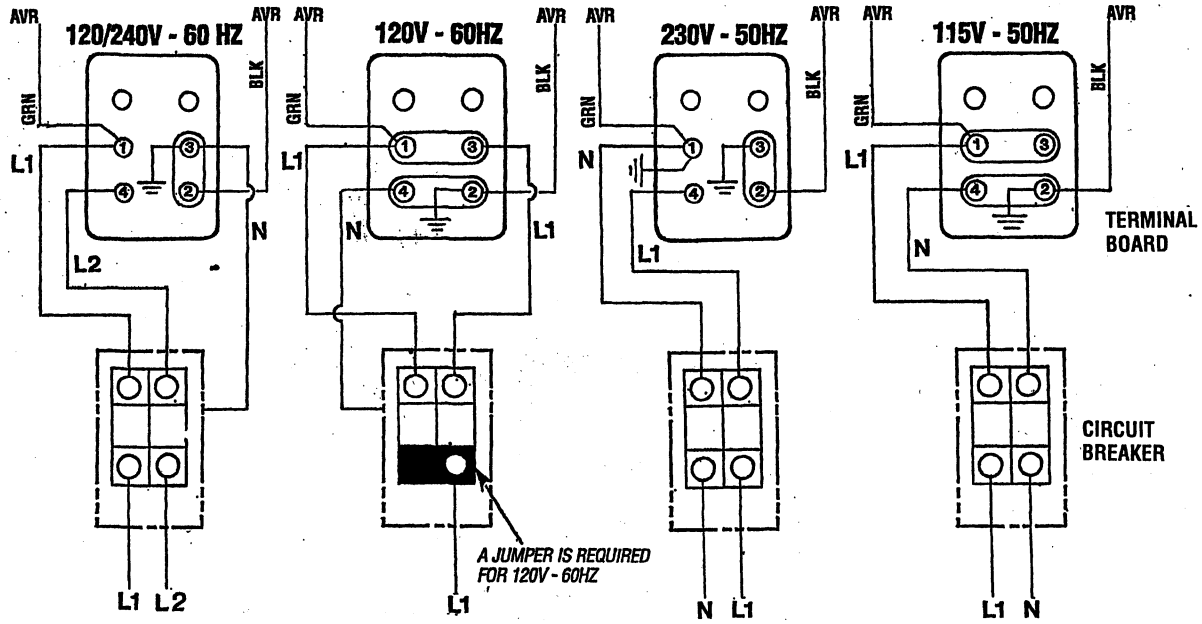
GENERATOR AC VOLTAGE CONNECTIONS

BE THREE PHASE 6 STUD / 12 WIRE TERMINAL BLOCKS

NOTE: *For output leads from the AC terminal block used terminal ends for 1/4" studs that accept multi-strand copper wire sized for the average rating from the hot lead connection.*



GENERATOR AC VOLTAGE CONNECTIONS BE SINGLE PHASE



GENERATOR AC VOLTAGE CONNECTIONS

AC VOLTAGE CONNECTIONS

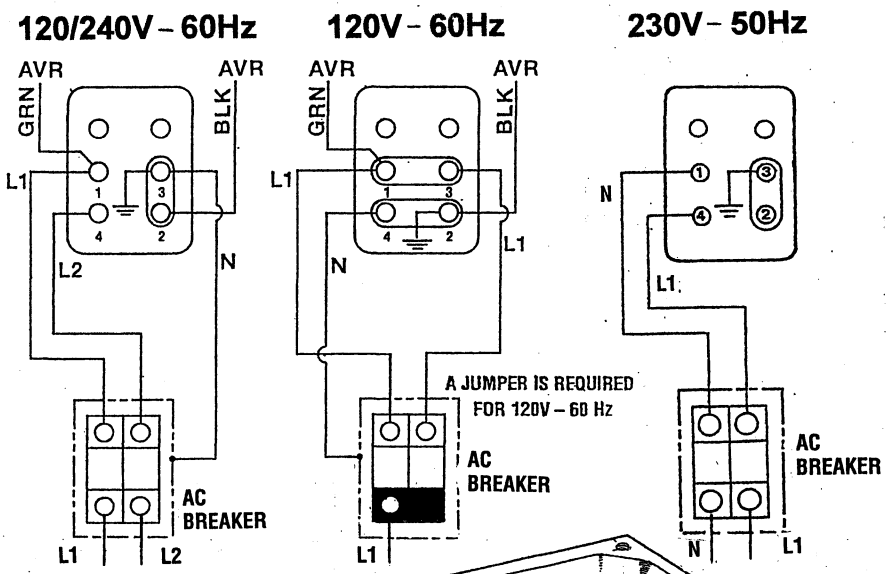
NOTE: The frame ground wire (white/green) must be properly positioned when changing the AC output configuration of the AC terminal block. For making connections to the AC terminal block, use terminal ends for 1/4 inch studs that will accept multi strand copper wire sized for the amperage rating from 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

Frequency is a direct result of engine/generator speed: 1800 rpm = 60 hertz; 1500 rmp = 50 hertz.

