Workshop Manual

C
2(0)

Engine

3.0GS-A/B/C
3.0GL-A/B/C

NOTES

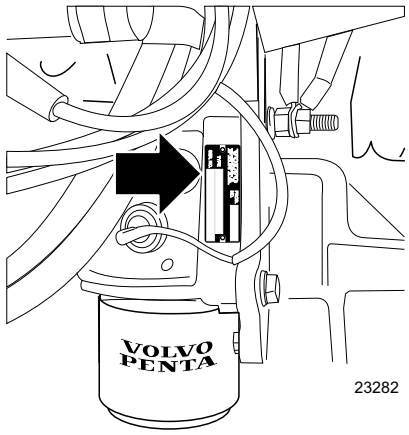
Model Identification

All stern drive system components must be matched for either single or dual engine installations. Failure to properly match engine, transom bracket and sterndrive will result in poor boat performance, and risk damage to engine and drive because of incorrect drive gear ratio.

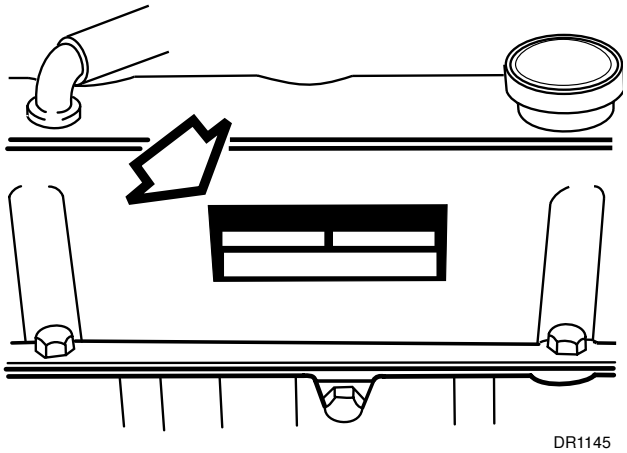
Model identification is located on the engine, and MUST correspond with the transom shield and sterndrive numbers as listed in the Product Matrix sheet available separately.

Engine Model Number

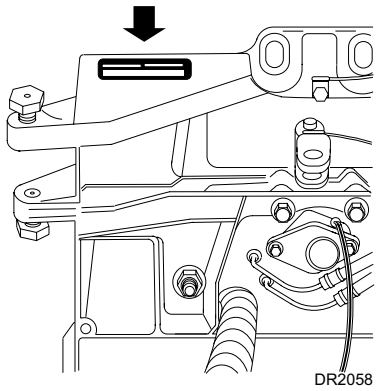
All Engine Models



GS, and GL Engines

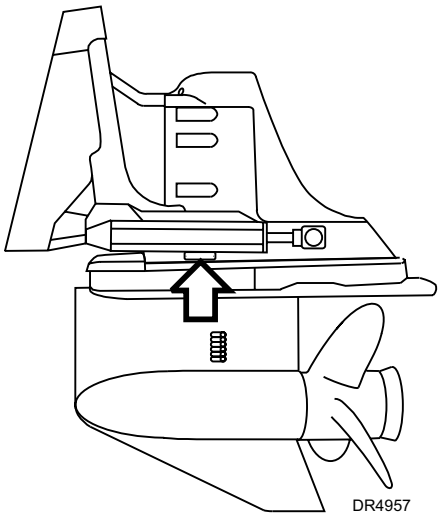


Transom Shield Model Number Location



Sterndrive Model Number Location

SX and DP-S



Section 1: General Information

This service manual is divided into sections concerning various systems and assemblies. Refer to the **Contents** to locate the section covering the system or assembly requiring service. Each section title page has an additional listing that will describe the sections contents in more detail. Be sure to read the **Safety Section** at the end of this manual, and pay special attention to all safety warnings as they appear throughout the text. Since models are subject to change at any time, some photos may not depict actual product.

Good Service Practice

Service required for stern drives is generally one of three kinds:

- **Normal care and maintenance** - which includes putting a new stern drive into operation, storing engines, lubrication, and care

under special operating conditions such as salt water and cold weather.

- **Operating malfunctions** - due to improper engine or drive mounting, propeller condition or size, boat condition, or the malfunction of some part of the engine. This includes engine servicing procedures to keep the engine in prime operating condition.
- **Complete disassembly and overhaul** - such as major service or rebuilding a unit.

It is important to determine before disassembly just what the trouble is and how to correct it quickly, with minimum expense to the owner.

When repairing an assembly, the most reliable way to ensure a good job is to do a complete overhaul on that assembly, rather than just to replace the bad part. Wear not readily apparent on other parts could cause malfunction soon after the repair job. Repair kits and seal kits contain all the parts needed to ensure a complete repair, to eliminate guesswork, and to save time.

Repair time can also be minimized by the use of special tools. Volvo Penta special tools are designed to perform service procedures unique to the product that cannot be completed using tools from other sources. They also speed repair work to help achieve service flat rate times. In some cases, the use of substitute tools can damage the part.

Preparation for Service

Proper preparation is extremely helpful for efficient service work. A clean work area at the start of each job will minimize tools and parts becoming misplaced. Clean an engine that is excessively dirty before work starts. Cleaning will occasionally uncover trouble sources. Obtain tools, instruments and parts needed for the job before work is started. Interrupting a job to locate special tools or repair kits is a needless delay.

⚠ **Caution! Use proper lifting and handling equipment.**

Working on stern drives without proper equipment can cause damage and personal injury.

Always use clean fresh fuel when testing engines. Troubles can often be traced to the use of old or dirty fuel.

Service Policy

It is a Volvo Penta policy to provide dealers with service knowledge so they can give professional service demanded by today's consumer. The Volvo Penta Training Centers, frequent mailing of Service Bulletins, Letters and Promotions, Special Tools and this Service Manual represent the latest effort to assist dealers in giving consumers the best and most prompt service possible. If a service question does not appear to be answered in this manual, you are invited to write to the Volvo Penta Service Department for additional help. Always be sure to give complete information, including engine model number and serial number.

Replacement Parts

⚠ **When replacement parts are required, always use genuine Volvo Penta parts, or parts with equivalent characteristics, including type, strength, and material. Failure to do so may result in product malfunction and possible injury to the operator and/or passengers.**

Parts Catalogs

Parts Catalogs contain exploded views showing the correct assembly of all parts, as well as a complete listing of the parts for replacement. These catalogs are helpful as a reference during disassembly and reassembly, and are available from Volvo Penta Parts.

Special Service Tools

Volvo Penta has specially designed tools to simplify some of the disassembly and assembly operations. These tools are illustrated in this Service Manual, in many cases in actual use. All special tools can be ordered from Volvo Penta Parts. Individual purchasers of Service Manuals must order Special Tools through an authorized dealer.

Product References, Illustrations & Specifications

Volvo Penta reserves the right to make changes at anytime, without notice, in specifications and models and also to discontinue models. The right is also reserved to change any specifications or parts at any time without incurring any obligation to equip same on models manufactured prior to date of such change. All information, illustrations and specifications contained in this manual are based on the latest product information available at the time of printing. The right is reserved to make changes at anytime without notice.

All photographs and illustrations used in this manual may not depict actual models or equipment, but are intended as representative views for reference only. The continuing accuracy of this manual cannot be guaranteed.

The purpose of an engine tune-up is to restore power and performance that has been lost through wear, corrosion or deterioration of one or more parts or components. In the normal operation of an engine, these changes can take place gradually at a number of points, so that it is seldom advisable to attempt an improvement in performance by correction of one or two items only. Time will be saved and more lasting results will be obtained by following a definite and thorough procedure of analysis and correction of all items affecting power and performance.

Economical, trouble-free operation can better be ensured if a complete tune-up is performed once every year, preferably in the spring. Components that affect power and performance can be divided into three groups:

- Components affecting compression
- Components affecting ignition
- Components affecting fuel system

Tuning the Engine

Tune-up procedures should cover these groups in the order given. While the items affecting compression and ignition may be handled according to personal preference, correction of items in the fuel system group should not be attempted until all items affecting compression and ignition have been satisfactorily corrected. Most of the procedures for performing a complete engine tune-up will be covered in greater detail in this manual. This section will deal mainly with the order of procedures involved in tuning the engine.

Engine Compression Testing

During all work done around the engine, while the engine is running or being cranked, use extreme care to avoid getting fingers or clothing caught in any belts, pulleys, or other moving parts.

2. Visually inspect stern drive unit for leaks, missing parts or other obvious defects. **Replace deteriorated parts.**
3. Compression check: Proper compression is essential for good engine performance. An engine with low or uneven compression cannot be properly tuned.
   - Operate engine to normal operating temperature.

⚠ **Caution!**

Engine must not be started and run without water for cooling.

- Remove any foreign matter from around spark plugs by blowing out with compressed air.
- Remove and inspect all spark plugs. Install thread-type compression gauge in spark plug hole.

To Prevent Sparking

⚠ **Warning!**

Failure to disable the ignition system during compression testing may cause fire or explosion by igniting gasoline fumes present during cranking.

—Remove (grey) 2-wire connector, with purple and grey wires, at ignition coil.

—With choke and/or throttle plates wide open, crank engine through at least four compression strokes.

Test Conclusion

The indicated compression pressures are considered normal if the lowest reading cylinder is within 75% of the highest.

Example:

If the highest pressure reading was 140 PSI, 75% of 140 is 105. Therefore, any cylinder reading less than 105 PSI indicates an improperly seated valve, worn valve guides, piston, cylinder, or worn or broken piston rings. Any cylinder reading 105 PSI or greater is within specifications, and compression is considered normal.

If one or more cylinders read low, squirt approximately one tablespoon of engine oil on top of the pistons in the low reading cylinders. Repeat compression pressure check on the cylinders.

1. If compression improves considerably, the piston rings are at fault.
2. If compression does not improve, valves are sticking or seating poorly, or valve guides are worn.
3. If two adjacent cylinders indicate low compression pressures and squirting oil on the pistons does not increase the compression, the cause may be a cylinder head gasket leak between the cylinders. This problem could allow engine oil and/or coolant to enter the cylinders. It is recommended the following quick reference chart be used when checking cylinder compression pressures. The chart has been calculated so that the lowest reading number is 75% of the highest reading.

After checking cylinder compression, repairs should be made as necessary. Subsequent adjustments to an engine that does not have proper compression will not measurably improve performance or cor-

Table 1: Compression Pressure Limit

Max. PSI	Min. PSI	Max. PSI	Min. PSI	Max. PSI	Min. PSI	Max. PSI	Min. PSI
134	101	154	115	174	131	194	145
136	102	156	117	176	132	196	147
138	104	158	118	178	133	196	148
140	105	160	120	180	135	200	150
142	107	162	121	182	136	202	151
144	108	164	123	184	138	204	153
146	110	166	124	186	140	206	154
148	111	168	126	188	141	208	156
150	113	170	127	190	142	210	157
152	114	172	129	192	144	212	158

rect operational problems. After verifying compression, check ignition and fuel system components.

Ignition System Components

- Spark Plugs
- Spark Plug Leads
- Distributor Cap
- Rotor
- Ignition Coil
- High Tension Lead
- Ignition Switch
- Circuit Wiring and Connectors

Fuel System Components

- Fuel Tank Pickup and Screen
- Fuel Tank Vent
- Anti-Siphon Valve (if equipped)
- Fuel Octane and Quality
- Boat Fuel Lines and Valves
- External Engine Fuel Filter
- Fuel Pump(s) and Line
- Carburetor Fuel Filter or Screen
- Carburetor Adjustments
- Engine PCV Valve
- Flame Arrestor

All of the above listed components are not necessarily part of an engine tune-up, but must be considered when attempting to correct engine/boat performance problems. Repair or replace components only as required.

⚠ **Do not substitute automotive parts. Volvo Penta marine components meet U.S. Coast Guard regulations for external ignition proof operation and marine use. Volvo Penta marine components are specially designed not to cause ignition of fuel vapors in the bilge or engine compartment. The use of automotive parts can result in fire and explosion.**

Intake Manifold Vacuum Testing

Test Procedures

1. Install a vacuum gauge to a good intake manifold source (usually at the PCV valve port), following the gauge manufacturer's instructions. Start and warm up the engine.
2. Observe the vacuum gauge while operating the engine over a range of engine speeds.

Test Results

1. A steady vacuum reading between 14 and 19in. Hg. (47-64 kPa) at idle indicates an engine in good mechanical condition.
2. A vacuum reading below 14 in. Hg. (47 kPa) at idle, indicates an engine that is not developing enough vacuum. Further testing for base mechanical problems is needed.
3. Possible causes of low intake manifold vacuum are late ignition timing, low compression, poor engine sealing, leaks at vacuum lines and connections or bad MAP sensor.
4. If the gauge fluctuates at idle, possible causes are sticking or leaking valves, or an ignition miss.
5. If the gauge fluctuates at idle but smooths out as engine RPM increases, check for bad valves or camshaft.
6. If the gauge fluctuates more with increases engine RPM, check for weak or broken valve springs, bad valves, ignition miss, or a leaking head gasket.
7. If the vacuum gauge fluctuates regularly with each engine cycle, check for a bad valve.
8. If the vacuum reading drops steadily as engine RPM increases, check the exhaust system between the engine and vertical drive for restrictions.

9. See table and chart below and on the following page for more information.

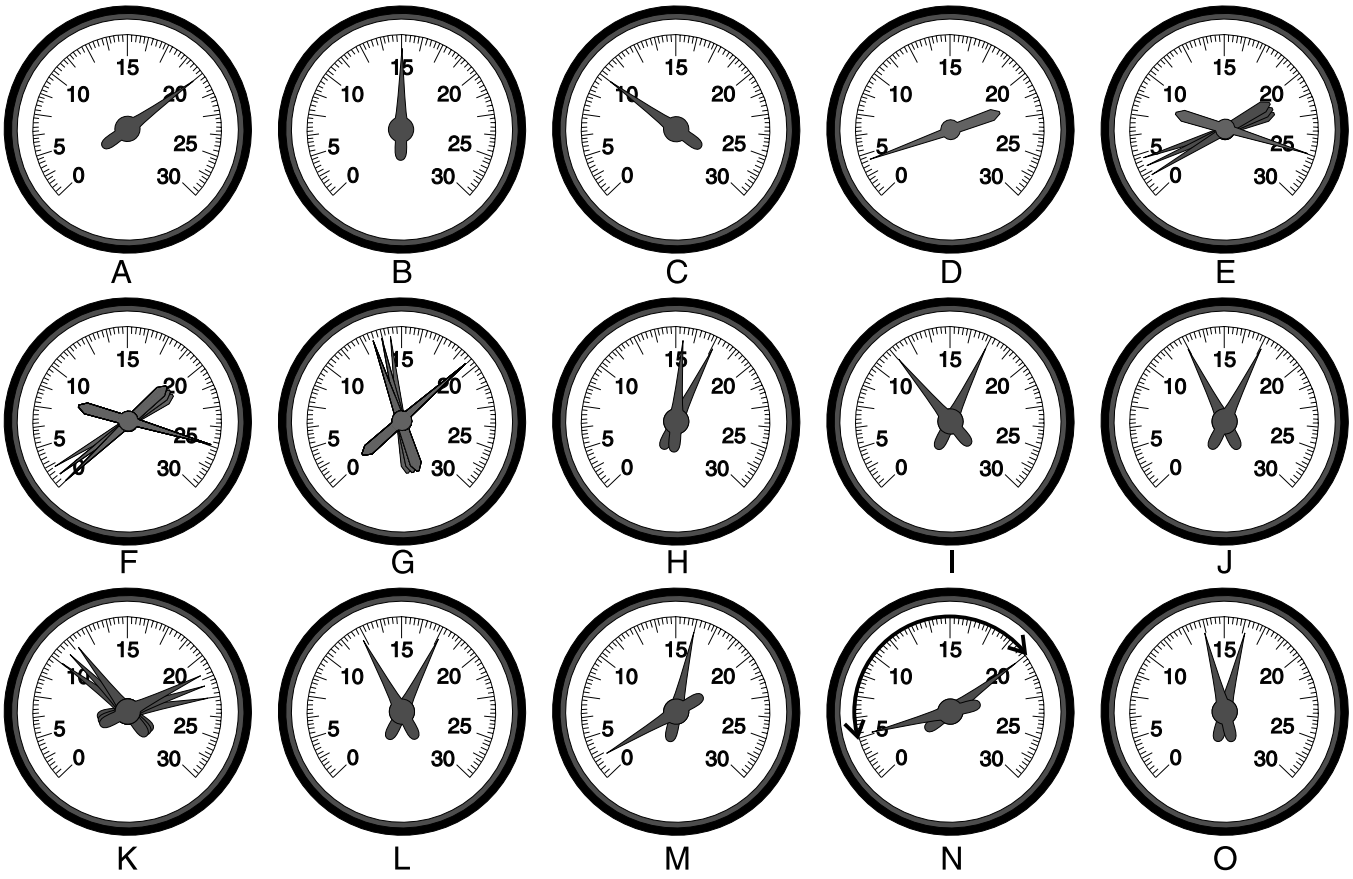


Table 2: Vacuum Gauge Readings

Pos	Condition	Reading
A	Normal at Idle	14-19 in. Hg. (47-64 kPa)
B	Late Ignition Timing	11-17 in. Hg. (37-57 kPa)
C	Late Valve Timing	8-15 in. Hg. (27-50 kPa).
D	Intake Leak	Low but steady reading
E	Normal Acceleration	Drops to 2 then rises to 25 when throttle is rapidly increased and decreased.
F	Worn Rings	Drops to 0, then rises to 22 when throttle is rapidly increased and decreased
G	Sticking Valve(s)	Normally steady, intermittently flicks downward approx. 4 in. Hg. (13 kPa) from highest level.
H	Leaking Valve	Drops 2 in. Hg. (6 kPa) from highest reading.
I	Burned or Warped Valve	Evenly spaced down-scale flicker approximately 5 in. Hg (17 kPa).
J	Worn Valve	Oscillates Approximately 4 in. Hg. (13 kPa).
K	Weak Valve Springs	Violent oscillations as RPM increases.
L	Improper Idle Mixture	Floats slowly between 13-17 in. Hg. (44-57 kPa)

Table 2: Vacuum Gauge Readings

Pos	Condition	Reading
M	Restricted Exhaust	Normal when first started. Drops to approx. 0 as RPM increases
N	Head Gasket Leak	Floats between 5-20 in. Hg. (17-68 kPa)
O	Defective Ignition Component	Slight float between 14-16 in. Hg. (47-54 kPa)

Gasoline Requirements

⚠ **DANGER!**

Gasoline is extremely flammable and highly explosive under certain conditions. Always stop engine and do not smoke or allow open flames or sparks near the boat when refuelling gas tanks. When filling the gas tank, ground the tank to the source of gasoline by holding the hose nozzle firmly against the side of the deck filler plate, or ground it in some other manner. This action prevents static electricity buildup which could cause sparks and ignite fuel vapors.

USE ONLY UNLEADED FUEL. Use lead-free gasoline with the following minimum or higher octane specification:

Inside the U.S.: (R+M)/2 (AKI) = 87
Outside the U.S.: (RON) = 90

If fuels with 89 AKI pump posted (93 RON) octane number or higher are used an increase in power can be expected with EFI models.

Premium fuels contain injector cleaners and other additives that protect the fuel system and provide optimum performance.

⚠ **Caution!**

Engine damage resulting from the use of gasoline with octane 86 AKI (89 RON) and lower is considered misuse of the engine and will void the engine warranty. *Volvo Penta* suggests the use of 89 AKI or higher fuels. These fuels have additives that are beneficial to maximum engine performance and long life of service components.

To prevent gum formation and corrosion in the fuel system, use a Marine Fuel Stabilizer in the gasoline.

Gasoline Containing Alcohol

Many brands of gasoline being sold today contain alcohol. Two commonly used alcohol additives are Ethanol (ethyl alcohol) and Methanol (methyl alcohol).

See the Owner's Manual for you boat to determine if the boat's fuel system is compatible with alcohol blended fuels. if it is compatible, your engine may be operated using gasoline blended with no more than 10% Ethanol (ethyl alcohol) meeting the minimum octane specifications.

Caution!

Do not use any gasoline which contains Methanol (methyl alcohol).

See the boat's Operators Manual to determine if the boats fuel system is compatible with alcohol blended fuels. If it is, your engine may use gasoline blended with no more than 10% Ethanol (ethyl alcohol) meeting the minimum octane specification. **Do not use any gasoline which contains METHANOL (methyl alcohol).**

Continued use of **METHANOL** (methyl alcohol) fuel will cause serious damage to the fuel system.

If you use gasoline containing alcohol, be aware of the following:

- The engine will operate leaner. This may cause engine problems such as vapor lock, low speed stalling, or hard starting.
- Alcohol blended fuels attract and hold moisture. Moisture can cause fuel tank corrosion. Inspect fuel tanks at least annually. Replace corroded or leaking fuel tanks.
- Frequently inspect non-metallic parts of fuel system and replace if excessively stiff, deteriorated or leaking.

Fuel leakage can contribute to a fire and/or explosion.

Crankcase Oil

Initial factory fill is a high quality motor oil for API Service SJ. During the break-in period (20 hours), frequently check the oil level. Somewhat higher oil consumption is normal until piston rings are seated. The oil level should be maintained in the safe range between the Add and Full marks on the dipstick. This range represents approximately 1 litre (1 quart). If it is necessary to add or change the motor oil, use a quality oil with API service category SJ.

Caution!

Do not fill above full mark. Overfilling results in high operating temperatures, foaming (air in oil), loss of power, low oil pressure and overall reduced engine life.

At the end of the break-in period (20 hours), change the crankcase oil and replace the oil filter. Refer to Lubrication and Inspection Chart for recommended oil change intervals.

NOTE! The use of multi-viscosity oils, such as 10W-30 or 10W-40, is not recommended.

Draining and Filling the Engine Crankcase

If using Volvo Penta Premium Synthetic Engine Oil, drain and refill crankcase every 200 hours of operation or once a year, whichever occurs first.

If using oil other than Volvo Penta Premium Synthetic Engine Oil, drain and refill crankcase every 100 hours of operation or once a year, whichever occurs first.

DANGER!

To prevent fire and explosion, always make sure engine compartment is free of gasoline fumes before using any spark-producing tools such as the electric drill motor used with oil withdrawal pump kit.

Check the motor oil level frequently with the dipstick. When oil is to be changed, remove dipstick and withdraw oil from crankcase through withdrawal/dipstick tube. The oil withdrawal tube is provided so oil does not have to be drained into the bilge. Withdraw oil with a suction pump.

Fill the crankcase to the specified capacity with a quality motor oil labelled for service category SJ. When changing motor oil, select from the following chart the SAE viscosity that matches the temperature range in which the boat will be operated. If it is necessary to add motor oil, use motor oil of the same viscosity.

Table 3: Temperature Viscosity Recommendations

If the lowest Anticipated Temperature is:	The Following SAE Viscosity Oils are Recommended
32° F (0° C) and above	SAE 30
0° F (-18° C) to 32° F (0° C)	SAE 20W-20
Below 0° F (-18° C)	SAE 10

NOTE! Disregard any reference to multi-viscosity oil printed on engine. Such reference is intended for automotive use only and not marine application.

⚠ **Caution!**

Do not fill above full mark. Overfilling results in high operating temperatures, foaming (air in oil), loss of power, low oil pressure and overall reduced engine life.

Table 4: Crankcase Capacities

Model	Less Filter	With Filter
3.0GL/GS	3.5 qts. (3.3 liters)	4.0 qts. (3.8 liters)

Oil Filter Replace the oil filter whenever the motor oil is changed. This filter is a self-contained, screw-on type. To remove, unscrew filter canister counterclockwise and discard. When attaching a new filter, be sure the gasket is lightly lubricated with motor oil. Hand tighten only, run engine and check for leaks. Do not run engine without supplying cooling water. See *Parts Catalog* for model and filter requirements.

Power Steering

Maintain the level with Volvo Penta Power Trim/Tilt & Steering Fluid. Approved power steering fluids such as GM power steering fluid or Dexron II automatic transmission fluid can also be used. Do not overfill the pump reservoir.

Steering System Lubrication

Every 60 days, grease the steering ram with Volvo Penta grease.

Power Trim/Tilt Fluid Level

At the beginning of each boating season, check the fluid level in the reservoir as follows:

- Level should be between the “MIN” and “MAX” marks on the reservoir.
- If necessary, add DuraPlus™ Power Trim/Tilt & Steering Fluid. Replace the cap and tighten securely.

Off-Season Storage

There are nine steps that must be completed for Off-Season Storage Preparation

When gasoline engines are removed from service for long periods (2 months or more), it is important that they are correctly stored or protected (internally). Today’s gasoline blends are not as stable as in the past and consideration must be given if the fuel will not be used within a short time or if the engine is being placed in storage. Failure to properly stabilize the fuel can damage fuel system components and is not considered as warrantable a defect that would be covered and repaired under the limited express warranty.

Boat manufacturers should follow the gasoline storage mixture section for testing prior to shipment.

Note! Volvo Penta has discontinued the fuel stabilizer #3855832, a suitable replacement can be purchased locally at most marine supply stores.

Limited Use

If the vessels fuel within the tank(s) will not be consumed within a 30-day period from the time of filling, a gasoline fuel stabilizer must be added as per the manufacturer’s instructions. This will help prevent the fuel from breaking down and causing reduced engine performance fuel system clogging or damage from uncontrolled combustion.

Storage

If the boat is being placed into storage, a gasoline fuel stabilizer must be added to the tank(s) as per the manufacturers instructions. The amount of stabilizer required is determined by the quantity of fuel and the length of time it will be placed in storage. The maximum period that fuel can be stabilized is six months due to limitations of the stabilizers and fuels.

⚠ **DANGER!**

Any fuel leakage should be corrected immediately to prevent possible fire and/or explosion.

Caution!

Do not run engine out of fuel or run the electric fuel pumps dry more than 20 seconds. Running the electric fuel pumps dry will cause fuel pump damage.

Step 1. Prepare a storage mixture

In addition to stabilization of the fuel, it is highly desirable to have the valves and cylinders coated with a light film of oil previously accomplished through fogging. Today's fuel injection manifolds are designed with a complex air channel design that will not allow the traditional fogging oils to be injected past the throttle plate while running. The oil will get stuck in the plenum and never reach the cylinders. Together with the stabilizer, two-cycle motor oil can be added to a fuel mixture for stabilization purposes.

- Using an outboard motor six-gallon fuel tank, add two-cycle motor oil at a ratio of 50:1 (one pint to 6 gallons) and stabilizer at one ounce per gallon (unless stated otherwise on the manufacturers label). Mix well.
- Disconnect boat fuel line at engine fuel pump. Attach the storage mixture fuel tank.
- Connect a suitable engine flush device if the boat is not in the water.
- Run the engine on the storage mixture for approximately 5 minutes at 1500 RPM. This will ensure that all fuel system and internal engine components are thoroughly protected. Do not operate the engine above 1500 RPM as the water pump demand may exceed the supply, damaging the pump.
- Reduce the engine speed to idle and stop the engine.
- Reconnect the fuel fitting and check for fuel leaks.

Step 2. Change Motor Oil and Oil Filter:

- Engine should first be operated under load until oil is thoroughly warmed up. If oil is allowed to warm up before draining, a more complete draining will be accomplished. In addition, accumulated impurities will be held in suspension by the oil and be removed during draining operation.
- Remove motor oil by siphoning it out of oil withdrawal tube. Follow the procedure under **Draining and Filling the Engine Crankcase.**
- Install a new oil filter and fill crankcase with recommended oil.

Caution!

Sterndrive must be submerged in water or an accessory flushing adaptor must be used while operating engine. When using a flushing adaptor, remove propeller before starting engine to prevent accidental contact with rotating propeller.

- With sterndrive in full down position, run engine at a fast idle for a few minutes to distribute clean oil through engine.

- Shut off engine and check oil level. Check oil filter gasket for leaks. Add oil if necessary to bring oil level up to, but not over, the full mark.

Step 3. Change Vertical Drive Lubricant: Drain and refill with fresh DuraPlus™ GL-5 Synthetic Gear Lubricant or Mobilube 1 SHC Fully Synthetic SAE 75W-90 (meeting or exceeding MIL-L-2105C or D, API GL-4 or 5) gear lubricant. Refer to Vertical Drive Service Manual.

Step 4. Fog Engine:

- Warm up engine to ensure fuel conditioner is throughout fuel system. Use 1/2 pint (0.24 liter) of Fogging Oil 12 oz. (355 ml) spray can to fog engine.
- Remove flame arrester from carburettor. Following instructions on container, bring engine up to a fast idle and slowly pour or spray 2/3 of fogging oil into carburettor. Keep engine running while pouring fogging oil into carburettor throat.

Step 5. Drain Cooling System When draining the cooling system, raise or lower the bow of the boat to position the engine in a level horizontal plane. This will provide complete drainage of the engine block and manifolds. If the bow is higher or lower that the stern, some water may be trapped in the engine block or manifolds.

Improper or incomplete draining may result in freeze damage to the engine, manifolds, sterndrive, or other components. Freeze damage is not covered under Volvo Penta's Limited Warranty.

3.0GS-A Front

1. Disable ignition system See "Engine Compression Testing" on page 3
2. Remove inlet and outlet hoses from raw water pump and crank the engine with starter 1-2 revolutions.
3. Reconnect ignition system.

Starboard

4. Disconnect and drain large hose at circulation pump

Port

5. Remove exhaust manifold drain plug. Clear hole with a small wire to ensure complete drainage.
6. Remove cylinder block drain plug, clear hole with small wire to ensure complete drainage.

3.0GS-B/C Front

1. Disable ignition system See "Engine Compression Testing" on page 3
2. Remove inlet and outlet hoses from raw water pump and crank the engine with starter 1-2 revolutions.
3. Reconnect ignition system.

Starboard

4. Disconnect and drain large hose at circulation pump

Port

5. Remove exhaust manifold drain plug. Clear hole with a small wire to ensure complete drainage.
6. Remove cap from engine flush hose and lower hose into bilge.

3.0GL-A/B/C/D Front

1. Disable ignition system See “Engine Compression Testing” on page 3
2. Remove inlet and outlet hoses from raw water pump and crank the engine with starter 1-2 revolutions.
3. Reconnect ignition system.

Starboard

4. Disconnect and drain large hose at circulation pump

Port

5. Remove exhaust manifold drain plug. Clear hole with a small wire to ensure complete drainage.
6. Remove cylinder block petcock drain stem, clear hole with small wire to ensure complete drainage.

Preparation for Boating After Storage

1. Install all drain plugs. Install cooling hoses and clamps. Check condition of hoses, manifold end caps and clamps. Connect hoses to engine and tighten clamps securely. Install boat drain plug, if removed.
2. Remove the distributor cap and rotor. Wipe the inside of the distributor cap dry with a clean cloth and spray with *DuraPlus™ Corrosion Spray*. Replace the rotor and cap.
3. Clean the battery terminals. With the ignition switch in the "OFF" position, install the battery and attach the battery cables. Spray terminals with *DuraPlus™ Corrosion Spray*.
4. **Open the fuel shut-off valve (if so equipped) and check all fuel line connections for leaks.**
5. Check the flame arrestor and clean if necessary. **Reinstall, make sure all parts are in place and tighten nut securely.**
6. Make a thorough check of the boat and engine for loose or missing nuts and screws. Pump the bilge dry and air out the engine compartment.

⚠ **Danger!**

To prevent a possible explosion, operate the blower as recommended by the boat manufacturer before starting engine. If the boat is not equipped with a bilge blower, open engine cover or hatch prior to starting and leave open until after engine is running.

If operating boat in water, tie boat securely to dock to prevent forward or backward movement.

When using a flushing adaptor, remove the propeller before starting engine to prevent accidental contact with rotating propeller.

7. Test run engine: Launch boat or use a flushing adaptor installed on Sterndrive.

⚠ **Caution!**

Do not start engine out of water unless using a flushing adaptor. Always turn water on before starting engine. Control water pressure as full water pressure may cause damage to supply pump and engine.

8. With engine compartment open, start the engine. **Monitor the voltmeter, oil pressure and water temperature gauges frequently to be sure all systems are operating properly.** Check for fuel, oil, and water leaks.

Engine Break-in

All engines have been run for a short period of time as a final test at the factory. You must follow the Engine Break-In procedure during the first 20 hours of operation to ensure maximum performance and longest engine life.

NOTE!

To ensure proper lubrication during the break-in period, do not remove factory break-in oil until after the 20-hour break-in is completed.

First Two Hours

For the first five to ten minutes of operation, operate engine at a fast idle (above 1500 RPM). After engine has reached operating temperature, momentarily reduce engine speed, then increase engine speed, to assist break-in of rings and bearings.

During the remaining first two hours of operation, accelerate to bring boat onto plane quickly and bring throttle back to maintain a planing attitude. During this period, vary the engine speed frequently by accelerating to approximately three-fourths throttle for two to three minutes, then back to minimum planing speed. Maintain planing attitude to avoid excessive engine load.

DO NOT RUN ENGINE AT A CONSTANT RPM FOR PROLONGED PERIODS OF TIME DURING THE BREAK-IN PERIOD.

Next Eight Hours

During next eight hours, continue to operate at approximately three-fourths throttle or less (minimum planing speed). Occasionally reduce throttle to idle speed for a cooling period. During this eight hours of operation it is permissible to operate at full throttle for periods of less than two minutes.

DO NOT RUN ENGINE AT A CONSTANT RPM FOR PROLONGED PERIODS OF TIME DURING THE BREAK-IN PERIOD.

Final Ten Hours

During the final ten hours of break-in, after warming engine to operating temperature, it is permissible to operate at full throttle for five to ten minutes at a time. Momentarily reduce then increase engine speed to

assist break-in of rings and bearings. Occasionally reduce engine speed to idle to provide cooling periods.

DO NOT RUN ENGINE AT A CONSTANT RPM FOR PROLONGED PERIODS OF TIME DURING THE BREAK-IN PERIOD.

During break-in period, be particularly observant during initial running of engine, as follows:

1. Check crankcase oil level frequently. Maintain oil level in safe range, between “add” and “full” marks on dipstick.

NOTE! If you have a problem getting a good oil level reading on dipstick, rotate dipstick 180° in tube.

2. Watch oil pressure gauge. If gauge indication drops below the normal operating oil pressure range (See “Engine Specifications” on page 88) whenever boat attitude is changed (i.e. turning, climbing on plane, etc.), it may be the oil pickup screen is not covered with oil. Check crankcase dipstick, and add oil to crankcase if required. DO NOT OVERFILL. If oil level is correct and condition still exists, check for possible gauge or oil pump malfunction.

NOTE! Oil pressure will rise as RPM increases, and fall as RPM decreases. In addition, cold oil will generally show higher oil pressure for any specific RPM than hot oil. Both of these conditions reflect normal engine operation.

3. Watch engine temperature indicator to be sure there is proper water circulation.

Caution

Failure to follow the break-in procedure will void the engine warranty.

At end of break-in period (20 hours), remove motor oil and replace oil filter. Fill crankcase with recommended 4-cycle motor oil, See “Draining and Filling the Engine Crankcase” on page 9

Operation After Break-in

After break-in, the engine can be operated at any RPM from idle to full throttle. However, cruising at 3600 RPM or less saves fuel, reduces noise, and prolongs engine life.

When starting a cold engine, always allow engine to warm up gradually. Never run engine at full throttle until engine is thoroughly warmed up. Be sure to check oil level frequently during the first 50 hours of operation, since oil consumption will be high until piston rings are properly seated.

Submerged Engine or Water Ingestion in Cylinders

In the unlikely event that the water level in the boat should get high enough to enter the engine, or water should enter the engine's cylinders through the intake or exhaust system, remove the boat from water as quickly as possible.

1. Remove spark plugs immediately (See “Spark Plug” on page 32), and crank engine to remove water from cylinders. Do not attempt to crank engnine with water present in cylinders, internal engine damage will result.

⚠ **Caution!**

Disable ignition system before cranking engine with spark plugs removed, See “To Prevent Sparking” on page 4.

2. Drain, flush and refill crankcase with new oil, See “Draining and Filling the Engine Crankcase” on page 9
3. Change oil filter, See “Oil Filter” on page 10

It is imperative that all water is removed from the engine and immediately lubricate all internal parts. All electrical devices must also be dried and inspected for water damage. Delay in completing these actions may allow extensive engine damage. Ensure the fuel system is not contaminated with water before attempting to start engine.

Frequently check engine compartment for gasoline fumes and excessive water accumulation; water depth in bilge should be kept well below flywheel housing.

Water entry through the intake or exhaust system is not considered a defect in the engine and is excluded from coverage under the limited express warranty.

20-Hour Check

1. Change engine oil and oil filter.
2. Check power trim/tilt reservoir for proper fluid level.
3. Clean and inspect the ceramic filter located under the fuel pump.
4. Check flame arrestor for proper mounting.
5. Start engine and check complete fuel system for leaks.
6. Lubricate steering cable ram with Volvo Penta grease P/N 828250. Check power steering pump reservoir for correct fluid level on models equipped with power steering. Failure to properly lubricate the steering system could lead to loss of steering control.
7. Check shift system for proper adjustment and operation. Verify cable attachment clamp on pivot housing is fully seated and secure. Inspect cable anchor and cotter pin at shift linkage on stern drive for proper installation and free movement.
8. Inspect exhaust system. Tighten all hose clamps, and check for leaks. Verify all clamps on exhaust and u-joint bellows are properly located and tightened.
9. Check tension on drive belt.
10. Check all engine mount screws, stern drive mounting nuts and transom shield mounting nuts for tightness.
11. **3.0GS-A/B/C, 3.0GL-A** models only: Check and adjust carburetor for correct idle mixture and RPM. Adjustments should be made in the water with normal load for accuracy. Adjusting on a trailer or garden hose may result in accurate idle speed adjustment.
12. Check for any deficiencies, malfunctions, signs of abuse, etc. Correction of any problems at this time will prevent the worsening of a minor problem and help ensure a trouble-free boating season.
13. Check oil level in Sterndrive and add as necessary with GL-5 Synthetic Gear Lubricant or Mobilube 1 SHC Fully Synthetic SAE

75W-90 (meeting or exceeding MIL-L-2105C or D, API GL-4 or 5) gear lubricant.

14. Make sure engine can achieve maximum rated RPM with normal load. See “Engine Specifications” on page 88.

Positive Closed Ventilation System

A malfunctioning crankcase ventilation system may be indicated by loping or rough engine idle. Do not attempt to compensate for this idle condition by disconnecting the crankcase ventilation system and making adjustments. The removal of the crankcase ventilation system from the engine will adversely affect fuel economy and engine ventilation with resultant shortening of engine life. To determine whether loping or rough idle condition is caused by a malfunctioning crankcase ventilation system, perform the following tests.

With Engine Idling

1. Remove PCV valve from its mounting, but leave vacuum inlet side connected to hose. If the valve is functioning properly and not plugged, a hissing noise will be heard as air passes through valve. A strong vacuum will be felt when a finger is placed over valve inlet. Check for vacuum leaks in hose line and at all connections.
2. Reinstall PCV valve, then remove crankcase air inlet hose at flame arrestor connection. Loosely hold a small piece of stiff paper (such as a 3 x 5 memo card or parts tag card) over opening at end of inlet hose. After a minute or so, (to allow crankcase pressure to lower) the piece of paper should be sucked against hose opening with a noticeable force.

With Engine Stopped

Remove PCV valve from its mounting and shake it. A metallic clicking noise should be heard, indicating that valve parts are free, and not sticking.

If ventilation system passes these two tests, it can be considered functionally OK, and no further service is required. If it fails either test, replace PCV valve and repeat Engine Idling Test.

If system still does not pass test, clean ventilation system hoses and all passages to induction system in accordance with established procedures.

Servicing PCV Valve

⚠ **Caution!**

Do not attempt to clean crankcase ventilation regulator valve. It should be replaced.

Clean crankcase ventilation system connection(s) on intake manifold by probing with a flexible wire or bottle brush. Clean hoses, tubes and associated hardware with a low-volatility, petroleum-base solvent and dry with compressed air.

Troubleshooting - System Isolation

The following is to help you isolate a malfunction of one or possibly several systems. After determining which systems are related to the malfunction, refer to the individual system troubleshooting charts to isolate the specific cause.

Table 5: System Isolation

Engine Does not Start	Cranking System	Engine should crank at specified RPM. If not, check for 1. Discharged or dead Battery 2. Loose or corroded connections 3. Cranking System Troubleshooting Chart in the Electrical Ignition/ Fuel Service Manual
	Ignition System	Must have good spark at spark plugs. If not, check the: 1. Distributor Cap 2. Coil and spark plug leads 3. Ignition timing 4. Automatic spark advance 5. Appropriate Ignition Troubleshooting Chart in the Electrical/Ignition/Fuel Service Manual. 6. EFI Models: Refer to EFI Diagnostic Manual
	Fuel System	Carburetor accelerator pump should squirt fuel into the Venturi when throttle is advanced. If not, check the: 1. Fuel Tank, valves, and lines 2. Fuel pump and filter 3. Carburetor and Filter 4. Boat Fuel System Troubleshooting Chart 5. Carburetor Troubleshooting Chart 6. Engine Fuel System Troubleshooting Chart
Engine Runs Improperly		Check the following: 1. Compression 2. Ignition system 3. Fuel system and carburetor 4. Lubrication system 5. Cooling System 6. Sterndrive and propeller 7. PCV Valve 8. Engine Troubleshooting Guides

Engine Troubleshooting Guides

EFI Engines Only: Refer to EFI Diagnostic Service Manual.

These guides were written to help you trace the symptoms of the trouble to the source, without having to read through and prove every possibility. Much of the information here will be familiar to well informed mechanics.

Also, many factors will seem insignificant but when you think of it, usually the toughest problem to troubleshoot is caused by the smallest error. The greatest aid to solving a service problem is information. Start gathering information from the boat operator and write it on his job card or work ticket. Find out pertinent facts, such as:

- When did this trouble start?
- How was the boat loaded?
- Did the trouble occur suddenly, or start gradually?

Analyze this information and try to match it to similar situations you have experienced in the past. Keep in mind the fundamental rules:

- COMPRESSION - Mixture inducted into cylinder and compressed.
- SPARK - Proper intensity at the proper time.
- FUEL - Proper mixture of air and fuel.

These are very old rules, but necessary for the engine to run. Use these charts and the service information they refer to. Do not try to remember tolerances, settings, measurements, etc., as they are written in the service manual. Leave your mind free to analyze the problem.

Following is a list of the troubleshooting guides which may be found on the pages indicated.

Engine Will Not Crank

Starter Circuit - Check:

- Battery condition: weak, dead, sulfated, bad cells
- Battery cables for loose or corroded connections
- Shorted or open ignition switch

- Starter motor and solenoid for shorts, grounds or open circuits
- Starter assist solenoid/starter relay
- Circuit breakers
- Wiring from battery to ignition switch
- See ***Electrical/Ignition/Fuel Service Manual***

Engine Cranks, But Will Not Start

Ignition Circuit - Check:

- Primary circuit wiring from ignition switch to ignition coil/ignition module
- Secondary circuit wiring from coil to spark plug
- Spark plugs for proper gap, fouling, burned electrodes, cracked or dirty insulator
- See ***Electrical/Ignition/Fuel Service Manual***
- Low battery voltage

Fuel System - Check:

- Quantity and condition of fuel in boat tank
- Operation and flow capacity of boat anti-siphon valve
- Fuel tank vent is unrestricted
- Fuel tank pick-up screen is clean
- Correct diameter/unrestricted boat fuel lines
- Fuel shutoff and multiple tank valves are open and operating properly
- Fuel pump vent hose for signs of fuel or oil that would indicate a fuel pump failure.
- Fuel pump/relay/circuit breaker operation
- External fuel filter canister and carburetor filter
- Carburetor accelerator pump
- See ***Electrical/Ignition/Fuel System Service Manual***

Cylinder Compression - Check

- Conduct test following procedure in this section, and compare readings to Compression Limit Chart.