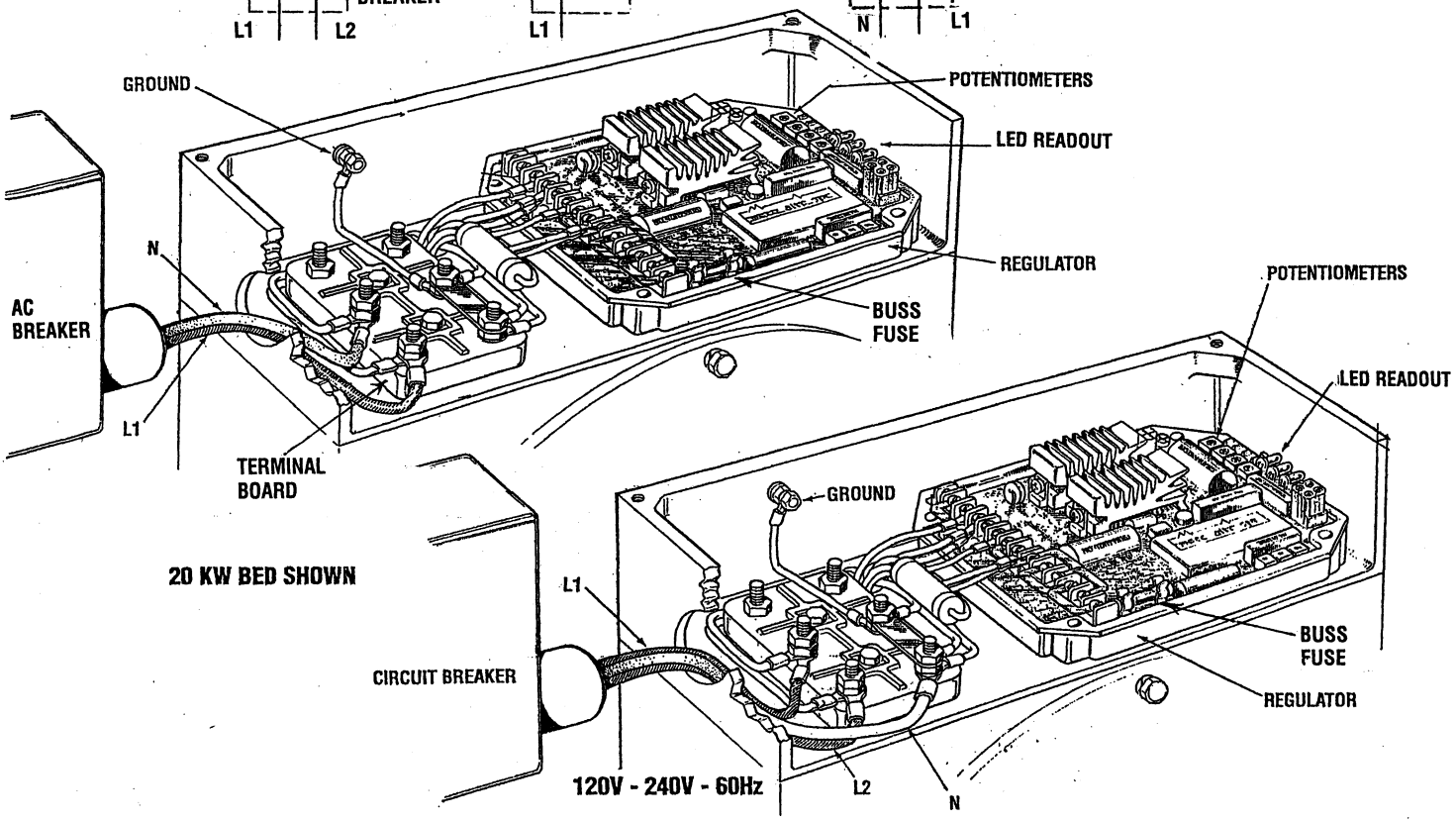
NOTE: *The white/green ground wire may be removed in those installations where the AC circuit has a separate neutral and ground circuit. This will prevent the unit from being a ground source in the vessel.*

BE SINGLE PHASE



SBEG AC BREAKERS PART NUMBERS

20.0 KW	#042300
16.0 KW	#042718
22.5 KW	#039493
18.7 KW	#052606

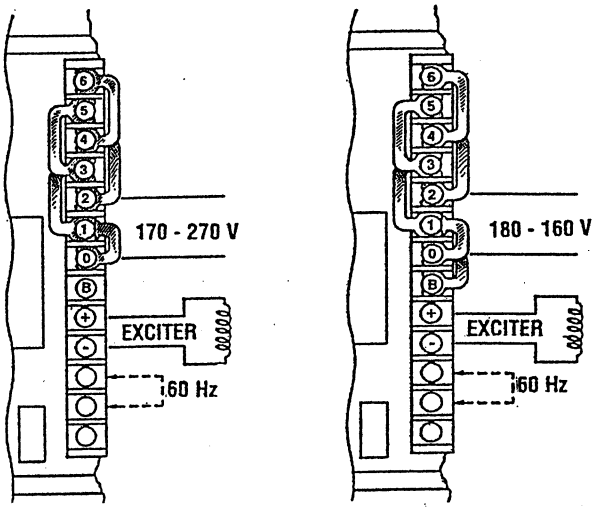


GENERATOR AC VOLTAGE CONNECTIONS

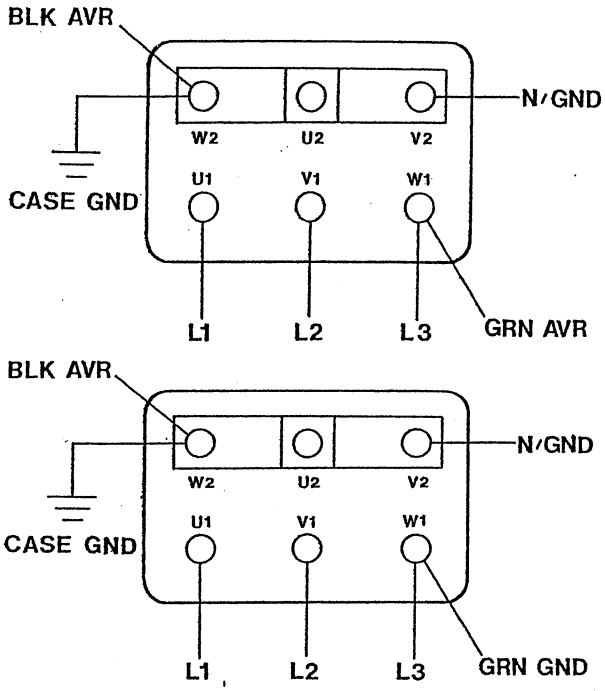
DESCRIPTION

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.*

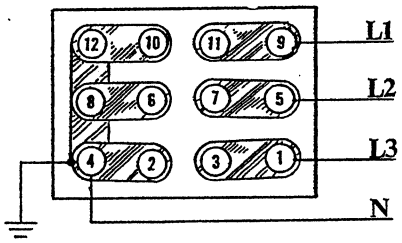


3 PHASE VOLTAGE REGULATOR



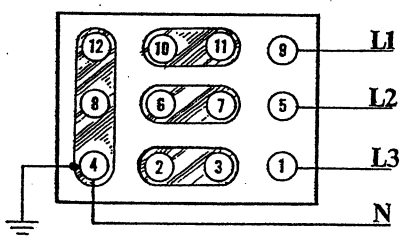
BE THREE PHASE (SIX WIRE)