Hard Starting - Cold Engine

Ask these questions first:

Has Engine Always Done This? Check:

1. Carburetor choke operation and adjustment
2. Fuel lines for obstructions
3. For debris inside fuel tank
4. See ***Electrical/Ignition/Fuel System Service Manual***

Was Engine Used For A Long Time?(more than two months)

Check:

1. For clean external canister and carburetor fuel filters
2. Empty carburetor float bowl due to evaporation
3. Water in fuel due to condensation
4. Fuel quality deterioration
5. See ***Electrical/Ignition/Fuel System Service Manual***

Is This A New Condition?

Check:

1. Carburetor choke operation and adjustment
2. Carburetor accelerator pump
3. Fuel system for leaks, dirt, or obstructions
4. Engine timing and ignition system
5. See ***Electrical/Ignition/Fuel System Service Manual***

Hard Starting - Hot Engine

Ask these questions first:

Has Engine Always Done This? Check:

1. Carburetor choke operation and adjustment
2. See ***Electrical/Ignition/Fuel System Service Manual***

Is This A New Condition? Check:

1. Brand, type or octane of fuel
2. Spark plugs
3. Water in fuel
4. Condition of battery and cables
5. Starter motor for overheat damage

Did Engine Refuse To Start After Being Run? Check:

1. Ignition system primary circuit
2. Ignition coil(s)/ignition module
3. Engine timing
4. Carburetor choke operation and adjustment
5. See ***Electrical/Ignition/Fuel System Service Manual***

Engine Runs Rough

If Fuel Injected, see ***EFI Diagnostic Workshop Manual***

If At Slow Speed - Check:

1. Idle speed and idle mixture
2. Engine timing and spark plugs
3. Fuel pump pressure
4. Water or contaminants in fuel
5. Carburetor or manifold vacuum leak
6. Internal carburetor fuel leak
7. See ***Electrical/Ignition/Fuel System Service Manual***

If At High Speed - Check:

1. Air leak on suction side of fuel system
2. Too low octane fuel
3. Ignition system secondary circuit
4. Engine timing
5. Wrong model or size carburetor, improper main jets or power valve, defective secondary fuel circuit, secondary vacuum diaphragm failure
6. External canister and carburetor fuel filters
7. Fuel pump pressure
8. Engine compression
9. Water or contaminants in fuel, water in cylinders
10. See General Information section and Electrical/Ignition/ Fuel System Service Manual

Engine Noises and Vibrations

Valves - Hydraulic Lifters

1. Rapping only when starting (oil too heavy for prevailing weather, varnish on lifter, oil needs to be changed)
2. Intermittent rapping (leakage at lifter check ball)
3. Idle noise (excessive leak down rate, faulty check ball seat)
4. Generally noisy (excessive oil in crankcase, stuck lifter plunger)
5. Loud noise at operating temperature (scored lifter plunger, fast leak down rate, oil viscosity too light for prevailing weather or operating temperatures)
6. See appropriate Engine section

Ignition System (Ping or Knock)

1. Improper tuning
2. Incorrect spark plug wire routing
3. Use higher octane fuel
4. See Electrical/Ignition/Fuel Service Manual

Cooling System

1. Supply pump
2. Loose belts, pulleys
3. See ***Cooling System*** section

Mountings

1. Loose, broken or worn engine mounts
2. Loose lag screws holding mounts to stringer

Crankshaft Balancer or Flywheel

1. Loose bolt(s)

Alternator

1. Loose pulley, worn bearings
2. Loose mounting bolts

Sterndrive

1. Failed Ujoints or gimbal bearing
2. Damaged internal drive components
3. Worn, bent or broken propeller hub or blades
4. Loose, worn or damaged engine coupler

Engine Overheats - Check:

1. Actual engine temperature by verifying with an accurate thermometer at the thermostat housing
2. Gauge operation and wiring circuit
3. Sending unit operation and wiring circuit
4. Supply pump, circulating pump and belt(s)
5. Water intake screens for blockage
6. Thermostat
7. Water supply hoses
8. Engine timing
9. Water leaks on pressure side of supply pump
10. Air leaks on suction side of supply pump including the transom shield and sterndrive.
11. Engine compression

Engine Dies Out

Loss Of, Or Out Of, Fuel - Check:

1. Fuel gauge operation and wiring
2. Fuel level in tank
3. Water or debris in fuel
4. Fuel pickup tube and screen blockage
5. Fuel tank vent blockage
6. Plugged external canister or carburetor fuel filters
7. Air leak on suction side of fuel system
8. Fuel leak on pressure side of fuel system
9. Inoperative, restricted or incorrectly sized anti-siphon valve
10. Boat fuel lines too small in diameter
11. Fuel pump pressure and suction
12. Carburetor cleanliness and operation
13. See ***Electrical/Ignition/Fuel System Service Manual***

Loss Of Ignition - Check:

1. Primary and secondary ignition circuits
2. Ignition switch
3. Circuit breakers
4. Wiring between engine and dash
5. Main engine harness wiring
6. See ***Electrical/Ignition/Fuel Service Manual***

Engine Stops Or Dies Out Due To Seizure - Check:

1. Vertical drive for internal damage
2. Oil pressure gauge and crankcase oil level
3. Temperature gauge and cooling system operation
4. Internal engine components as required

Engine Won't Reach Operating RPM - Check:

1. Propeller pitch or diameter, damaged blades, slipping hub
2. Crankcase oil volume
3. Marine growth on hull and drive
4. Fuel type or octane
5. Wrong Sterndrive gear ratio
6. Operating at high altitude
7. Restricted carburetor air intake
8. Restricted exhaust outlets in engine, transom bracket or drive
9. Poor cylinder compression
10. Carburetor size and type correct for engine
11. Fuel pump pressure and vacuum
12. Boat overloaded, or load improperly placed
13. Engine overheating
14. Engine timing and ignition system operation
15. Remote control cables and linkage for proper attachment and travel

Defective Engine Lubricating System

Engine Components - Check:

1. Clogged or incorrect oil filter
2. Worn oil pump gears, cover or shaft
3. Worn or collapsed oil pump relief valve spring, or foreign material caught on valve seat
4. Oil pump relief valve plunger loose in cover
5. Damaged filter bypass grommet
6. Clogged oil pickup screen, broken tube or housing
7. Plugged crankshaft or blocked oil galleys
8. Dirty or defective hydraulic lifters, clogged push rod passages
9. Poor quality, incorrect viscosity or quantity of oil
10. Oil level too high - too much oil in the crankcase
11. Incorrect hose routing on remote filter systems

12. Water in crankcase oil from condensation, defective head gasket, oil cooler, or cracked manifold/block water passages

Oil Pressure Warning System - Check:

1. Oil gauge/warning horn operation and wiring
2. Engine temperature
3. Oil pressure gauge and warning horn sender operation and wiring
4. Oil level too high or too low, oil level should be within the “Safe” range on the dipstick

Low Battery Voltage After Short Storage

Engine/Boat Components - Check:

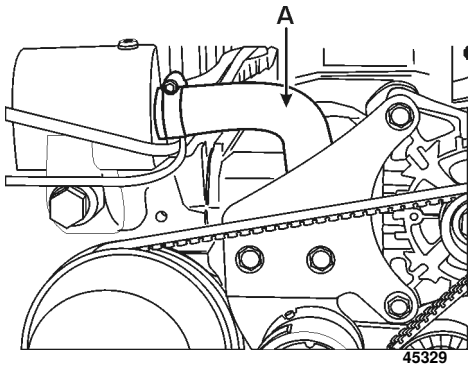
1. All electrical accessories including ignition circuit off
2. Disconnect main battery negative cable from battery
3. Connect ammeter or voltmeter in series between negative battery cable and negative battery post
   - Meter reading of “0” indicates no draw, test battery and charging system
   - Meter movement no matter how slight indicates draw from battery
4. Disconnect main engine harness 10-Pin Connector
   - Meter drops back to “0”, problem caused by boat system, continue to isolate each boat electrical accessory until problem is found
   - Meter does not drop back to “0”, problem caused by engine electrical system, continue to isolate each engine electrical accessory until problem is found
5. Repair or replace components as necessary

Section 2: Engine Mechanical 3.0 Liter

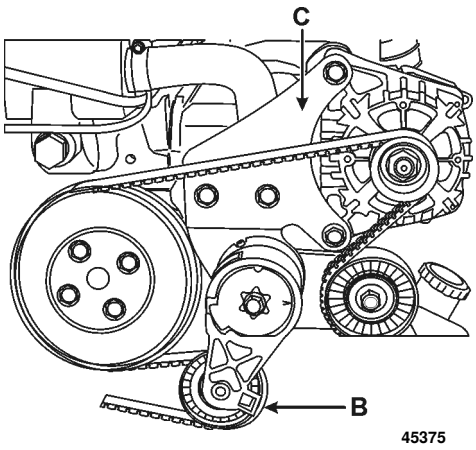
Intake/Exhaust Manifold

Removal

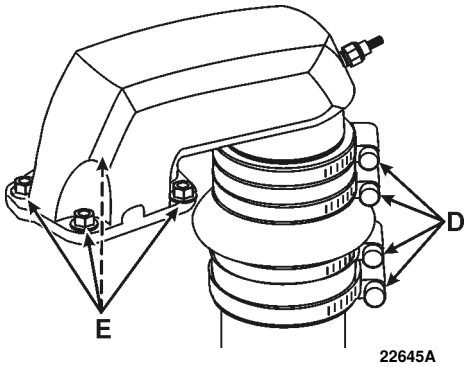
1. Disconnect battery cables at battery. Remove throttle cable from anchor block and actuating bracket See “Throttle Cable From Engine” on page 123
2. Drain water from block and exhaust manifold See “Draining Engine Block or Exhaust Manifold” on page 133
3. Remove carburetor from intake manifold. Follow the instructions in Electrical/Ignition/Fuel Systems Service Manual.



4. Disconnect water hose (**A)** running between manifold end cap and thermostat housing.



5. Release tension from belt tensioner (**B)** and remove the serpentine belt. Remove alternator and mounting bracket (**C)**.



⚠ **Caution!**

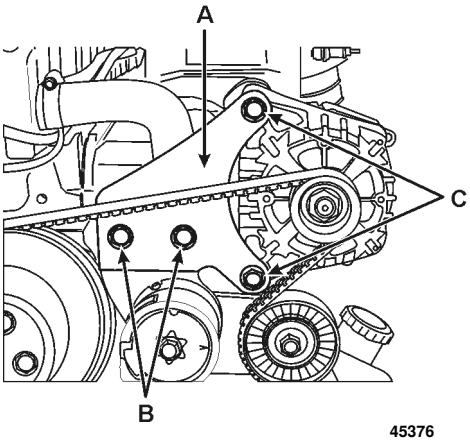
Remove boat from water before removing exhaust elbow. Water may enter the boat.

6. Loosen upper hose clamps (**D)** securing exhaust hose to high rise elbow. Loosen and remove screws and lock washers (**E)** securing elbow to manifold and remove the throttle linkage plate and elbow.
7. Remove six bolts securing manifold to cylinder head, then pull manifold off of head. Discard gasket.
8. Clean all gasket surfaces of cylinder head and manifold and check for cracks on the manifold casting.

Installation

1. Position a new gasket over the manifold studs on the head. Use a gasket sealer if leakage has occurred. Carefully install the manifold in position making sure that the gasket is correctly placed.
2. Install six bolts while holding the manifold in place. Tighten bolts finger tight, then alternately tighten to 20-25 ft. lb. (27-34 N•m) working from the center towards the ends.
3. Apply gasket sealer to a new elbow gasket and place it on the manifold. Push the elbow into the exhaust hose, then install the elbow, throttle linkage plate, lock washers, and screws. Tighten the screws to 12-14 ft. lb. (16-19 N•m).
4. Install carburetor using a new mounting gasket following the instructions in Electrical/Ignition/Fuel Systems Service Manual.

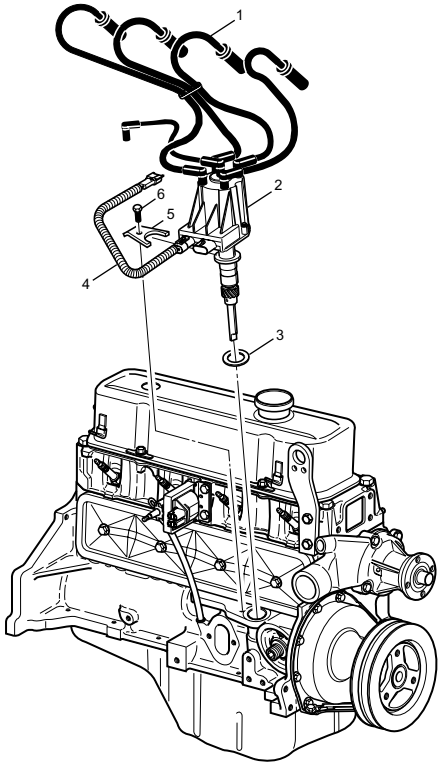
Install water hose from thermostat housing to manifold (**A)**.



5. Install alternator with mounting bracket (**A)**. Tighten screws (**B)** to 26-30 ft. lb. (35-41 N•m). Reinstall belt following the procedures found in the General Information section of this manual. Tighten the alternator screws (**C)** to 26-30 ft. lb. (35-41 N•m).
6. Reconnect throttle cable to anchor block and actuating bracket. Secure with cotter pin.
7. Connect battery cables. Start engine and check for fuel leaks.

Distributor

Removal

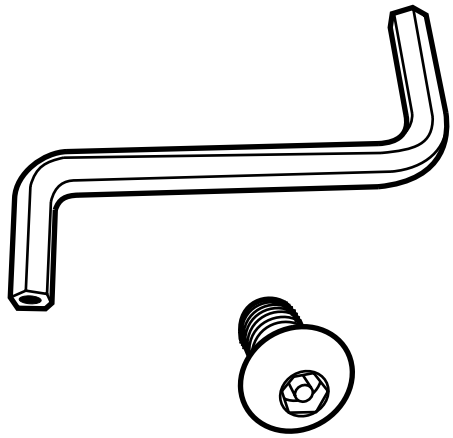


1. Disconnect the secondary ignition wires (1) from the spark plugs and the ignition coil.
2. Disconnect the primary ignition harness (4) from the ignition coil. Do not remove the wires from the distributor unless it is necessary.
3. Remove the distributor hold down bolt (6).

NOTE! Use special tool P/N 888863 on 3.0GL-B and later engines to remove distributor hold down bolt.

4. Remove the distributor (2) and gasket (3).

Installation



NOTE! To ensure correct ignition timing, the distributor must be installed in the correct position. Position the engine at top dead center on number one cylinder. The distributor cap must be removed in order to position the rotor when installing the distributor.

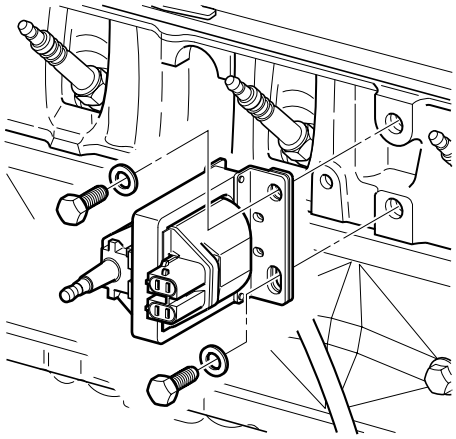
1. Install the distributor (2) and new gasket (3), making sure the distributor rotor is pointing to number one tower on the distributor cap.
2. Install the distributor hold down (5) and bolt (6). Tighten the hold down bolt to 27 N•m (20 lb ft).

NOTE! California Air Resource Board (C.A.R.B.) requires a tamper proof screw on 3.0GL-B model and later engines operated in California.

3. Connect the primary ignition harness (4) to the ignition coil.
4. Connect the secondary ignition wires (1) to the spark plugs and the ignition coil.
5. Set ignition timing, See “Setting Initial Timing” on page 56 in Electric, Fuel and Ignition Workshop Manual P/N 7743454.

Ignition Coil

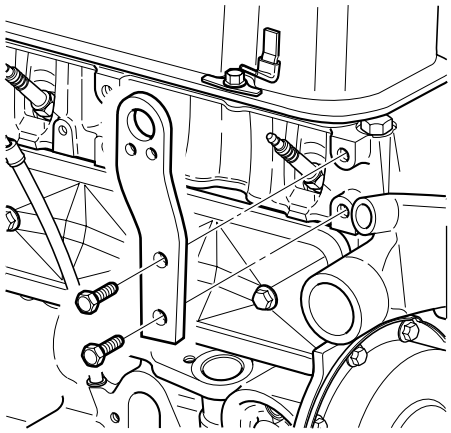
Removal and installation



1. Remove the ignition coil bracket attaching bolts.
2. Remove the ignition coil.
3. Install the ignition coil.
4. Install the ignition coil bracket attaching bolts. Tighten the attaching bolts to 22 N•m (16 lb ft).

Lift Bracket

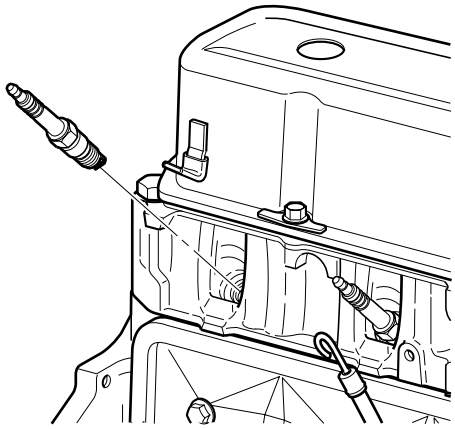
Removal and Installation



1. Remove the lift bracket bolts.
2. Remove the lift bracket.
3. Install the lift bracket.
4. Install the lift bracket bolts. Tighten the lift bracket bolts to 54 N•m (40 lb ft).

Spark Plug

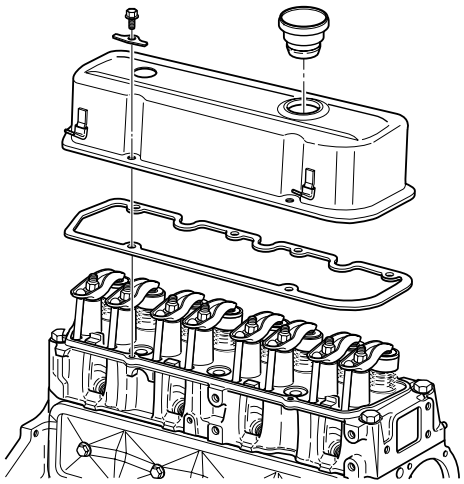
Removal and Installation



1. Clean the area around the spark plug seat with compressed air to prevent dirt from entering the cylinders when the spark plug is removed.
2. Using 5/8 in. spark plug socket, remove spark plug.
3. Set the spark plug gap to 0.045 in (1.14 mm)
4. Install the spark plugs.
5. Tighten the spark plugs to 30 N•m (22 lb ft).

Rocker Arm Cover

Removal

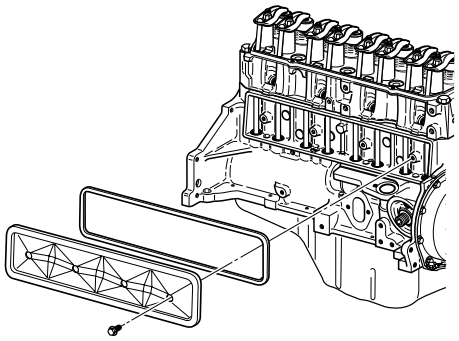


1. Remove the rocker arm cover bolts.
2. Remove the rocker arm cover.
3. Remove the gasket.

Installation

1. Install a new rocker arm cover gasket.
2. Install the valve rocker arm cover.
3. Install the rocker arm bolts. Tighten the rocker arm cover bolts to 4.5 N•m (40 lb in).

Pushrod Cover



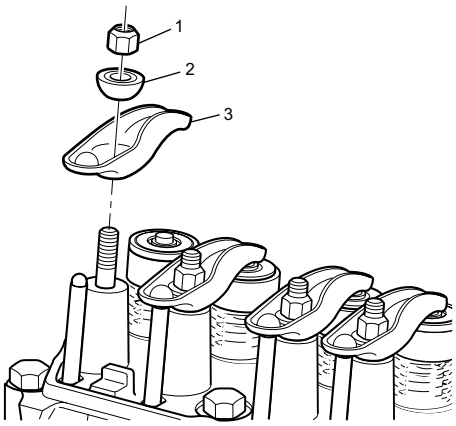
Removal

1. Remove the pushrod cover bolts.
2. Remove the pushrod cover.
3. Remove the gasket.

Installation

1. Install a new pushrod cover gasket.
2. Install the pushrod cover.
3. Install the pushrod cover bolts. Tighten the pushrod bolts to 4.5 N•m (40 lb in).

Valve Rocker Arm and Pushrod



Removal

1. 1.Remove the following components from the cylinder head:
   a. The valve rocker arm nuts (1).
   b. The valve rocker arm balls (2).
   c. The valve rocker arms (3).

Installation

2. Install the following components:
   a. The valve rocker arms (3).
   b. The valve rocker arm balls (2).
   c. The valve rocker arm nuts (1).

Valve Lash Adjustment

⚠ **Warning!**

If adjusting the valves while the engine is installed in the boat, be sure the ignition system is disabled by disconnecting the purple and grey wire connector on the ignition coil before attempting to rotate the engine with the valve cover removed.

3. Adjust the rocker arm nuts as follows:

a. Turn the crankshaft until the mark on the crankshaft pulley lines up with “0” on the timing tab and number 1 cylinder is at top dead center.

b. Place fingers on the number 1 valves as the mark approaches “0.” If the valves move as the mark approaches “0,” the engine is on number 4 top dead center and should be rotated one more revolution in order to reach number 1 top dead center.

c. With the engine at number 1 top dead center, adjust the following valves:

—The exhaust valves 1,3

—The intake valves 1,2,4

4. Adjust the correct valves as follows:

a. Back off the rocker arm nut until the lash is felt in the valve pushrod.

b. Tighten the rocker arm nut until all the lash is removed.

c. Zero lash can be felt by moving the pushrod up and down between your thumb and forefinger until there is no more movement.

d. When all the free play is gone, tighten the valve rocker arm nut 1 additional turn (360 degrees).

e. Turn the crankshaft 1 revolution until the mark on the crankshaft pulley lines up with “0” on the timing tab. This is number 4 top dead center.

f. With the engine at number 4 top dead center, adjust the following valves:

—The exhaust valves 2,4

—The intake valves 3

g. Back off the rocker arm nut until the lash is felt in the valve pushrod.

h. Tighten the valve rocker arm nut until all the lash is removed.

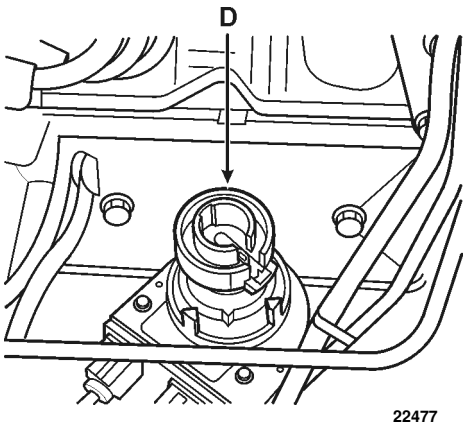
i. Zero lash can be felt by moving the valve pushrod up and down between your thumb and forefinger until there is no more movement.

j. When all the free play is gone, tighten the valve rocker arm nut 1 additional turn (360 degrees).

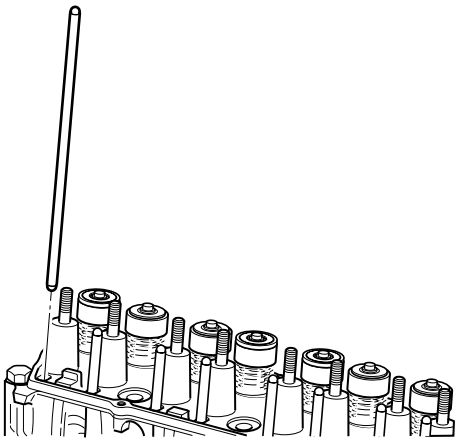
Hydraulic Valve Lifter

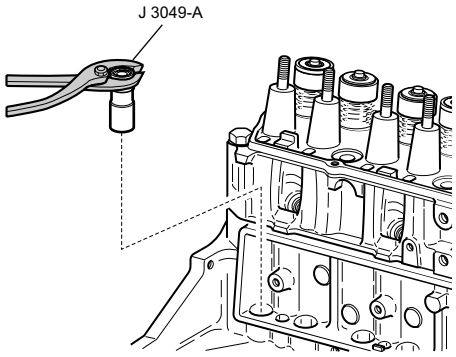
Removal

1. With air hose and cloths, clean dirt from cylinder head and adjacent parts to avoid getting dirt into engine. It is extremely important that no dirt gets into the valve lifters.
2. Disconnect ventilation hose, fuel line, and fuel pump overflow hose. Remove rocker arm cover See “Rocker Arm Cover” on page 32
3. Loosen rocker arm nuts and pivot the rocker arms free of the push rods.
4. Disconnect spark plug wires at plugs. Remove high tension lead from coil. Remove both connectors from coil. Remove coil and mounting bracket from cylinder head See “Ignition Coil” on page 31
5. Remove both connectors at distributor. Take off cap, note distributor rotor **(D)** position and remove distributor See “Distributor” on page 30
6. Remove push rod cover and gasket See “Pushrod Cover” on page 33



7. Remove push rods and lift out valve lifters that require service. Place lifters in a wooden block having numbered holes, or use other suitable means of identifying them according to original position in the engine.

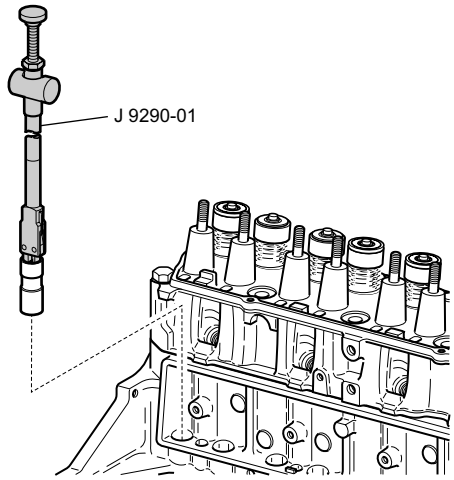




Tools Required

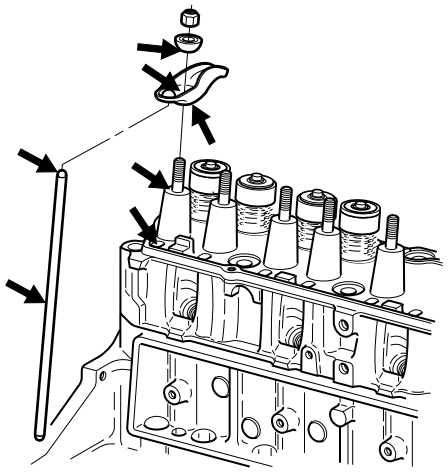
- J 3049 Valve Lifter Remover (Plier Type)
- J 9290-01 Valve Lifter Remover (Slide Hammer Type)

8. Use the J 3049 in order to remove the valve lifters.



9. If the valve lifters cannot be removed with the J 3049 use the J 9290-01 in order to remove the valve lifters.

Valve Train Components Inspect (Cylinder Head)

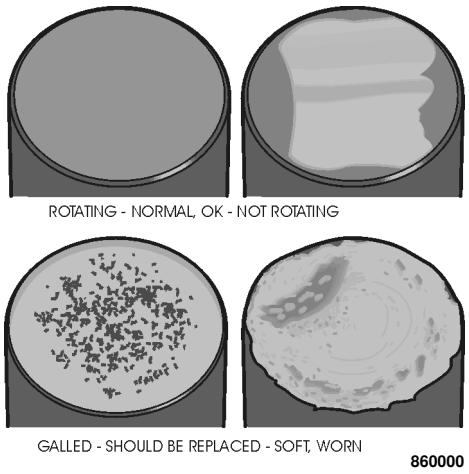


1. Inspect the following areas:

- The valve rocker arms and ball at the mating surfaces. These surfaces should be smooth and free of scoring or other damage.
- The valve pushrod sockets and valve stem mating surfaces. These surfaces should be smooth with no scoring or exceptional wear.
- The valve pushrods for bends or scored ends.

2. If less than a complete set of lifters is being removed, immediately disassemble and inspect one or two for presence of dirt or varnish. If lifters contain dirt or varnish, it is advisable to replace all lifters. Otherwise, it will be satisfactory to service only those lifters that are not operating properly.

3. Examine the cam contact surface at lower end of lifter body. If this surface is excessively worn, galled or otherwise damaged, discard the lifter assembly. In this case, also examine the mating camshaft lobe for excessive wear or damage.

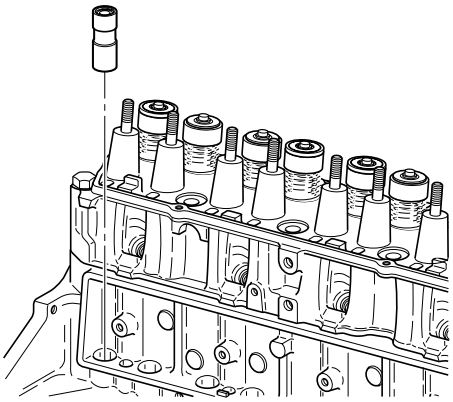


ROTATING - NORMAL, OK - NOT ROTATING

GALLED - SHOULD BE REPLACED - SOFT, WORN

Installation

NOTE! Before installing any new lifters, coat the bottom of each lifter with Molykote Lubricant or its equivalent.



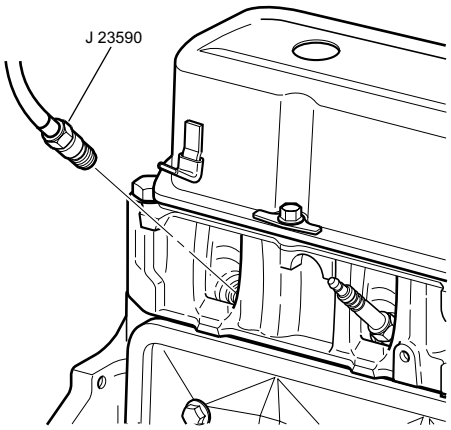
1. Install valve lifters in cylinder block. If any new lifters or a new camshaft has been installed, an additive containing EP lubricant such as GM Engine Super Oil Supplement must be added to the crankcase oil for break-in.
2. Install push rods onto lifters and install push rod cover with a new gasket.
3. Install distributor (position rotor to mark on housing and block). Install coil and bracket. Connect both connectors to coil. Install distributor cap and attach spark plug and coil wires. Connect both connectors to distributor.
4. Install shift bracket assembly.
5. Pivot rocker arms in place and turn adjusting nuts the amount necessary to eliminate lash.

Valve Spring and Seal Repair

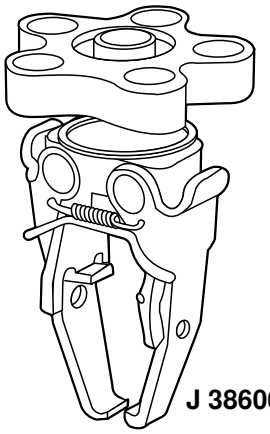
Removal

⚠ **Caution! Wear safety glasses**

1. Remove rocker arm cover, See “Rocker Arm Cover” on page 32
2. Remove spark plug, rocker arm, and push rod on the cylinder(s) to be serviced.



3. Install Air Line Adapter tool **J-23590** to spark plug port and apply compressed air to hold the valves in place.



4. Using valve spring compressor J 38606 to compress the valve spring, remove the valve locks, valve cap and valve spring and damper.

NOTE! Do not remove the spring from the compressor unless the spring needs testing or replacement.

5. Remove the valve stem oil seal.

Installation

1. Install seal over valve stem and seat against head.
2. Set the valve spring and damper, valve shield and valve cap in place. Install oil seal in the lower groove of the stem, making sure the seal is flat and not twisted.

A light coat of oil on the seal will help prevent twisting.

3. Install the valve locks and release the compressor tool making sure the locks seat properly in the upper groove of the valve stem.

Grease may be used to hold the locks in place while releasing the compressor tool.

4. Using Vacuum Pump **J-23738-A**, apply vacuum to the valve cap to make sure no air leaks past the seal.
5. Install spark plug and tighten to 20 ft. lb. (27 N•m).
6. Install and adjust valve mechanism See “Valve Lash Adjustment” on page 34

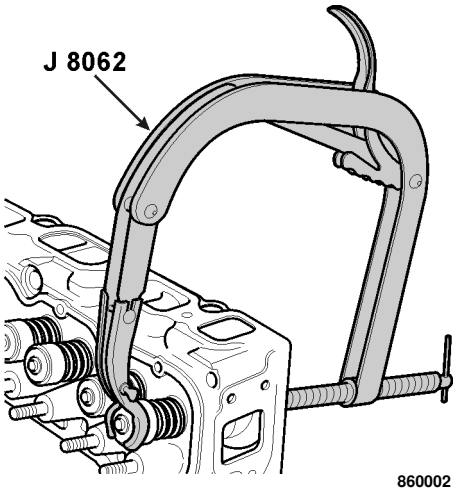
Cylinder Head

The condition of the cylinder head and valve mechanism significantly determines the power, performance and economy of the valve-in-head engine. Extreme care should be exercised when conditioning the cylinder head and valves. Maintain correct valve stem to guide clearance, correctly grind valves and valve seats, and properly adjust valves.

Removal

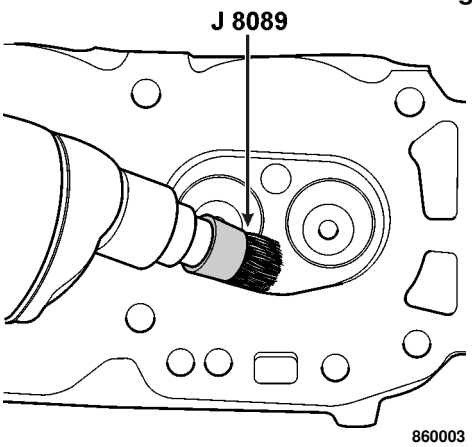
1. Remove intake and exhaust manifold See “Intake/Exhaust Manifold” on page 28
2. Disconnect coolant hoses at thermostat housing. Disconnect spark plug wires and remove spark plugs.
3. Disconnect fuel line retaining clips at thermostat housing and cylinder head. Disconnect wire harness from the temperature sending unit, leaving harness clear of clips on rocker arm cover. Remove thermostat housing assembly from front of cylinder head. Disconnect fuel line at the fuel pump and remove.
4. Remove the rocker arm cover. Next, back off the rocker arm nuts and pivot the rocker arms to clear the push rods. Remove the push rods.
5. Remove the ignition coil and bracket.
6. Remove the cylinder head bolts, cylinder head, and gasket. Place the cylinder head on two blocks of wood to prevent damage to the head.

Disassembly

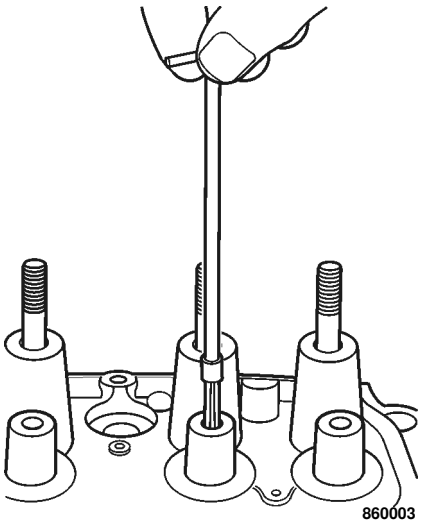


1. Remove rocker arms nuts, ball seats and rocker arms. Use tool **J-8062**, compress the valve springs and remove valve stem keys. Release the spring compressor tool and remove exhaust valve rotator or intake valve cap, shield, spring and seals.
2. Remove valves from bottom of cylinder head and place them in a rack in their proper sequence so they can be assembled in their original positions.

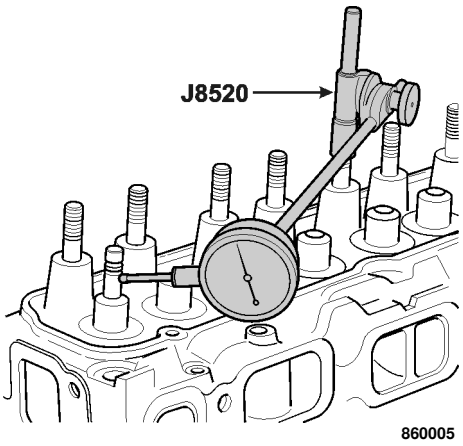
Cleaning



1. Clean all carbon from combustion chambers and valve ports using tool **J-8089**. Inspect the cylinder head for cracks in the exhaust ports, combustion chambers, or external cracks to the water chamber. Clean carbon deposits from head gasket mating surfaces.



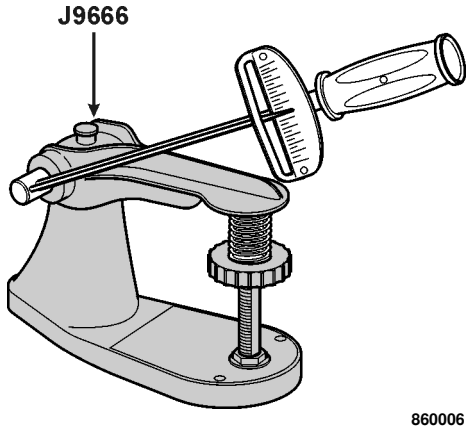
2. Thoroughly clean the valve guides. Clean all carbon and sludge from push rods and rocker arms.
3. Clean valve stems and heads on a buffing wheel. Inspect the valve for burned head, worn seat, cracked faces, or damaged stems.
4. Wash all parts in cleaning solvent and dry them thoroughly. Check fit of valve stems in their respective bores.



5. Measure valve stem clearance as follows: Clamp a dial indicator on one side of the cylinder head rocker arm cover gasket rail, locating the indicator so that movement of the valve stem from side to side (crosswise to the head) will cause a direct movement of the indicator stem. The indicator stem must contact the side of the valve stem just above the valve guide. With the valve head dropped about 1/16 in. off the valve seat; move the stem of the valve from side to side using light pressure to obtain a clearance reading. If clearance exceeds specifications it will be necessary to ream valve guides for oversize valves as outlined.

NOTE! Excessive valve stem to bore clearance will cause lack of power, oil consumption, rough idling and noisy valves, and may cause valve breakage. Insufficient clearance will result in noisy and sticky functioning of the valves and disturb engine smoothness of operation. Intake valve stem to bore clearance should be 0.001-0.0027 in. (0,025-0,007 mm). Exhaust valve stem to bore clearance should be 0.0007-0.0027 (0,01778-0,06858 mm). By using a micrometer and a suitable hole gauge, check the diameter of the valve stem in three places; top, center and bottom. Insert hole gauge in valve guide bore, measuring at the center. Subtract highest reading of valve stem diameter from valve guide bore center diameter to obtain valve to valve guide clearance. If clearance is not within limits use next oversize valve and ream bore to fit using suitable reamer.

6. Check valve spring tension with tool **J-9666** spring tester.

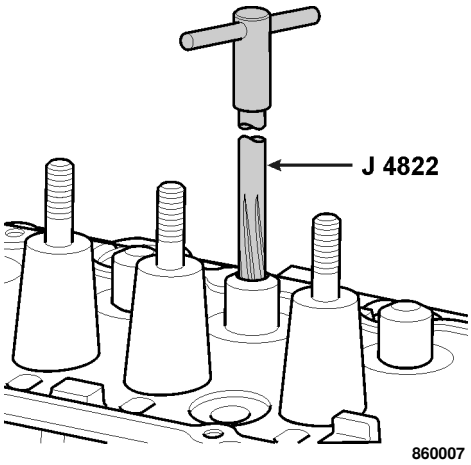


NOTE! On all models, springs should be compressed to 1.61 in. (40,89 mm) at which height it should check 100-110 pounds (444-490 N). Weak springs affect power and economy and should be replaced.

7. Check valve lifters for free fit in block. The end that contacts the camshaft should be smooth. If this surface is worn or rough, the lifter should be replaced. If lifter is damaged, check the corresponding camshaft lobe for damage.

Repair

Valve Guide Bore



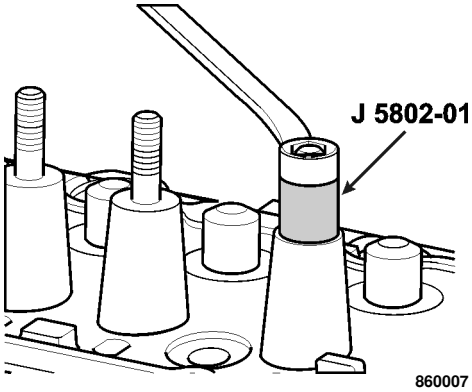
Valves with oversize stems are available for inlet and exhaust valves in the following sizes: 0.0003 in., 0.015 in., and 0.030 in. Use the 11/32 in. diameter reamer sizes from reamer tool set **J-5830-02** which are: **J-4822** standard; **J-5830-1**, 0.003 in oversize, **J-5830-2**, 0.015 in. oversize and **J-5830-3**, 0.030 in. oversize to ream the bores for the new valves.

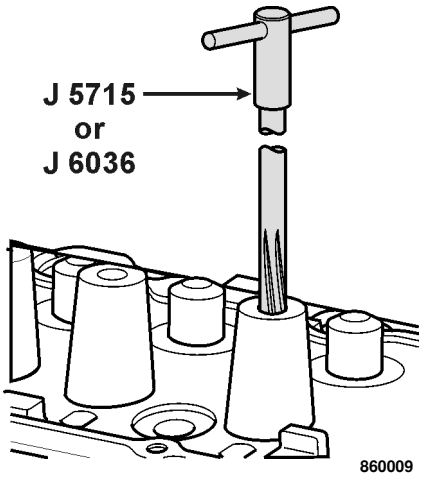
Rocker Arm Studs

Rocker arm studs that have damaged threads may be replaced with standard studs. If the studs are loose in the head, oversize studs (available in 0.003 in. or 0.013 in. oversize) may be installed after reaming the holes as follows:

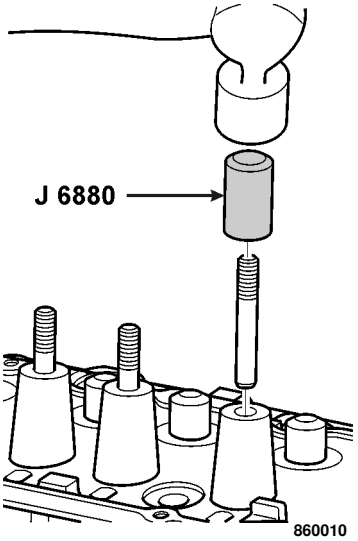
NOTE! Do not attempt to install oversize stud without reaming stud hole.

a. Remove old stud by placing tool **J-5802-01** over the stud. Install nut and flat washer, and remove stud by turning nut.



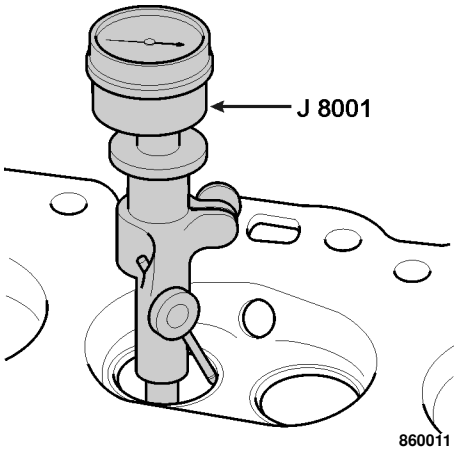


b. Ream hole for oversize stud. Use tool **J-5715** for 0.003 in. oversize and tool **J-6036** for 0.013 in. oversize.



c. Coat press-fit area of stud with a hypoid axle lubricant. Install new stud using tool **J-6880**. Tool should bottom on head.

Valve Seats



Reconditioning the valve seats is very important, because seating of the valve must be perfect for the engine to deliver the power and performance built into it.

Another important factor is the cooling of the valve heads. Good contact between each valve and its seat in the head is imperative to ensure that the heat in the valve head will be properly carried away.

Several different types of equipment are available for reseating valve seats; the recommendations of the manufacturer of the equipment being used should be carefully followed to attain proper results.

Regardless of what type of equipment is used, however, it is essential that valve guides be free from carbon or dirt to ensure proper centering of pilot in the guide.

a. Install expanding pilot in the valve guide bore and expand pilot by tightening nut on top of pilot.

b. Place roughing stone or forming stone over pilot and just clean up the valve seat. Use a 46° stone for both the inlet and exhaust valve seats.

c. Remove roughing stone or forming stone from pilot, install finishing stone on pilot and cut just enough metal from the seat to provide a smooth finish.

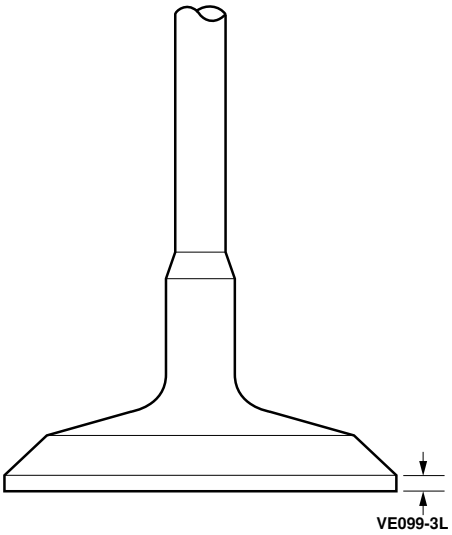
d. Narrow down the valve seats to the proper width for the intake and exhaust. See Engine Specifications.

NOTE! This operation is done by grinding the port side with a 30° stone to lower seat and a 60° stone to raise seat.

e. Remove expanding pilot and clean cylinder head carefully to remove all chips and grindings from above operations.

NOTE! Valve seats should be concentric to within 0.002 in. total indicator reading.

Valves



Valves that are pitted can be refaced to the proper angle, ensuring correct relation between the head and stem on a valve refacing machine. Valve stems which show excessive wear, or valves that are warped excessively should be replaced. When a valve head which is warped excessively is refaced, a knife edge will be ground on part or all of the valve head due to the amount of metal that must be removed to completely reface. Knife edges lead to breakage, burning or pre-ignition due to heat localizing on this knife edge. If the edge of the valve head is less than 1/32 in. thick after grinding, replace the valve.

a. If necessary, dress the valve refacing machine grinding wheel to make sure it is smooth and true. Set chuck at 45° mark for grinding valves.

b. Clamp the valve stem in the chuck of the machine.

c. Start the grinder and move the valve head out in line with the grinder wheel by moving the lever to the left.

d. Turn the feed screw until the valve head just contacts wheel. Move valve back and forth across the wheel and regulate the feed screw to provide light valve contact.

e. Continue grinding until the valve face is true and smooth all around valve. If this makes the valve thin the valve must be replaced as the valve will overheat and burn.

f. Remove valve from chuck and place stem in “V” block. Feed valve squarely against grinding wheel to grind any pit from rocker arm end of stem.

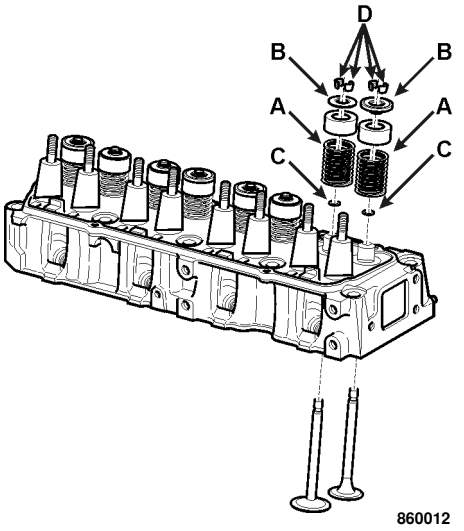
NOTE! Only the extreme end of the valve stem is hardened to resist wear. Do not grind end of stem excessively.

g. After cleaning valve face and cylinder head valve seat of grinding particles, make pencil marks about 1/4 in. apart across the valve face, place the valve in cylinder head and give the valve one-half turn in each direction while exerting firm pressure on face of valve.

h. Remove valve and check face carefully. If all pencil marks have not been removed at the point of contact with the valve seat, it will be necessary to repeat the refacing operation and again recheck for proper seating.

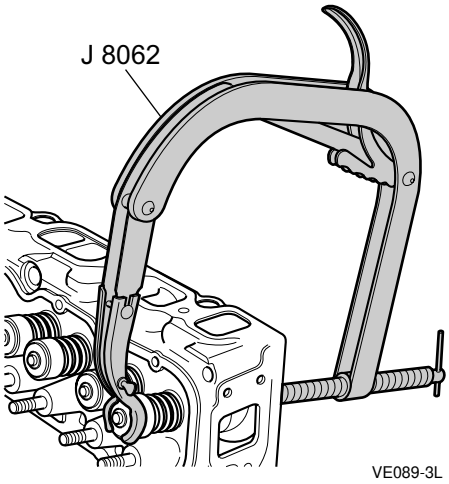
i. Grind and check remaining valves in the same manner.

Assembly

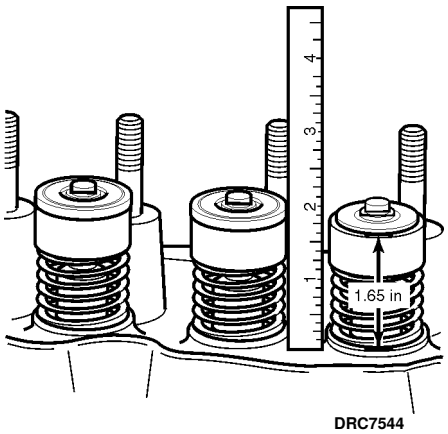


1. Starting with number one cylinder, place the exhaust valve in the port, and place the valve spring (**A)** and cap (**B)** in position. Place spring and cap on exhaust valves. Then, using tool **J-8062**, compress the spring and install the oil seal **(C)** and valve keys **(D)**. See that the seal is flat and not twisted in the valve stem groove and that the keys seat properly in the valve stem groove.

Place valve springs in position with the closed coil end toward the cylinder head.



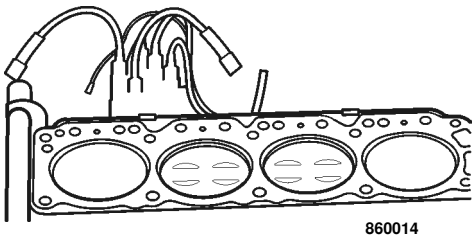
2. Assemble the remaining valve, valve springs, spring caps, oil seals and valve keys in the cylinder head using tool **J-8062**. Check seals by placing a vacuum cup over valve stem and cap, squeeze vacuum cup to make sure no oil leaks past oil seal.



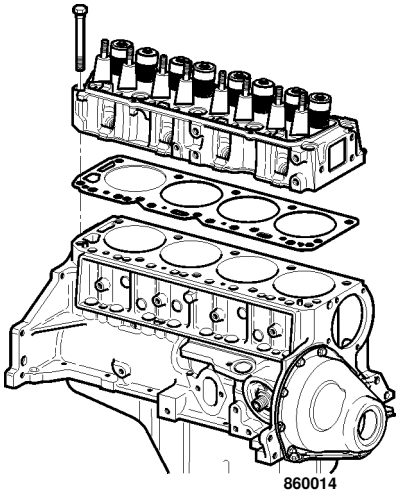
3. Check the installed height of the valve springs using a narrow, thin scale to measure from the top of the shim or spring seat in the head, to the top of the valve spring cap. If this is found in excess of 1.65 in. (41,91 mm), install a valve spring seat shim, approximately 1/16 in. (1,858 mm) thick. At no time should the spring be shimmed to give an installed height of less than 1.65 in. (41,91 mm).

NOTE! If springs are to be changed with cylinder head installed,
See "Valve Spring and Seal Repair" on page 37

Installation



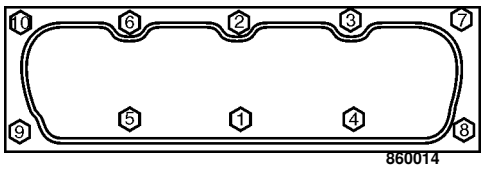
1. The gasket surfaces of both the head and the block must be clean and free of any foreign matter, and free of nicks or heavy scratches.
2. Cylinder head bolt threads in the block must be cleaned as well as the threads on the cylinder head bolts. Dirt will affect bolt torque.



3. Place a new cylinder head gasket in position over the dowel pins in the cylinder block. On engines with a steel gasket coat both sides of a new gasket with a thin, even coat of Volvo Penta Gasket Sealing Compound. Too much sealer will hold the beads of the gasket away from the block or head.

NOTE! The 3.0 Liter engine has a special marine head gasket. Do not substitute an automotive head gasket.

4. Carefully guide cylinder head into place over dowel pins and gasket. Coat threads of cylinder head bolts with Permatex No. 2. Install the bolts and run them down to the block.



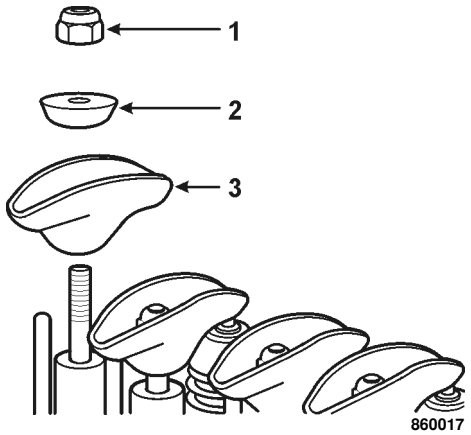
5. Tighten the cylinder head bolts, with a torque wrench, in three progressive steps following the sequence shown.

   Step 1 - 35 ft. lb. (47 N•m)

   Step 2 - 65 ft. lb. (88 N•m)

   Step 3 - 90 ft. lb. (122 N•m)

6. Install valve push rods down through openings in the cylinder head and seat them in lifter sockets.

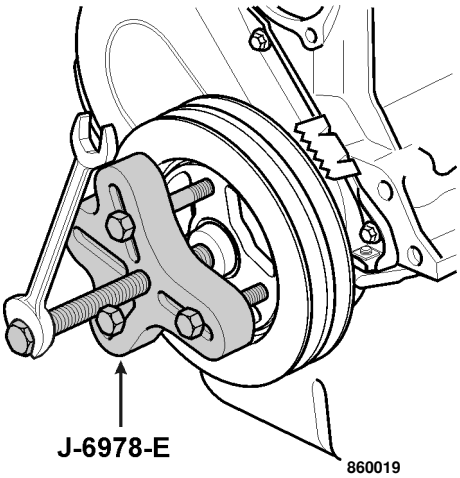


7. Install rocker arms (**3)**, balls (**2)**, and nuts (**1)**. Tighten rocker arm nuts until all push rod play is taken up.
8. Install thermostat housing using a new gasket. Attach coolant hoses.
9. Clean all spark plugs with abrasive-type cleaner, inspect for damage (replace if necessary) and set the gap at 0.045 in. (1.14 mm) using a wire gauge. Install the spark plugs. Tighten spark plugs to 20 ft. lb. (27 N•m).
10. Install coil and connect both connectors to coil. Connect wire to temperature sending unit.
11. Clean manifold gasket surfaces and install new gasket over manifold studs. Position manifold and slide it into place over the studs, making sure it seats against the gasket. Install bolts and nuts and tighten as described under heading Intake/Exhaust Manifold.
12. Adjust valve lash See “Valve Lash Adjustment” on page 34 Install rocker arm cover and gasket. Tighten screws to 40 in. lb. (5 N•m).
13. Connect throttle linkage and adjust See “Installation of Shift and Throttle Cables” on page 117

14. Connect fuel line and overflow hose to carburetor and install fuel line support clamps (two). Clean and install flame arrestor.
15. Start engine and check for fuel, coolant, and exhaust leaks.

Timing Gear Cover

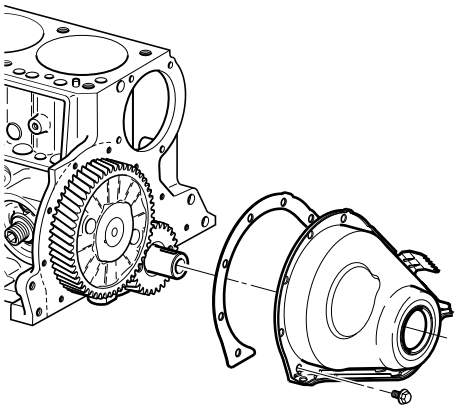
Removal



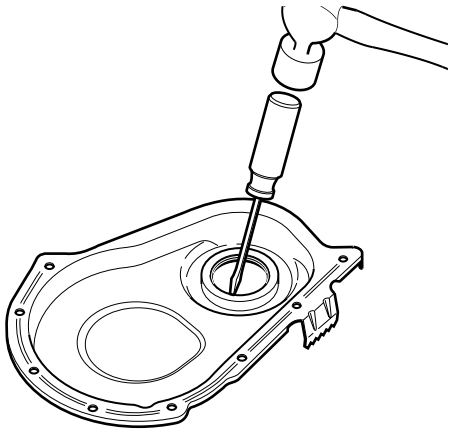
1. Drain coolant from block and exhaust manifold.
2. Securely support engine and remove front engine mount.
3. Remove alternator and power steering belts. Next remove harmonic balancer and pulley assembly from pulley hub.
4. Install puller tool **J-6978-E** to pulley hub with three 3/8-24 x 2 in. bolts and remove hub. Remove puller tool.
5. Remove circulating pump pulley.
6. Remove crankcase oil drain tube cap and withdraw oil with a suction pump.
7. Disconnect oil drain tube and remove.
8. Remove timing gear cover attaching screws. Remove cover and gasket.

Oil Seal Replacement

Engine Front Cover Removal

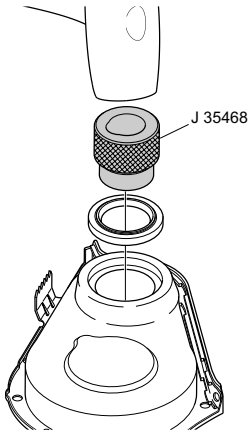


1. Remove oil pan See “Oil Pan Replacement” on page 75
1. Remove the engine front cover bolts.
2. Remove the engine front cover.
3. Remove the gasket.
4. Discard the gasket.



5. Remove the oil seal from the front cover.
6. Clean the engine front cover in solvent.
7. Inspect the engine front cover for damage to the gasket surface or the oil seal surface.

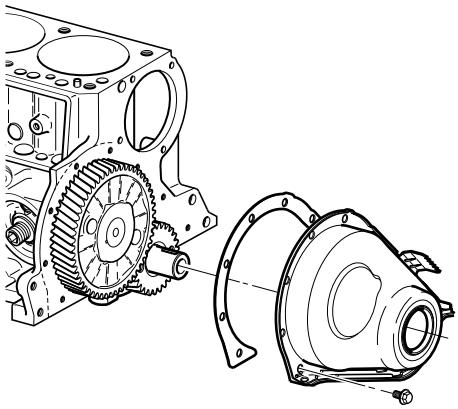
Installation



Tools Required

- J 35468 Engine Front Cover Aligner and Oil Seal Installer

1. Use the J 35468 in order to install the engine front cover oil seal.

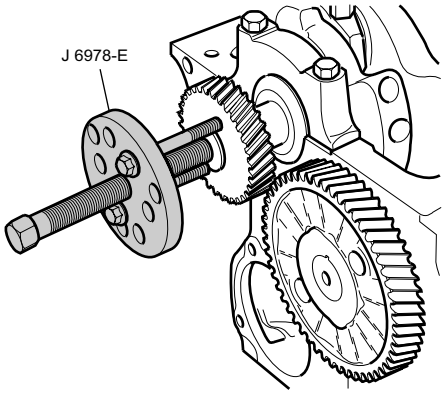


2. Install the engine front cover gasket.
3. Install the engine front cover and bolts. Tighten engine front cover bolts to 3.4 N•m (30 lb in).
4. Install oil pan See “Oil Pan Replacement” on page 75

Crankshaft Sprocket

Removal

1. Remove Timing gear cover See “Timing Gear Cover” on page 46

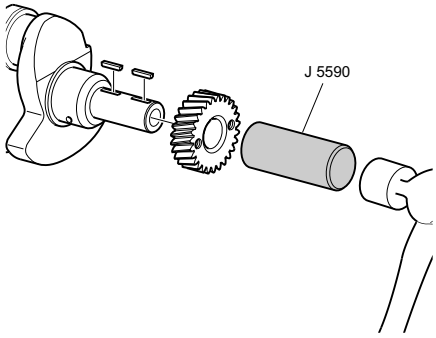


Tools Required

- J 6978-E Crankshaft Sprocket Puller

2. Use the J 6978-E in order to remove the crankshaft sprocket.
3. If necessary, remove the crankshaft keys.

Installation

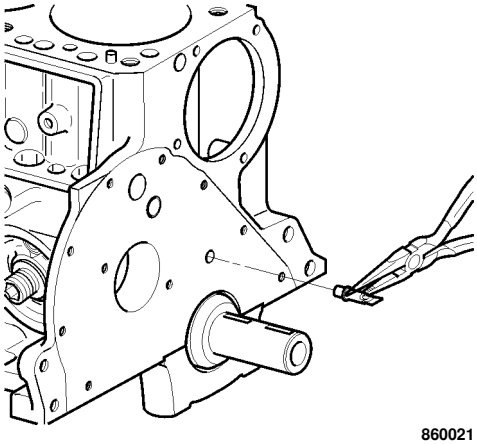


Tools Required

- J 5590 Crankshaft Sprocket Installer

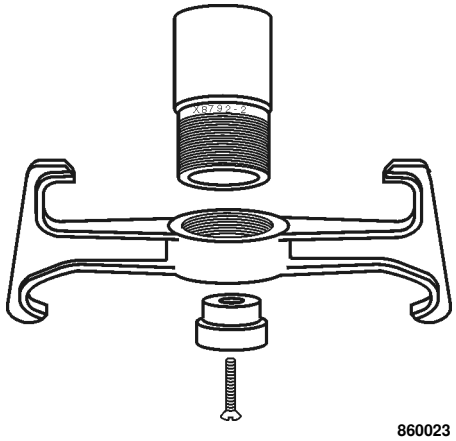
1. Install the keys into the crankshaft keyways.
2. Use the J 5590 in order to install the crankshaft sprocket.
3. Install timing gear cover See “Timing Gear Cover” on page 46

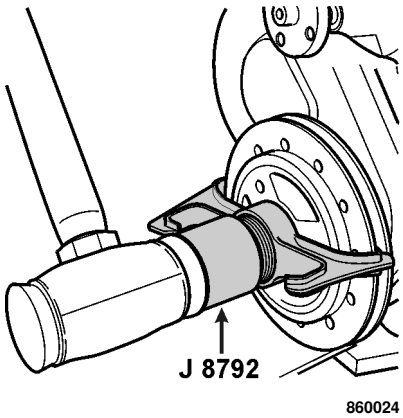
Timing Gear Nozzle Replacement



Remove old nozzle with pliers. Drive new nozzle in place using a suitable light plastic or rubber hammer.

Harmonic Balancer Installation





1. Coat oil seal contact area on harmonic balancer with engine oil. Position hub over crankshaft and key, and start hub into position with a mallet. Using tool **J-8792**, drive hub onto crankshaft until it bottoms against crankshaft gear.

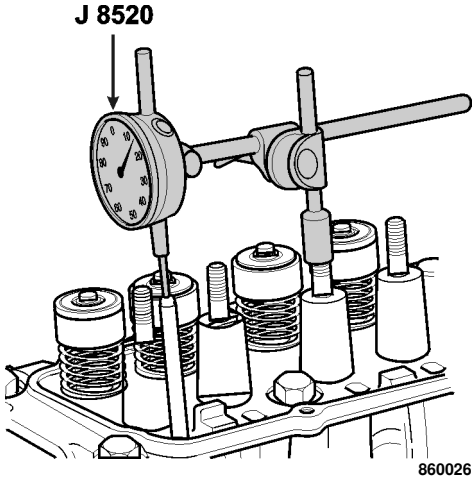
NOTE! Crankshaft extends slightly through hub and a hollow tool is necessary to drive hub completely into bottomed position.

NOTE! There are two 3/8 in. (9.925 mm) holes and one 5/16 in. (7.938 mm) hole that must be matched on hub in order to properly position timing mark.

2. Install circulating pump pulley.
3. Install alternator and power steering belts and adjust to specifications.
4. Install front engine mount.
5. Fill engine crankcase with proper amount of oil.
6. Lake or tank test unit and check for leaks.

Camshaft

Measuring Camshaft Lift
J 8520

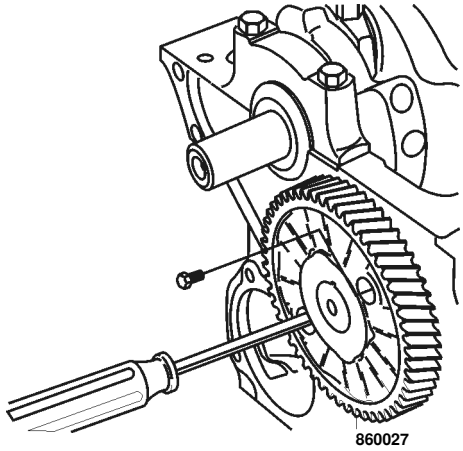


NOTE! Remove both connectors from ignition coil.

If improper valve operation is indicated, measure the lift of each push rod in consecutive order and record the readings.

1. Remove valve cover and rocker arms.
2. Position indicator with ball socket adapter (tool **J8520**) on push rod.
3. Rotate crankshaft slowly in the direction of rotation until the lifter is on the heel of the cam lobe. At this point, the push rod will be in its lowest position.
4. Set dial indicator on zero. Rotate the crankshaft slowly, or attach an auxiliary starter switch and “bump” the engine over, until the push rod is in the fully raised position.
5. Compare the total lift recorded from the dial indicator with specifications. The correct lift is 0.25294 inch ± 0.001 inch (6,4247 ± 0,0254 mm).
6. Continue to rotate the crankshaft until the indicator reads zero. This will be a check on the accuracy of the original indicator reading.
7. If camshaft readings for all lobes are within specifications, remove dial indicator assembly. Install and adjust valve mechanism.

Removal



1. Withdraw oil from crankcase. Drain coolant from block and exhaust manifold.
2. Remove valve cover and gasket. Loosen valve rocker arm nuts and pivot rocker arms clear of push rods.
3. After noting position of rotor, remove distributor.
4. Remove coil, side cover, and gasket. Remove push rods and valve lifters.
5. Remove crankshaft pulley and hub. Disconnect oil drain tube. Remove oil pan and timing gear cover.
6. Remove two camshaft thrust plate screws by working through holes in camshaft gear.
7. Remove the camshaft and gear assembly by pulling it out through the front of the block.

NOTE! Support shaft carefully when removing so as not to damage camshaft bearings.

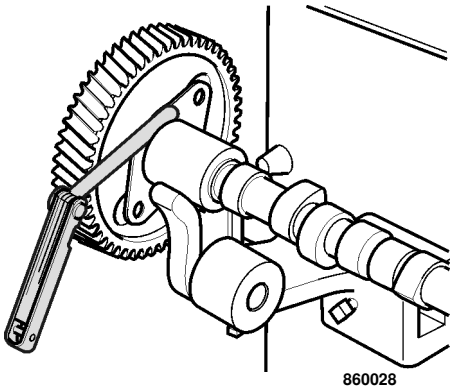
Inspection

The camshaft has three bearings, all with the same journal diameter of 1.8677 in. to 1.8697 in. (47,440 to 47,490 mm). These dimensions should be checked with a micrometer for an out-of- round condition. If the journals exceed 0.001 in. (0,025 mm) out-of-round, the camshaft should be replaced.

The camshaft should also be checked for alignment. The best method is by use of “V” blocks and a dial indicator. The dial indicator will indicate the exact amount that the camshaft is out of true. If it is out more than 0.002 in. (0,051 mm) dial indicator reading, the camshaft should be replaced. When checking, the high reading of the dial indicator indi-

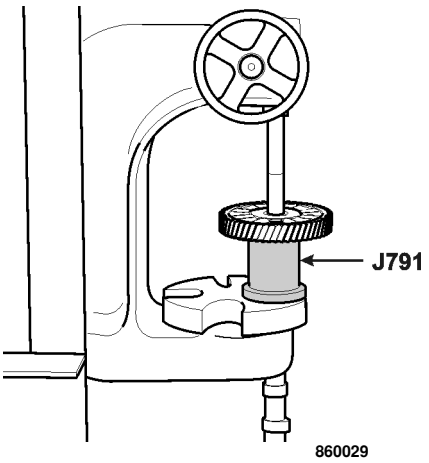
cates the high point of the shaft. Examine the camshaft bearings and if any bearing needs replacement, replace all bearings.

Gear and Thrust Plate



If the inspection indicated that the camshaft, gear and thrust plate were in good condition, the camshaft end play should be checked. This clearance should be 0.003 in. to 0.008 in. (0,0762 to 0.2032 mm).

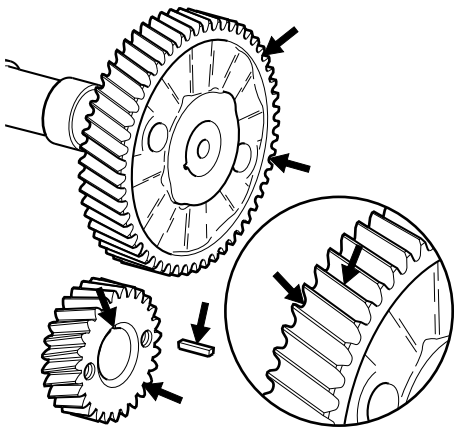
Disassembly



If the inspection indicated that the shaft, gear or plate should be replaced, the gear must be removed from the shaft. Support the camshaft gear and press shaft out of gear.

NOTE! Thrust plate must be positioned so that woodruff key in shaft does not damage it when shaft is pressed out of gear. Also, support the hub of the gear or the gear will be seriously damaged.

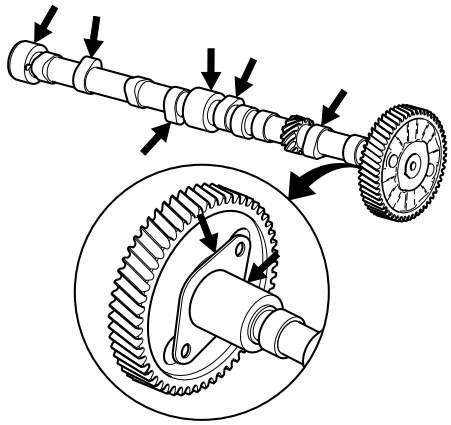
Crankshaft and Camshaft Sprocket Inspect



8. Inspect the crankshaft and camshaft sprockes for the following:

- The camshaft and crankshaft sprockets for wear.
- One edge of worn teeth or that are no longer concentric.
- The valley between worn teeth.
- The keys and crankshaft keyways for wear.

Camshaft and Bearings Clean and Inspect

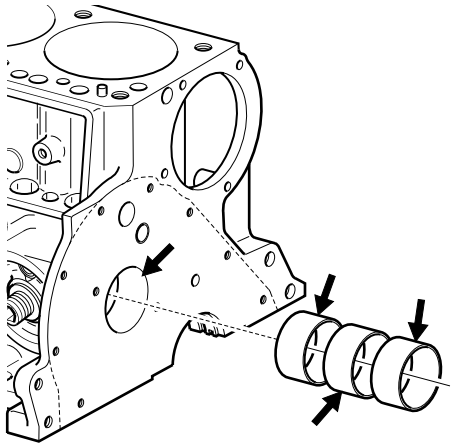


Tools Required

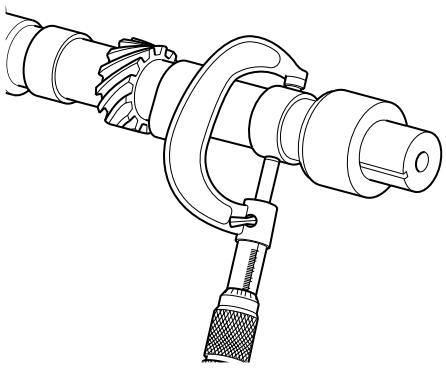
- J 7872 Magnetic Base Indicator Set

⚠ **Caution! Wear safety glasses.**

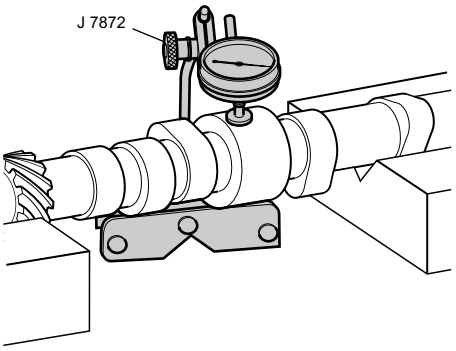
1. Clean the camshaft in solvent.
2. Dry the camshaft with compressed air.
3. Inspect the camshaft bearing journals for scoring or excessive wear.
4. Inspect the camshaft valve lifter lobes for scoring or excessive wear.
5. Inspect the camshaft retainer plate for wear.



6. Inspect the camshaft bearings for proper fit in the engine block. Camshaft bearings have an interference fit to the engine block and should not be loose in their engine block bearing bores.
7. 7.Inspect the camshaft bearings for excessive wear or scoring. Bearings with excessive wear or scoring must be replaced.



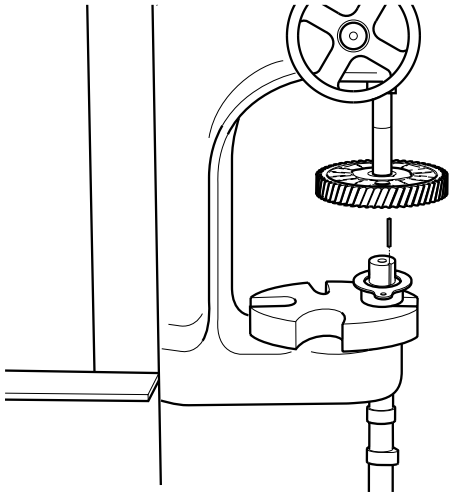
8. Measure the camshaft for out-of-round, taper or undersize with a micrometer. Refer to Engine Mechanical Specifications.



9. Support the camshaft front and rear journals on V-blocks.
10. Measure the camshaft run-out at the intermediate journal with J 7872. Refer to Engine Mechanical Specifications.
11. Replace camshaft if measurements are not within specifications.

Assembly

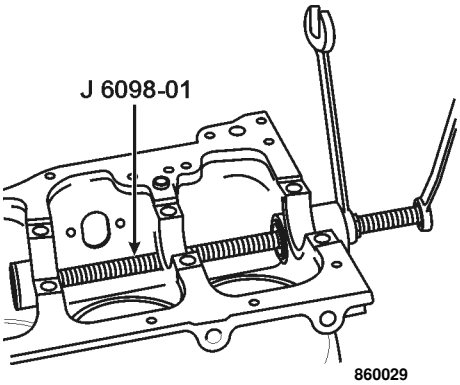
To assemble camshaft gear thrust plate and gear spacer ring to camshaft, proceed as follows:



1. Firmly support shaft at back of front journal in an arbor press. Place gear spacer ring and thrust plate over end of shaft, and install woodruff key in shaft keyway.
2. Install camshaft gear and press it onto the shaft until it bottoms against the gear spacer ring. The end clearance of the thrust plate should be 0.003-0.008 in. (0,0762-0,2032 mm)

Camshaft Bearings

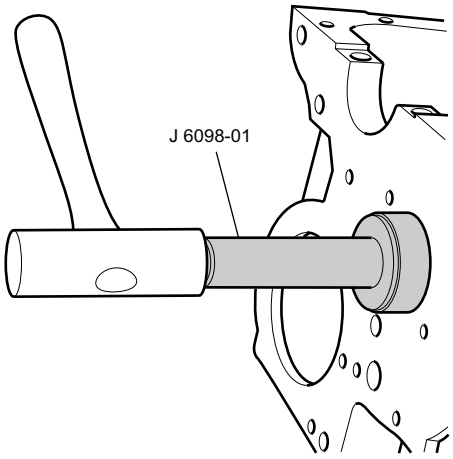
Removal



Camshaft bearings can be replaced while the engine is disassembled for overhaul, or without complete disassembly of the engine after camshaft and flywheel have been removed. Operation is easier if crankshaft is also removed. See Crankshaft in this section.

1. With camshaft and flywheel removed, drive out expansion plug for rear cam bearing by driving from inside.
2. Position bearing pilot in inner bearing. Install nut on puller screw far enough so puller screw can be threaded into pilot while nut extends out front of block.
3. Install remover section onto puller screw, and then install screw through cam bore and thread it into pilot.
4. Using two wrenches, hold screw shaft and turn puller nut to remove bearing.
5. Remove pilot from shaft and install on drive handle with shoulder to handle. Drive out front and rear bearings from outside to inside of block.

Installation



Tools Required

- J 6098-01 Camshaft Bearing Installer

NOTE!

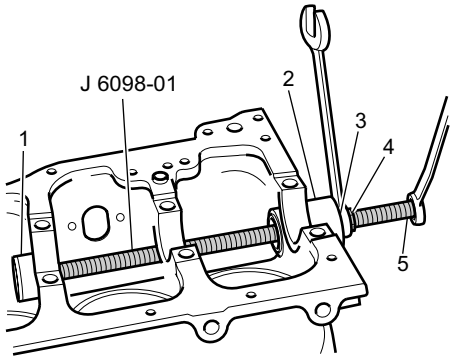
- A loose camshaft bearing may be caused by an enlarged, out of round or damaged engine block bearing bore.
- The outer front and rear camshaft bearings must be installed first. These bearings serve as guides for the tool pilot and help center the inner bearings during the installation process.
- The camshaft bearing oil holes must align with the oil galleys in the engine block. An improperly aligned camshaft bearing oil galley hole will restrict oil flow to the bearing and camshaft journal.

1. Use the J 6098-01 in order to install the front and rear camshaft bearings:

a. Assemble the bearing tool to the driver handle.

b. Align the oil holes.

c. Drive the front and the rear camshaft bearings inward toward the center of the engine block.



2. Use the J 6098-01 in order to install the inner camshaft bearings. Repeat the following steps for each of the inner camshaft bearings:

a. With the nut (4) and the thrust washer (3) installed to the end of the puller screw threads, index the pilot in the camshaft front bearing and install the puller screw through the pilot (2).

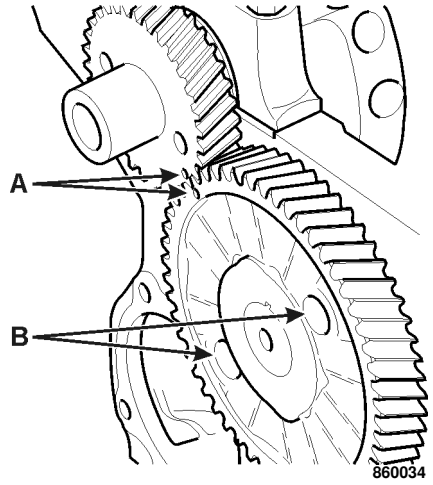
b. Index the camshaft bearing in the bore. Make sure you align the oil galley holes.

c. Install the puller screw through the bearing bore and bearing to be installed and assemble bearing tool (1) to the puller screw with the shoulder toward the bearing. Make sure that enough threads are engaged.

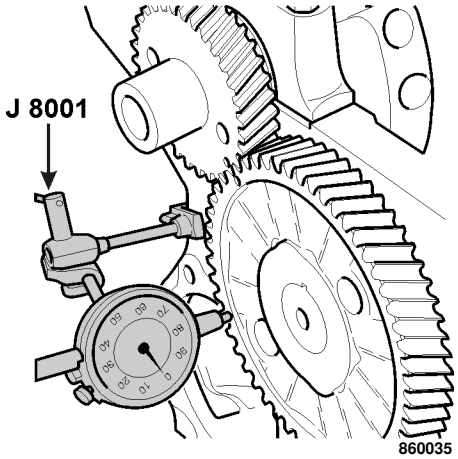
d. Using two wrenches, hold the puller screw (5) while you turn the nut in order to draw the bearing into the bore. When the bearing has been pulled into the bore, remove the bearing tool and the puller screw and check the alignment of the bearing oil hole to the bore oil hole.

3. Install a new camshaft rear bearing hole plug. Coat the plug outside diameter with GM P/N 1052080 sealant, or the equivalent.

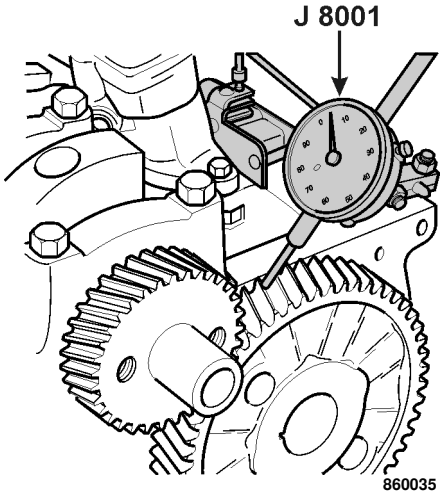
Camshaft Installation



1. If crankshaft has been removed, install it at this time. Follow procedures under the title Crankshaft in this section. If a new camshaft is to be installed, coat cam lobes with GM Super Engine Oil Supplement (G.M. P/N 1051858) and add rest of can to crankcase oil.
2. Install the camshaft assembly in the engine block, being careful not to damage bearings or cam.
3. Turn crankshaft and camshaft so that the valve timing marks **A** on the gear teeth will line up, then push camshaft into position. Install camshaft thrust plate to block screws (**B: screw access holes**) and tighten them to 80 in. lb. (9 N.m).



4. Check camshaft and crankshaft gear runout with a dial indicator **J8001**. The camshaft gear runout should not exceed 0.004 in. (0.102 mm) and the crankshaft gear runout should not exceed 0.003 in. (0.076 mm).
5. If gear runout is excessive, the gear will have to be removed, and any burrs cleaned from the shaft or the gear replaced.

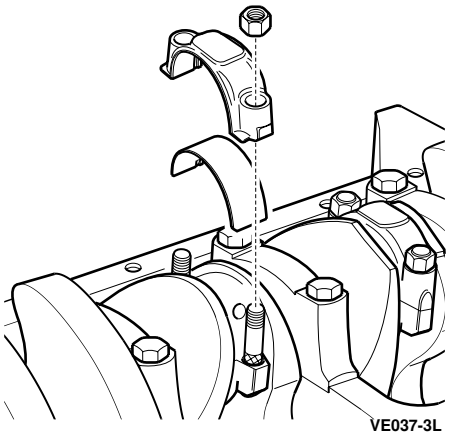


6. Check the backlash between the timing gear teeth with a narrow feeler gauge or dial indicator **J8001**. The backlash should not be less than 0.004 in. (0,102 mm) nor more than 0.006 in. (0.152 mm).
7. Install timing gear cover with new gaskets. Install oil pan with new gaskets and sealer. Connect oil drain tube.
8. Install harmonic balancer as described under title Timing Gear Cover in this section.
9. Install valve lifters and push rods. Install side cover with a new gasket and sealer. Attach coil and wires. Install distributor, positioning rotor to reference mark.
10. Pivot rocker arms over push rods. Adjust valve lash as outlined under heading Valve Lash Adjustment.
11. Add oil to engine. Install the alternator and power steering belts, then adjust tension. Check and adjust timing.

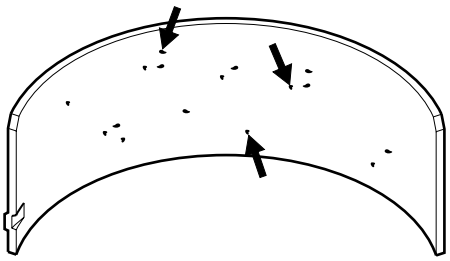
Crankshaft

Crankshaft and Bearings Clean and Inspect (Connecting Rod Bearing Clearance)

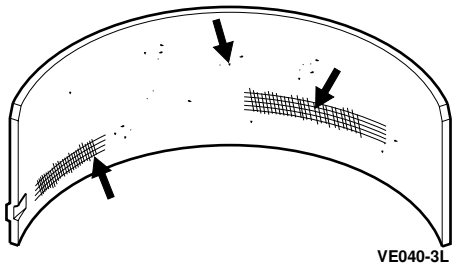
NOTE! Connecting rod bearings are a precision insert type. Connecting rods are of a powdered metal design and cannot be shimmed or filed for bearing fit. If clearances are found to be excessive, a new bearing and/or connecting rod are required. Do not rotate the crankshaft while gauging plastic is between the crankshaft journal and the bearing surface.


VE037-3L

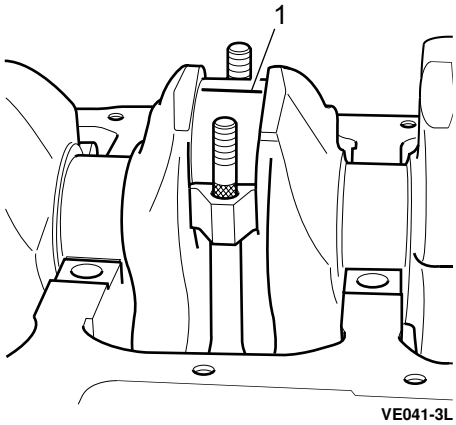
1. Remove the connecting rod nuts.
2. Remove the connecting rod cap and bearing.


VE039-3L

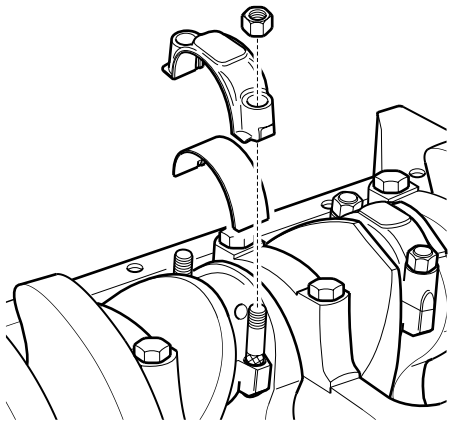
3. Inspect the crankshaft bearings for craters or pockets. Flattened sections on the bearing halves also indicate fatigue.


VE040-3L

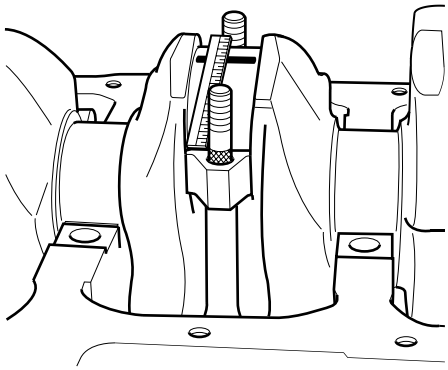
4. Inspect the crankshaft bearings for excessive scoring or discoloration.
5. Inspect the crankshaft bearings for dirt or debris imbedded into the bearing material.



6. Install the gauging plastic (1) onto the connecting rod bearing journal. Install the gauging plastic the full width of the journal.

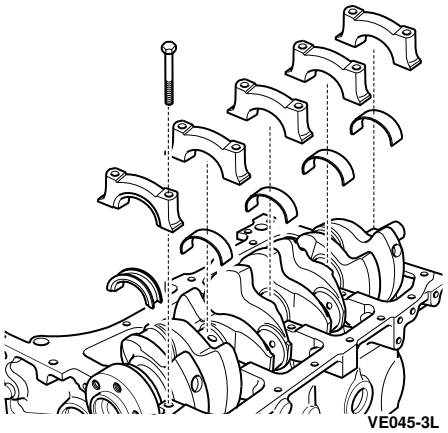


7. Install the connecting rod cap and bearing. Tighten the nuts evenly to 61 N•m (45 lb ft).
8. Remove the connecting rod nuts.
9. Remove the connecting rod cap and bearing.