PARALLEL WYE (STAR)



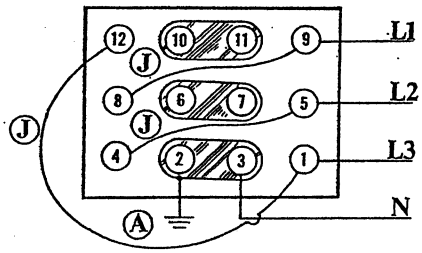
L-N – 120 VAC 1Ø 60 Hz
L-N – 110 VAC 1Ø 60 Hz

SERIES WYE (STAR)



L-L – 450 VAC 3Ø 60 Hz
L-N – 265 VAC 1Ø 60 Hz

SERIES DELTA



L-L – 240 VAC 3Ø 60 Hz
L2, L3-N – 120 VAC 1Ø 60 Hz

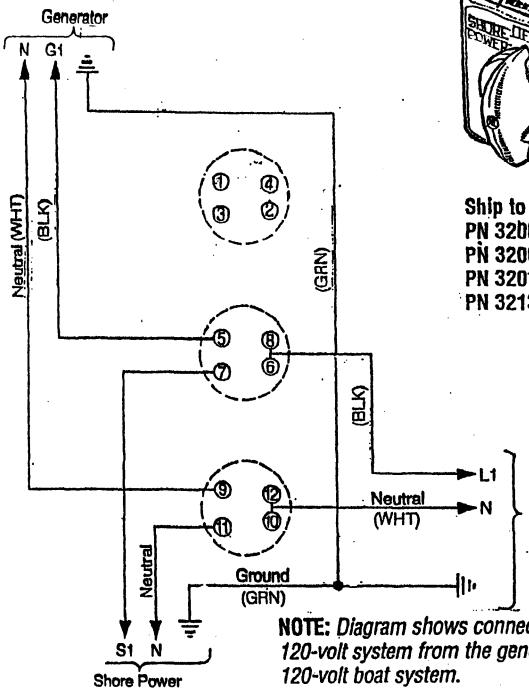
BE THREE PHASE (TWELVE WIRE)

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

SINGLE LINE 120 VOLT SYSTEM



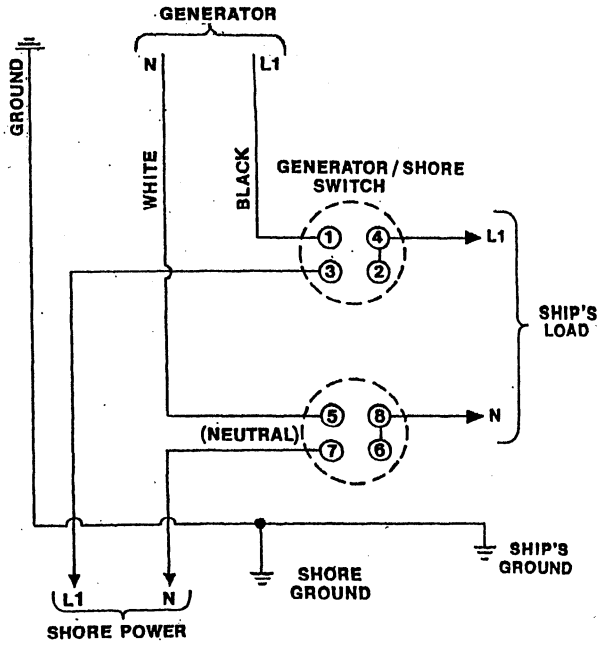
NOTE: *Diagram shows connections for a two wire, 120-volt system from the generator with three wire, 120-volt boat system.*

Ship to Shore Switch (3 Pole)
PN 32008 40 Amps/Pole
PN 32009 80 Amps/Pole
PN 32010 125 Amps/Pole
PN 32133 200 Amps/Pole

NOTE: *Ship to shore switches are available at your WESTERBEKE dealer.*

230 VOLT/50 HERTZ TWO WIRE CONFIGURATION

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



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.

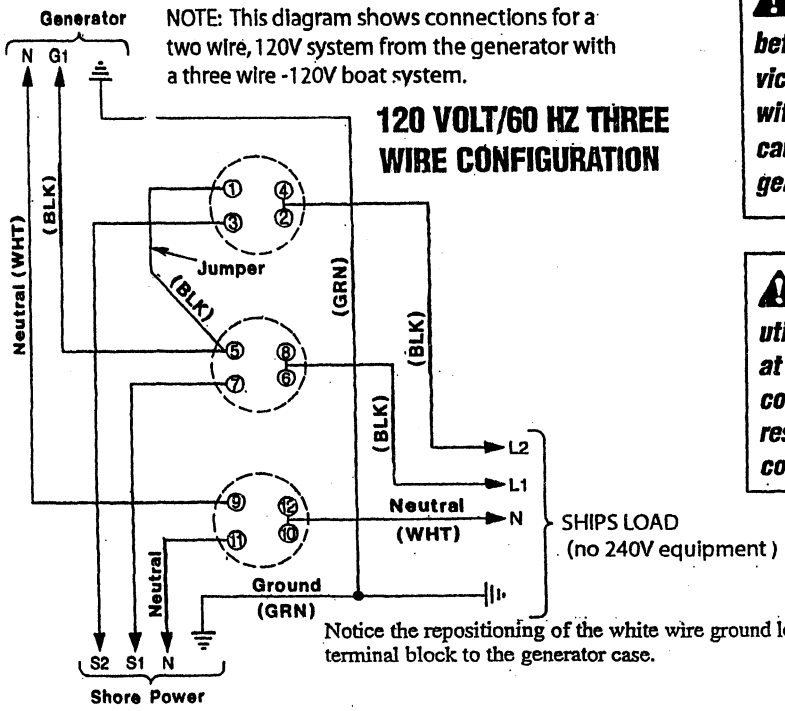
Switching Shore Power to Generator Power