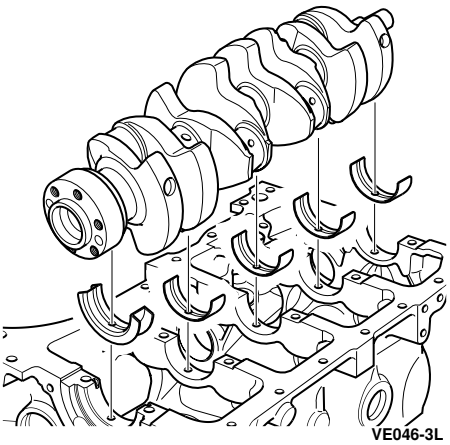


10. Measure the gauging plastic at its widest area using the scale supplied with the plastic gauging kit.
11. Compare the measurements to Engine Mechanical Specifications.

Crankshaft , Bearings and Bearing Cap Removal

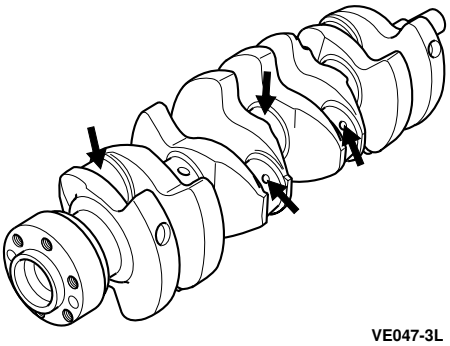

VE045-3L

1. Remove the crankshaft bearing cap bolts.
2. Remove the crankshaft bearing caps.


VE046-3L

3. Remove the crankshaft.
4. Remove the crankshaft bearings from the bearing caps and from the engine block.

Crankshaft and Bearings Clean and Inspect

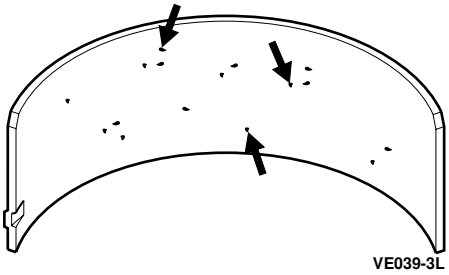

VE047-3L

Tools Required

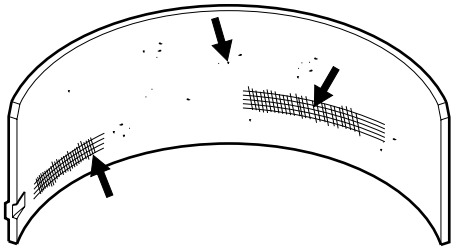
- J 7872 Magnetic Base Indicator Set

Caution: Wear safety glasses in order to avoid eye damage.

1. Clean the crankshaft in solvent.
2. Inspect the crankshaft oil passages for restrictions.
DR4649
3. Dry the crankshaft with compressed air.
4. Inspect the crankpins for scoring or wear.

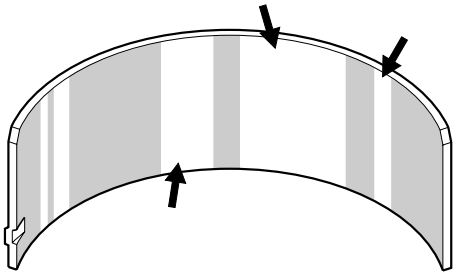

VE039-3L

5. Inspect the crankshaft bearings for craters or pockets. Flattened sections on the bearing halves also indicate fatigue.


VE040-3L

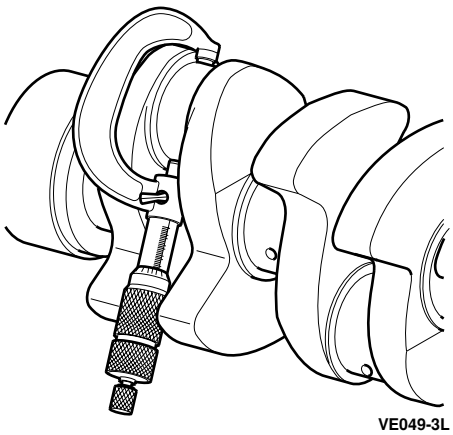
6. Inspect the crankshaft bearings for excessive scoring or discoloration.

7. Inspect the crankshaft bearings for dirt or debris imbedded into the bearing material.

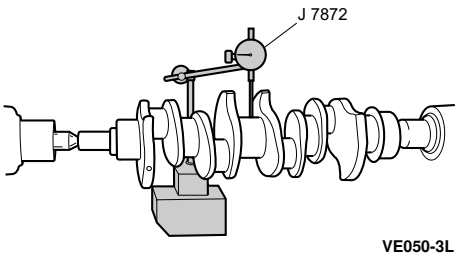


8. Inspect the crankshaft bearings for improper seating indicated by bright, polished sections of the bearing.

- If the lower half of the bearing is worn or damaged, both the upper and lower halves must be replaced.


VE049-3L

9. Measure the crankpins for out-of-round, taper or undersize with a micrometer. Refer to Engine Mechanical Specifications.



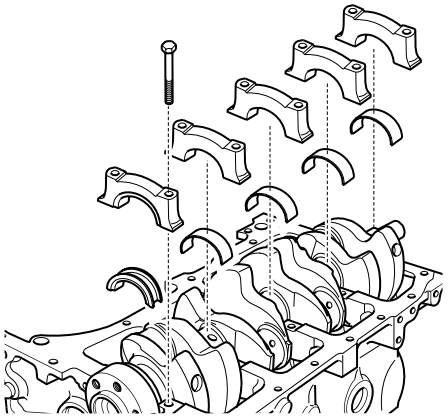
VE050-3L

10. Support the crankshaft front and rear journals on V-blocks.

11. Measure the crankshaft run-out at front and rear intermediate journals with J 7872. Refer to Engine Mechanical Specifications.

12. Replace or recondition crankshaft if measurements are not within specifications.

Crankshaft and Bearings Clean and Inspect (Main Bearing Clearance)

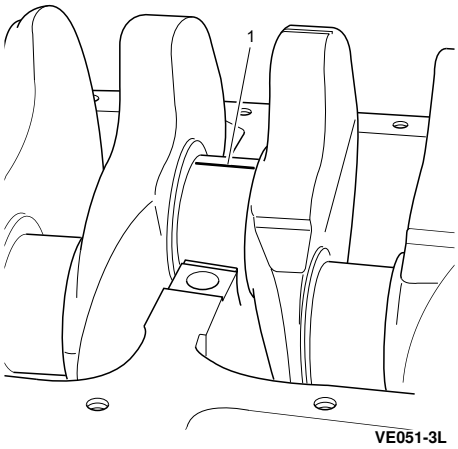


VE045-3L

NOTE! Crankshaft main bearings are a precision insert type. Main bearing caps are machined with the engine block for proper clearance and cannot be shimmed or filed for bearing fit. Crankshaft bearing clearances are critical. If the clearances are found to be excessive, new bearings and/or engine block and cap repair may be required.

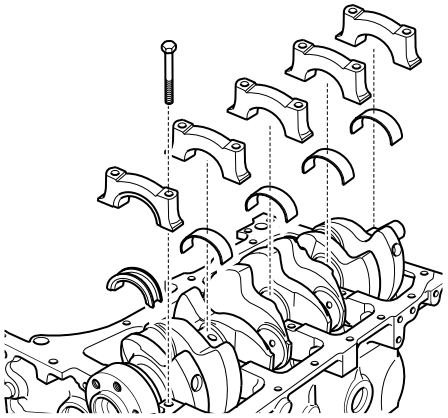
NOTE! Do not rotate the crankshaft while gauging plastic is between the crankshaft journal and the bearing surface.

1. Remove the crankshaft bearing cap bolts.
2. Remove the crankshaft bearing caps.

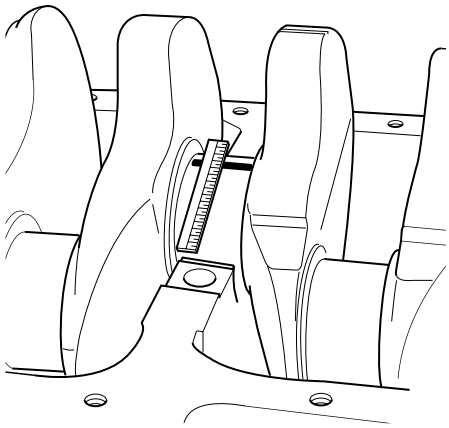


VE051-3L

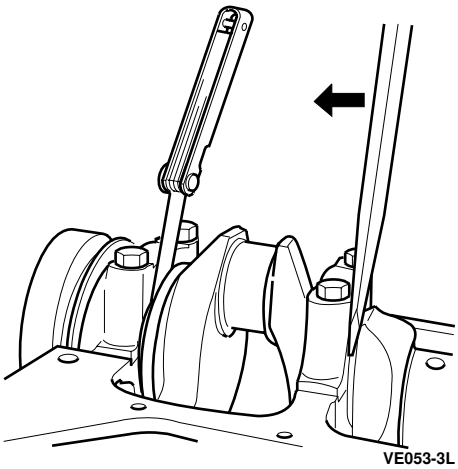
3. Install gauging plastic (1) onto the crankshaft journal. Install the gauging plastic the full width of the crankshaft bearing journal.



4. Install the bearing, bearing cap and bolts. Tighten the crankshaft bearing cap bolts to 88 N•m (65 lb ft).
5. Remove the crankshaft bearing cap bolts.
6. Remove the crankshaft bearing caps.

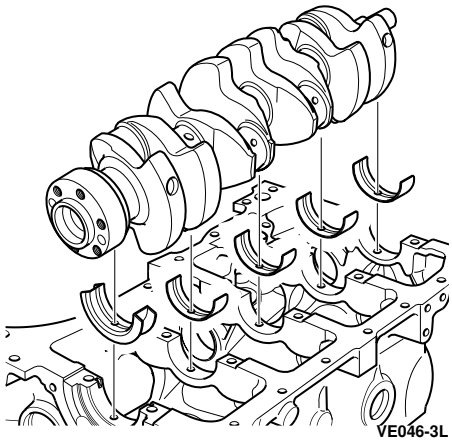


7. Measure the gauging plastic at its widest area using the scale supplied with the plastic gauging kit.
8. Compare the measurements to Engine Mechanical Specifications.
   - If the gauging plastic shows irregularity in the journal exceeding 0.025 mm (0.001 in), remove the crankshaft and measure the journal with a micrometer.
   - If the clearance is greater than Engine Mechanical Specifications, select and install an undersized bearing set. Measure the clearance with gauging plastic.
   - If clearance cannot be brought to specifications, grind the crankshaft for use with the next undersized bearing.


VE053-3L

9. Use a dial indicator or feeler gauge in order to measure end play between the front of the rear of the crankshaft bearing cap and the crankshaft thrust surface in order to determine the crankshaft end play.
10. If you use a feeler gauge, measure between the thrust surface of the crankshaft bearing and the crankshaft. Refer to Engine Mechanical Specifications.

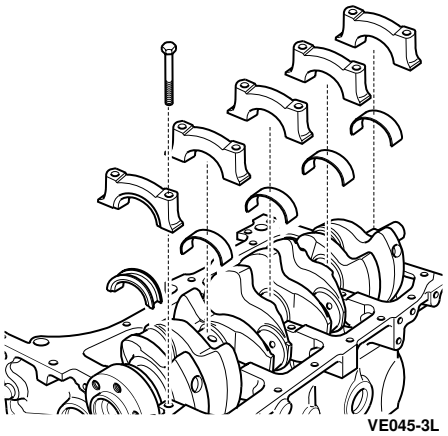
Crankshaft, Bearings and Bearing Cap Installation


VE046-3L

NOTE!

- Crankshaft bearing caps must be installed to the proper location and direction.
- When installing the crankshaft bearings, align the locating tabs on the bearings with the locating notches in the engine block journal bore and the bearing cap.
- Always install crankshaft bearings with their machined partner. Do not file bearings or mix bearing halves.

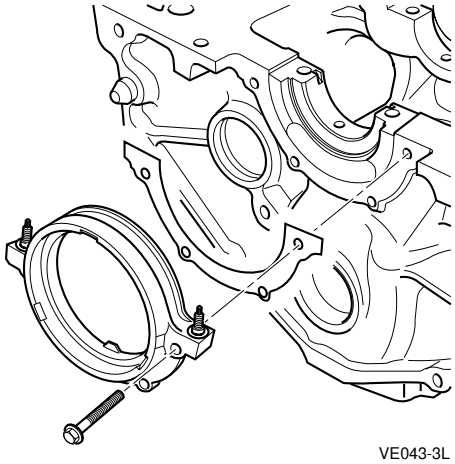
1. Install the crankshaft bearings into the engine block and the crankshaft bearing caps.
2. Coat the crankshaft bearings with clean engine oil.
3. Install the crankshaft.


VE045-3L

4. Install the crankshaft bearing caps with the crankshaft bearings.
5. Be sure that the cap directional arrows point toward the front of the engine block and the cap is in its original position.
6. Install the crankshaft bearing cap bolts.
7. Thrust the crankshaft rearward in order to set and align the thrust bearings and the bearing caps.
8. Thrust the crankshaft forward in order to align the rear faces of the rear crankshaft bearings.
9. Tighten all of the bolts to 88 N•m (65 lb ft).

Crankshaft Rear Oil Seal and Housing

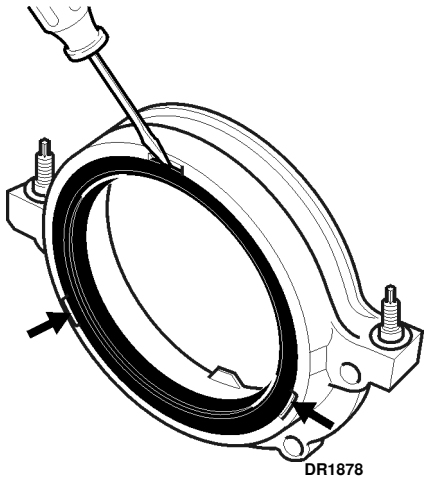
Removal


VE043-3L

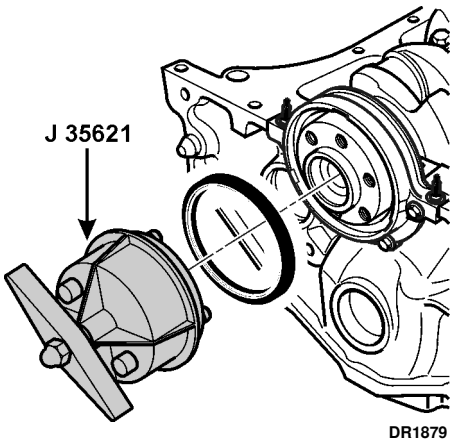
1. Remove the crankshaft rear oil seal housing bolts.
2. Remove the crankshaft rear oil seal housing, seal and gasket.

Rear Main Bearing Oil Seal Replacement

NOTE! Care should be taken when removing the rear crankshaft oil seal so as not to nick the crankshaft sealing surface.


DR1878

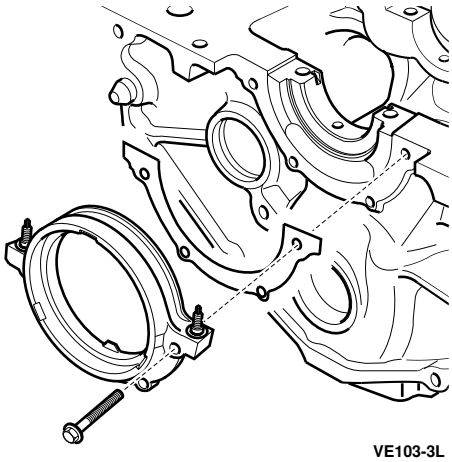
1. Insert a screwdriver into the notches provided in the seal retainer and pry the seal out. Take care not to damage the crankshaft sealing surface.
2. Inspect chamfer on crankshaft for grit, loose rust, and burrs. Clean seal running surface on the crankshaft with a non-abrasive cleaner.



Crankshaft Rear Oil Seal and Housing

3. Lubricate the inner and outer diameter of new seal with engine oil. Install the seal on **J-35621**. Position **J-35621** against the crankshaft. Thread the attaching screws into the tapped holes in the crankshaft.
4. Tighten screws securely. This will ensure the seal is installed squarely over the crankshaft. Turn handle until it bottoms then remove **J-35621**.

Installation

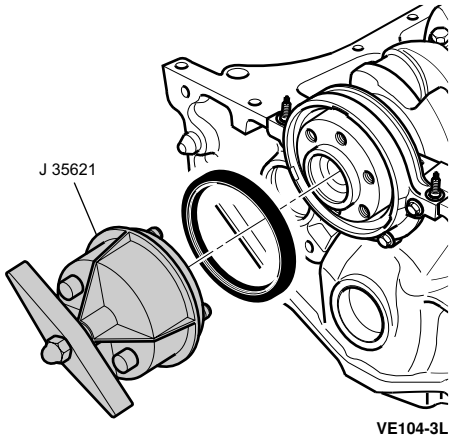


Tools Required

- J 35621 Crankshaft Rear Oil Seal Installer

NOTE! Always use a new crankshaft rear oil seal and new crankshaft rear oil seal housing gasket when you install the crankshaft rear oil seal housing.

1. Install the new gasket and the crankshaft rear oil seal housing on to the studs.
2. Install the rear oil seal housing nuts and bolts.
3. Tighten the crankshaft rear oil seal housing nuts and bolts to 15 N•m (135 in lb).



4. Coat the new oil seal entirely with clean engine oil.
5. Install the seal onto the J 35621.
6. Install the J 35621 onto the rear of the crankshaft. Tighten the screws snugly in order to ensure that the seal will be installed squarely over the crankshaft.
7. Install the crankshaft rear oil seal onto the crankshaft and into the crankshaft rear oil seal housing. Tighten the wing nut on the J 35621 until the oil seal bottoms.
8. Remove the J 35621 from the crankshaft rear oil seal housing.

Oil Seal Retainer Replacement

1. Remove Flywheel and oil pan. Remove screws, nuts and seal retainer. Remove gasket.
2. Remove rear crankcase oil seal as previously stated and clean gasket surfaces on block and seal retainer.

NOTE! Whenever seal retainer is removed, a new retainer gasket and rear crankshaft oil seal must be installed.

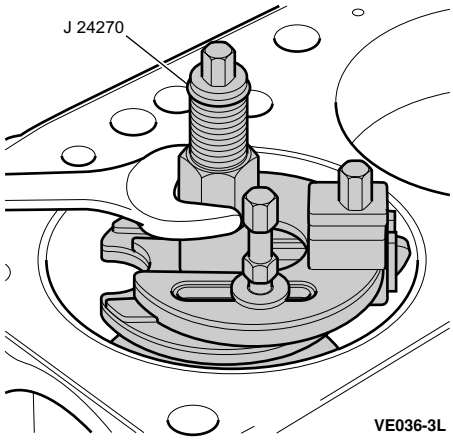
3. Attach gasket to block. No sealer is required. Install seal retainer, screws and nuts. Tighten to 135 in. lb. (15 N•m).
4. Install oil pan. Install rear crankshaft oil seal as outlined previously. Install flywheel.

Piston and Connecting Rod

Piston and Rod Removal

1. Withdraw crankcase oil. Disconnect oil drain tube. Remove oil pan.
2. Drain coolant from block and exhaust manifold, then remove cylinder head.

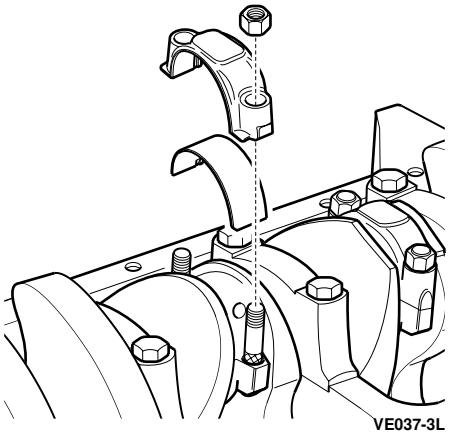
Removal



Tools Required

- J 5239 Connecting Rod Guide Tool
- J 24270 Ridge Reamer

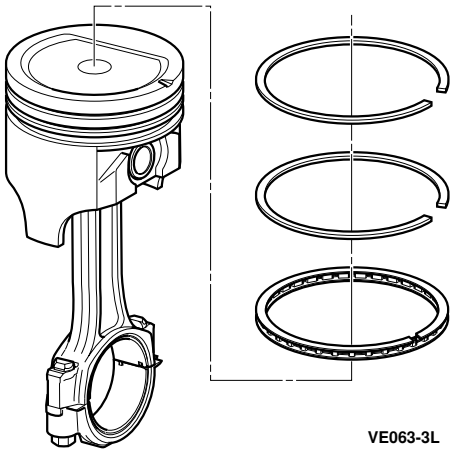
1. Remove the ring ridge as following:
2. Turn the crankshaft until the piston is at the bottom of the stroke.
3. Place a cloth on top of the piston.
4. Use the J 24270 to remove the cylinder ring ridge.
5. Turn the crankshaft so the piston is at the top of the stroke.
6. Remove the cloth.
7. Remove the cutting debris.



NOTE! Place matchmarks or numbers on the connecting rods and the connecting rod caps. Upon removal of the piston and connecting rod assembly, install the connecting rod caps to the matching connecting rods.

8. Remove the connecting rod nuts.
9. Remove the connecting rod cap.
10. Remove the connecting rod bearings.
    - Keep bearings with the original connecting rod and connecting rod cap.
    - Wipe the oil from the bearings.
    - Wipe the oil from the crankpins.
11. Use the J 5239 in order to remove the connecting rod and the piston out of the engine block.
12. Use a hammer and tap lightly on the end of the connecting rod guide tool to remove the piston and connecting rod assembly from the cylinder bore.

Disassemble

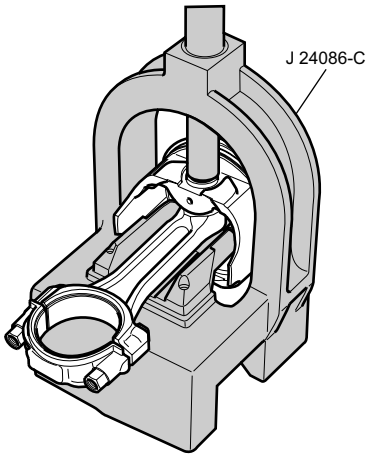

VE063-3L

Tools Required

- J 24086-C Piston Pin Removal Set

1. Remove the piston rings from the pistons.

2. Remove the pin from the piston.

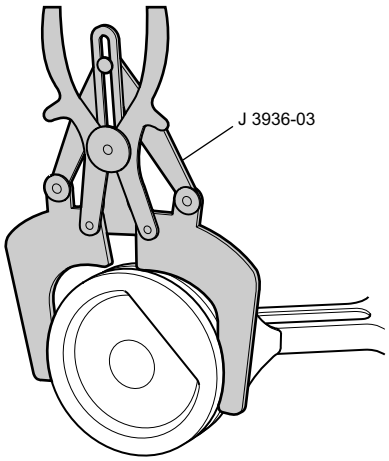


Caution!

After the J 24086-C Installer bottoms on the support assembly, do not exceed 34,475 kPa (5000 psi) or the tool may be damaged.

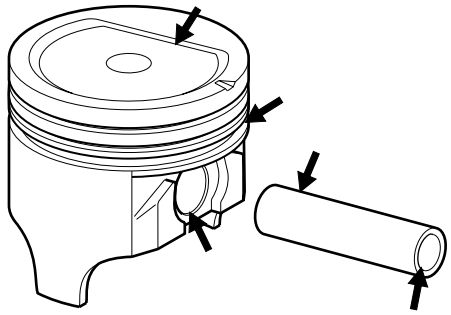
Clean and Inspect

1. Clean the piston ring grooves with a groove cleaner.



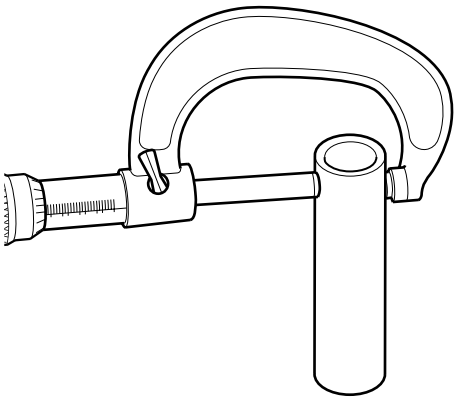
Note! Clean varnish from piston skirts and pins with a cleaning solvent. DO NOT WIRE BRUSH THE PISTON SKIRT. Clean the ring grooves with a groove cleaner, and make sure oil ring holes and slots are clean.

Inspect the piston for cracked ring lands, skirts or pin bosses, wavy worn ring lands, scuffed or damaged skirts, or eroded areas at top of the piston. Replace pistons that are damaged or otherwise show signs of excessive wear.

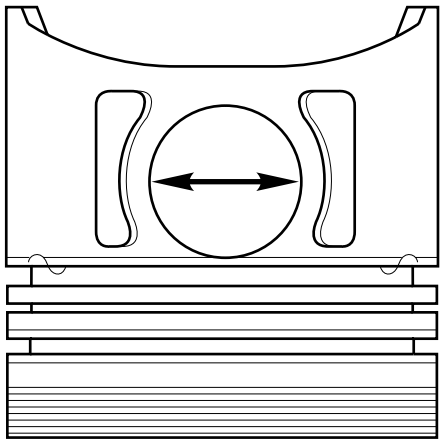


⚠ **Caution! Wear safety glasses.**

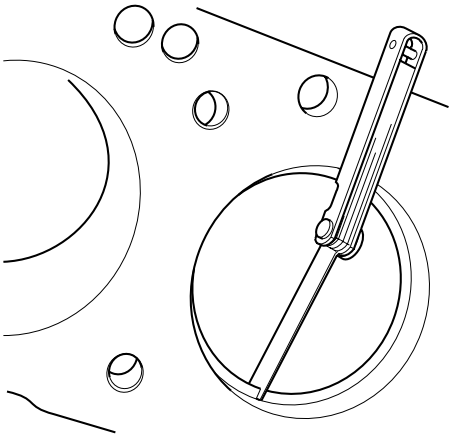
2. Clean the connecting rod in cleaning solvent.
3. Clean the varnish from the piston skirts and the pins with cleaning solvent
4. Dry the components with compressed air.
5. Do not use a wire brush in order to clean any part of the piston.
6. Clean the piston oil ring holes and the slots.
7. Inspect the connecting rod for twisting, nicks and cracks. Replace any damaged connecting rods.
8. Inspect the pistons for the following conditions:
   - Cracked ring lands, skirts or pin bosses.
   - Nicks or spurs in the grooves that may cause binding.
   - Warped or worn ring lands.
   - Scuffed or damaged skirts.
   - Eroded areas at the top of the piston.
   - Worn piston bores and piston pins.
9. Replace pistons that are damaged or show signs of excessive wear.



10. Measure the pin bore-to-piston clearance.
    a. The piston pin bores and the piston pins must be free of varnish or scuffing when being measured.
    b. Use a micrometer in order to measure the piston pin.



    c. Use an inside micrometer in order to measure the piston pin bore. Replace the piston and piston pin if the clearance is in excess of 0.0254 mm (0.001 in).
    d. Match the piston and piston pin. Do not service separately.



11. Measure the piston compression ring end gap.

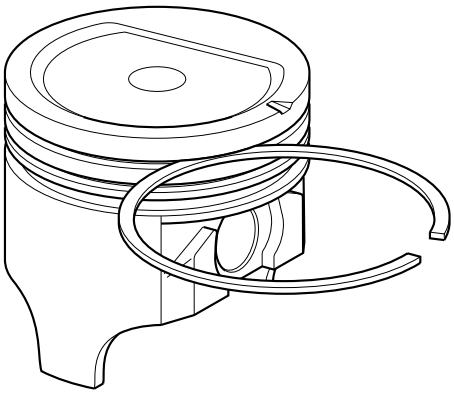
NOTE! Fit each compression ring to the cylinder in which it will be used.

a. Place the compression ring into the cylinder bore.

b. Push the compression ring into the cylinder bore approximately 6.5 mm (0.25 in) above the ring travel. The ring must be square to the cylinder wall.

c. Use a feeler gauge in order to measure the end gap.

d. Select another size ring set if the end gap exceeds specifications.

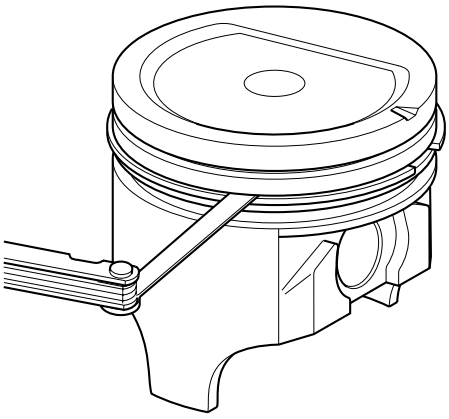


12. Measure the piston ring side clearance.

a. Roll the piston ring entirely around its ring groove on the piston.

b. Dress the groove with a fine cut file if the ring groove causes binding.

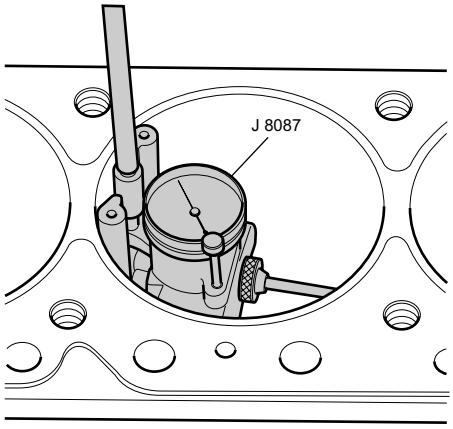
c. Replace the piston ring if a distorted piston ring causes binding.

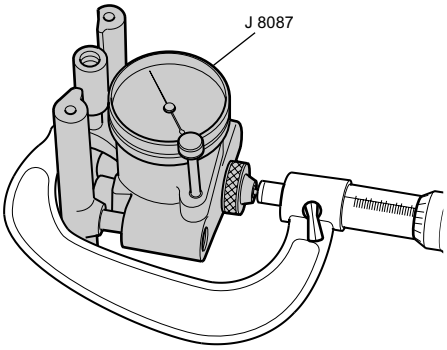


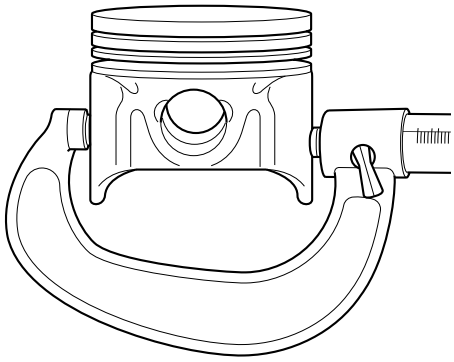
d. Use a feeler gauge in order to measure the side clearance of the piston ring and groove.

e. Try another piston ring if the side clearance is too small.

Piston Selection







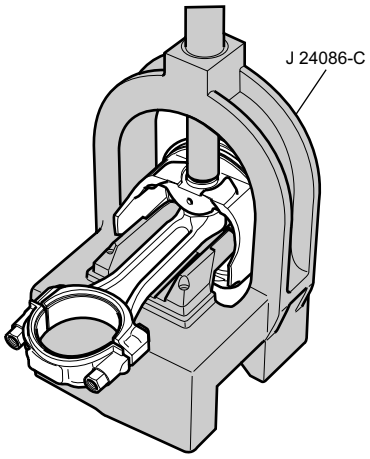
NOTE! Measurements of all components should be taken with the components at normal room temperature.

For proper piston fit, the engine block cylinder bores must not have excessive wear or taper.

A used piston and pin set may be reinstalled if, after cleaning and inspection, they are within specifications.

1. Inspect the engine block cylinder bore. Refer to Cylinder Block Clean and Inspect.
2. Inspect the piston and piston pin. Refer to Piston and Connecting Rod Clean and Inspect.
3. Use a boring gauge in order to measure the cylinder bore diameter at a point of 66 mm (2.5 in) from the top of the cylinder bore.
4. Measure the bore gauge with a micrometer and record the reading.
5. With a micrometer or caliper at a right angle to the piston, measure the piston 11 mm (0.433 in) from the bottom of the skirt.
6. Subtract the piston diameter from the cylinder bore diameter in order to determine piston-to-bore clearance.
7. For proper piston-to-bore clearance, Refer to Engine Mechanical Specifications.
8. If the proper clearance cannot be obtained, select another piston and measure for the clearances. If the proper fit cannot be obtained, the cylinder bore may require boring or honing. Refer to Cylinder Boring and Honing.
9. When the piston-to-cylinder bore clearance is within specifications, permanently mark the top of the piston for installation to the proper cylinder.

Assemble



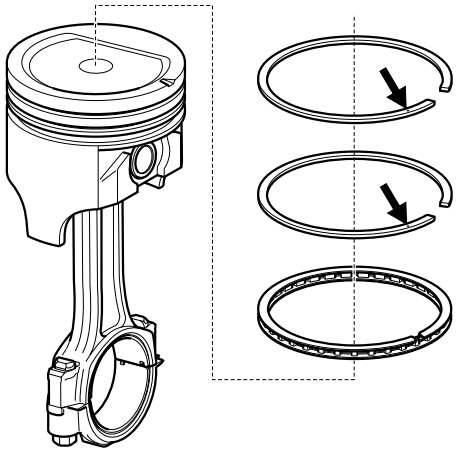
Tools Required

- J 24086-C Piston Pin Removal Set

NOTE! When assembling the piston and connecting rod, the flange or the heavy side on the connecting rod must face toward the front of the piston (stamped arrow in top of the piston head).

1. Install the piston pin and connecting rod assembly.

- Lubricate the piston pin holes in both the piston and the connecting rod assembly.
- Press the piston pin into the piston and connecting rod assembly using the J 24086-C.
- Inspect for freedom of movement of the piston on the piston pin.

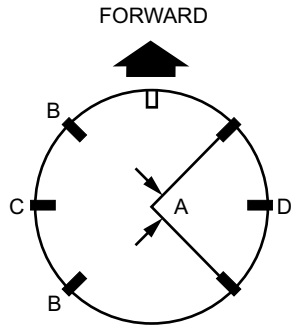


2. Install the piston rings onto the piston.

The marked side of the piston rings must face toward the top of the piston.

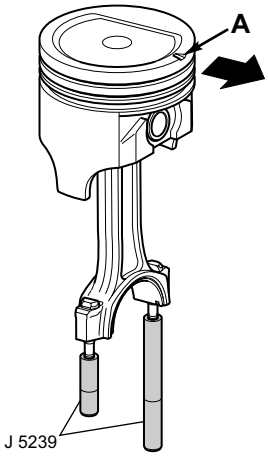
3. Use the following procedure in order to locate the piston ring gaps

- Install the oil ring spacer in groove and insert anti-rotation tang in oil hole.
- Hold the spacer ends together and install lower oil ring rail with the gap properly located.
- Install the upper oil ring rail with the gap properly located.
- Flex the oil ring assembly to make sure the rings are free.
- Install the lower compression ring.
- Install the upper compression ring.



(A) Oil ring spacer gap
(B) Oil ring gap
(C) Lower compression ring gap
(D) Upper compression ring gap

Installation



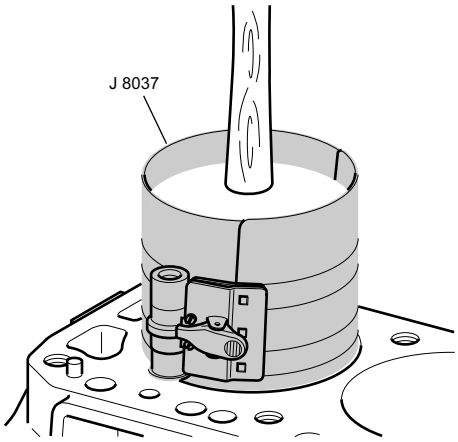
Tools Required

- J 5239 Guide Set
- J 8037 Piston Ring Compressor

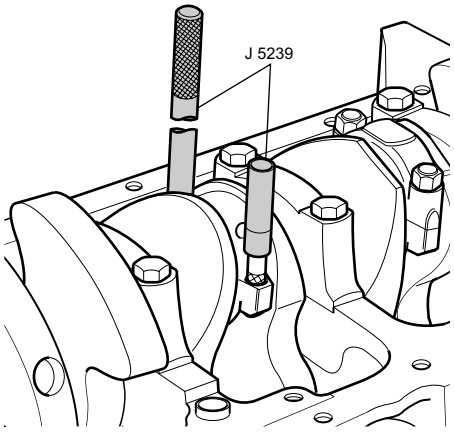
Important

- The piston and cylinder bore have been measured and the bore has been sized for the proper clearance. Install the piston and connecting rod assembly into the proper cylinder bore.
- The piston alignment mark (A) MUST face the front of the engine block.

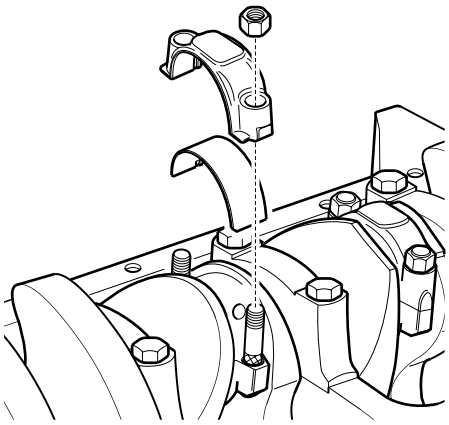
1. Lubricate the following components with clean engine oil:
   - The piston.
   - The piston rings.
   - The cylinder bore.
   - The bearing surfaces.
2. Install the connecting rod bearing into the connecting rod and bearing cap.
3. Install the J 5239 onto the connecting rod.
4. Install the J 8037 or equivalent onto the piston and compress the piston rings.



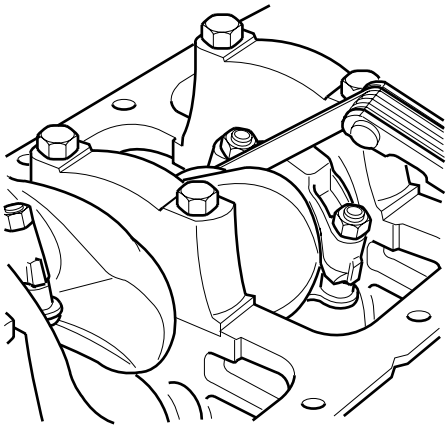
5. Install the piston assembly into its matched bore with the stamped arrow facing forward.
6. Use the J 8037 and the J 5239 and lightly tap the top of the piston with a wooden hammer handle.
   - Hold the J 8037 firmly against the engine block until all of the piston rings enter the cylinder bore.
   - Use the J 5239 in order to guide the connecting rod onto the crankshaft journal.



7. Remove the J 5239.



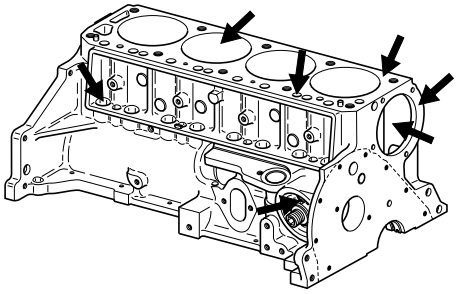
8. Install the connecting rod cap and nuts. Tighten the nuts evenly to 61 N•m (45 lb ft).

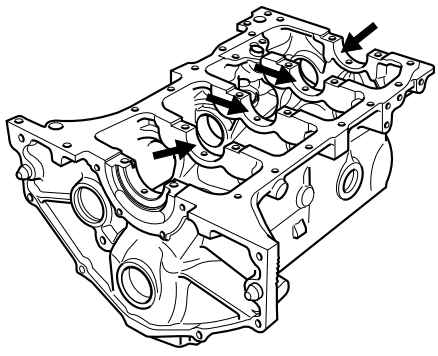


9. When all of the connecting rod bearings are installed, tap each connecting rod assembly lightly parallel to the crankpin in order to make sure that they have clearance.
10. Use a feeler gauge or a dial indicator in order to measure the side clearance between the connecting rod caps. Refer to Engine Mechanical Specifications.

Cylinder Block

Clean and Inspect





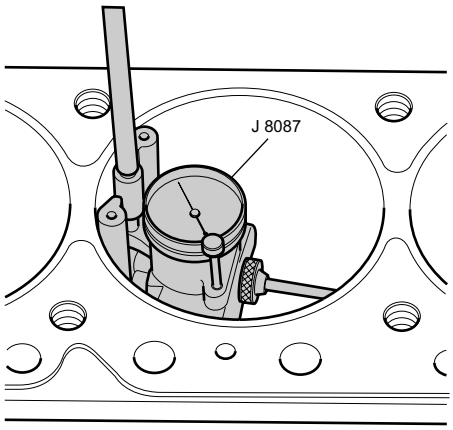
1. Clean the following areas:
   - The engine block in solvent, removing all sludge, dirt or debris

⚠ **Caution! Wear safety glasses.**

   - Dry the block with compressed air.
   - The gasket surfaces.
   - The coolant passages.
   - The oil passages.
   - The main bearing caps.
2. Inspect the following areas:
   - The cylinder walls for excessive scratches, gouging or ring ridge.
   - The coolant jackets for cracks.
   - The valve lifter bores for excessive scoring or wear.
   - The crankshaft bearing webs for cracks.
   - The gasket sealing surfaces for excessive scratches or gouging.
   - The oil passages for restrictions.

- All threaded bolt holes for thread damage.

Cylinder Bore Measurements



Tools Required

- J 8087 Cylinder Bore Gauge

1. Use the J 8087 in order to check cylinder bore taper and out-of-round as follows:
   a. Set the gauge so that the thrust pin must be forced in about 1/4 in to enter the gauge in the cylinder bore.
   b. Center the gauge in the cylinder and turn the dial to “0.”
   c. Work the gauge up and down to determine the taper.
   d. Turn the gauge to different point around the cylinder to determine the out-of-round condition. Refer to Engine Mechanical Specifications.

Boring Procedure

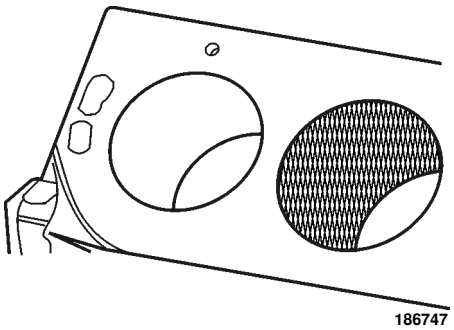
1. Before you start the honing or reboring process, measure all new pistons with the micrometer, contacting at points exactly 90× from the piston pin centerline. Select the smallest piston for the piston fitting See “Piston Selection” on page 67 Slightly varied pistons in a set may provide correction, in case the first piston is too loosely fitted.
2. Before you use any type of boring bar, file the top of the cylinder block in order to remove any dirt or burrs. If you do not check the cylinder block, the boring bar may be tilted, this could result in the rebored cylinder wall being at incorrect right angles from the crankshaft.
3. Carefully follow the instructions furnished by the boring bar manufacturer regarding the use of the equipment.
4. When you rebore cylinders, make sure all crankshaft bearing caps are in place. Tighten the bearing caps to the proper torque to avoid distortion of the bores in the final assembly. The crankshaft must be clear of the boring cutter when you bore each cylinder. Cover or tape the crankshaft bearings and other internal parts to protect during the boring or honing process.

Honing Procedure

1. When honing the cylinders, follow the Hone manufacturerís recommendations for use, cleaning and lubrication. Use only clean, sharp stones of the proper grade for the amount of material you remove. Dull, dirty stones cut unevenly and generate excessive heat. When using coarse or medium-grade stones, leave sufficient metal so that all stone marks may be removed with the fine stones you use for finishing in order to provide for proper clearance.
2. During the honing process, thoroughly clean the cylinder bore. Check for a correct fit of the piston you select for the individual cylinder.
3. When honing to eliminate taper in the cylinder, make full strokes of the hone in the cylinder. Repeatedly check the measurement at the top, the middle and the bottom of the bore.

Notice!Handle the pistons with care. Do not force the pistons through the cylinder until you hone the cylinder to the cor-

rect size. The piston can be distorted through careless handling.



4. When finished honing a cylinder bore to fit a piston, move the hone up and down at a sufficient speed to obtain very fine, uniform surface finish marks in a cross hatch pattern at 45-65 degrees.
5. The finish marks should be clean but not sharp. The finish marks should be free from imbedded particles and torn or folded metal.
6. By measuring the piston to be installed at the sizing point specified and by adding the average of the clearance specification, you can determine the finish hone cylinder measurement. *See "Torque Specifications" on page 86* Measure the block and the piston at normal room temperature.
7. True up the refinished cylinder bores to have less than the specified out-of-round or taper. You must final hone each bore in order to remove all stone or cutter marks and in order to provide a smooth surface.
8. For piston-to-bore tolerance specifications, *See "Torque Specifications" on page 86*
9. After final honing and before the piston is checked for fit, clean the bores with hot water and detergent. Scrub the bores with a stiff bristle brush and rinse the bores thoroughly with hot water. Do not allow any abrasive material to remain in the cylinder bores. This abrasive material will wear the new rings, the cylinder bores and the bearings lubricated by the contaminated oil. After you wash the bore, brush the dry bore clean with a power-driven fiber brush.
10. Permanently mark the piston for the cylinder to which the piston has been fitted.
11. Apply clean engine oil to each bore in order to prevent rusting.

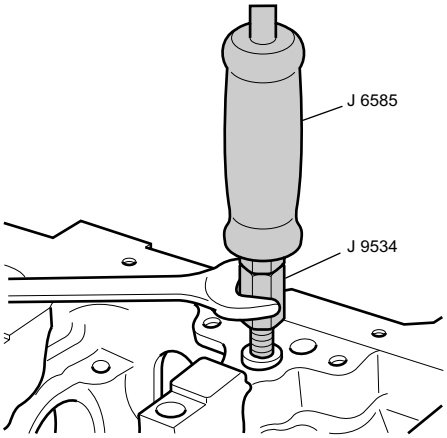
Distributor Lower Bearing

The distributor lower bearing is a bronze bushing pressed into the lower side of the engine block. Its upper inside diameter pilots the distributor shaft, and the outside diameter extending below the block pilots the oil pump.

Some engines have a thrust washer at the upper end of the bushing bore. The thrust washer, where used, may be replaced at the same time the bushing is replaced.

The lower bushing will ordinarily require only a clearance or wear check during engine overhaul. When distributor shaft-to-bushing clearance exceeds 0.0035 in. (0,0889 mm) the bushing should be replaced as follows with oil pump and distributor removed:

Removal



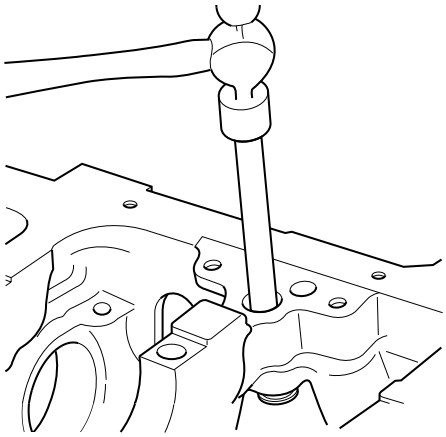
Tools Required

- J 9534 Distributor Lower Bushing Remover
- J 6585 Slide Hammer

1. Install tool **J-9534** into bushing and using a slide hammer, remove the bushing.

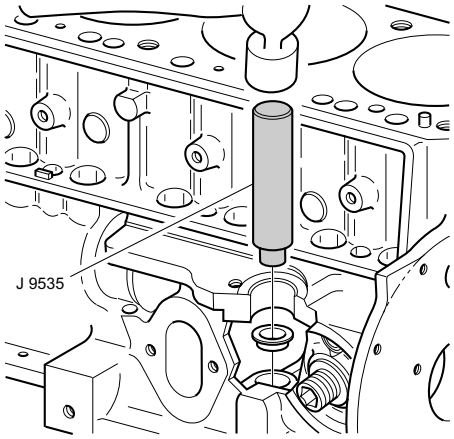
CAUTION!

Protect your eyes from fragments. Wear safety glasses when striking these tools, handles, drivers, etc. Tool end may mushroom after being repeatedly struck. Always grind off any rolled edges before using tool. Use soft face hammers whenever possible.

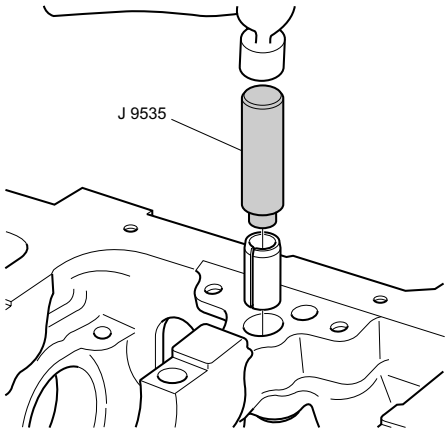


2. Using a drift up through bushing bore, drive thrust washer (if installed) out of bore and remove from block.
3. Clean bushing bore in block and check for burrs or damage.

Installation



4. If thrust washer was removed, start new washer in position in bore and drive into place using tool **J-9535**.
5. Using tool **J-9535** with driver-bolt in driver handle, install driver into new bushing from large inside diameter.

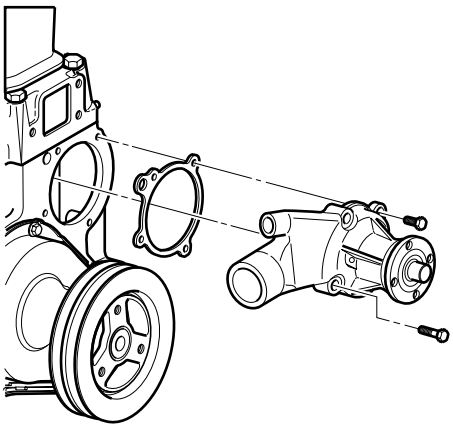


6. Place bushing and driver on block and drive the bushing in position. Depth is determined by tool bottoming against the block.
7. Remove tool from bushing. It is possible that the bushing with minimum I.D. will collapse enough, during installation, to slightly seize the installer arbor. If this happens, remove installer tool using slide hammer in driver bolt hole of driver handle.

NOTE! This will not damage the bushing and the tool is designed for this purpose, should it occur.

Circulating Pump

Removal



1. Remove drain plugs on port side and drain coolant from block and exhaust manifold. Disconnect water hose from circulating pump.
2. Loosen four screws holding circulating pump pulley to circulating pump.
3. Remove the serpentine belt. Remove circulating pump pulley and bolts. Unscrew bolts and remove the circulating pump from the engine.

NOTE! Pull the pump straight out of the block first, to avoid damage to impeller.

Inspection

If the seal is leaking replace the pump. If the bearing is rough or allows excessive sideways movement of the shaft, replace the pump. If the impeller has excessive erosion replace the pump.

4. Inspect the circulating pump for the following:
   - Gasket sealing surfaces for excessive scratches or gouges.
   - Excessive side-to-side play in the pulley shaft.
   - Leakage at the water inlet housing or rear cover gaskets areas.
   - Leakage at the water pump vent hole.
   - A stain around the vent hole is acceptable. If leakage occurs at the vent hole with the engine running and the cooling system pressurized, replace the pump.

Installation

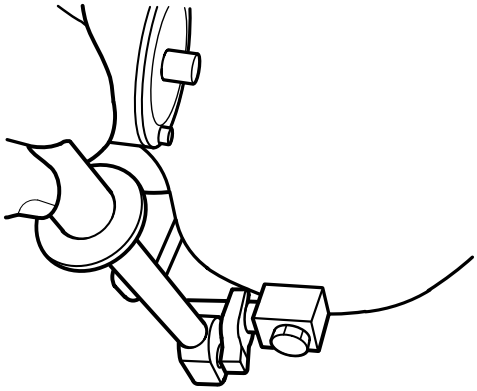
NOTE! This pump has a special shaft and bearing assembly and a special seal assembly intended for marine service. Do not substitute with an automotive pump.

1. Apply Volvo Penta Gasket Sealing Compound to a new pump to block gasket. Install pump assembly on cylinder block and tighten bolts to 20 N•m (15 ft. lb.)
2. Install circulating pump pulley. Install serpentine belt.

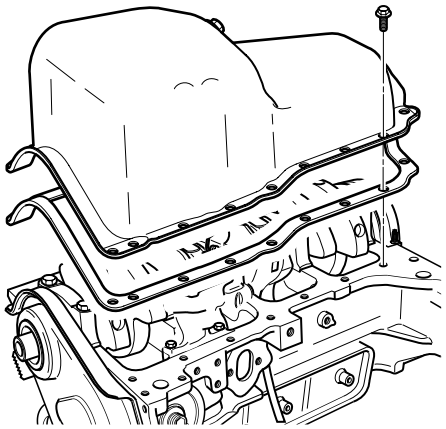
3. Connect coolant hoses to circulating pump. Install the drain plugs in the engine block and exhaust manifold. Tighten the plugs securely. Test the unit and check for leaks.

Oil Pan Replacement

Oil Dipstick Tube Removal

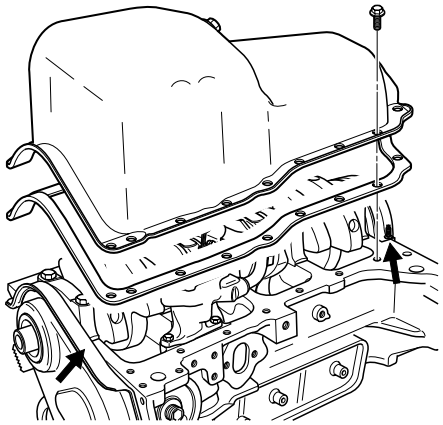


1. Remove oil using a suction pump.
2. Remove oil dipstick tube.



3. Remove the oil pan bolts.
4. Remove the oil pan.
5. Remove the gasket.
6. Discard the gasket.

Installation

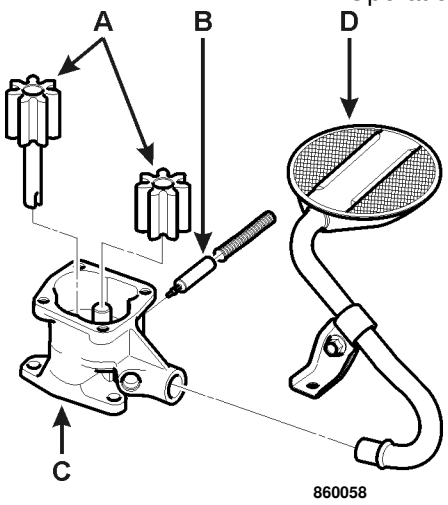


NOTE! Apply the sealer 25 mm (1.0 in) in either direction of the radius cavity of the junctions.

1. Apply a small amount of sealer, GM P/N 1052914 or equivalent, 10 mm (0.393 in) wide and 20 mm (0.787 in) long at the engine front cover to engine block junction.
2. Apply a small amount of sealer, GM P/N 1052914 or equivalent, 25 mm (1.0 in) long at the crankshaft rear oil seal housing to engine block junction.
3. Install the new oil pan gasket.
4. Install the oil pan.
5. Install the nuts and bolts to the oil pan.
6. Tighten the rear oil pan nuts to 18.6 N•m (165 in lb).
7. Tighten the oil pan bolts to the crankcase to 9 N•m (80 in lb).
8. Tighten the oil pan bolts to the front cover to 5 N•m (45 in lb).
9. Tighten the oil pan studs to the oil seal retainer to 1.7 N•m (15 in lb).

Oil Pump

Operation



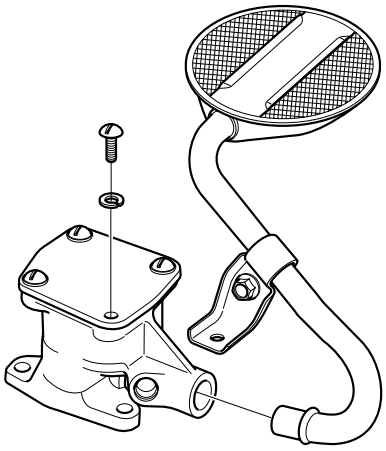
The oil pump consists of two gears (**A)** and a pressure relief valve **(B)** enclosed in a two-piece housing **(C)**. The pump is driven from the distributor driveshaft which in turn is driven by a helix gear on the camshaft.

The oil pump is flange mounted to the cylinder block with two bolts, and piloted on the outside of the lower distributor bronze bearing. Oil pressure passes through an opening in the mounting flange to the cylinder block, then into the full flow oil filter. The pump cover is equipped with the pressure regulator valve that regulates oil pressure at approximately 40-60 PSI (135.1-202.6 kPa) at 2000 RPM. The pump intake is of the fixed screen type. A mesh screen (**D)** filters out small particles of dirt and sludge which may be present.

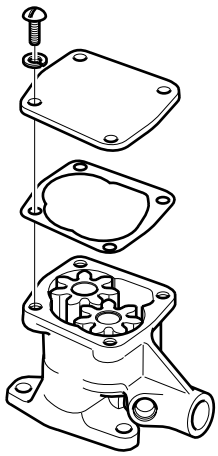
NOTE! A baffle incorporated on the intake screen has been designed to eliminate pressure loss due to sudden surging stops, turns, and acceleration.

In the event that a screen becomes plugged a steel grommet opens and bypasses oil to the pump.

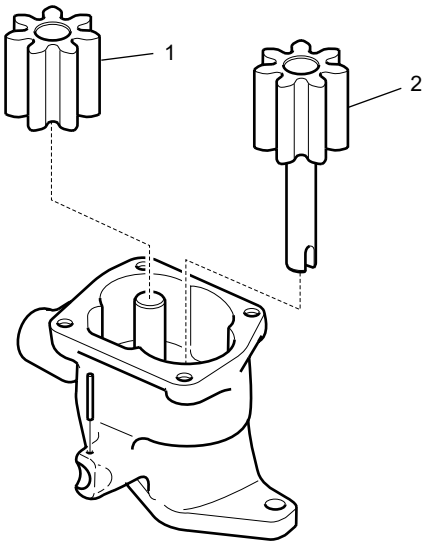
Removal and Disassembly



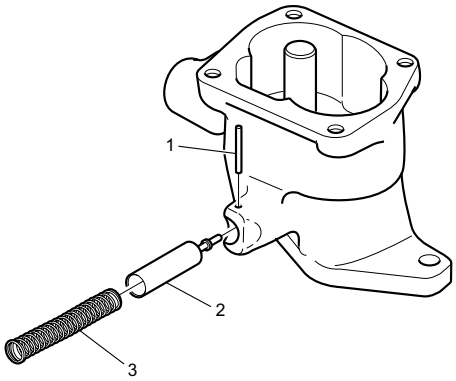
1. Drain the oil. Disconnect oil withdrawal tube. Remove screws, oil pan and gasket. Remove oil withdrawal tube fitting from oil pan.
2. Remove oil pickup tube clamp bolt. Remove two flange mounting bolts. Remove pump and screen as an assembly.



3. Remove the cover bolts.
4. Remove the pump cover.

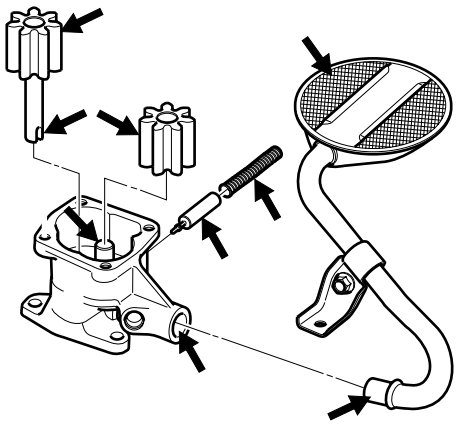


5. Remove the drive gear (2) and the driven gear (1). Matchmark the gear teeth for assembly.



6. Remove pressure regulator valve and valve parts. If necessary, remove oil pump suction pipe and screen by pulling from pump housing.
7. Wash all parts in cleaning solvent and dry using compressed air.

Clean and Inspect



NOTE! The internal parts of the oil pump are not serviced separately. If the oil pump components are worn or damaged, replace the oil pump as an assembly.

The oil pump pipe and screen are to be serviced as an assembly. Do not attempt to repair the wire mesh portion of the pipe and screen assembly.

1. Clean all of the parts in cleaning solvent.

Caution: Wear safety glasses.

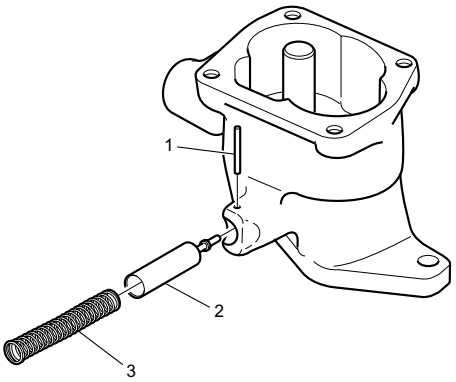
2. Dry the parts with compressed air.
3. Inspect the following areas:
   - The oil pump housing and cover for cracks, scoring, casting imperfections and damaged threads.
   - The drive gear shaft (If the shaft is loose in the oil pump housing, replace the oil pump).
   - The pressure relief valve for scoring and sticking (Burrs may be removed with a fine oil stone).
   - The pressure relief valve spring for loss of tension.

- The oil pump screen for broken wire mesh or looseness (If the pipe is loose or has been removed from the screen, the oil pump screen must be replaced).
- The gears for chipping, galling and wear.

NOTE! If the drive gear and driveshaft are worn, replace the entire oil pump.

- The drive gear and driveshaft for looseness and wear.

Assemble



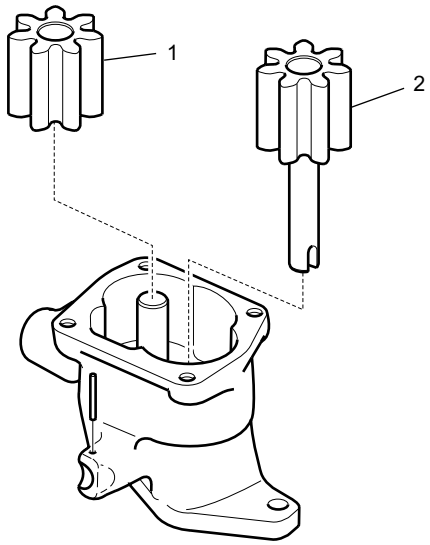
Tools Required

- J 21882 Oil Suction Pipe Installer

NOTE! Replace the pressure relief valve spring when you reuse the oil pump.

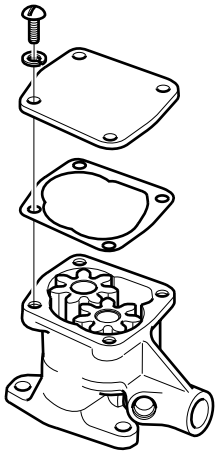
1. Install the following items:

- The pressure relief valve (2).
- The pressure relief valve spring (3).
- The retaining pin (1).

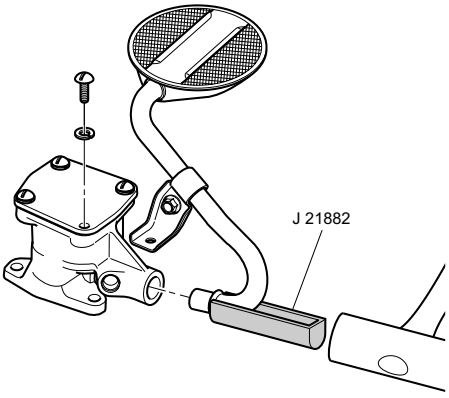


2. Coat the drive gear, the driven gear and the housing gear surfaces with clean engine oil.

3. Install the drive gear (2) and the driven gear (1) into the pump body. Align the matchmarks on the gears. Install the smooth side of the gear toward the pump cover.



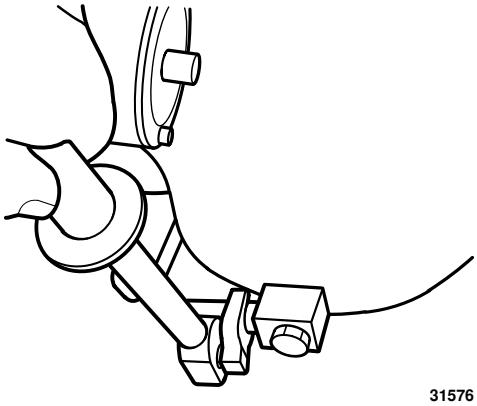
4. Install the pump cover.
5. Install the cover bolts. Tighten the bolts to 8 N•m (72 in lb).



6. Inspect the pump for smoothness of operation by turning the oil pump driveshaft by hand.
7. Install the oil pump screen.
   a. If removed, replace the oil pump screen. The oil pump screen must have a good press fit into the oil pump body.
   b. Mount the oil pump in a soft jawed vise.
   c. Apply sealer to the end of the pipe.
   d. Use the J 21882 and a soft-faced hammer in order to tap the oil pump screen into the pump body. The screen must align parallel with the bottom of the oil pan when it is installed.

NOTE! Oil pump should slide easily into place. If not, remove and relocate slot or determine other problem.

Oil Dipstick Tube Installation

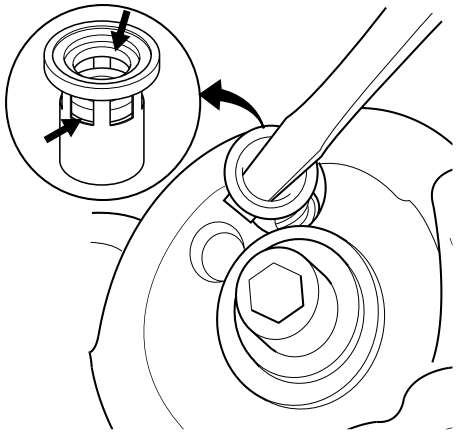


8. Attach and tighten oil pickup tube clamp.
9. Install oil pan using new gaskets and seals.
10. Install withdrawal tube fitting to pan; leave screw loose. Orient fitting and attach withdrawal tube. Then tighten both fitting screw and flare nut to 15-18 ft. lb. (20-24 N•m).
11. Fill crankcase with oil.

Oil Filter Bypass Valve

Inspection Remove the oil filter and check the spring and fiber valve for operation. Check for a cracked or broken valve.

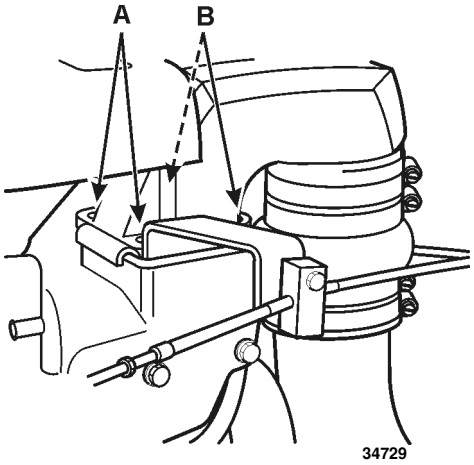
Replacement If replacement is necessary:



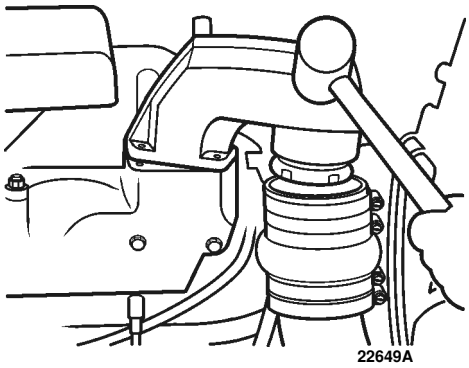
1. Remove the valve by prying it out with a screwdriver.
2. Install a new valve and seat it by tapping into place using a 9/16 in. thin wall deep socket and hammer.
3. Install oil filter according to manufacturer's instructions.

Exhaust Elbow Replacement

Removal

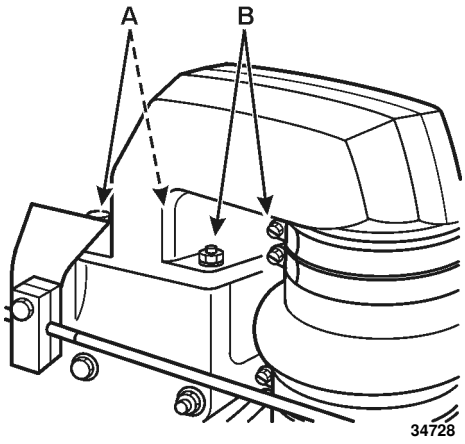


1. Loosen all four hose clamps. Lubricate exhaust pipe with a soapy water solution, and slide hose down off exhaust elbow.
2. Loosen hose clamp and disconnect cooling hose from inside of exhaust elbow. Then remove hose fitting.
3. Remove the two screws **(A)** and swing anchor bracket out of the way. Then remove the two nuts and lock washers (**B)**.

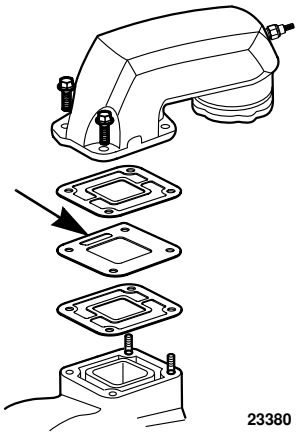


4. Loosen the elbow with a soft hammer, then lift it off the manifold. Remove and discard the elbow gaskets. Retain the restrictor plate.

Installation



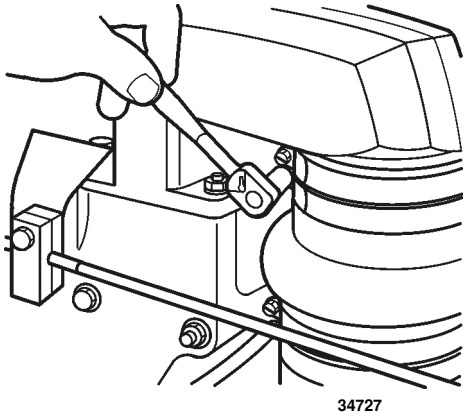
1. Thoroughly clean the manifold and elbow gasket surfaces. Apply Volvo Penta Gasket Sealing Compound to both sides two new gaskets.



2. Sandwich the restrictor plate between the two new gaskets. The slot in the restrictor plate should be positioned inboard toward the engine block. Place the gaskets and restrictor plate on the manifold.

Note! Disregard any stamped markings on the restrictor plate.

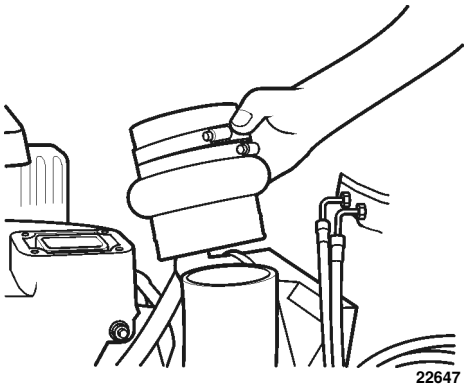
3. Mount the elbow on the manifold. Install the throttle anchor bracket, and secure with the two screws (**A)** and the two nuts and lock washers **(B)**. Tighten all four to 12-14 ft. lb. (16-19 N•m). Slide the exhaust hose all the way onto the elbow.
4. Install hose fitting on the inside of elbow and connect cooling hose.



5. Position the upper clamps in the top two channels and tighten them securely. Position the two lower clamps in the channels and tighten them securely.
6. Reconnect throttle cable to carburetor and throttle linkage plate. Secure with cotter pin.

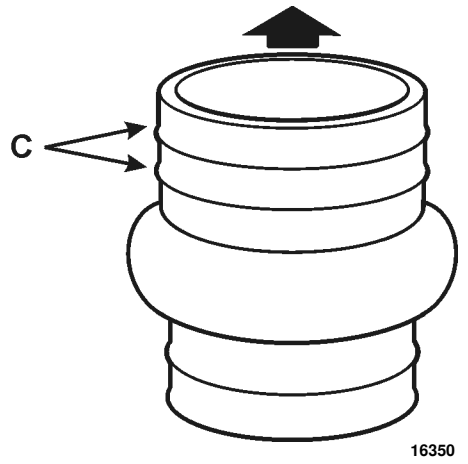
Exhaust Hose Replacement

Removal



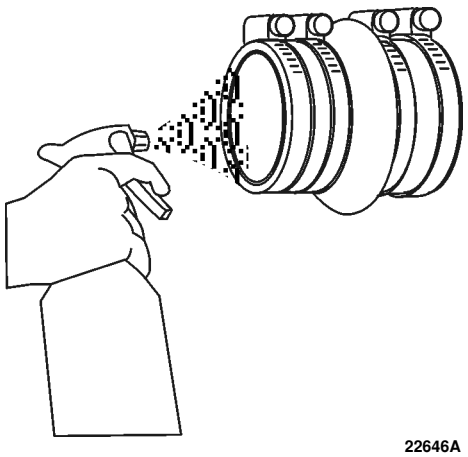
1. Remove high rise exhaust elbow following procedure in High-Rise Exhaust Elbow Replacement.
2. Remove clamps and slide hose off exhaust pipe.

Installation



NOTE! One end of exhaust hose has two ribs C around the circumference. Position this end up when installing hose to ensure secure attachment.

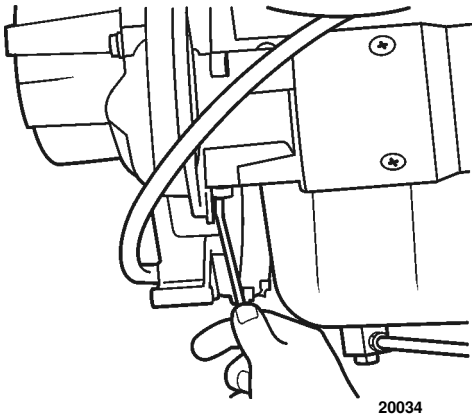
1. Place two No. 64 hose clamps VP P/N 3853791 over exhaust pipe if they were removed.



2. For ease of installation lubricate inside diameter of hose with a soapy water solution, and slide hose all the way onto exhaust pipe. Place two No. 64 clamps VP P/N 3853791 around top section of hose.

Engine Coupler Replacement

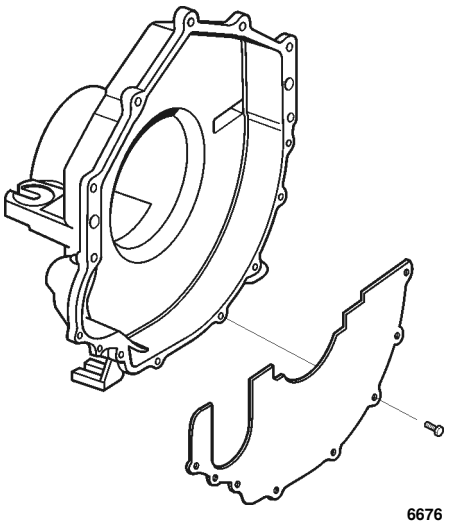
Removal



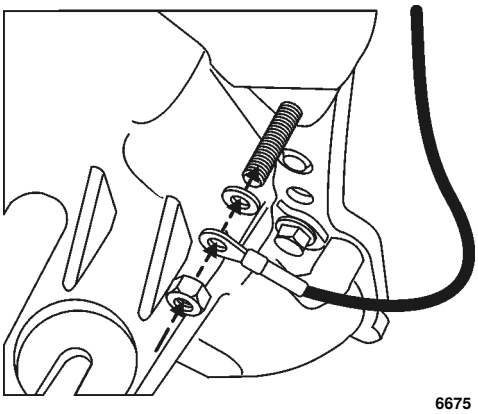
1. Remove engine from boat following instructions in Engine Removal and Installation section.

NOTE! If coupler is being replaced due to coupler failure (rubber hub or splined hub), check engine alignment after installing new coupler. See Engine Alignment in Engine Removal and Installation section.

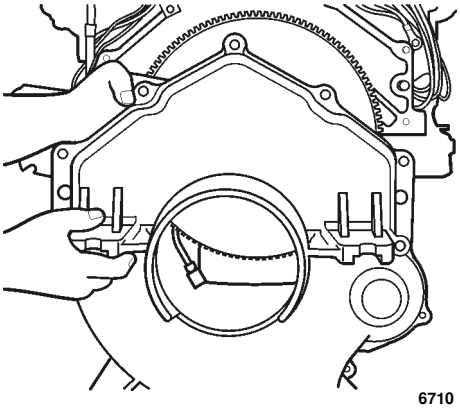
2. Cut tie strap holding flywheel housing drain hose (if equipped) to starter motor.



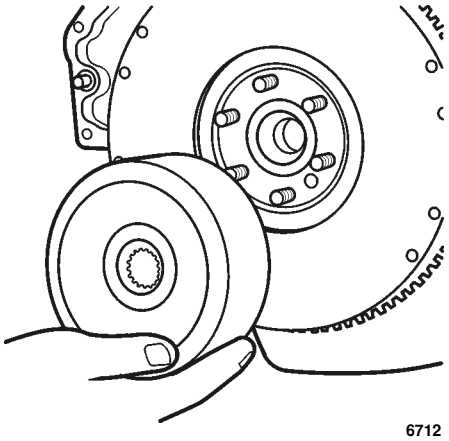
3. Take out screws holding flywheel housing cover, then slide out cover.



4. Remove nut, lock washer, and ground leads from ground stud. Remove inner nut, lock washer and washer. Remove similar ground stud hardware on opposite side of block.
5. Remove screws and washers holding 10 pin connector and relay, and move bracket aside.
6. Unscrew remaining flywheel housing bolts, lock washers and washers. Note position of clamps so they can be installed in original position.


6710

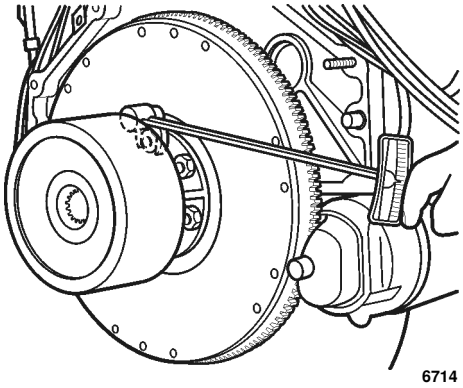
7. Lift flywheel housing off engine block and set aside.


6712

8. Unscrew six locknuts, then pull coupler off flywheel.

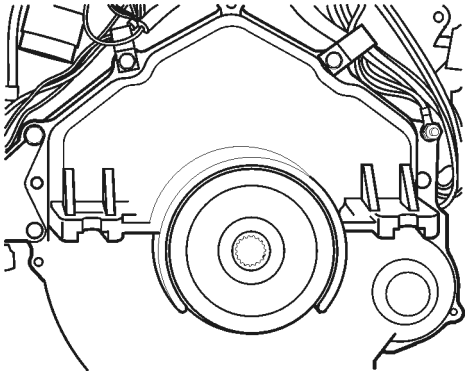
NOTE! If studs are loose or show any signs of movement they must be replaced. The threaded portion of the stud should not have any play in the crankshaft. If studs are replaced, they must be locked in place using VP P/N 1161075 thread locking compound and torqued to 10-15 ft. lb. before installing coupler.

Installation

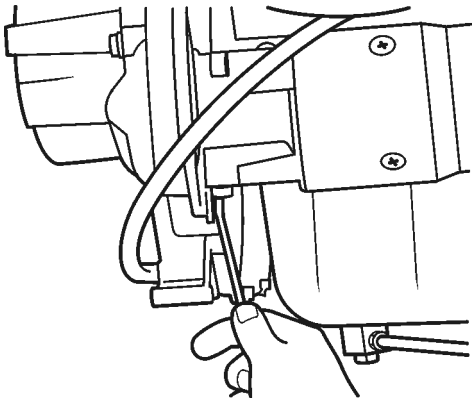

6714

1. Slide coupler onto crankshaft studs. Install new locknuts. Use a crowfoot wrench and tighten nuts to 40-45 ft. lb. (54-61 N•m).

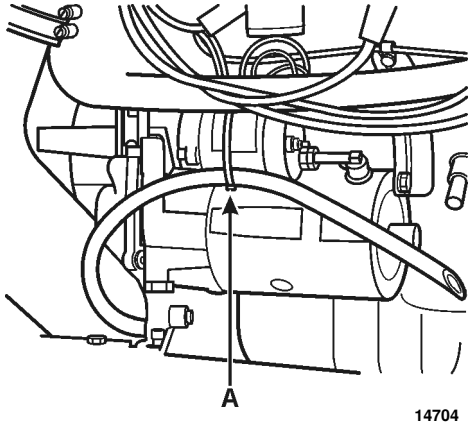
NOTE! Do not reuse coupler locknuts. Always install new locknuts when coupler or flywheel is removed.


6711A

2. Install flywheel housing. Place clamps in their original positions, and attach 10 pin connector and relay bracket. Tighten screws to 28-36 ft. lb. (38-49 N•m).
3. Place washer, lock washer and nut on ground stud. Tighten inner nut to 35-40 ft. lb. (47-54 N•m). Attach electrical leads to ground stud. Install lock washer and tighten outer nut securely. Install ground stud hardware on opposite side of block.


20034

4. Slide flywheel cover up into place. Install screws and tighten them to 60-84 in. lb. (7-9 N•m).



14704

5. Attach flywheel housing drain hose (**A)** (if equipped) to starter motor with tie strap.
6. Install engine in boat following instructions in Engine Removal and Installation section.

Torque Specifications

Torque Specifications

Application	N•m	Ft. Lb.	In. Lb.
Alternator - Bracket to Engine	35-41	26-30	
Camshaft Retainer Bolts	9		80
Connecting Rod Cap Nuts	61	45	
Crankshaft Main Bearing Cap Bolts (except rear main bearing)	75-95	55-70	
Crankshaft Main Bearing Cap Bolts (rear main bearing)			
Step 1	14-16	10-12	
Step 2	75-95	55-70	
Crankshaft Rear Oil Seal Retainer Nuts	17-20		150-180
Cylinder Head Bolts			
Step 1	47	35	
Step 2	88	65	
Step 3	122	90	
Distributor Hold Down Bolt	27	20	
Exhaust Elbow	16-19	12-14	
Flame Arrestor Cover	3,4-4,5		30-40
Flame Arrestor Stud	7-9		65-80
Flywheel/Coupler Nuts	67-74	50-55	
Flywheel/Coupler Studs	14-20	10-15	
Flywheel Cover	7-9		60-84
Flywheel Housing Bolts (bell housing)	38-49	28-36	
Flywheel Housing Nuts(bell housing)	47-54	35-40	
Front Cover Bolts	3-4		27-35
Front Engine Mounts (use VP 1161075-5)	47-56	35-42	
Front Lift Bracket Bolts	27-41	20-30	
Ignition Coil Bracket Attaching Nuts and Bolt	22	16	
Intake/Exhaust Manifold Nuts and Bolts	27-34	20-25	
Oil Dipstick Tube Fitting to Oil Pan	20-24	15-18	
Oil Dipstick Tube Flare Nut to Fitting	20-24	15-18	
Oil Filter	Gasket contact + one turn		
Oil Pan Nuts (rear)	19		165
Oil Pan Bolts (to crankcase)	9		80
Oil Pan Bolts (to front cover)	5		45

Torque Specifications

Application	N•m	Ft. Lb.	In. Lb.
Oil Pan Studs to Oil Seal Retainer or Crankcase	2		15
Oil Pressure Sender - Adaptor	14-19	10-14	
Oil Pressure Sending Unit	14-19	10-14	
Oil Pump Cover	8		72
Oil Pump to Block	14		120
Oil Pump Pickup	7		60
Power Steering Pump Bracket Bolts	35-41	30-36	
Power Steering Pump Bracket Studs	18-20	13-15	
Pushrod Cover Bolts	5		40
Rocker Arm Cover Bolts	5		40
Spark Plugs	30	22	
Starter Motor	41-49	30-36	
Starter Motor Bracket	22-26	16-19	
Thermostat Housing	16-22	12-16	
Water Pump (circulating)	20	15	
Water Pump (supply)	18-23	13-17	
Water Tempreture Sending Unit	24-30	18-22	

Use a reliable torque wrench to tighten the parts listed to prevent straining or distorting the parts or possibly damaging the threads. These specifications are for clean threads only. Dirty threads produce friction which prevents accurate measurement of tightness. It is important that these torque specifications be strictly observed. Overtightening to any extent may damage threads, thus preventing proper torque from being obtained, requiring replacement or repair of the damaged part.