⚠ 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.***

⚠ 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.***

NOTE: This diagram shows connections for a two wire, 120V system from the generator with a three wire -120V boat system.

120 VOLT/60 HZ THREE WIRE CONFIGURATION



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

EXHAUST SYSTEM MAINTENANCE

DESCRIPTION

The catalyst is critical to minimizing exhaust emissions like CO. Any water intrusion into the engine's exhaust system will likely quickly compromise the proper operation of the catalyst.

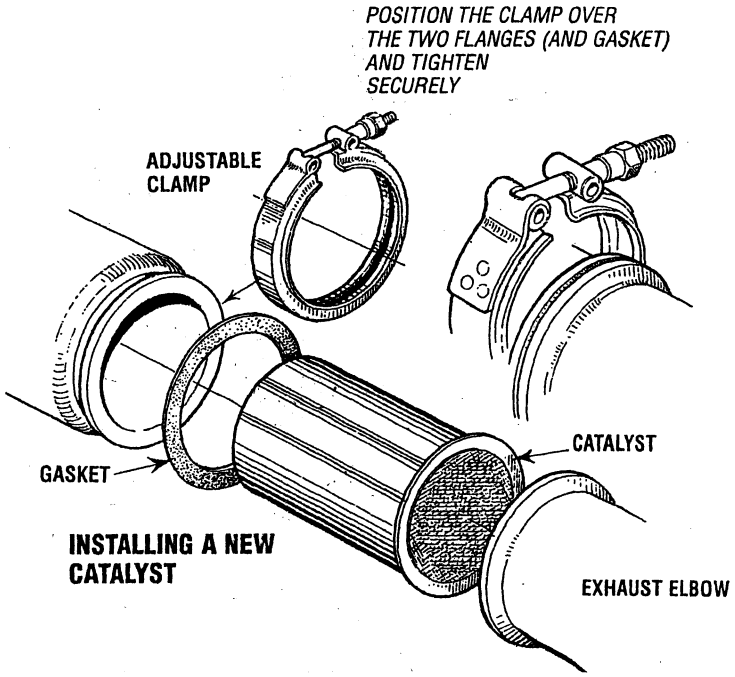
Westerbeke's exhaust system installation instructions dated July 2013 must be adhered to.

NOTE: *Water intrusion is not a product defect and is not covered under warranty, neither Westerbeke's normal product warranty nor the emissions specific warranty mandated by various regulating authorities such as EPA and CARB.*

INSPECTION

Maintenance of any components affecting the flow of air into the engine or the flow of fuel to the engine is critically important. Fuel filters, air filters, flame arrester screens MUST be properly maintained.

Inspection of the catalyst at the prescribed intervals is critically important. The exhaust elbow is removed by loosening the metal clamp to provide a view of the output surface of the catalyst. Any visual irregularity of the normal flush, honeycomb appearance is most likely a result of water intrusion. The cause of the irregularity must be identified and addressed. If there is irregularity, the catalyst and sealing gasket must be replaced. The water injected exhaust elbow casting must be inspected also for corrosion and replaced as needed. Upon careful reassembly of the catalyst, new sealing gasket, and exhaust elbow, check for the presence of CO while the engine is running. This must be performed with a CO analyzer.



NOTE: *The exhaust temperature switch should always be attached to the upper most mounting of the two available on the elbow.*

ENGINE TROUBLESHOOTING

The following troubleshooting tables are based upon certain engine problem indicators and the most likely causes of the problems.

When troubleshooting indicates an electrical problem, see the *ELECTRICAL SYSTEM WIRING DIAGRAM* as these may reveal other possible causes of the problem which are not listed below.

NOTE: *The engines control system (electrical system) is protected by a 8 Ampere manual fuse located on the control panel. The generator has an AC circuit breaker at the control panel which should be in the off position when performing troubleshooting.*

CAUTION: When servicing or replacing DC components, turn off the 20 amp DC circuit breaker.

PROBLEM	PROBABLE CAUSE
Engine does not crank.	1. Voltage drop at starter solenoid terminal. 2. Engine circuit breaker has tripped. 3. 8 amp fuse/holder is faulty. 4. Battery is low or dead. 5. Loose battery connections. 6. Faulty wire connection. 7. Faulty start switch. 8. Faulty starter relay. 9. Faulty starter solenoid. 10. Raw water filled cylinders.
Engine starts, runs but then shuts down.	1. Faulty shutdown switch. (oil pressure, coolant or exhaust temperature). 2. Dirty fuel/water separator filter. 3. Faulty speed sensor. 4. Low oil level in sump. 5. Faulty fuel pump. 6. High engine water or exhaust temperature. 7. Air in the fuel system.
Engine starts, runs but does not come up to speed.	1. Faulty mag. pick-up sensor. 2. ECU faulty. 3. Fuel pump. 4. Fuel supply to engine restricted. 5. Throttle actuator binding. 6. Actuator or electrical connections faulty. 7. AC generator overload./short. 8. Air intake restricted. 9. Exhaust restricted. 10. Air in fuel system.