Engine Specifications

Engine Specifications

Application	Metric	English
General Data		
Engine Type	L4	
Displacement	3.0L	181 CID
Bore	101.60 mm	4.000 in
Stroke	91.44 mm	3.60 in
Compression Ratio	9.25:1	
Firing Order	1-3-4-2	
Spark Plug Gap	1.14 mm	0.045
Thermostat Opens at	71° C	160° F
Full Throttle Operating Range	4200-4600	
Lubrication System		
Oil Pressure (Minimum - Hot)	41.4 kPa at 1000 RPM 124.1 kPa at 2000 RPM 165.5 kPa at 4000 RPM	6.0 psig at 1000 RPM 18.0 psig at 2000 RPM 24.0 psig at 4000 RPM
Oil Capacity (With Oil Filter Change)	3.81 L	4.00 Qts
Oil Pump Type	Gear Driven	
Cylinder Block		
Bore Diameter	101.5873-101.6635 mm	3.9995-4.0025 in
Bore Out-of-Round limit	0.0508 mm	0.002 in
Bore Taper (Thrust Side) Limit	0.0254 mm	0.001 in
Bore Taper (Relief Side) Limit	0.0254 mm	0.001 in
Piston		
Piston-To-Bore Clearance Limit	0.0889 mm	0.0035 in
Piston Rings		
Compression Ring Groove Clearance Limit	0.09906 mm	0.0039 in
Compression Ring End Gap (top ring)	0.88 mm	0.035 in
Compression Ring End Gap (second ring)	0.88 mm	0.035 in
Oil Ring Groove Clearance		
Oil Ring End Gap	1.016 mm	0.04 in
Piston Pin		
Diameter	23.545-23.548 mm	0.9270-0.9271 in
Clearance in Piston Limit	0.0254 mm	0.001 mm

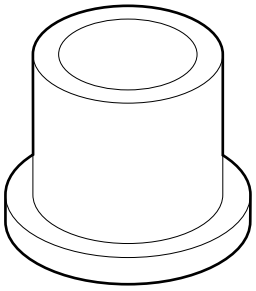
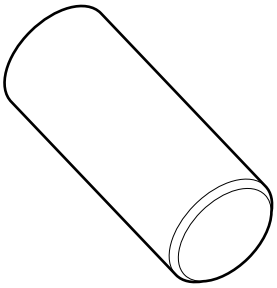
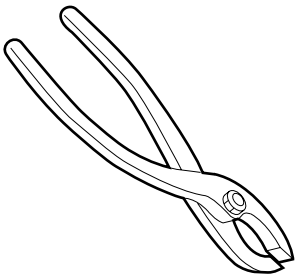
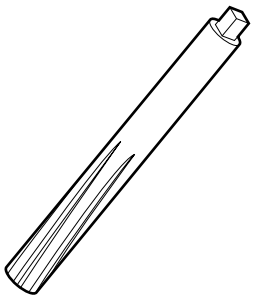
Engine Specifications

Application	Metric	English
Fit in Connecting Rod	0.02032-0.050292 mm (interference)	0.0008-0.00198 in (interference)
Crankshaft		
Crankshaft Journal Diameter (All)	58.3666-58.4047 mm	2.2979-2.2994 in
Crankshaft Journal Taper Limit	0.0254 mm	0.001 in
Crankshaft Jounal Out-of-Round Limit	0.0254	0.001 in
Crankshaft Bearing Clearance Limit #1 - #4	0.0254-0.0635 mm	0.001-0.0025 in
Crankshaft Bearing Clearance Limit #5	0.0381-0.0889 mm	0.0015-0.0035 in
Crankshaft End Play	0.05-0.1524 mm	0.002-0.006 in
Crankshaft Sprocket Runout	0.07 mm	0.003 in
Connecting Rod		
Connecting Rod Journal Diameter	53.2892-53.3273 mm	2.0980-2.0995 in
Connecting Rod Journal Taper Limit	0.0254 mm	0.001 in
Connecting Rod Journal Out-of-Round Limit	0.0254 mm	0.001 in
Rod Bearing Clearance Limit	0.0762 mm	0.003 in
Rod Side Clearance	0.1524-0.4318 mm	0.006-0.017 in
Connecting Rod Length CL to CL	144.7800	5.700 in
Camshaft		
Journal Diameter	47.440-47.490 mm	1.8677-1.8697 in
End Play	0.0762-0.2032 mm	0.003-0.008 in
Camshaft Sprocket Runout Limit	0.1 mm	0.004 in
Timing Sprocket Teeth Backlash	0.10-0.15 mm	0.004-0.006 in
Lobe Lift Intake	6.4247 mm	0.25294 in
Lobe Lift Exhaust	6.4247 mm	0.25294 in
Lobe Lift Wear Limit	±0.0254 mm	±0.001 in
Valve System		
Valve Lifter	Hydraulic	
Rocker Arm Ratio	1.75:1	
Valve Lash	Zero Lash + ½ - 1 turn	
Face Angle	45 Degrees	
Seat Angle	46 Degrees	
Seat Runout Limit	0.05 mm	0.002 in
Seat Width Intake	1.27-1.778 mm	0.050-0.070 in
Seat Width Exhaust	1.524-2.032 mm	0.060-0.080 in

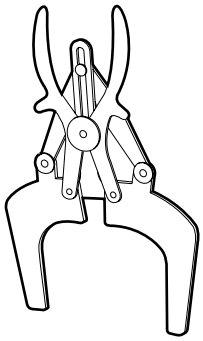
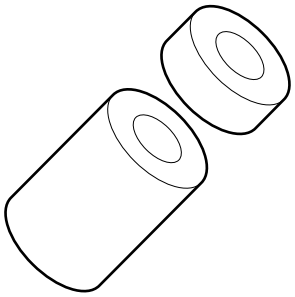
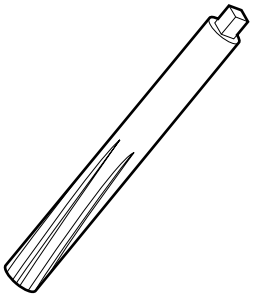
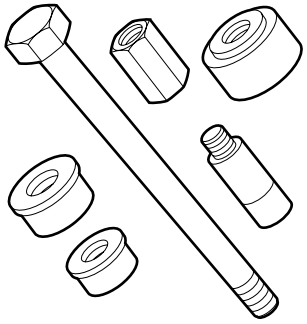
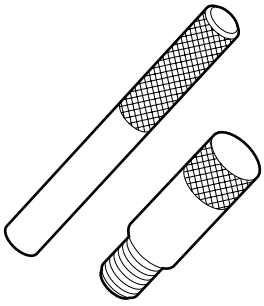
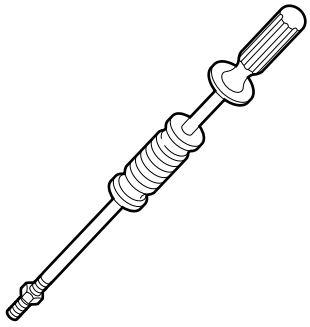
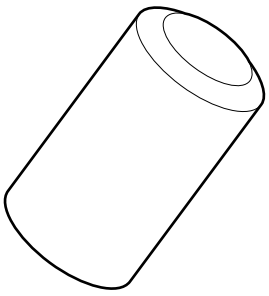
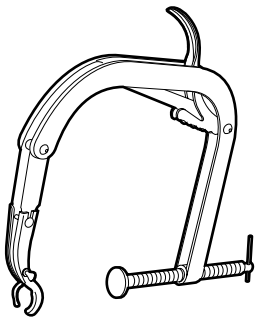
Engine Specifications

Application	Metric	English
Stem Clearance Intake Limit	0.09398 mm	0.0037 in
Stem Clearance Exhaust Limit	0.1193 mm	0.0047 in
Valve Spring Free Length	52.324 mm	2.06 in
Valve Spring Pressure Closed	444-490 N @ 40.89 mm	100-110 lb @ 1.61 in
Valve Spring Pressure Open	925-987 N @ 30.99	208-222 lb @ 1.22 in
Valve Lift Intake	11.25 mm	0.443 in
Valve Lift Exhaust	11.25 mm	0.443 in
Cylinder Head Warpage		
Cylinder Head Deck (measured within a 152.4 mm (6 in) area	0.0762 mm	0.003 in
Cylinder Head Deck (measured overall length of cylinder head)	0.1778 mm	0.007 in

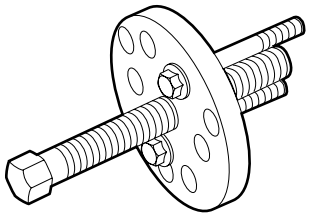
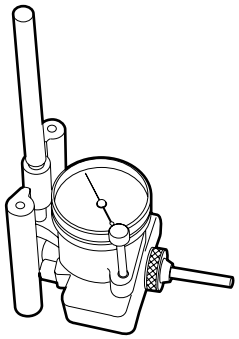
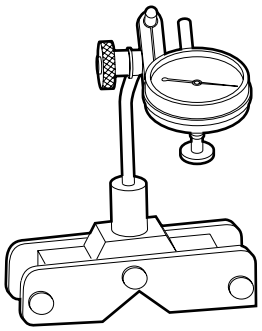
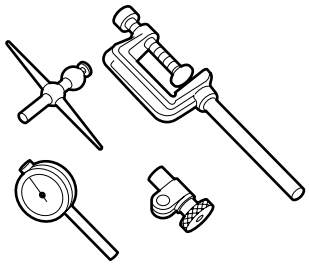
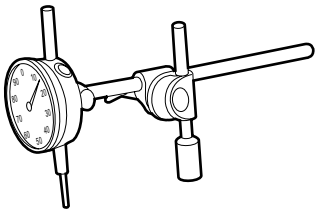
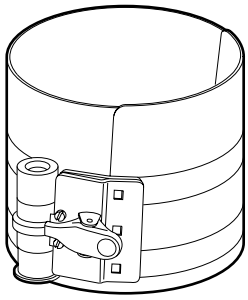
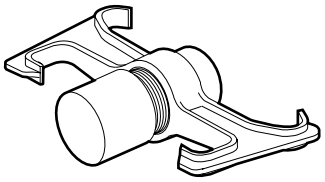
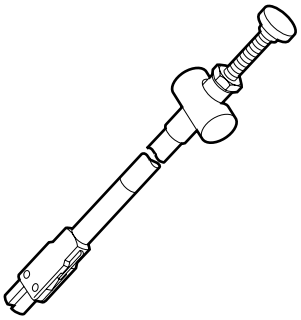
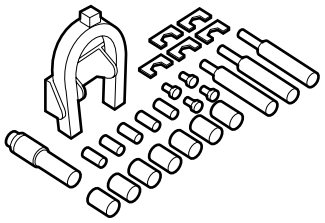
General Motors Special Tools

	J 791 Camshaft Sprocket Remover		J 5590 Crankshaft Sprocket Instal-later
	J 3049-A Valve Lifter Remover		J 5715 or J 6036 Rocker Stud Hole Reamer

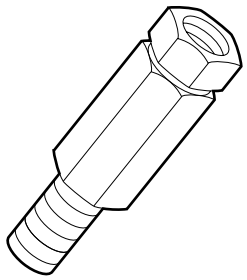
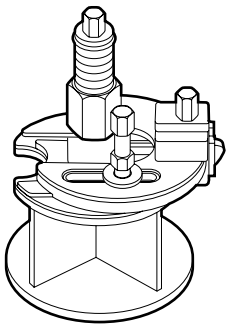
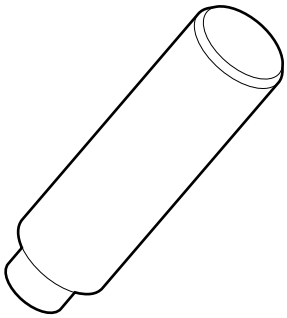
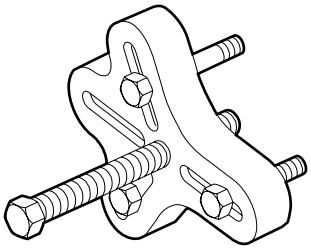
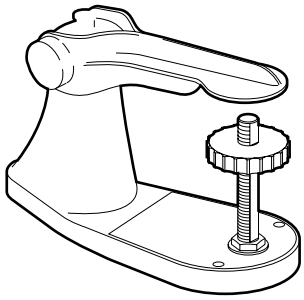
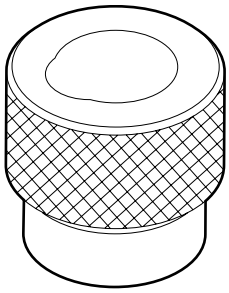
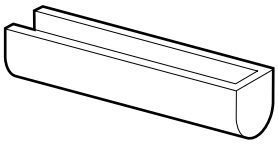
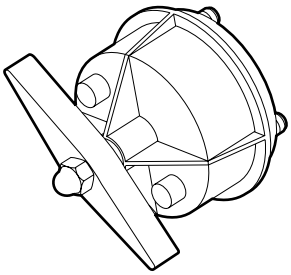
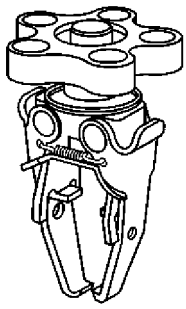
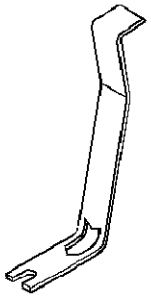
General Motors Special Tools

	J 3936-03 Piston Ring Groove Cleaner		J 5802-01 Rocker Arm Stud Remover
	J 4822 Valve Guide Reamer		J 6098-01 Camshaft Bearing Remover/Installer
	J 5239 Connecting Rod Bolt Guide Set		J 6585 Slide Hammer
	J 6880 Rocker Arm Stud Remover		J 8062 Valve Spring Compressor

General Motors Special Tools

	J 6978-E Crankshaft Sprocket Puller		J 8087 Cylinder Bore Gauge
	J 7872 Magnetic Base Dial Indicator		J 8089 Carbon Remover Brush
	J 8001 Dial Indicator		J 8520 Camshft Lobe Lift Indicator
	J 8037 Piston Ring Compressor		J 8792 Crankshaft Pulley Installer
	J 9290-01 Valve Lifter Rmover (Slide Hammer Type)		J 24086-C Piston Pin Remover/ Installer Set

General Motors Special Tools

	J 9534 Distributor Lower Bushing Remover		J 24270 Ridge Reamer
	J 9535 Distributor Lower Bushing Installer		J 24420-C Universal Crankshaft Pulley Remover
	J 9666 Valve Spring Tester		J 35468 Engine Front Cover Aligner and Oil Seal Installer
	J 21882 Oil Pump Suction Pipe Installer		J 35621 Crankshaft Rear Oil Seal Installer
	J 38606 Valve Spring Compressor		J 5892-D Vave Spring Compressor

Order Directly from:

Kent-Moore Tool Division
28635 Mound Road
Warren, MI 48092
(800) 345-2233
http://www.spxkentmoore.com

Price and ordering information are available from Kent-Moore Tool Division.

For additional service information not covered in this manual, obtain the appropriate Chevrolet Engine Service Manual from:

Helm Inc.
P. O. Box 07130
Detroit, MI 48207
(800) 782-4356
http://www.helminc.com

Material Required

Molykote Lubricant
Volvo Penta Gasket Sealing Compound P/N 1161059
3M Adhesive
Permatex No. 2
GM Super Engine Oil Supplement
Plastigage (Green)
RTV Sealer
API “SJ” SAE 30 Heavy Duty Synthetic Motor Oil

Section 3: Steering System

Special Tools

Volvo Penta Special Tools

Rod Holder 3854367-4

Pump Pulley Installer 9995444-8

Pump Pulley Remover 9995443-0

Kent-Moore Special Tools

Pressure Gauge J-5176-E

Thermometer J-5421

Sealants, Lubricants and Adhesives

Cleaning Solvent

Volvo Penta Grease

Volvo Penta Power Trim/Tilt & Steering Fluid

Volvo Penta Thread Sealing Agent

Loctite Primer

⚠ **Safety Warnings**

Before working on any part of the steering system, read the Safety section at the end of this manual.

When replacement parts are required, use genuine Volvo Penta or parts with equivalent characteristics including type, strength and material. Failure to do so may result in product malfunction and possible injury to the operator and/or passengers.

When working on an engine that is running or being cranked, use extreme care to avoid getting hands, fingers or clothing caught in the alternator, power steering supply pump and circulating pump belts, pulleys and other moving parts.

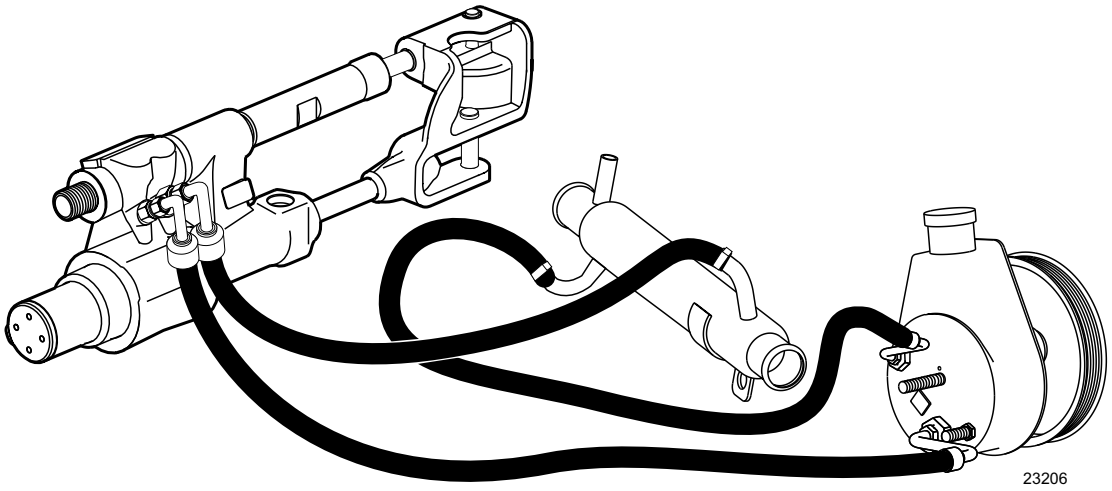
Power Steering System

Description

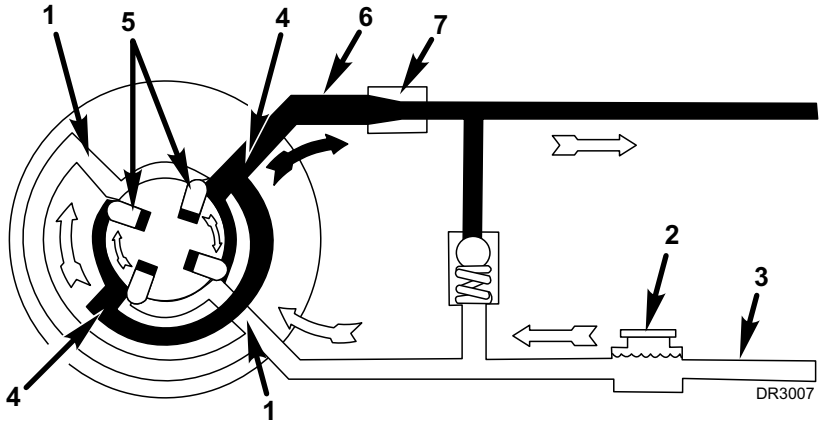
The power steering system consists of a mechanical cable from the helm to the inner transom plate, an engine mounted pump, an oil cooler, and a power cylinder to move the sterndrive steering arm.

The hydraulic pump is mounted on the front of the engine and is belt driven by the crankshaft pulley. The reservoir fill cap has a dipstick attached.

- The control valve and cylinder is a single unit mounted to the inner transom bracket.
- The oil cooler is a heat exchanger that uses engine cooling water to keep the hydraulic fluid cool.
- A high pressure hydraulic hose carries fluid from the pump to the control valve, and low pressure hoses and carry the fluid from the valve to the oil cooler, and back to the reservoir.
- The steering cable casing attaches to the steering cylinder valve.
- The cable ram passes through the valve and attaches to the clevis. The drive steering arm is also attached to the clevis.



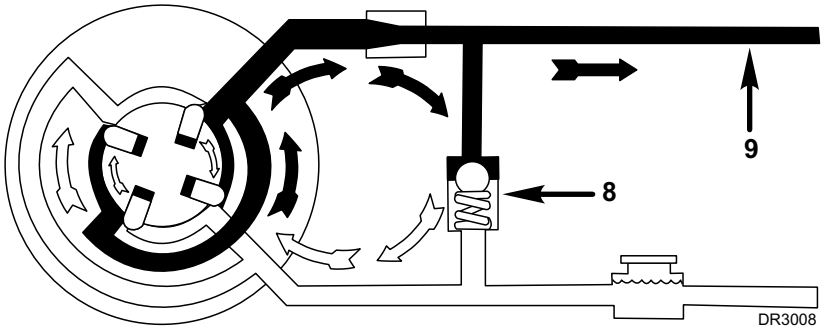
Pump Operation



During normal operation, fluid is drawn into dual pump intake ports (1) from the reservoir (2). The reservoir is supplied by a low pressure return line (3) from the power steering oil cooler. The pump output is through ports (4). The vanes (5) are held out against the pump bore by pressure behind the vanes. The pump has sufficient output (6) to allow quick boat maneuvers even at engine idle RPM. The pump output at high RPM is limited to about 2.3 gallons per minute by a flow restriction orifice (7).

The pump output pressure is determined by the resistance to flow of the system. When no steering changes are being made, the pressure will be about 50-100 PSI. When there is steering input, the pressure will be higher and will depend on the steering forces required due to

the boat attitude, drive trim position, throttle position and quickness of the maneuver.



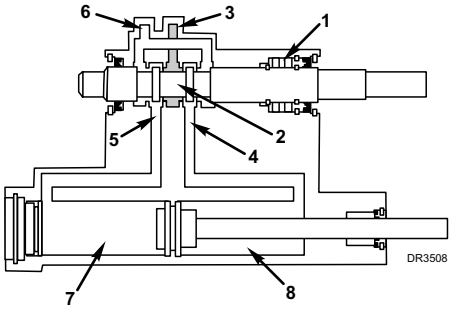
The pump is protected from the very high pressures by a pressure relief valve (8) that is located in the pump body. If the steering load becomes extremely high, the relief valve will open and limit the output pressure (9) to about 1,000-1,100 PSI.

Internal damage to the pump will occur if the system is operated at relief valve pressure for more than a few seconds.

The pump has a metric output fitting. Use only a hose with a metric fitting.

System Operation

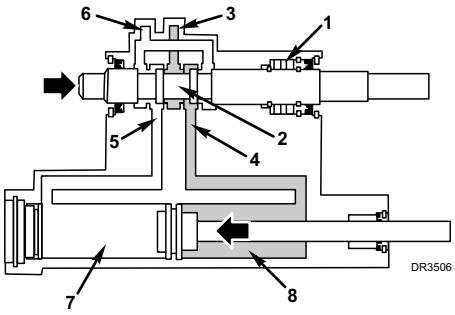
No Steering Input - Steering Wheel Not Turning



When there is no steering input from the helm, the spring (1) keeps the spool valve (2) centered. Fluid from the pump enters the control valve through the pressure port (3), flows past both cylinder ports (4 and 5) with little restriction, then through the return port (6) and back to the reservoir in the power steering pump. There is a small amount of equal force at both ends (7) and (8) of the cylinder and the cylinder does not move.

With no steering input, the sterndrive is held in one position and the boat moves in a constant turn or in a straight line.

Steering To Port - Steering Wheel Turning To Left

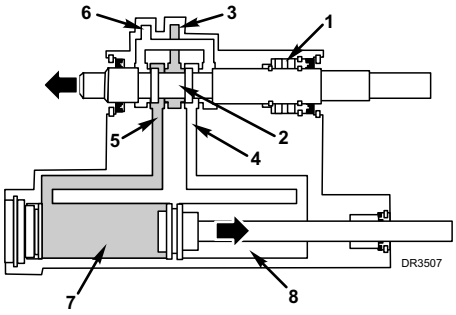


When the helm is turned to port (either turning boat to left or straightening from a right turn) the steering arm is pulled to starboard. The steering cable casing pushes the valve spool (2) to port. Fluid from the pump enters the valve at (3) and is routed to the rod-end outlet (4) and to the low volume side end of the cylinder (8). The pump pressure moves the piston and steering arm to starboard. Fluid in the high volume side of the cylinder (7) is forced out through the valve (5) from to return port (6) and back to the reservoir. As long as the helm is turning to port this motion continues, swinging the sterndrive to port.

When the helm input stops (steering wheel not turning), the steering cable stops pulling the steering arm to starboard, and the steering casing stops pushing the valve spool to port. When the spring (1) moves the valve spool to a “centered” position, hydraulic fluid is again routed past both cylinder outlets. The steering cylinder has an equal force at

both ends and stops moving. The steering system is then back to the **No Steering Input** condition described previously.

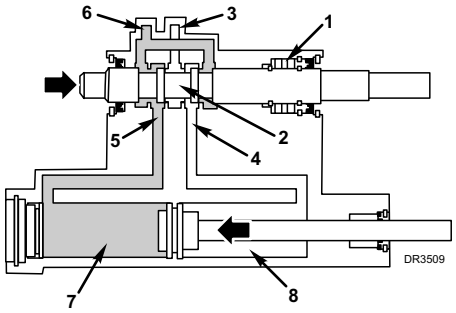
Steering To Starboard - Steering Wheel Turning To Right



When the helm is turned to starboard (either turning boat to right or straightening from a left turn), the steering arm is pushed to port. The steering cable casing pulls the valve spool (2) to starboard. Fluid from the pump enters the valve at (3) and is routed to the piston-end outlet (5) and to the high volume side of the cylinder (7). The pump pressure moves the piston and steering arm to port. Fluid at the low volume side of the cylinder (8) is forced out and through the valve from (4) to return port (6) and back to the reservoir. As long as the helm is turning to starboard this motion continues, swinging the sterndrive to starboard.

When the helm input stops (steering wheel not turning), the steering cable stops pushing the steering arm to port, and the steering casing stops pulling the valve spool to starboard. When the spring (1) moves the valve spool valve to a “centered” position, hydraulic fluid is again routed past both cylinder outlets. The steering cylinder has an equal force at both ends and stops moving. The steering system is then back at the No Steering Input condition described previously.

Steering Without Power Assist

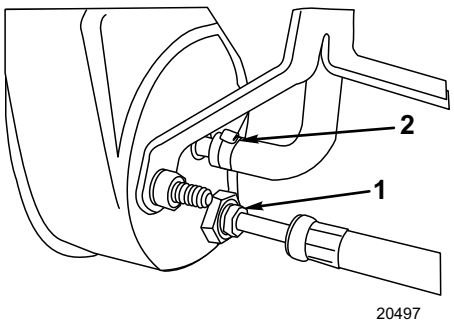


If the steering system is not providing power assist, the operator may still steer the boat. Turning the steering wheel to port causes the steering cable to pull the steering arm to starboard. This causes the cable casing to push the valve spool valve (2) to port against the stop about 0.125 in. (3,18 mm). The steering cable then transmits the full manual effort to pull the steering arm.

The fluid (7) ahead of the piston is forced out of the cylinder through outlet (5) into the valve, and through return port (6) back to the reservoir. Additional fluid is drawn out of the reservoir through the pressure inlet (3) and (4) to the opposite side of the piston.

More steering effort is required since all of the power required to steer the boat must be supplied by the operator, and additional force is required to move the fluid through the system when the pump is not operating.

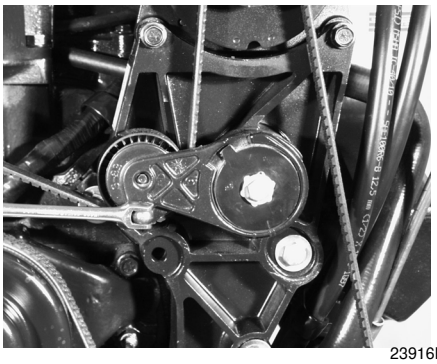
Pump Removal



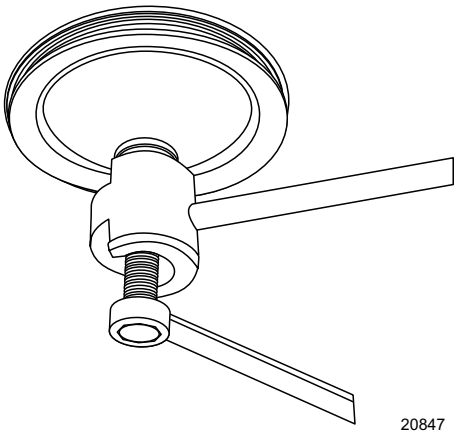
1. Place an oil drain pan under pump. Disconnect high pressure hose (1) and return hose (2) at pump. Do not lose O-ring on pressure hose fitting. Secure hose ends in a raised position to prevent fluid draining from hoses. Cap or tape ends of hoses to keep out dirt. Drain pump completely before removing.

NOTE! Some engine models may have the return line secured with a crimp style clamp. This type clamp is disposable and must be replaced with a worm screw type hose clamp during reassembly.

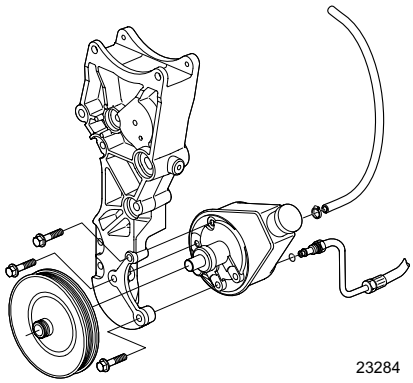
Serpentine Belt Models Only


23916B

1. On models with serpentine belt, release tension on the belt tensioner and remove the belt.

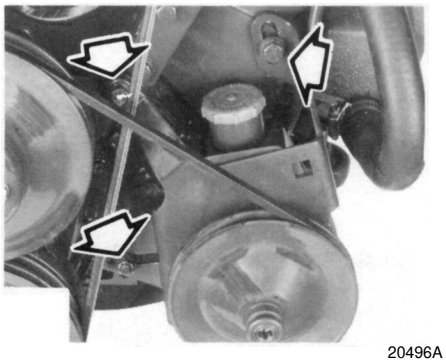

20847

2. Remove pump pulley using special tool Volvo Penta P/N 9995443.

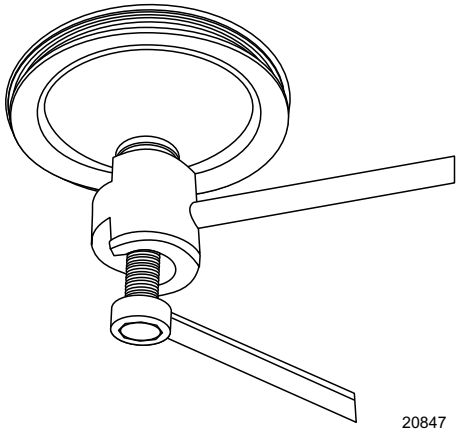

23284

3. Remove three bolts securing pump to mounting bracket and remove pump.

V-Belt Models Only

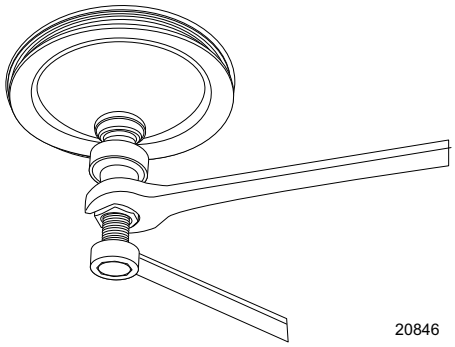

20496A

4. Loosen pump bracket mounting screws and remove drive belt.
5. Remove pump mounting screws and remove pump from engine.

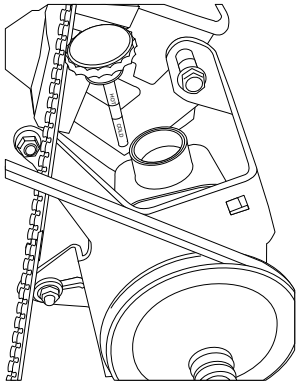

20847

6. Remove pump pulley using Pulley Remover, Volvo Penta P/N 9995443, then remove bracket from pump.
7. Remove mounting screws that secure the bracket to the pump and remove bracket.

Pump Installation

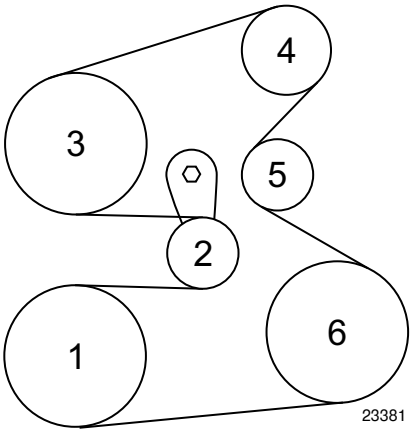

20846

1. Attach mounting bracket to pump.
2. Attach pulley using Pulley Installer, Volvo Penta P/N 9995444-8.
3. Mount pump bracket loosely on the engine.
4. Make sure O-ring is in place and in good condition, then connect high pressure hose fitting. Tighten fitting to 15-26 ft. lb. (20-35 N•m).
5. Connect return hose to reservoir. Tighten hose clamp to 12-17 in. lb. (1,4-2,0 N•m).


20509

6. Fill pump reservoir with Volvo Penta Power Trim/Tilt & Steering Fluid. Bleed pump, hoses, and valve by turning pulley clockwise (as viewed from front of engine) until reservoir no longer shows air bubbles. Keep reservoir filled while purging air from system.

Serpentine Belt Models Only



23381

Release belt tensioner and install belt as shown.

1 Crankshaft
2 Belt tensioner
3 Circulating water pump
4 Alternator
5 Idler Puller
6 Power Steering Pump

V-Belt Models Only

7. Install drive belt and adjust belt tension See “Power Steering Pump Belt Adjustment” on page 103. Do not pry against pump reservoir while tightening belt.
8. Bleed entire system as outlined under Purging Air From Steering System.

Hydraulic Fluid

NOTE!

Only use approved power steering fluid such as Volvo Penta Power Trim/Tilt & Steering Fluid. If this fluid is not available, use an automatic transmission fluid labeled Dexron or Dexron II.

Checking Fluid Level

1. Run engine and rotate steering wheel lock-to-lock for a reasonably long period of time to warm up steering fluid, then shut engine off. Remove reservoir filler cap and check if fluid level is at “HOT” mark on dipstick.
2. If fluid level is low, add recommended hydraulic fluid to bring fluid up to “HOT” mark on dipstick. Replace filler cap.

⚠ **Caution!**

Do not overfill a cold reservoir. Fluid could overflow when system reaches operating temperature.

Purging Air From Steering System

When system components have been serviced, pump must be refilled with fluid before engine is started. Perform the following steps to purge air from the steering system.

⚠ **Caution!**

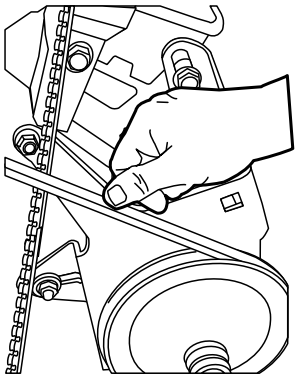
Do not run pump even momentarily without fluid. Pump will be ruined or severely damaged.

1. With engine “OFF,” turn helm all the way to port. Add power steering fluid to bring fluid level to “COLD” mark on dipstick.
2. Start engine, run momentarily and shut off engine. Recheck fluid level and fill to “COLD” mark. Repeat this step as necessary until system no longer requires additional fluid.
3. Complete purging of air from system by starting engine and turning wheel slowly lock-to-lock. Maintain fluid level above pump body in reservoir.
4. Returning fluid with air in it will often be in the form of foam and will have a light tan or red appearance. Maintain fluid level high enough so foam is not drawn into pump inlet. All air must be eliminated from fluid before normal steering action can be obtained. If excessive foam accumulates in reservoir it must be removed, or let unit stand for an hour and repeat steps above.
5. After all air has been purged, return wheel to centered position. Continue to run engine for several minutes and then shut engine off.
6. With engine “OFF” and with fluid at normal operating temperature, recheck to make sure fluid level is at “HOT” mark on dipstick.
7. Water test the boat to make sure the steering functions normally and is free from noise.

Power Steering Pump Belt Adjustment

Serpentine Belt Models The belt tension is maintained by a belt tensioner. No adjustment is necessary.

V- Belt Models



16067

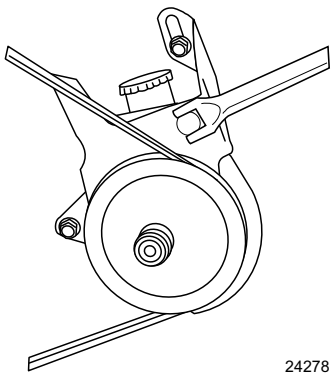
Caution!

Improper power steering belt adjustment will cause a loss of power steering assist, resulting in hard steering.

Check power steering belt tension midway between the circulating pump pulley and the power steering pump pulley.

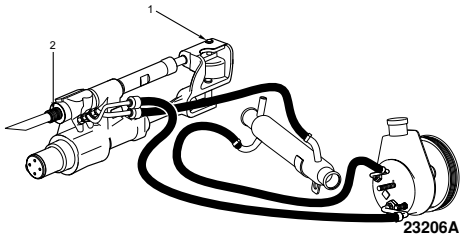
To increase belt tension: Loosen pump mounting bracket screws, insert a 1/2 in. breaker bar into the square hole in the pump mounting bracket, and pivot pump away from engine as shown. While maintaining pressure on pump, retighten all mounting screws. Recheck belt tension. Never pry against the pump reservoir or pull filler neck.

The belts used for the power steering pump are heavy-duty. DO NOT replace with automotive belts.



24278

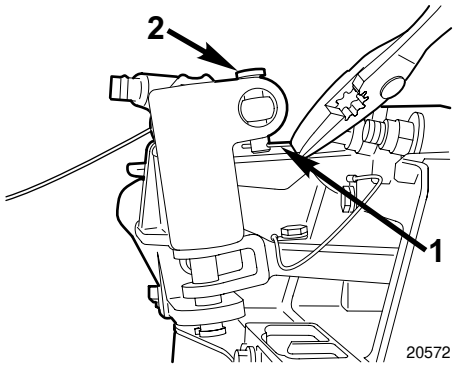
Steering Cylinder



23206A

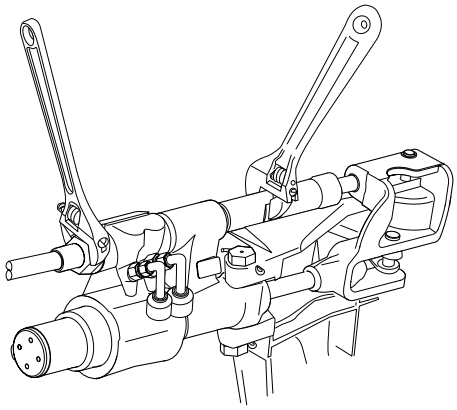
The steering cylinder assembly is a combination power cylinder and control valve. A piston rod clevis (1) provides the attachment to the steering arm and steering cable ram. The steering cable casing attaches to the threaded valve (2).

Cylinder Removal

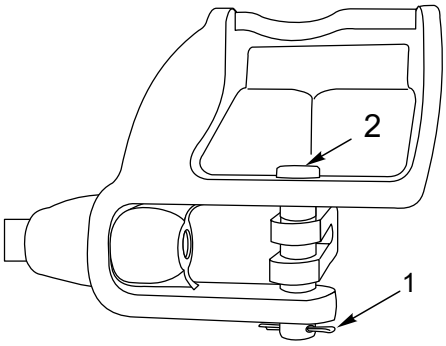


20572

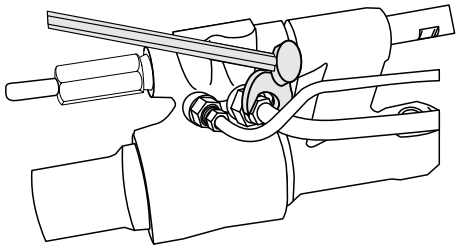
1. Turn helm to port full lock position. Remove the cotter pin (1) and the steering cable pin (2).



2. Hold steering tube with wrench. Loosen steering cable anchor nut and pull steering cable out of valve.



3. Remove cotter pin(1), then pull pin(2) out of clevis and steering arm.

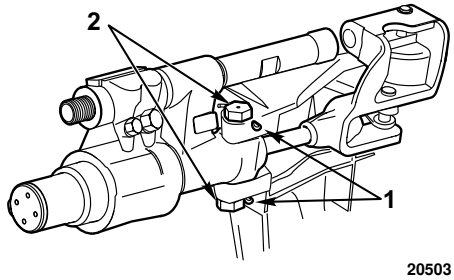


23328

4. Remove both hose fittings from the valve. Raise hoses and cover the ends to keep out dirt.

⚠ **Caution!**

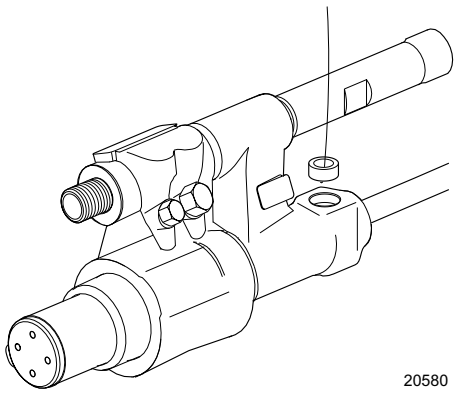
Do not move cylinder rod in or out until cylinder has been drained completely. A dangerous spray of fluid can discharge from the cylinder ports if the rod is moved in or out.



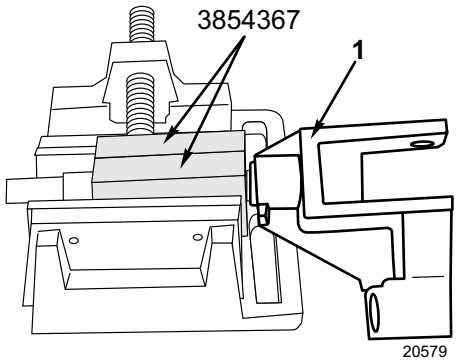
20503

5. Remove cotter pins (1) and loosen both anchor screws (2) until steering cylinder assembly can be removed.

Cylinder Servicing

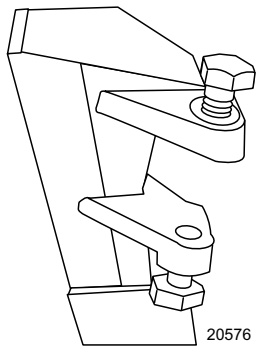


1. Pry out steering pivot bushings if they are to be replaced. If necessary they may be carefully drilled in two places with a 1/16 in. (1,5 mm) drill bit and then removed.
2. New bushings should be lubricated and pushed into place.

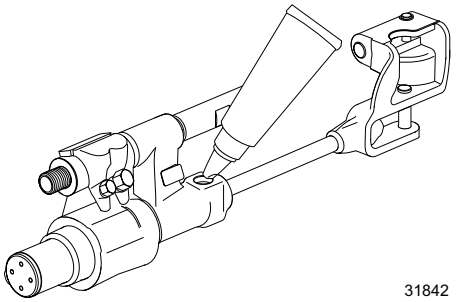


3. The cylinder rod should be wrapped with heavy paper or pasteboard and held in a vise with Rod Holder, Volvo Penta P/N 3854367-4. To remove unscrew the clevis (1).
4. To reinstall clevis, coat threads with Volvo Penta locking fluid P/N 1161053 and tighten to 23-28 ft. lb. (31-38 N•m).

Cylinder Installation



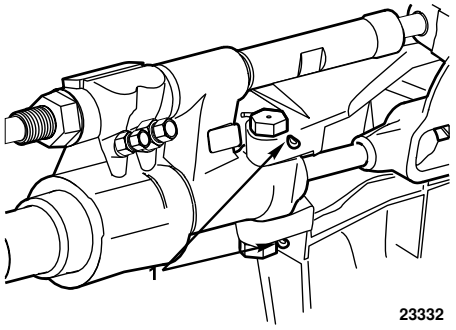
1. Install anchor screws flush with inside of inner transom bracket.


31842

2. Apply Volvo Penta Grease to both bushings.

⚠ **Caution!**

Filling the bushing pockets full with grease can cause the screws to hydraulically lock and break the transom plate when tightened.

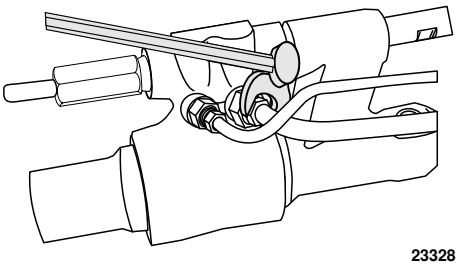


23332

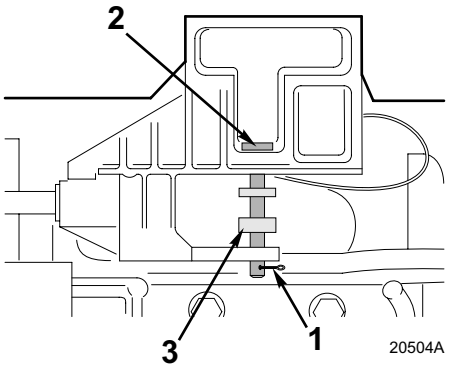
3. Position steering cylinder assembly on inner transom bracket. Align bushings of steering cylinder with screws. Hand start both anchor screws to ensure alignment and engagement into bushings. Tighten anchor screws to 40-45 ft. lb. (54-61 N•m).
4. Install cotter pins through holes (1) in transom bracket from transom side. Spread ends of cotter pins to secure.

⚠ **Caution!**

Do not move cylinder rod if cylinder contains any fluid. A dangerous spray of fluid may discharge from the ports.


23328

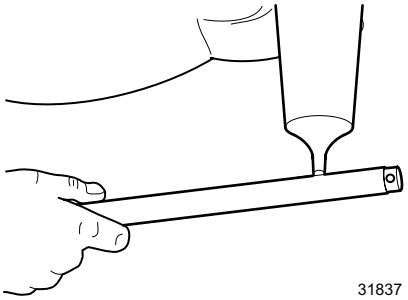
5. Connect hoses to cylinder. Start each fitting by hand. Tighten pressure fitting to 10-12 ft. lb. (14-16 N•m). Tighten return fitting to 15-17 ft. lb. (20-23 N•m).



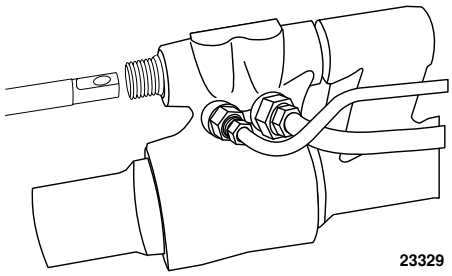
20504A

6. Pull steering arm (3) into hydraulic cylinder clevis. Align holes and install large pin (2) from top of arm. **Secure large pin by installing and spreading ends of cotter pin (3)**.