PROBLEM	PROBABLE CAUSE
Engine cranks but fails to start.	1. Out of fuel. 2. Bad ignition coil. 3. Faulty spark plug. 4. Unplugged distributor wire. 5. Faulty electrical connection. 6. Air in the fuel system.
Engine hunts.	1. ECU gain adjustment needed. 2. Faulty fuel pump. 3. Mag. pick-up sensor needs adjustment. 4. Low DC battery voltage. 5. Generator overload. 6. Valves need adjustment.
Engine misfires.	1. Poor quality fuel. (lower than 89). 2. Incorrect timing. 3. Dirty flame arrester. 4. Cracked distributor cap. 5. Faulty ignition wires. 6. Throttle actuator linkage binding. 7. High exhaust back-pressure. 8. Valve clearances are incorrect.
Engine backfires.	1. Spark plug wires are connected wrong. 2. Incorrect timing. 3. Dirty flame arrester. 4. Cracked distributor cap. 5. High exhaust back-pressure.
Engine overheats.	1. Coolant loss. Pressure test cooling system. Refill. 2. Faulty raw water pump impeller. 3. Belts are loose or broken. 4. Raw water pump worn. 5. Faulty thermostat. 6. Heat exchanger restricted.

ENGINE TROUBLESHOOTING

PROBLEM	PROBABLE CAUSE
Low oil pressure.	1. Low oil level. 2. Wrong SAE type oil in the engine. 3. Faulty or wrong type oil filter. 4. Relief valve is stuck. 5. Faulty oil pump. 6. Faulty engine bearings. 7. Faulty oil filter.
High oil pressure.	1. Dirty oil or wrong SAE type oil in the engine. 2. Relief valve is stuck.
No DC charge to the starting battery.	1. Loose/corroded battery charge circuit connection(s). 2. Faulty alternator regulator. 3. Faulty DC alternator. 4. Slipping alternator drive belt. 5. Broken alternator drive belt.

PROBLEM	PROBABLE CAUSE
Blue exhaust smoke discharge from the engine.	1. Lube oil is diluted. 2. High lube oil level. 3. Crankcase breather hose is clogged. 4. Valves are worn or adjusted incorrectly. 5. Piston rings are worn or unseated.
Black exhaust smoke discharge from the engine.	1. Dirty flame arrester. 2. Lube oil is diluted. 3. Valves are worn or incorrectly adjusted. 4. Piston rings are worn or unseated. 5. Cankcase breather hose is clogged.
Poor Performance at generator speed.	1. Fuel pump clogged. Remove and replace. 2. Throttle body filter screen dirty. 3. Fuel filter contaminated.

CHECK ENGINE LIGHT (YELLOW)

When the **Check Engine Light** is illuminated, the PC Interface Diagnostics will indicate the problem.

NOTE: *To properly troubleshoot the **Check Engine Light**, the PC Interface Diagnostics MUST be used to properly determine the fault cause.*

PROBLEM	PROBABLE CAUSE
WideBand O^2 Sensor.	1. Sensor Failure. 2. Sensor wiring issue.
Crossing Stoich.	1. Sensor failure. 2. Sensor wiring issue. 3. Air intake obstructed.
O^2 Sensor out of range.	1. Air intake obstructed.

NOTE: *To extinguish the **Check Engine Light** once the fault is corrected. The unit must be put through three (3) consecutive successful start and stop sequences, each having a run period of approximately four (4) running minutes.*

If your models are OBDI (on board diagnostics) utilize the diagnostics found in the Diagnostic Software Kit #055410 to properly diagnose faults showing on the LED fault indicator lights on the unit's control panel. The following models are OBDI compliant.

20.0 SBEGA **EC10 OBD1**
22.5 SBEGA **Software is used with these models.**

20.OSBEG **EC10**
22.5SBEG **Software is used with these models.**

To sample exhaust emissions on installed OBD compliant generators, gain access to the exhaust stream by removing the test port plug on the exhaust elbow. Be sure to reinstall the plug securely when testing is complete.

DATA LOGGING (TROUBLESHOOTING AID)

Test procedures for Data Logging with Gasoline Diagnostic Software-PC Interface

DESCRIPTION

The Diagnostic software is a valuable tool in diagnoising engine problems. It should not replace basic troubleshooting techniques or common sense. Some of our products such as the 5.0 and 6.5 SBEG and 8.0 to 14.0 SBEG, along with non-OBD 20.0 and 22.5 SBEG do no have an idle mode. That means that the engine must be running before the PC interface can begin communication. Models such as the OBD versions like 20.0 and 22.5 SBEGA do have an idle mode and PC interface can begin communications before the engine is actually running. Once you have determined which type you have, the following procedures will help gather valuable information.

Start off by collecting data from the time that the engine is started. If you have a genset that has the idle mode, start the PC interface communicating and data logging before you start the engine. If you have an engine that does not have an idle mode, start the PC Interface as soon as possible after the engine is running. Let the engine warm up for about 10 to 15 minutes before trying to apply an AC load. Monitor and record AC volts and amps if possible.

After the engine is warmed up, start applying an AC load by turning on various devices. Let the unit run at each load change for a couple of minutes so that the unit is stable. Monitor and record AC volts and amps if possible at each load site. Continue to as AC load until the unit is at or near full power rating. Power is determined by multiplying the AC voltage times the AC amperage. This will determine if the unit is overloaded or not.

After loading up the genset, begin to reduce the AC load. Allow the unit run at each load site for a couple of minutes to stabilize. Continue to reduce the AC load and monitor voltage and amperage until there is no AC load on genset. This will give a technician a baseline of what is happening when the engine is running under a controlled load condition.

Finally, after running the controlled baseline test, this might sound strange, but sometimes the customer might know a particular scenario that will cause a problem for the unit. Sometimes we hear customers say that the unit runs fine for awhile and when the air conditioner shuts off, something happens. Try repeating the scenario that the customer mentions. Always start by recording date from the start up for a least a couple of minutes with no load on the generator to get a starting point. Then continue to record data until the problem shows up.