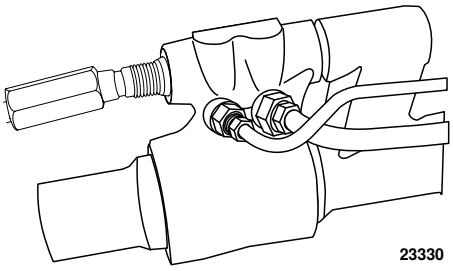
Cable Installation



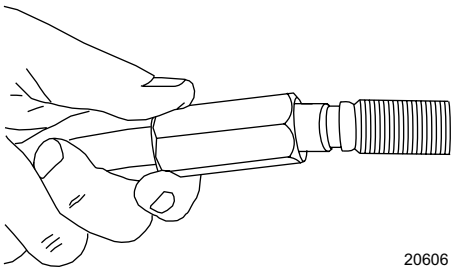
1. Turn the steering wheel to fully extend the steering cable ram to its maximum extension. Lubricate the full length of the steering cable ram with Volvo Penta Grease.



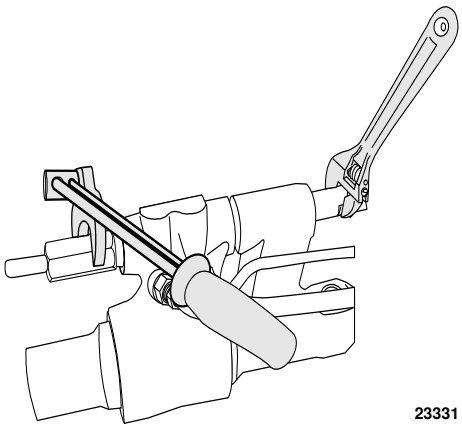
2. Retract steering cable ram and insert ram through valve.



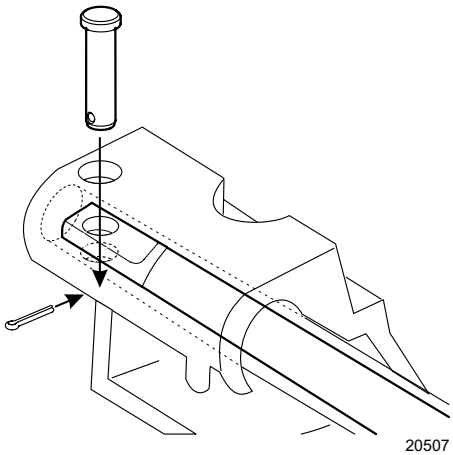
3. Hold steering cable anchor nut back on cable casing to make certain the steering cable is completely seated in end of valve.



4. While holding steering cable tight against valve, thread steering cable anchor nut onto valve until snug.


23331

5. Hold cable tube with a 22 mm wrench on the flat. Attach a crow-foot wrench at 90° to a torque wrench and tighten the steering cable to the cable anchor nut to 120 in. lb. (14 N•m).

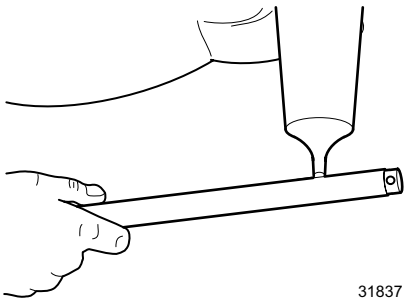

20507

6. Align cable ram with steering cylinder clevis and install small pin from top of clevis. Secure small pin by installing and spreading ends of cotter pin.
7. Fill system with fluid and remove all air. See “Purging Air From Steering System” on page 103.

⚠ **Warning!**

Ensure all steering system cotter pins are properly installed and secure.

Lubrication


31837

Lubricate the steering ram with Volvo Penta Grease every 50 hours or once a season, which ever comes first.

Due to local conditions, it may be necessary to lubricate your steering ram at more frequent intervals.

Hoses

⚠ **Caution!**

Do not start engine with any power steering hose disconnected.

The pump output fitting has metric threads. Do not attach a hose with SAE threads to the pump fitting.

After connecting power steering hoses, make sure that there's ample clearance between the hoses and drive belts and other components. Hoses installed out of position may rub during operation and be damaged.

If fluid return hose is removed at pump, be sure to use a "worm drive" clamp when reinstalling it.

System Diagnosis

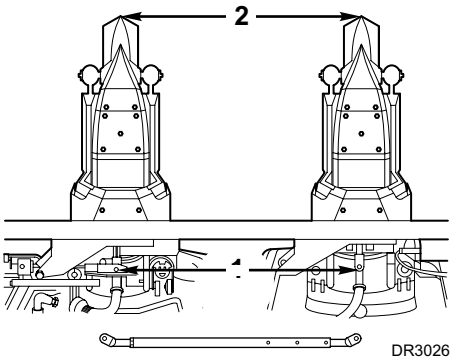
Complaints of faulty steering are frequently the result of problems other than the steering cylinder assembly or pump. Conditions such as hard or loose steering, or vibrations, are often related to such factors as the drive belt; pump and cylinder mounting; fluid level; or incorrect installation of the steering cable. These factors should be checked and corrected before disassembling or replacing parts of the steering system.

System Checks

Many factors affect power operation of the steering system. Some of the most common problem areas are:

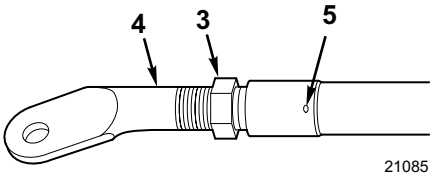
- Fluid level.
- Loose or worn drive belt, or oily belt.
- Steering cable jammed against something in boat at stern.
- Steering cable too short or steering cable too long.
- Loosely mounted components.
- Loose pump pulley.

Tie Bar Adjustment - Twin Engine Installation



On deep Vee shaped boat hulls, a toe-in condition should be created for improved performance and efficiency. A commonly used toe-in condition is one in which dimension (1) will be 1/4 to 3/8 in. (6,35 to 9,53 mm) less than dimension (2).

NOTE! Hold tension on the sterndrives when measuring.



Remove the steering tie bar from the port tiller arm. Loosen jam nut (3). Turn jam nut out 1/16 to 3/32 in. (1,59 to 2,38 mm) as required, and screw in steering tie bar end. Retighten the jam nut.

⚠ **Caution!**

Threads of the port tie bar must be visible through the inspection hole (5) to insure adequate thread engagement between the rod and tube. Failure to ensure proper threads engagement could result in component failure resulting in possible loss of steering control.

Power Steering System Diagnosis Chart

Table 1:

Condition	Possible Cause	Correction
SYSTEM NOISE:		
Pump noise "chirp.”	Loose belt.[a]	Adjust belt tension to specification.
Belt squeal.	Loose belt.[a]	Adjust belt tension to specification.[a]
"Hissing" sound.	Some noise exists in all power steering systems. "Hiss" may be expected when turning the steering wheel, particularly at low speed.	"None; a slight ""hiss"" is normal and in no way affects steering.
Rattle	Pressure hose touching other parts of engine.	Adjust hose position.
Rattle or chuckle.	Steering system looseness.	Check cable nut and cylinder pivot points for wear or looseness. Replace bushings if necessary.
Groan	Low fluid level.	Find and repair leak. Fill reservoir and bleed system.
	Air in fluid.	Fill reservoir, find and repair leak. Check connections, bleed system.
Growl	Excessive back pressure caused by hose restriction.	Locate restriction and correct. Replace part if necessary.
Pump growl	Incorrect steering cable adjustment. Cable to boat interference.	Adjust cable per procedure. Eliminate interference.
Whine in pump.	Pump shaft bearing scored.	Flush system, replace pump.
SYSTEM OPERATION:		
Excessive wheel kickback or loose steering (not boat wander).	Steering cable attachment loose.	Replace pin. Tighten steering cable anchor nut.
	Air in system.	Add fluid to pump reservoir and bleed system. Check all connections.
Steering wheel surges or jerks when turning with engine running, especially during slow speed operation.	Loose pump belt.	Adjust tension to specification.
	Air in fluid.	Fill reservoir, find and repair leak. Bleed system.
	Insufficient pump pressure.	Replace pump if defective.

Table 1:

Condition	Possible Cause	Correction
Momentary increase in effort when turning wheel fast to right or left.	Pump belt slipping.	Tighten or replace belt. If oily, fix leak.
	Low fluid level.	Fill reservoir and bleed system.
	High internal leakage.	Replace pump if defective.

a. Does not apply to serpentine belt systems

External Leakage

General Procedure

1. Wipe suspected area dry.
2. Check for overfilled reservoir.
3. Check for fluid aeration and overflow.
4. Check hose connections - tighten if necessary.
5. Determine exact point of leakage.
6. When service is required, replace component.

Leakage Checks

Although some leaks are easily found, seepage type leaks may be difficult to pinpoint. Locate seepage leaks as follows:

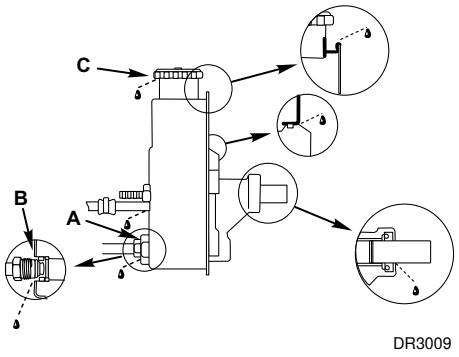
1. With the engine off, wipe the complete power steering system dry (pump, hoses, and connections).
2. Check the fluid level in the pump reservoir and adjust as directed.
3. Start the engine and turn the steering wheel from stop-to-stop several times.
4. Find the exact area of leakage.

Easily Fixed Leaks

1. Loose clamp on pump return hose.
2. Loose pump or cylinder hose fitting. If fittings are not cross-threaded, tighten to correct torque. See Torque Specifications.
3. Damaged O-ring on pump pressure fitting. Replace O-ring.
4. External leakage of power cylinder. Replace power cylinder.
5. Leakage of fluid in cooling water. Replace oil cooler.
6. Damage or cracked hose. Replace hose.

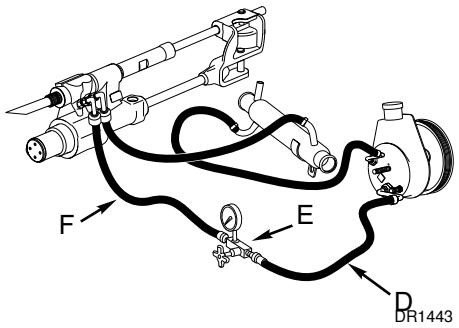
If the return hose is removed, the clamp must be replaced with a worm drive clamp. Replace leaky hoses.

Pump Leakage



1. An overfilled pump reservoir can cause a leak. The fluid in the steering system expands as it heats up during normal usage and fluid level rises in reservoir. Excess fluid is forced through the breather cap hole where it may be sprayed over the engine by the drive belt.
2. Install new O-ring. Tighten hose fitting (A) to 15-26 ft. lb. (20-35 N•m). If leakage persists, replace pump or hose as required.
3. Check torque on fitting (B). Tighten to 37-75 ft. lb. (50-102 N•m). If fitting is not loose, replace pump.
4. Check fluid level (C). If leakage persists with fluid at correct level and cap tight, replace cap or pump.
5. Some non-repairable pump leakage areas are marked with the oil-drop symbol. If leakage occurs in these areas, replace pump.

Pump Pressure Test



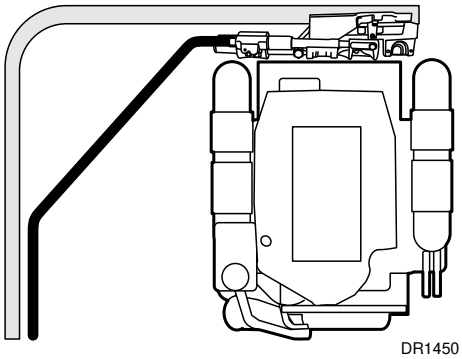
1. With engine off, disconnect high pressure (output) hose at pump. Use a spare pressure hose (D) to install Kent-Moore Tool, J-5176 (E) between pump and steering cylinder pressure hose (F). Gauge must be positioned between shutoff valve and pump. Connect steering cylinder pressure hose to shutoff valve. Open shutoff valve.
2. Remove filler cap from pump reservoir and check fluid level. Fill pump reservoir to full mark on dipstick. Start engine, momentarily hold steering wheel against stop, and check connections at tool for leakage.
3. Bleed system as outlined under Purging Air From Steering System.
4. Insert Kent-Moore Thermometer Tool, J-5421 into reservoir filler opening. Start the engine and move steering wheel from stop-to-stop several times until thermometer indicates that hydraulic fluid has reached its normal operating temperature of approximately 150° to 190° F (65° to 88° C).
5. Check fluid level; add fluid if required. When engine is at normal operating temperature, the pressure reading on the gauge (valve open) should be in the 50-100 PSI (345-690 kPa) range. If pressure exceeds specifications, check the hoses for restrictions.
6. Pump relief valve pressure can be checked by momentarily closing the shutoff valve. Do not leave valve closed longer than it takes to read gauge; high hydraulic pressures are developed. Relief valve pressure is approximately 1000-1100 PSI (6895-7584 kPa).

Replace pump if fluid pressures or temperature do not meet specifications.

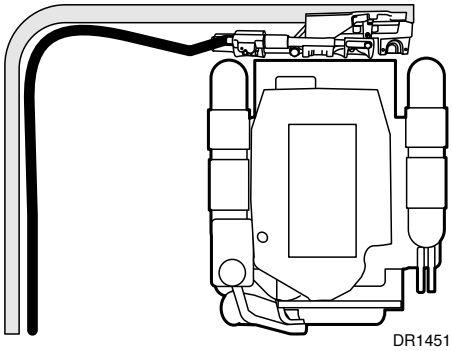
Cable Installation Problems

The hydraulic valve reacts to steering cable casing movement. Total valve movement is about 1/4 inch. This small motion is sufficient to operate the valve and direct hydraulic pressure to the appropriate side of the steering cylinder. Any restriction of movement of the steering cable casing at the stern of the boat will limit or restrict the movement of the valve and will result in hard steering in one or both directions.

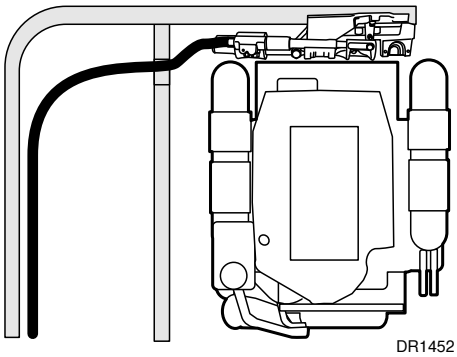
When replacing the steering cable, the following points must be followed for proper power steering system operation:


DR1450

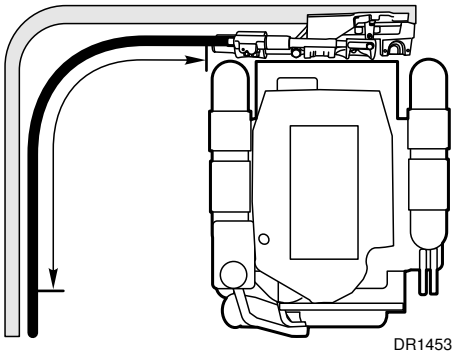
1. Do not install a cable that is too short. Inadequate length will put tension on the cable casing, and cause binding of the steering cable. This will restrict valve movement, cause hard steering to port and a tendency to self steer to starboard.


DR1451

2. Do not install a cable that is too long. Excessive length will push on the cable casing, and cause binding of the steering cable. This will restrict valve movement, cause hard steering to starboard and a tendency to self steer to port.
3. Do not position steering cable in a sharp bend of less than 6 in. radius. Tight bends will cause binding and limit control valve movement. This will contribute to hard or uneven steering, or rough steering wheel movement.


DR1452

4. Do not jam anything against cable at the engine end. Do not bind cable against inside of boat or against fuel tanks, battery boxes or flotation blocks. Jamming the steering cable will restrict steering cable movement and cause hard steering.


DR1453

5. Do not interfere with or restrict steering cable movement through the last 90° of bend to the engine. Cable retainers, clips, clamps or tie straps should not be used in a manner that will restrict the cable movement near the engine. Do not attach wiring harness or control cables to this end of the steering cable.

NOTE! Do not restrict steering cable casing movement. Any restriction of the cable also restricts the valve movement. This will limit or stop hydraulic assist, or may hold the valve in one steering mode.

Feedback To The Helm

The steering system requires at least a little friction in the helm (and cable) to prevent hydrodynamic forces on the gear case from feeding back and turning the steering wheel without the operator activating the power assist system. This may happen on single engine installations (or on twin engines having both drives rotating in the same direction).

Run the boat in a straight line in opposite directions at normal cruising speed with the drive trimmed in both a “bow up” position and in a “bow down” position. In each trim position, momentarily release the steering wheel to see if the wheel is turned by the gear case, and in which direction.

If the steering wheel turns to both starboard and port, then helm friction must be increased slightly. This will allow the power steering system to hold the desired steering position.

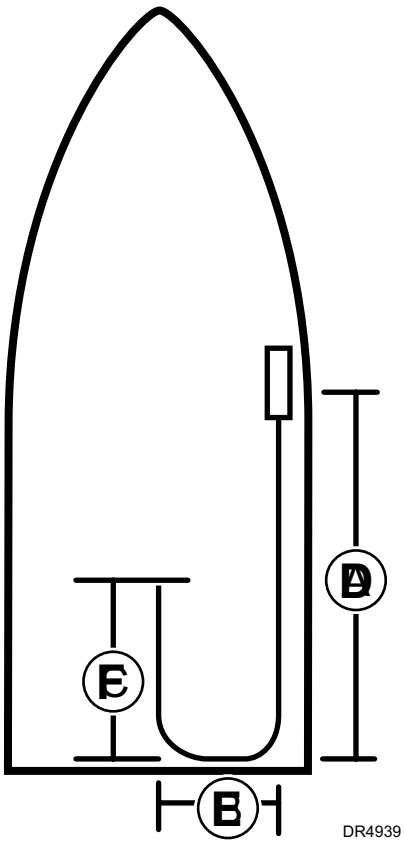
If the helm always turns in one direction (when it turns), it may be caused by a steering cable that is too short, too long, or has restricted movement. See Cable Installation Problems. Twin engine problems may be corrected by adjusting the tie bar for “toe-in” or for “toe-out” of the sterndrives. Refer to Tie Bar Adjustment found in this section.

NOTES

Section 4: Throttle & Shift Control System

Installation of Shift and Throttle Cables

Shift cable should “PULL” for forward gear on right-hand rotation SX and DP-S propeller applications. Shift cable should “PUSH” for forward gear on left-hand rotation SX propeller applications. Throttle cable should “Push” to close for Volvo Penta remote controls. Failure to do so could result in loss of control of the boat and possible injury to the boat occupants.



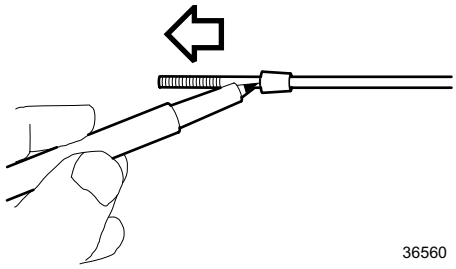
DR4939

1. If the remote control shift and throttle cables are installed in the remote controls, proceed to Check Remote Control Shift Cable Stroke.
2. If the remote control shift and throttle cables have not been installed, the following procedure will permit you to order the correct length remote control shift and throttle cables.
3. Measure the proposed route of the remote control shift and throttle cables. All bends must have a radius greater than 6 inches (15,2 cm).
   - Remote control shift cable: Add (A)+(B) plus 20 in. (50.8 cm), round up to next cable length.
   - Remote control throttle cable: Add (A)+(B)+(C) plus 4 in. (10.1 cm), (C is to center of throttle arm pin). Round up to next cable length.

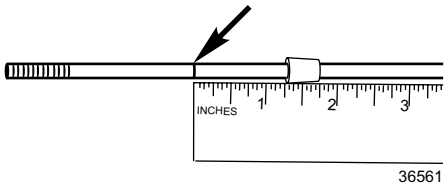
⚠ **Caution!**

When removing shift and throttle cables from the packing box, DO NOT bend the cables tighter than a 6 inch radius.

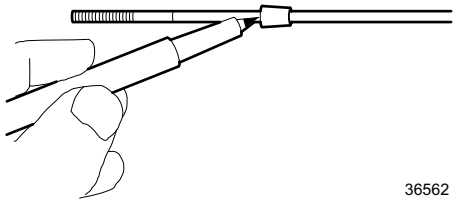
Check Remote Control Shift Cable Stroke



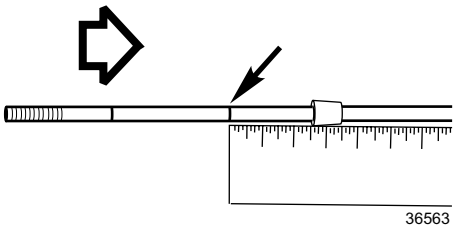
1. Move the remote control handle to the wide-open-throttle position in the direction needed to retract the shift cable. Pull out cable core wire to remove end play. Mark cable core wire at end of casing.



2. Return remote control shift handle to the neutral detent position. Measure and record the distance between the mark and end of casing.



3. Mark cable core wire at end of casing with control in the neutral detent position.



4. Move the remote control handle to the wide-open-throttle position in the direction needed to extend the shift cable. Push in on cable core wire to remove end play. Measure and record the distance between mark and end of casing.
   - The distance between forward and neutral must be no less than 1¼ in. (31.8 mm) and no greater than 13/8 in. (35.0 mm).
   - The distance between neutral and reverse must be no less than 1¼ in. (31.8 mm) and no greater than 13/8 in. (35.0 mm).

NOTE! Check your remote control installation instructions, if your measurements are not within these specifications. Make sure the cables are attached correctly inside the control box and move in the proper direction for your application before continuing. Refer to the remote control installation instructions for this information. All control boxes must meet these minimum and maximum specifications in order for the shift system to function properly.

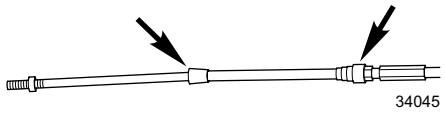
Installation of SAE Cables to Engine/ Drive

NOTE! If the throttle cable is attached to the throttle arm and anchor block, remove it from both. The throttle cable must be disconnected from the throttle arm prior to shift cable installation and adjustment to prevent “loading” the control box and adversely affecting shift adjustments.

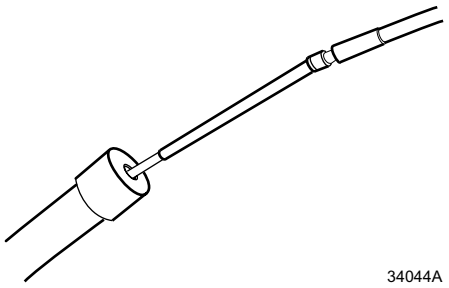
Before beginning, shift remote control handle into NEUTRAL detent position; the propellers should rotate freely.

NOTE! Remote control shift and throttle cables must be SAE type cables.

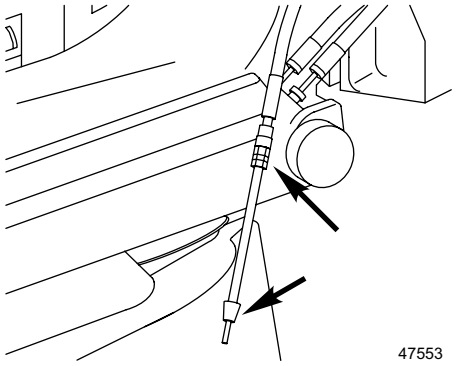
Shift Cable to Sterndrive



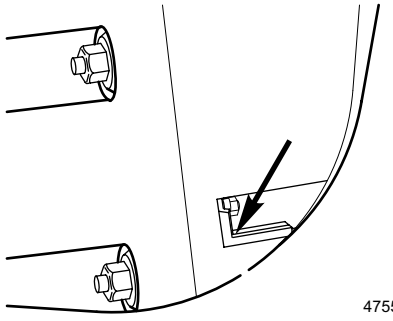
1. Note position of small seal and large seal on the shift cable, Remove and retain jam nut, small seal, and large seal from the shift cable.



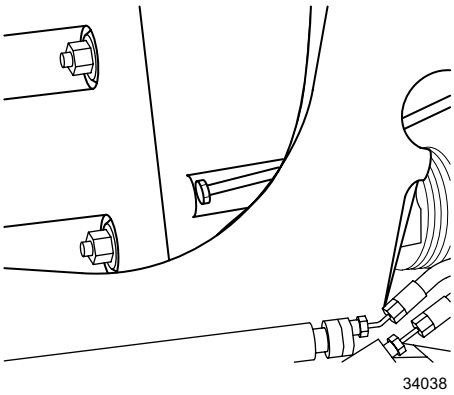
2. Apply a light coat of Volvo Penta Grease to the end of the remote control shift cable casing. Slide shift cable through shift cable tube until it appears on the outside of the transom.



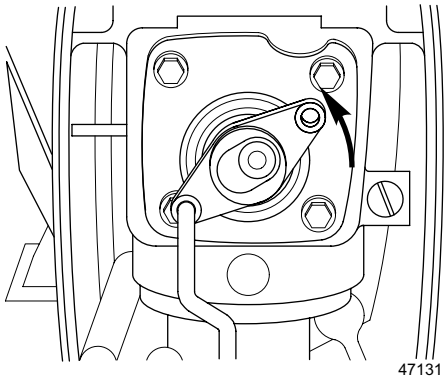
3. For ease of installation of shift cable, turn sterndrive to port. Reinstall the retained large seal and small seal onto the shift cable in the same position as noted in step 1.



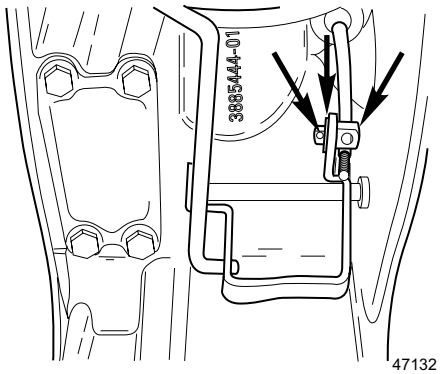
4. Loosen cable clamp screw and pull clamp out.



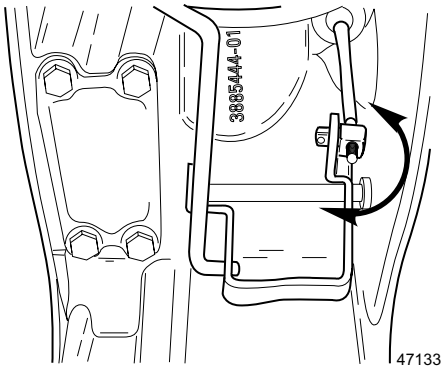
5. Slide shift cable through pivot housing and sterndrive. Slide clamp in fully, engaging the shift cable anchor groove. Tighten clamp screw to 61- 97 in. lb. (7-11 N•m). Check that cable clamp is fully engauged into the shift cable slot after torquing the screw.



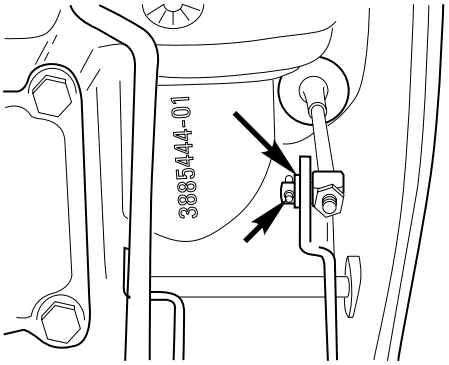
6. Rotate shift lever to extend bell crank.



7. Remove cotter pin, flat washer, and anchor pin.



8. Thread anchor pin halfway onto remote control cable end.



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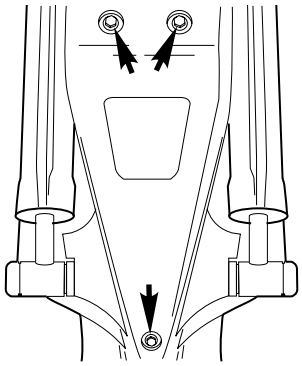
9. Rotate shift lever back to neutral detent position, then move remote control handle to its neutral detent position. Turn anchor pin IN or OUT until it aligns with center of bell crank slot.
10. Install anchor pin, flat washer, and cotter pin. Spread prongs of cotter to secure anchor pin. Install jam nut and tighten securely against anchor pin.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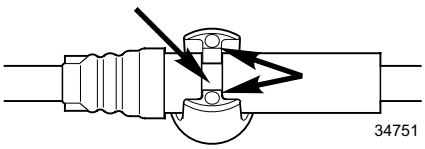
11. Reinstall rear cover and secure with three original screws. Tighten screws to 108-132 in. lb. (12-15 N•m).

Throttle Cable to Engine

Determine whether you have a “push-to-close” or “pull-to-close” remote control system. Cable attachment point at throttle arm is determined by direction of control cable movement. Incorrect attachment may cause hazardous boat operation.

NOTE! The remote control shift cable must be installed prior to throttle cable installation. This will ensure proper throttle and shift system operation when using single lever controls.

1. Position control handle in **NEUTRAL** and propeller should rotate freely. Turn propeller shaft and shift into the **FORWARD** gear detent position, then pull handle **HALFWAY BACK** towards **NEUTRAL**. This positions the control for proper throttle adjustment. Failure to follow this procedure can result in “hard shifting” out of **NEUTRAL**.
2. Make sure throttle lever is against idle stop screw.
3. Align internal bosses of trunnion with throttle cable groove. Press trunnion on throttle cable until seated.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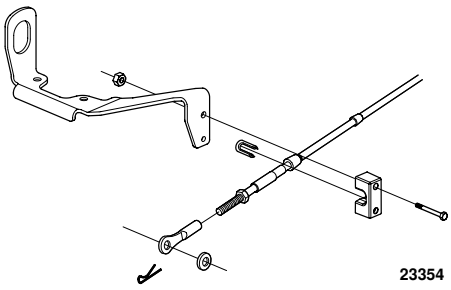
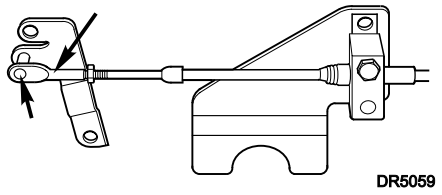

23354

4. The engine throttle cable anchor block bracket is part of the engine lifting bracket and is located port and aft on the exhaust-manifold.
5. Install open end of trunnion in anchor block. Install screw in anchor block and position throttle cable assembly in selected set of holes. Locknut must be against the anchor bracket, tighten it securely.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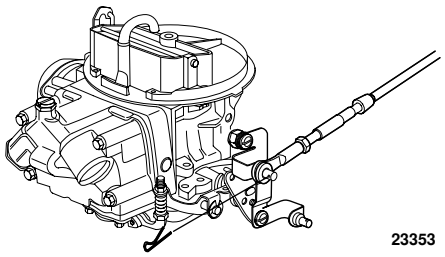
6. Throttle arm connector must have a minimum of 9 full turns or 1/4 in. (6,4 mm) of throttle cable thread engagement. Install throttle arm connector onto the throttle cable. Pull connector forward to remove all end play from throttle cable, then turn the connector in until hole aligns with the “push-to-close” or “pull-to-close” throttle arm stud.

NOTE! If throttle arm connector hole cannot be adjusted to align with the throttle arm, check for proper cable installation in the remote control box.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7. Install connector onto appropriate throttle arm stud. Install washer and cotter pin, and secure by spreading end of cotter pin. Tighten locknut against connector.

Neutral Start Switch Tests

Electrical

1. All switches must be in the “OFF” position, then disconnect battery cables at the battery before servicing electrical systems. Failure to do so could result in injury from:
   - shorted battery positive (B+), causing a burn or an electrical fire.
   - contact with moving parts, if the engine is accidentally cranked or started.
2. Move the control handle to the NEUTRAL position. Disconnect the yellow/red lead from the key switch and the yellow/red lead from the instrument wiring harness.
3. To test the continuity, calibrate an ohmmeter on high ohms scale. Connect the ohmmeter to the two leads. The meter should read zero (0).
4. Move the remote control handle to the FORWARD gear position. The meter should read infinity (∞). Move the remote control handle to the REVERSE gear position. The meter should read infinity (∞).

5. 5. If the meter does not show (∞), check the ohmmeter connections and test again. Replace the neutral start switch if the meter still fails to show (∞) when the remote control handle is in the FORWARD and REVERSE gear position. Refer to the procedures in Disassembly of Remote Control to replace the neutral safety switch.

Mechanical

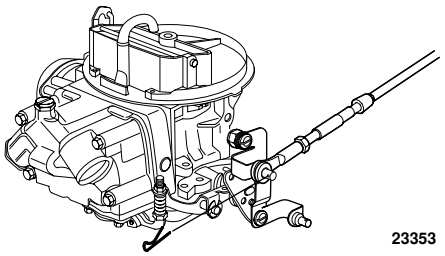
1. With the boat in water and the remote control in NEUTRAL, turn the ignition key to the start position. The engine should start.
2. Disengage the remote control handle and move it into the FORWARD warm-up position. The engine should start.
3. Disengage the remote control handle and move it into the REVERSE warm-up position. Again the engine should start. Move the remote control handle back into NEUTRAL.
4. Move the remote control handle to the FORWARD gear position. The engine should NOT start. Move the handle to the REVERSE gear position. Again the engine should NOT start.
5. If the engine starts when the remote control handle is in either the FORWARD or REVERSE gear position, replace the neutral start switch. Refer to the procedures in Disassembly of Remote Control to replace the neutral safety switch.

Removal of SAE Remote Control Cables

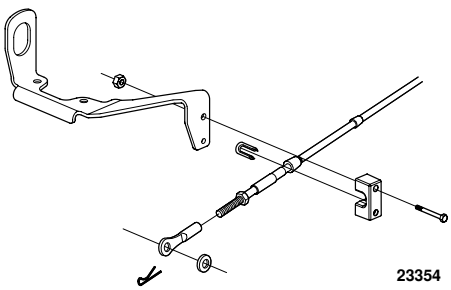
NOTE! Should it become necessary to remove or replace the remote control cables, the attachment at the engine and sterndrive is very important. Follow these steps for removal of remote control cables.

Before beginning, shift remote control handle into NEUTRAL detent position; the propeller should rotate freely.

Throttle Cable From Engine

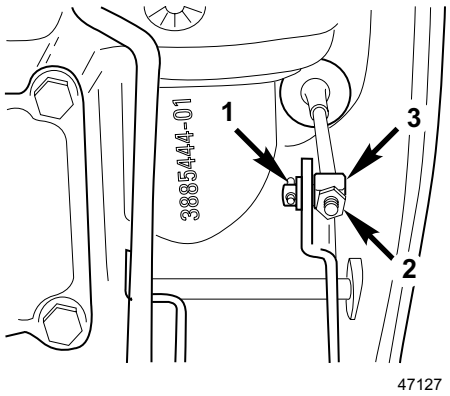


1. Remove cotter pin and flat washer from throttle arm.

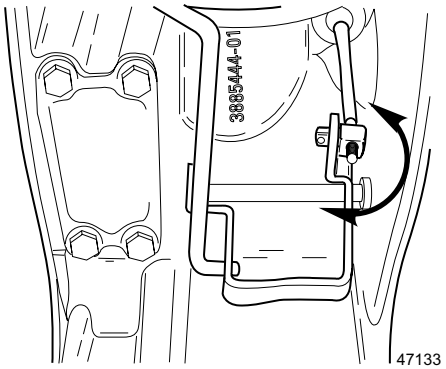


2. Loosen anchor retainer nut and rotate retainer away from cable trunnion. Remove throttle cable from throttle arm and anchor bracket.

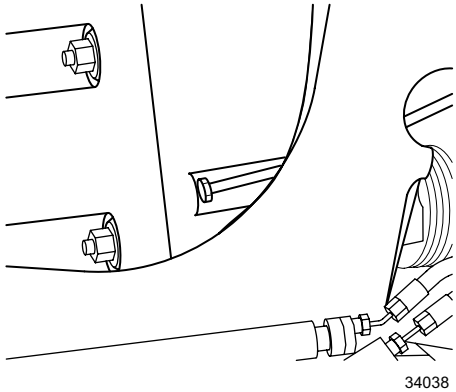
Shift Cable From Sterndrive



1. Remove drive's rear cover. Remove cotter pin (1) and flat washer from anchor pin (3). Remove jam nut (2) from shift cable core wire.



2. Remove anchor pin from bell crank slot. Unscrew anchor pin from shift cable core wire.

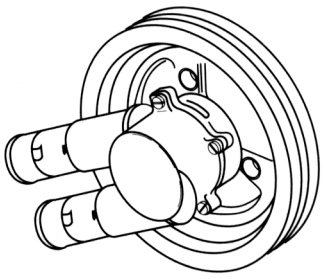


3. Loosen screw and slide retainer out of shift cable anchor groove. Pull the shift cable from drive and transom bracket cable tube.

Section 5: Cooling System

Description

Raw Water Cooled Engines



Cooling water for the engine is picked up at the water intakes on both sides of the sterndrive lower gearcase. Water is pulled upward through the lower gearcase until it enters a water tube that transfers it to the upper gear housing.

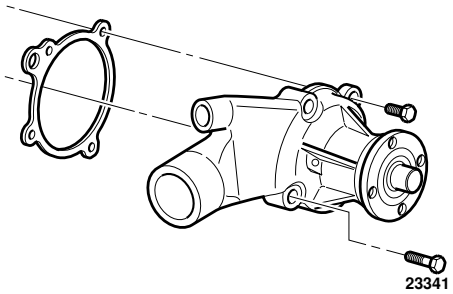
Water is pulled through the upper gear housing water passage where it meets a nipple and hose attached to the pivot housing. Water is routed through the transom mount assembly to a tube that's mounted on the inside of the gimbal housing. From this tube the water is drawn through a supply hose that's connected to the intake nipple of the supply pump.

Water is supplied to the engine by means of an impeller type pump (raw water supply pump). The raw water supply pump is mounted on the engine crankshaft. Water supplied to the engine is circulated in the engine by means of a centrifugal type pump (circulating pump).

The shape of the housing and/or liner cause an eccentric action of the impeller blades during engine operation. During periods of high speed operation, the resistance of the water on its way through the pump is sufficient to prevent the ends of the impeller blades from making con-

tact and following the inside perimeter of the pump housing. The blades merely flex in toward the center of the impeller to perform as a combination centrifugal and positive displacement pump.

During low speed operation the impeller functions as a positive displacement pump. At higher speeds it functions as a combination centrifugal and positive displacement pump. Water exits the outlet nipple of the supply pump under pressure and carried through a hose to the inlet nipple of the thermostat housing.



The circulating pump is mounted on the front of the cylinder block. It has a pulley bolted to the pump shaft hub at its forward end. This in turn is driven by means of a belt from the crankshaft pulley. The pump shaft and bearing assembly is pressed in the water pump housing. The bearing is permanently lubricated during manufacture and sealed to prevent loss of lubricant and entry of dirt. The pump is sealed against coolant leakage by a non-adjustable seal assembly pressed into the pump housing.

The water is now carried downward through the thermostat housing where it enters the flexible hose which attaches to the inlet pipe of the circulating pump. This inlet pipe is a part of the circulating pump housing and feeds the coolant into a low pressure area located at the axis of the impeller. Vanes on the rotating impeller cause the coolant to be thrown outward and into the cylinder block.

The cooling water flows rearward through the water jacket which surrounds each cylinder and extends below the lower limit of piston ring travel. After flowing the full length of the cylinder block, the water is forced upward through two passages and into the cylinder head. The water now flows forward in the cylinder head to cool the combustion chamber areas.

At the forward end of the cylinder head(s), the water enters the thermostat housing. If the water within the block is sufficiently warmed up, the thermostat will be open and a portion of the water will be pumped upward past the thermostat. The remainder will be returned via the flexible hose to the water pump for recirculation within the engine. The water which was pumped upward past the thermostat will enter the hose connected to the thermostat housing outlet and travel to the exhaust manifold.

At this point the water flows rearward through the manifold passages and into the high-rise elbow. All of the water that enters the high-rise elbow is mixed with the exhaust gases prior to entering the exhaust pipe(s) and hose(s). This mixture of exhaust gases and water then enters the exhaust passages of the gimbal housing, pivot housing and sterndrive where it is discharged under water.

When the engine cooling water is cold, as in first starting up, the thermostat will be closed and will not allow any of the water to pass through for eventual discharge overboard. Instead, the water will be carried via the flexible hose back to the circulating pump for recirculation within the block. While the water within the block is recirculating, the supply pump is pumping water to the block.

Since this water is not able to enter the cylinder block, it is necessary to provide a method of discharge. This is provided by the bypass passage within the thermostat housing. If this were not provided, the resulting water pressure would be enough to force the thermostat off its seat, resulting in a greatly increased warm-up period.

Cooling System Troubleshooting

Quiz Customer for the Following Information:

a. How old is unit, how many hours of operation? (Wear and corrosion.)

b. How long has problem existed? (Gradual or sudden.)

c. What were the operating conditions prior to problem? (Fresh or salt water, silt or sandy water.)

d. What previous repairs and service have been made on unit? (Tune-ups, impeller replacement, etc.)

e. At what RPM does problem occur? (Low, high.)

Possibilities To Consider:

a. Temperature Gauge Malfunction.

- Improper or defective sender unit
- Malfunctioning gauge - Check ground wire - substitute good gauge.

b. Engine Water Circulation Pump Malfunction.

- Loose alternator belt
- Impeller vanes worn - replace pump.
- Impeller shaft seal failure - replace pump.

c. Water Intake Screens Blocked.

d. Ventilation - Marine growth on keel, hull deformities, etc.

e. Ignition Timing

- Running with retarded timing (carbureted engines only) - Check timing.

Isolating Cooling Problem:

Air or exhaust gas entering cooling water:

a. **Procedure** - Replace water hose between thermostat housing and the supply pump with clear plastic hose. Operate unit in test tank or boat in water at RPM at which overheat occurs.

NOTE! If operating unit in test tank, run motor in neutral. Some test tanks may not have sufficient water volume to allow running engine in gear without creating turbulence. This can be picked up by the water intake and misconstrued as evidence of a cooling problem.

b. **Results and Conclusions** - No bubbles in hose, air/ exhaust is not entering cooling water. Bubbles in hose, air/exhaust is entering cooling water.

c. **Check for** - Defective lower gearcase water tube guide and seals; damaged water tube grommet; leaking water passage cover gasket or adaptor-to-gear housing gasket.

Insufficient water supply:

a. **Procedure** - Disconnect water supply hose from transom bracket at thermostat housing. Operate engine at specified idle RPM. Hold end of hose level with the top of the flame arrestor.

b. **Results and Conclusions** - A 1 inch (2,5 cm) head of water discharge, water supply is good. If less than 1/2 inch (1.2 cm), look for source of water loss.

c. **Check for** - Blocked intake screens; damaged impeller housing O-ring or impeller plate gasket; broken or worn impeller; defective pivot housing water passage O-ring or water drain screw seal; loose pivot housing-to-gimbal housing water hose clamps.

Thermostat malfunction

a. **Procedure** - Operate engine until indicated temperature exceeds 160°F (71° C). Touch hoses between thermostat and exhaust manifold.

b. **Results and Conclusions** - Hoses cold, thermostat is stuck closed. Hoses warm or hot, thermostat is good.

c. **Check for** - Thermostat stuck open or closed, defective thermostat O-ring, correct thermostat style for engine type, clear thermostat housing bypass passage.

Engine head gasket leakage

a. **Procedure** - Allow engine to cool. Replace water hose(s) between thermostat housing and exhaust manifolds) with clear plastic hose. Operate unit at RPM at which overheat occurs.

b. **Results and Conclusions** - No bubbles evident, head gaskets not leaking. Bubbles evident, head gaskets leaking.

c. **Check for** - Cylinder compression using appropriate tester, water in engine oil, water in cylinders, spark plugs wet with water.