If you have a unit with no *idle mode*, and the unit shut down under some kind of fault, the date log will automatically stop and save the file. If you have a unit with an *idle mode*, and the unit was to shut down under some kind of fault, you will have to manually stop the data log to save it. Or in the case of shutting of the DC circuit breaker, this will also cause the date log to stop and save itself.

USING THE DATA

All of the data that is being recorded is also being displayed on the PC Interface in the various boxes. The following information applies whether you are looking at the data file after it has been recorded or watching it live in the PC Interface. The data file can be opened in most spreadsheet software such as Microsoft Excel.

The data that is being collected is self explanatory and simple to follow. For example, the engine temp, air temp, oil pressure, and battery volts would be easy to understand, other items may be less familiar.

Speed

Simple enough, this is the speed that the engine is running. If the genset is set up to operate at 60 Hz, then the engine needs to run at 1800 rpm (belt driven units may be different). If the unit is set up for 50 Hz operation then the engine speed will be 1500 rpm.

When a genset is governing properly, you should see reading slightly above and below the desired speed. Even a well tuned engine will vary a little. The point is you should see readings above and below the desired speed. If you see speed readings remain more than 20 rpm above or below the desired speed for a prolonged period of time, there could be a problem, especially if this is noticed with no AC load applied.

If the speed is too high with no AC load applied, check the data box labeled Stepper Pos. (steps). The throttle is controlled by a stepper motor. Usually the step count for the engine running with no AC load is typically in the 20-30 steps range. A couple of steps above or below this range does not indicate a problem. However, if the step count is in the single digit numbers or even showing a zero, the problem maybe that the throttle body assembly may be out of calibration or not functioning properly. The stepper motor can only go to a position that it thinks is zero. If the calibration is off, the stepper cannot move the throttle closed enough to slow the engine down. An engine that has this problem will run at the proper speed once some AC load has been added. However, when that load is dropped, the speed will be too high, and in some cases may cause the engine to over-speed and shut down.

If the engine speed is too low with no AC load applied, there is probably a totally different problem. Again, look at the Stepper Position. Is the speed low but steps are high? This would mean that the throttle is being opened to compensate for loss of speed but the speed is not coming up. Check to make sure that the fuel level is full in the fuel system (no air) and that the fuel is good and the filters are clear. Check to make sure that the air intake screens are clean. Check to make sure that the spark plugs have not fouled. Bleed the fuel system to remove any air.

DATA LOGGING (TROUBLESHOOTING AID)

If the engine speed is okay when running with no AC load, but once underway with some AC load being aplied the speed drops and stays below the desired speed, first check the AC power by multiplying the total AC amperage times the AC volts to get the kilowatts. If this number is higher than what the unit is rated for, then it is overloaded., Shut off some of the devices until the speed returns to normal and check the power again. If there is only a small AC load applied and the speed cannot maintain, follow the same suggestions from the previous paragraph.

Pressure (kPa)

This is the pressure that exists in the intake manifold. At no-load, the kPa will be lower than at full load. The wider the throttle plate is open, the closer it gets to atmosphere which is about 100 kPa. Typically a genset running at no-load will see a kPa value around 30, while at full load it would be around 90 kPa. If the kPa is stuck at 70 and never moves then there is a problem with either the MAP sensor or the wiring to the MAP sensor, as 70 is a default value that is in the code.

WB Heater Set-point

This is the set-point in millivolts of the heater temperature in the Wideband 02 Sensor. Curently in all the units that do not have an *idle mode*, the set point is 893. In other units the set-point will vary but wll be displayed in this box.

WB Current Temp

This is the actual value in millivolts of the heater temperature in the Wideband 02 Sensor. If the heater is working properly, you will typically see values stay within 20 millivolts of the set-point. The higher the number is, the colder the heater is. Typically a reading in the 4000 area means that the heater is not working at all. If the value is swinging dramatically above and below the set-point, the sensor is probably failing. The sensor should be replaced.

Lambda

Lambda represents the ratio of the amount present in a combustion chamber compared to the amount that should have been present in order to obtain "perfect" combustion. Thus, when a mixture contains exactly the amount of oxygen required to burn the amount of fuel present the ratio will be one to one and lambda will equal 1,000. If the mixture contains too much oxygen for the amount of fuel (a lean mixture), lambda will be greater then 1,000. If a mixture contains too little oxygen for the amount of fuel (a rich mixture), lambda will be less than 1,000.

Perfect combustion requires an air/fuel ratio of approximately 14.7:1 (by weight) under normal condtions. Thus a lean air/fuel ratio of, say, 16:1 would translate to a lambda value of 1.088. (To calculate, divide 16 by 14.7.) A lamba of .97 would indicate an air/fuel ratio of 14.259:1 (derived by multiplying .97 by 14.7).

In these applications lambda readings should be 1,000. Because of the combustion involved this number will constantly be changing, ideally you should see the value of lambda fluctuating slightly above and below the 1,000 target.

Immediately after a startup, it is typical to see a rich readings for lambda. This is part of the startup process and usually takes a couple of minutes for sensors to warm up and take control of the air fuel mixture.

If you see a problem in this area first check the Wideband heater values to make sure that the heater is working. Remember that it takes about three minutes after starting an engine for it to be totally in control. Physically remove the sensor and check it for corrosion and build up of deposits from the water being injected through the exhaust. Salt water deposited on the sensor will be very damaging. If there is any evidence of build up, replace the sensor. Determine the cause for raw water getting on this sensor.

After checking the senor and the genset is running too rich, check the air intake screens and spark plugs to make sure they are clean and functioning properly. If the genset is running too lean, check the fuel levels and the quality of the fuel. Water in the gas is no good and will cause the genset to run lean.

Ip Current

Is the electrical value equivalent of the lambda reading. There is not much to learn from this number.

Lambda PW Trim

Is the fueling trim precentage that the wideband oxygen sensor is contributing. In most cases 15% is the maximum.

Wideband P, I & D Term

These values are the Wideband Sensor Heater Temperature control terms. These values will be constantly changing. It is more important to look at the WB Current Temp value.

Lambda P & I Term

These values are the lambda value controlling terms. Their job is to keep the lambda reading at 1,000 enriching or leaning the fueling.

NB STT (Narrowband Short Term Trim)

If your genset is equipped with a narrowband oxygen sensor, this will be the value of its contribution. Maximum contribution is 1%.

Stepper Pos (steps)

The throttle shaft is controlled by a stepper motor. The value displayed is in steps, zero steps being the closed position. Most units will run at no load in the 20 to 30 steps range, these values will vary from engine to engine.

Pulse Width

This is the fueling duration in milliseconds (ms). The value will be lower at no load than at full load.

Main Fuel Comp (%)

This is the fueling compensation that is derived from a value in the fuel table, which is based on the engine rpm and the MAP pressure.

Air Temp and Engine Temp Comp (%)

This is the fueling compensation based on the air temperature and engine temperature. This value can be both positive and negative. This value is added or subtracted from the main fuel compensation value.

Speed P, I & D Terms

These values reflect the engine speed governing process. These values are constantly changing and it is very hard to get any information from them, you should see these values constantly changing. If for some reason there are all zeroes in these columns than the engine is probably not running.

De-rated P Term

This code provided for the P(Proportional) Term, in the speed PID control, to be de-rated right after start-up for a short period of time. This allows the engine to warm up without having an aggressive P value which could cause hunting or instability when the engine is cold. On some older units there is also a trim pot on the top on the EUC that can manually de-rate the P value. This will be reflected in this box.

Frequency Option

This the value of the speed selector on the ECU, whether it is 50 or 60 Hz. Some interfaces may not show this column but will display the Frequency Option in the Title area at the top on the data log.

The Generator Frequency

The Generator Frequency is a function of engine speed. For most applications, 50 Hz operation is with an engine speed of 1500 rpm, while 60 Hz operation is with an engine speed of 1800 rpm.

ELECTRICAL TROUBLESHOOTING CHART

The following test procedures will require the use of a multimeter and the engine's wiring diagram (in this manual). Also refer to the relay testing page. WESTERBEKE recommends that these tests be performed by a qualified technician. **CAUTION:** When servicing or replacing DC components, turn off the 20 amp DC circuit breaker.

PROBLEM	TESTING *(12 VDC is battery + voltage measured to ground)*	INSPECTION/SOLUTION
Engine does not crank.....	Test for B+ (12v) at the circuit breaker to the PC board terminal T4.	Check for bad connections at the engine harness connector P1, Pin 1, the #14 red wire, or at the battery + on the starter. Check the connections at the PC board terminal 4 and at the circuit breaker
	If OK ↓	
	Test for B+ (12v) at the circuit breaker to the panel fuse end and to the PC board terminal T1.	Look for a bad connection from the circuit breaker to the fuse or at the PC board terminal T1. Replace the circuit breaker.
	If OK ↓	
	Test for B+(12v) from the fuse end to the PC board terminal T2.	Inspect the connections at the fuse or PC board terminal T2. Replace the fuse.
	If OK ↓	
	Test for B+(12v) at the crank relay K1 terminal 30.	Check for a bad connection at the engine harness connector P1, pin #3. Check the DC voltage at terminal #30 at the K1, K2, K3 and K4 relays.
	If OK ↓	
	Test for B+ (12v) at the start/stop switch terminals 2 and 10.	Look for bad connections at the panel connector S2, pin 1, white/black/red wire to the terminal PC board or at the start/stop switch terminals 2 and 10.
	If OK ↓	
	Test for B+ (12v) at the start switch terminal 1 when the switch is activated.	Replace the start switch.
	If OK ↓	
	Test for B+ (12v) at crank relay K1, terminal 86.	Check bus fuse (8 amp).
	If OK ↓	
	If OK ↓	
	Test for B+(12v) at crank relay K1 terminal 85. Activate the start switch and after a few seconds the voltage should drop below .5 volts.	Inspect for a bad connection at relay K1 terminal 8 orange wire or at ECU connector J2, Pin #8
	If OK ↓	
	Activate the start switch, after 4-5 seconds B+(12v) should be present at terminal 87 on relay K1.	Look for a bad connection at relay K1.
	If OK ↓	
	Activate the start switch, after 4-5 seconds check for B+(12v) at the start solenoid.	Look for a bad connection at crank relay K1, terminal 85 orange wire or at the ECU connector J2, pin #8.
	If OK ↓	
	Inspect the starter.	Check the connections at crank relay K1 terminal 87, yellow/red wire or at the start solenoid.

(CONTINUED)

ELECTRICAL TROUBLESHOOTING CHART

The following test procedures will require the use of a multimeter and the engine's wiring diagram (in this manual). Also refer to the relay testing page.WESTERBEKE recommends that these tests be performed by a qualified technician.

PROBLEM	TESTING *(12 VDC is battery + voltage measured to ground)*	INSPECTION/SOLUTION
Engine cranks but fails to start...	Test for B+ (12v) at terminals 30 and 86 on the K2 run relay	Check for bad connections at both terminals. Replace the K2 relay.
	If OK ↓	
	Test for B+ (12v) at run relay K2, terminal 85 and activate the start switch. Voltage should be less than 5 volts.	Inspect the connections at relay K2, terminal 85, or at the ECU connector J2, pin 19.
	If OK ↓	
	Activate the start switch, test for B+(12v) at relay K2 run relay, terminal 87.	Replace the K2 relay.
	NOTE: *For other possible causes (failure to start) such as fuel pump, speed sensor (MPU), ignition, etc, refer to the these sections in this manual.*	
Engine starts, runs but shuts down.....	Test for voltage across the oil pressure sensor terminals, with the engine running voltage should be less than 1.0 volts.	Faulty oil pressure sensor. Replace sensor/switch.
	If OK ↓	
	Test for voltage across the exhaust temperature switch, when the engine shuts down, it should read zero (0) volts.	Faulty exhaust temperature switch. Replace switch. Loss of coolant thru exhaust elbow. High exhaust temperature.
	If OK ↓	
	The engine temperature sensor maybe faulty.	Test sensor, refer to component testing in this manual.
With the PC interface, read the..... engine shutdown fault	Low DC battery charge level when cranking	Change battery/ Replace battery.
	If OK ↓	
	Speed loss	Check MPU and wiring. Replace MPU.
	If OK ↓	
	Shorted oil pressure sensor	Check wiring/replace sensor
	If OK ↓	
	External fault	Check fire suppression system for cause

WESTERBEKE 20.0KW TO 22.5KW SBEG ENGINE SPECIFICATIONS

LUBRICATION SYSTEM

General	Pressure fed system
Oil Filter	Full flow, paper element. spin-on type
Sump Capacity (Not including filter)	4.0 qts. (3.7 liters) (plus filter)
Operating Oil Pressure (Engine hot)	55 - 75 psi (3.8 - 5.2 kg/cm^2)
Oil Grade	API Specification of SJ, SL or SM SAE 15W-40 or 10W-40

ELECTRICAL SYSTEM

Start Battery	12-Volt, (-) negative ground Battery must be totally dedicated to the generator and maintained by the generators own engine DC charging alternator
Battery Capacity	800 - 1000 Cold Cranking Amps rated (CCA)
Starter	12 Volt, (-) negative ground
DC Charging	12 VDC belt driven alternator
DC Charging Cranking Amps	175 - 200 amps

GENERATOR COOLING

Air Requirements (60 Hertz @ 1800 rpm)	450 cfm (12.74 cmm)
Engine Combustion Air Requirements (60 Hertz @ 1800 rpm)	69.5 cfm (1.9 cmm)
Engine Cooling Air	200-250 cfm
Generator Cooling Air Requirements	250 - 300 cfm (60 Hertz @ 1800 rpm)

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

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

NOTE: *Provide forced air ventilation to keep compartment ambient temperature below maximum under all conditions.*

AC GENERATOR (Single Phase)

General - Single Phase	Brushless, four-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 220 Volts - 50 Hertz.	
Voltage Regulation	±2% no load to full load.	
Frequency Regulation	1.0% no load to full load.	
Rating (Volts AC)		
20.0KW - 60 Hz	120 volts 120/240 volts	166 amps 166/83 amps
16.0KW - 50 Hz	230 volts	69 amps
22.5.KW - 60 Hz	120 volts 120/240 volts	187 amps 187/93 amps
18.0Kw - 50 Hz	230 volts	78 amps

AC GENERATOR (3 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)	Low Voltage WYE High Voltage WYE DELTA	200 Volts 400 Volts 230 Volts
20.0KW - 60 Hz Amperage - 3 phase	Low Voltage WYE High Voltage WYE DELTA	70 Amps 35 Amps 60 Amps
16.0KW - 50 Hz Amperage - 3 phase	Low Voltage WYE High Voltage WYE DELTA	27.8 Amps 28.9 Amps 50.2 Amps
22.5.KW - 60 Hz Amperage - 3 phase	Low Voltage WYE High Voltage WYE DELTA	86.7 Amps 37.6 Amps 75.2 Amps
18.7KW - 50 Hz Amperage - 3 phase	Low Voltage WYE High Voltage WYE DELTA	67.5 Amps 33.7 Amps 58.7 Amps

WESTERBEKE 20.0KW TO 22.5KW SBEG ENGINE SPECIFICATIONS

ENGINE SPECIFICATIONS

Engine Type	Gasoline, four-cycle, four-cylinder, fresh water-cooled, Vertical, in-line overhead mechanism
Governor	1.0% 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
Inclination	Continuous 26° Temporary 30°
Horsepower Outlet	35hp at 1800rpm 28hp at 1500rpm
Weight	**20.0Kw** 741 lbs (336 kgs) **22,5Kw** 771 lbs (349 kgs) *(These engine weights are approximate)*
Fuel Consumption (at full amperage load approximate gph (lph)	**20.0Kw** 2.0 gph **16.0Kw** 6.3 lph **22.5.Kw** 2.2 gph **18.0Kw** 7.0 lph

TUNE-UP SPECIFICATIONS

Compression Pressure (Limit of difference between cylinders)	198.1 psi (14 kg/cm²) at 400 rpm
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)
Prark Plug Gap	0.028 - 0.033 in (0.7 - 0.8 mm)
Engine Timing	33° BTDC at 1800 rpm + or -1° (vacuum advance connected)

EXHAUST EMISSIONS SYSTEMS

Emission Control Systems	EPA Title 40, part 1048 Carb Title 13, chapter 9, article 4.5

IGNITION SYSTEM

General	Battery ignition 12V negative ground. Distributor with ignition module and igniter. Ignition coil and spark plug.
Distributor	Solid state type with signal generator and ignitor.
Timing	33° BTDC at 1800 rpm + or -1° (vacuum advance connected)
Throttle Body	Electronic fuel injection with Electronic Governor
Dwell	63° at 1800 rpm

FUEL SYSTEM

General	Electronic fuel injection
Fuel	Unleaded gasoline with an octane rating of 89 or higher. Loss of power may result from a lower Octane use. Ethanol blend no higher than 10% (E10)
Fuel Lift Pump (wet)	Electric-lift capacity of 6ft (18mm)
Fuel Filter (on engine)	Replaceable cartridge-screw on
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	170 - 190° F (77 - 88° 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)	9.0 qts (8.5 liters)

WESTERBEKE CORPORATION • MYLES STANDISH INDUSTRIAL PARK
150 JOHN HANCOCK ROAD, TAUNTON, MA 02780-7319 U.S.A.
TEL: (508) 823-7677 • FAX: (508) 884-9688 • Website: www.westerbeke.com

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