Cooling System Components

Hoses, Clamps, and Drain Plugs

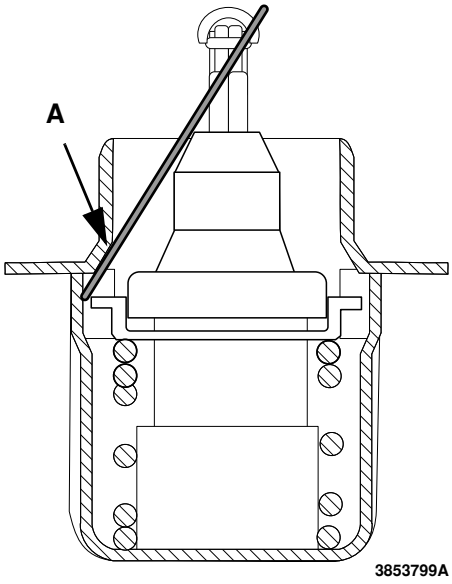
No special tools required.

Inspection Procedure: Examine all external cooling system components for leaks, wear, deterioration, and damage. Check all connections for tightness. Inspect hoses for cracks, checking or deterioration.

Repair Procedure: Repair or replace as required.

Water supply hoses used for replacement must conform to S.A.E. 20R3, class D-2.

Thermostat



A 160° F (71° C) thermostat is standard.

Inspection Procedure: Check for proper rating and style, corrosion, restricted movement, or broken spring.

Test Procedure - Immerse the thermostat and a thermometer in a container of water. Heat water. Thermostat should start to open between 157-163° F (70-73° C), and should open to 5/32 in. (3,96 mm) minimum (A) at 182° F (83° C).

Repair Procedure: None, replace unit.

Manifold and Elbow

No special tools required.

Inspection Procedure: Pressure check components for leaks. Disassemble and inspect for corrosion or accumulation of foreign material.

Repair Procedure: Rod out any accumulation of foreign matter built up in water passages. If evidence of porosity between water passages and exhaust chambers or exterior is found, replace component. Install new gaskets on reassembly.

Circulating Pump - Engine

No special tools required.

Inspection Procedure: Make sure belt tension is correct. With the engine running, observe the rotation of the circulating pump pulley. If the pulley does not run true it can cause excessive drive belt wear and damage to the circulating pump itself.

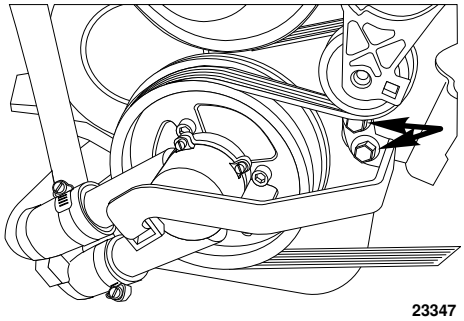
If the leakage of water occurs at the circulating pump while the engine is in operation, the pump may be loosely mounted to the engine, the shaft seal in front of the pump may be bad, the backing plate gasket may be defective, or the circulating pump mounting gaskets are leaking.

If the above inspections do not detect any defect, the pump must be removed and inspected for internal corrosion, blockage, or damage. Inspect impeller for erosion.

Repair Procedure: None, replace the pump.

NOTE! Volvo Penta marine engines have a special circulating water pump with stainless steel components and a special marine shaft seal assembly. Do not replace with an automotive water pump.

Supply Pump



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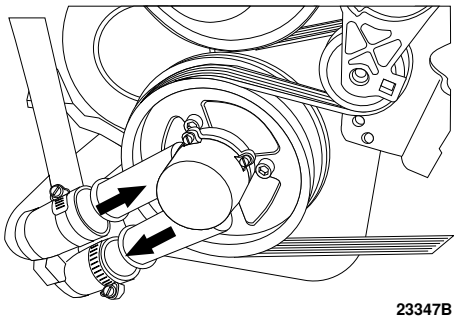
Removal

1. Drain engine, refer to Draining Engine Block or Exhaust Manifold on page 133.
2. Loosen bracket mounting screws and remove bracket.



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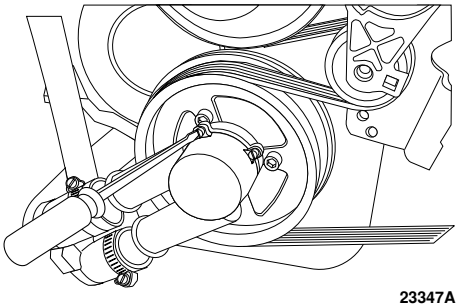
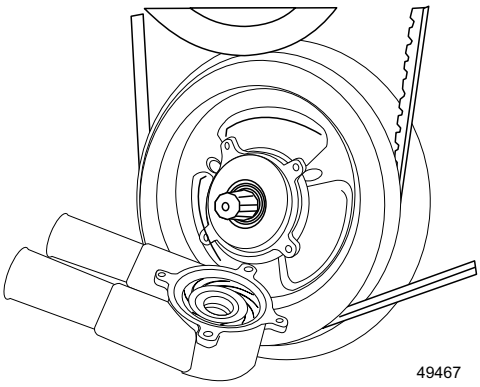
3. Loosen hose clamps and remove hoses from supply pump. Note: The upper hose is the inlet hose.

Impeller Removal



23347A

1. Remove the four screws securing the housing.



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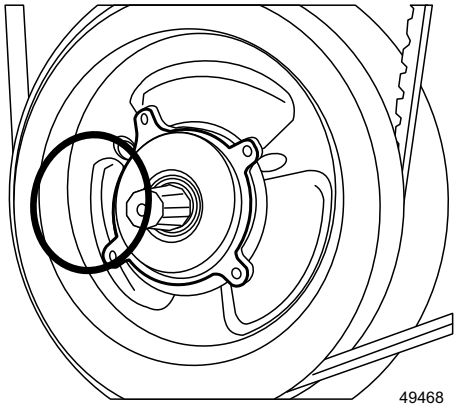
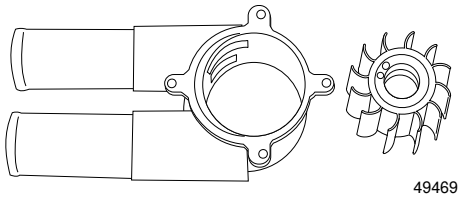
2. Remove pump housing.



3. Remove and discard O-ring.

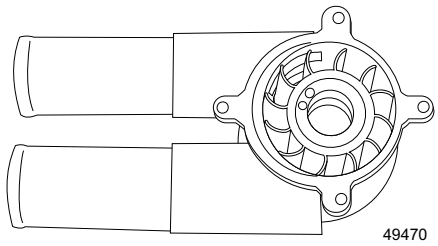


4. Grasp impeller securely and pull from housing.

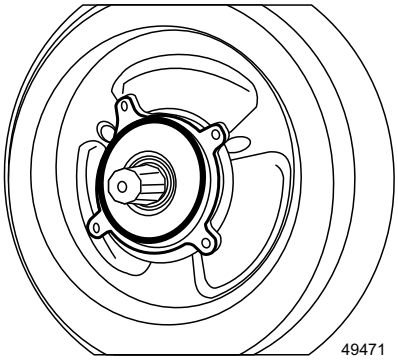
Cleaning and Inspection

1. Clean all parts with solvent and blow dry thoroughly.
2. Clean sealing surfaces.
3. Inspect impeller housing for wear, cracks, gouges and distortion caused by freezing. If the sides of the impeller appear to be worn burned or charred, replace if necessary.
4. Inspect impeller; if blades are set in a bent position, cracked or broken, or show flat instead of rounded edges on the housing contact surfaces, replace the impeller.
5. Check bearings for smooth operation.

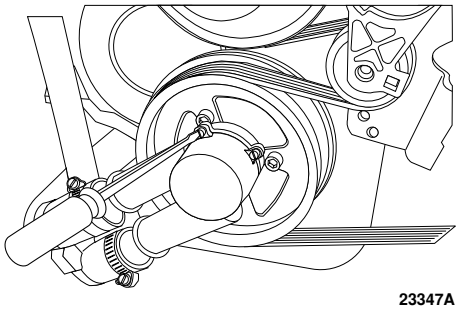
Impeller Installation



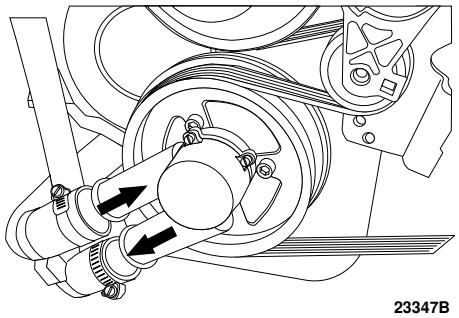
1. Apply a light coat of glycerine to impeller surfaces. Install impeller until seated in the housing.



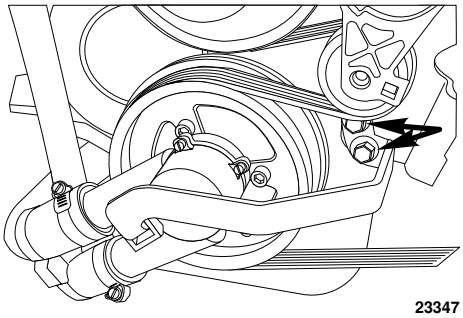
2. Apply a light coat of Volvo Penta Grease P/N 828250 to a new O-ring. Install the O-ring onto the pulley and shaft assembly.



3. Install pump and secure with four screws. Tighten screws to 19-24 in. lb. (2,2-2,8 N•m).



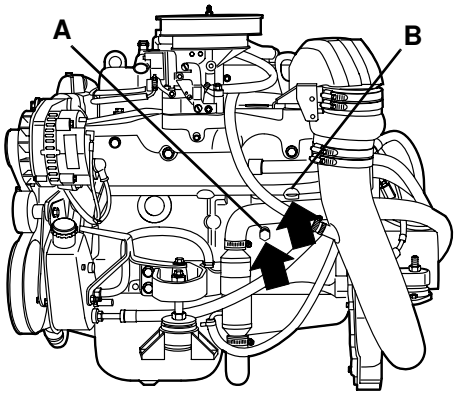
4. Attach the inlet hose to upper nipple and the outlet hose to the lower nipple. Tighten hose clamps securely.



5. Orient pump assembly. Install bracket and secure with screws. Tighten screws to 20-25 ft. lb. (27-34 N•m).

Draining Engine Block or Exhaust Manifold

3.0GS-A, 3.0GL-A/B/C/D



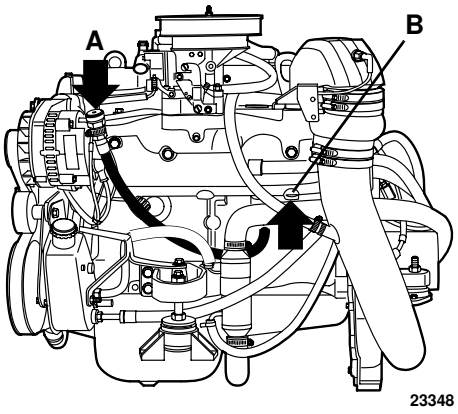
1. With the engine turned off, locate and open the engine drain petcocks or remove drain plug as applicable (A) located on the port side of the engine block.

⚠ **Caution!**

Be sure that all water is drained from the engine. If no water drains when the petcocks are opened, remove the petcocks and use a piece of wire to clear any obstructions from the drain hole. Failure to drain all the water from the engine may result in engine damage during freezing temperatures.

2. Remove drain plugs from exhaust manifold (B). Raise or lower the bow of the boat to ensure complete drainage. After the water has completely drained, reinstall the drain plug and torque to 29 N•m (22 ft. lb.)

3.0GS-B/C



1. Locate the engine flush connector (A) at the front of the engine and is connected to a nipple on the port side of the engine block. Connect a garden hose to the connector with the supplied adapter.

NOTE! The hose connection adapter supplied with the engine may not work in all geographic locations.

⚠ **Caution!**

Do not run the engine during the flushing procedure. Water is not supplied to the raw water pump and the pump impeller will be damaged.

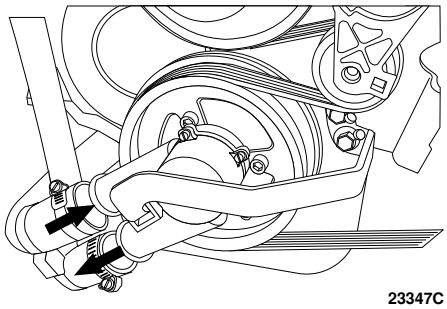
2. Turn the fresh water supply on and flush the engine with fresh water for 5 minutes to ensure the drain ports are open.
3. Turn off the fresh water supply and disconnect the garden hose from the engine flush connector. Lower the engine flush hose below the engine level and let drain.
4. After all of the water has drained out, reattach the hose cap and place back in original location.
5. Remove drain plug (B) from the exhaust manifold and let drain completely. Reinstall the drain plug and torque to 29 N•m (22 ft. lb.)

⚠ **Caution!**

If a garden hose with fresh water supply is unavailable, you must remove the hose nipple(s) from the engine to drain the engine block. To ensure all water is drained, clear the drain hole with a piece of wire. After the engine is drained reinstall the hose nipples and flush adapter as

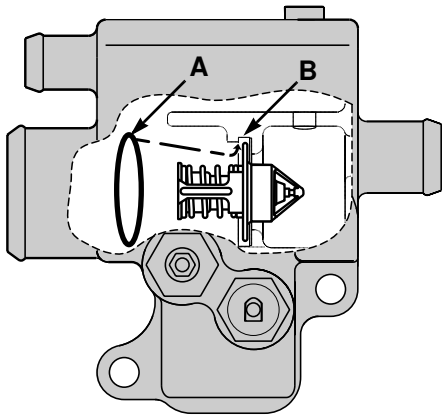
removed. The exhaust manifolds are drained as described previously.

Draining Supply Pump


23347C

1. Loosen and slide hose clamps back. Remove hoses from the pump and drain.
2. Crank the engine no more than 2 seconds (DO NOT START) to expel any water trapped in water pump. Reattach hoses.

Thermostat Replacement



45355C

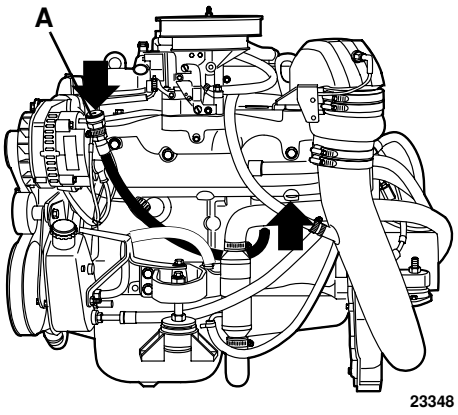
1. Remove all water hoses from the thermostat housing.
2. Remove thermostat housing from engine.
3. The thermostat is held in place by an O-ring (A). Pry the O-ring out of its groove, then lift the thermostat out of the housing.
4. Discard the housing gasket and O-ring. Thoroughly clean the housing and cylinder head gasket surfaces.
5. Place the thermostat in the housing. The temperature sensing element must face you when installed. Install a new O-ring to seal thermostat in housing. Make sure O-ring is completely seated in its groove.
6. Coat both sides of a new gasket with Volvo Penta Gasket Sealing Compound P/N 1161099 and place it on the manifold. Install two screws. Tighten the screws to 20-25 ft. lb. (27-34 N•m).
7. Connect the water supply hose to nipple and tighten hose clamp securely. Connect the three remaining water hoses and tighten hose clamps securely. Make sure lifting eye is positioned as shown.

⚠ **Caution!**

If the water supply hose is attached to the wrong nipple, the engine will overheat.

Engine Flushing

3.0GS-B/C



1. Locate the engine flush connector (A) at the front of the engine and is connected to a nipple on the port side of the engine block. Connect a garden hose to the connector with the supplied adapter.

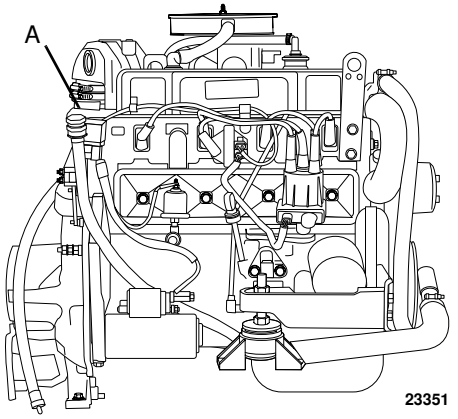
NOTE! The hose connection adapter supplied with the engine may not work in all geographic locations. If you need an adapter other than the one supplied, contact your Volvo Penta dealer for the correct adapter for you location.

⚠ **Caution!**

Do not run the engine during the flushing procedure for this model engine. Water is not supplied to the raw water pump and the pump impeller will be damaged.

2. Turn the fresh water supply on and flush the engine with fresh water for 5 minutes to ensure the drain ports are open.
3. If freezing temperatures are expected, drain engine, See “Draining Engine Block or Exhaust Manifold” on page 133.

3.0GL-A/B/C/D/E



1. If the engine is running, shut it down.
2. Remove the blue plastic cap (A) from the hose that is clamped to the starboard side of the engine. It is marked with the running engine flush symbol.
3. Connect a water hose from a fresh water source to the flush connector on the engine (A).
4. Turn water on full and start the engine.

⚠ **Warning!**

Be sure to keep people and objects clear of the propeller area during the flushing procedure. Accidental entanglement with the propeller is likely should the sterndrive be shifted into gear while the engine is running. Do not leave engine unattended while running.

5. Let engine idle until engine temperature stabilizes at its normal operating range. This will allow the thermostat to open and ensure the fresh water circulates throughout the engine.
6. After engine is flushed, shut engine the down.
7. Disconnect water hose and reinstall the cap.

CAUTION!

When re-installing the blue cap on the fresh water flush hose, tighten it by hand, then tighten 1/4 turn using a wrench. If the cap is too loose, air may be sucked in, causing the engine to overheat, resulting in damage.

Drain the engine if freezing temperatures are expected. For details on draining the engine, please See “Draining Engine Block or Exhaust Manifold” on page 133.

Numbers refer to Cooling System Flow Diagrams on the following pages.

1. **Intake Screen** - Blocked with debris.
2. **Water Tube Guide and Seal** - Improperly sealed.
3. **Water Tube** - Plugged with debris.
4. **Grommet** - Deteriorated, improperly seated.
5. **Upper Gear Housing** - Debris blocking passage, freeze damaged.
6. **Pivot Housing Seal** - Damaged, out of position, improperly sealed.
7. **Nipple O-ring** - Out of position, improperly sealed, damaged.
8. **Nipple** - Blocked by debris, freeze cracked, loose in housing.
9. **Water Hose and Clamps** - Clamps loose, hose collapsed or leaking.
10. **Transom Mount Water Tube** - Blocked by debris.
11. **Supply Pump (Engine Mounted)** - Failed seal, corroded or bad bearings, eroded impeller, leaking mounting gaskets or backing plate.
12. **Thermostat Housing** - Corroded, restricted, or leaking gasket.
13. **Thermostat** - Defective thermostat, or wrong type for engine; improperly seated or damaged O-ring.
14. **Belts** - Loose, or worn and slipping.
15. **Circulating Pump (Engine)** - Failed seal, corroded or bad bearings, eroded impeller, leaking mounting gaskets or backing plate.
16. **Cylinder Block Water Passages** - Corrosion, slag, blocked passages, or leaking core plugs.
17. **Cylinder Head** - Corrosion, slag, blocked passages or leaking gaskets.
18. **Exhaust Manifold, Elbows, Gaskets, and Hoses** - Gaskets improperly installed; corrosion, sand, or slag in manifold and elbows; hoses collapsed, burned through, or leaking.
19. **Exhaust Pipe and Seal** - Improperly sealed or installed, leaking.
20. **Bellows, Clamp, and Retainer** - Loose clamp, detached or torn bellows.
21. **Power Steering Cooler** - Restricted, or cracked and leaking.
22. **Intake Manifold** - Cracked casting, or leaking gasket(s).
23. **Engine Oil Cooler** - Restricted, or cracked and leaking.

In addition, check:

- **Ignition Timing**
- **Boat Hull** - Condition of hull, marine growth, or under- hull equipment.

Note! Fittings protruding through hull may cause air bubble streams which can be picked up by the lower gearcase and mixed with incoming cooling water to cause an overheat condition.

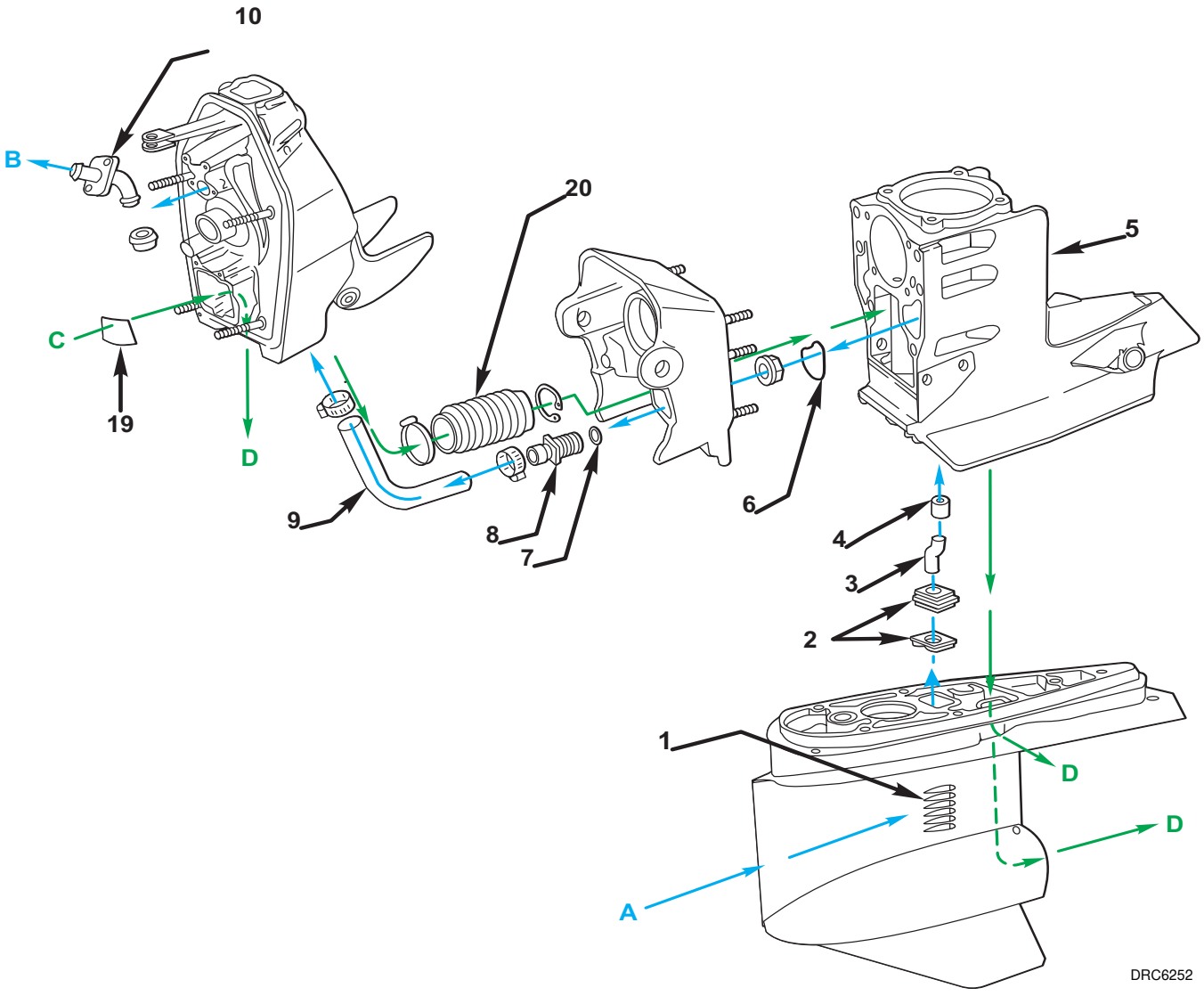
Sterndrive and Transom Bracket Cooling Schematic

A) Water In

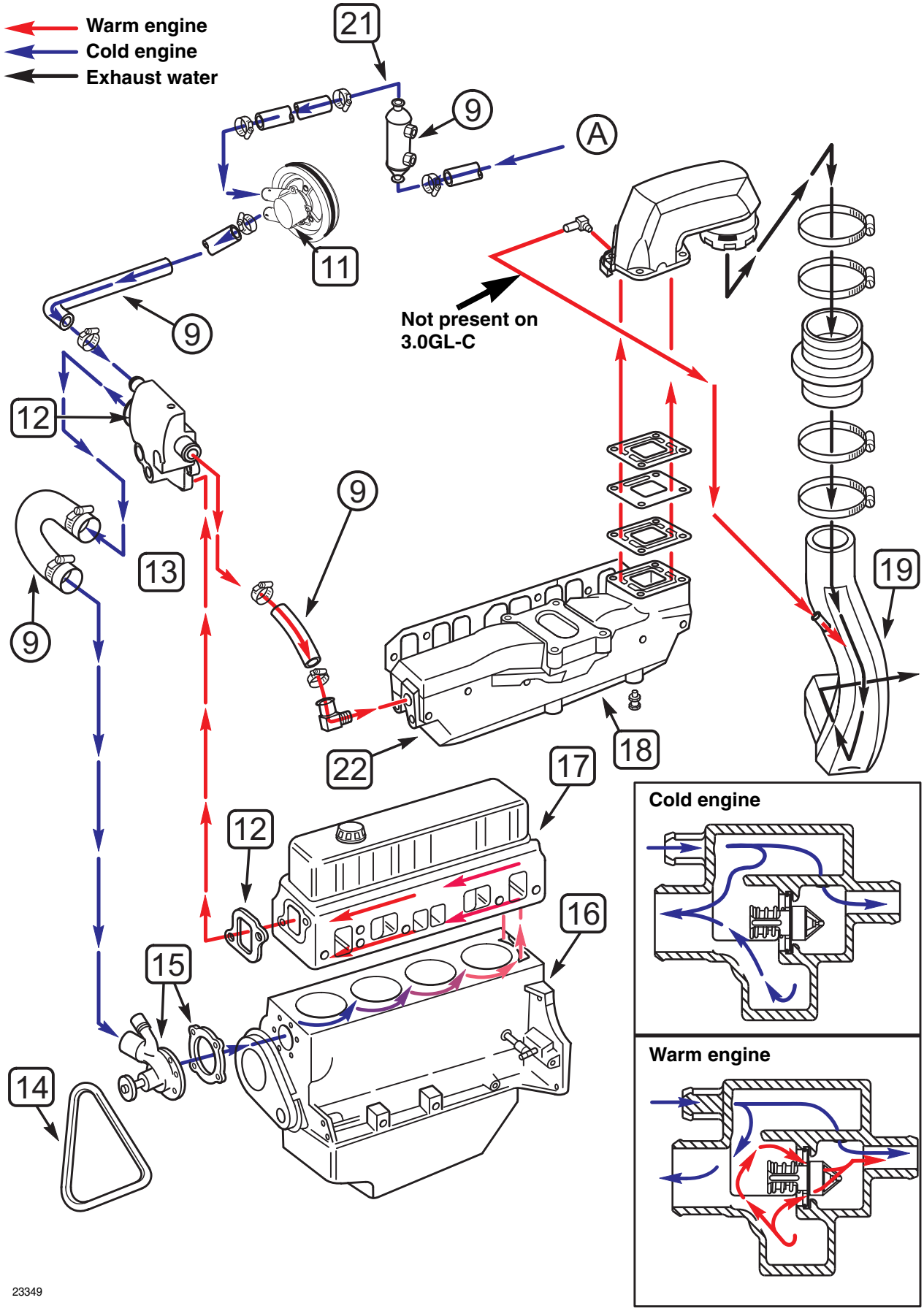
B) To thermostat housing

C) Return from exhaust pipe

D) Exhaust and water out



3.0GS/GL Engine Cooling Diagram



Section 6: Engine Removal and Installation

⚠ **Safety Warnings**

Before working on any part of the engine, read the Safety section at end of this manual.

Proper installation is important for the safe, reliable operation of all mechanical products. The procedures we recommend and describe in these instructions are effective methods to be followed when removing or installing the engine. Some of these methods require the use of tools specially designed for the purpose. The special tools should be used when and as recommended.

Special Tools

Alignment Tool 3851083-0

Universal Handle 3850609-3

Sealants, Lubricants and Adhesives

Volvo Penta Sealing Compound 1141570

Volvo Penta Grease 828250

3M Adhesive

Engine Removal

NOTE! Before removing engine, check engine height. See Determining Minimum Engine Height.

Check engine clearance between front of engine and engine compartment bulkhead prior to starting work. If clearance is less than 6 in. (15,2 cm), the sterndrive must be removed to disengage U-joint shaft from engine coupler. See Sterndrive and Transom Bracket Service Manual.

⚠ **Warning!**

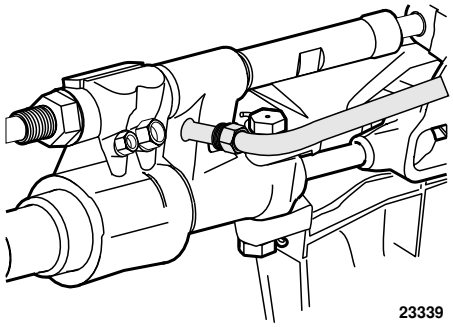
To prevent possible fire and explosion caused by ignition of fuel vapors which may be present in the engine compartment, remove the positive and negative cables from the battery.

Disconnect Battery

⚠ **Caution!**

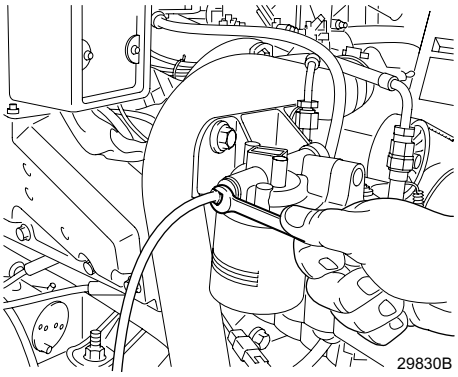
All switches must be in the "OFF" position prior to disconnecting the red (positive) and black (negative) cables from the battery. This will safeguard against permanent damage to electrical components.

Disconnect Power Steering Lines



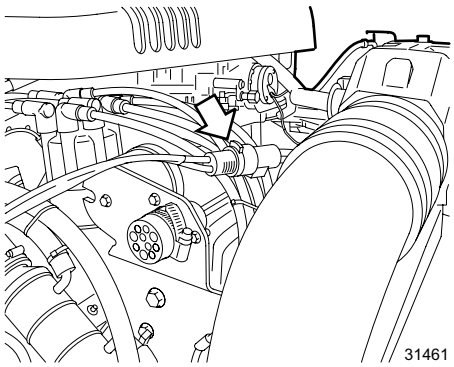
1. Disconnect both power steering lines at the steering cylinder.
2. Cover both steering cylinder openings and line fittings to prevent fluid loss and entry of contaminants. Tie lines onto engine higher than power steering pump to prevent damage and loss of oil during engine removal.

Disconnect Fuel Supply

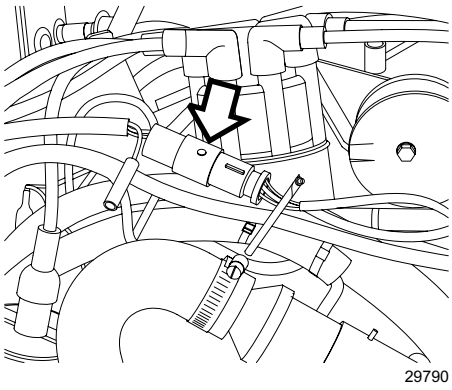


Disconnect boat fuel line at the fuel filter inlet. Seal end of fuel line and inlet opening.

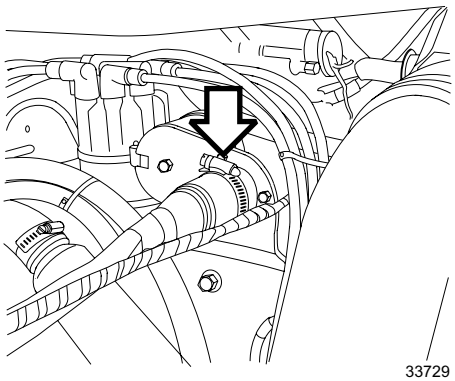
Disconnect Electrical Cables



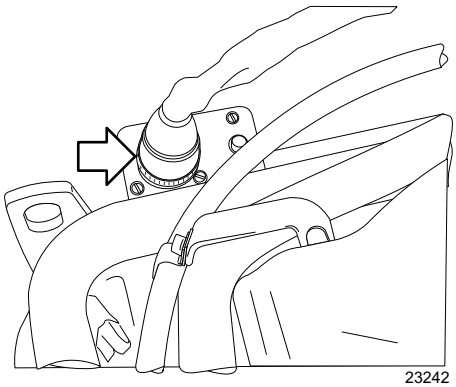
1. Disconnect the plastic two-wire trim/tilt motor connector.

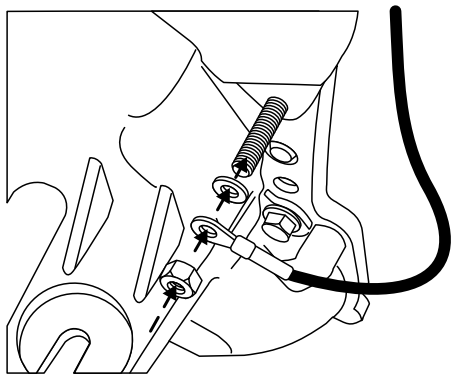


2. Remove wire retainer and unplug rubber two-wire trim/tilt sender connector. Cut tie strap securing sender cable, if required.



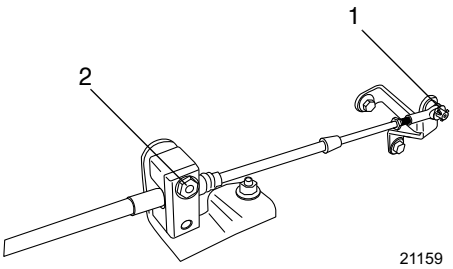
3. Unscrew worm clamp and disconnect large rubber instrument cable connector.





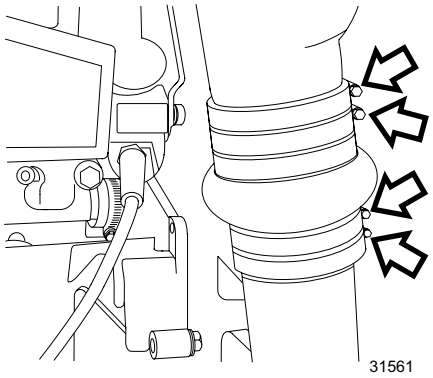
4. Disconnect ground wires to the engine block grounding studs.

Disconnect Throttle Cable



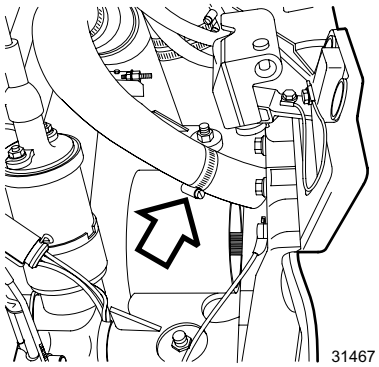
1. Remove cotter pin and flat washer (1) from throttle arm.
2. Loosen anchor retainer nut and rotate retainer away from cable trunnion. Remove throttle cable from throttle arm and anchor bracket.

Disconnect Exhaust Hose



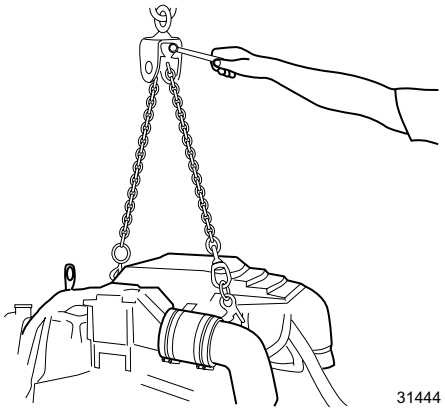
1. Loosen four clamps on lower exhaust hose. For ease of moving lower hose, lubricate exhaust pipe.
2. To free lower hose from intermediate pipe, pry or twist hose. Slide hose down onto exhaust pipe.

Disconnect Water Hose

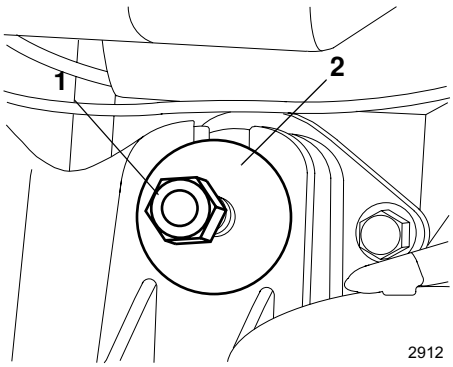


Loosen clamp and pull water supply hose off transom bracket water tube.

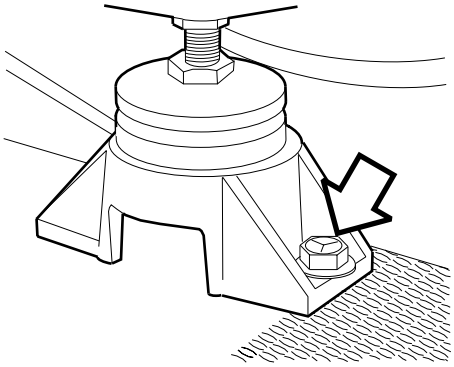
Separate Engine Mounts



1. Attach a hoist to lifting brackets of engine. Hoist must have a lifting capacity of at least 1500 lb. (680 kg).



2. Remove and retain both lock nuts (1) and both flat washers (2) from rear engine mounts.


29797

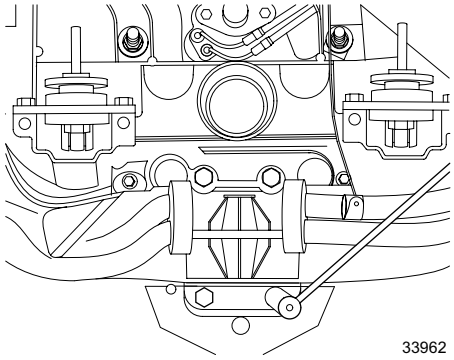
3. Remove and retain lag screws from front engine mounts.

If sterndrive was removed, lift engine out of engine compartment. If sterndrive was not removed, lift engine slightly and pull it forward to disengage U-joint shaft and flywheel coupler. With U-joint shaft clear of flywheel coupler, lift engine out of compartment.

Exhaust Pipe Replacement

Removal

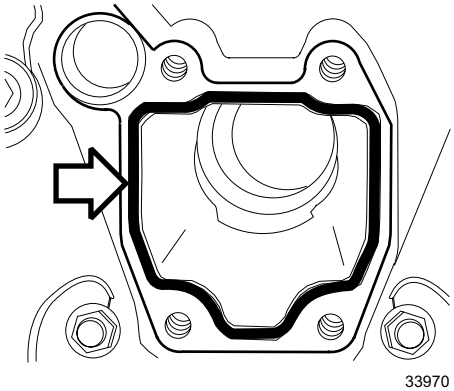
1. Remove engine following previous procedure.


33962

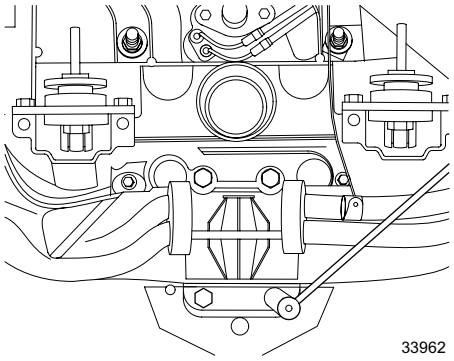
2. Remove and retain four exhaust pipe screws. Remove exhaust pipe and discard seal. Clean all material from transom bracket and exhaust pipe seal surfaces.

Exhaust pipe mounting holes have locking Heli-Coil® inserts. Do not clean screw holes with a thread tapping tool, otherwise locking feature will be destroyed and Heli-Coil will have to be replaced.

Installation


33970

1. Coat a new seal with 3M Scotch Grip Rubber Adhesive 1300 and place in transom bracket groove.
2. Apply Volvo Penta Sealing Compound P/N 1141570 to the four exhaust pipe mounting screws.

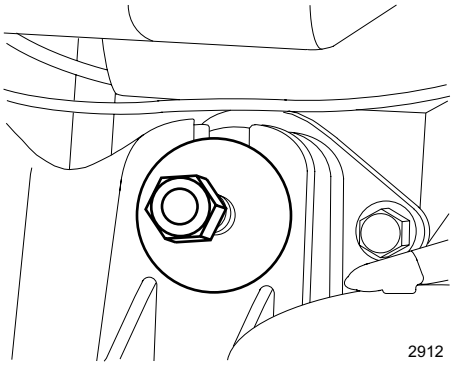

33962

3. Secure exhaust pipe to transom bracket with four screws. Tighten to 20-25 ft. lb. (27-34 N•m). Slide exhaust hoses and clamps onto exhaust pipes if they were removed.
4. Install engine.

Engine Installation

Attach Engine Mount

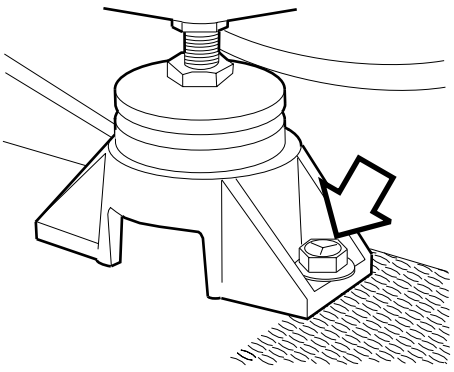
1. Lower engine into engine compartment:
   - If sterndrive was not removed, and engine crankshaft was not rotated, engage U-joint shaft with engine coupler and slide engine back onto rear mounts. If coupler and U-joint shaft will not align, either the engine or U-joint shaft will have to be rotated to allow engagement. If engine mount height was disturbed, engine must be realigned as described later.
   - If sterndrive has been removed, lower engine onto rear mounts.
2. Install flat washers into recesses of engine bracket and secure engine to mount with lock nuts. Tighten lock nuts to 28-30 ft. lb. (38-40 N•m).


2912

⚠ **Caution!**

Do not use an impact wrench or power driving tool to install the lock nuts onto the studs.

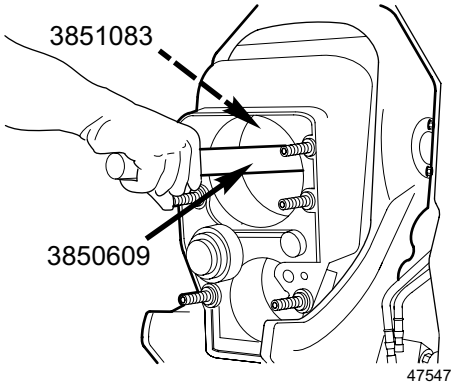
3. Install forward engine mount lag screws and tighten them securely.


29797

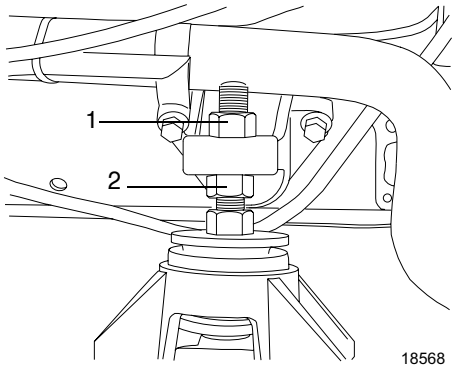
If sterndrive was not removed, go on to Exhaust Hose Attachment. If sterndrive was removed, continue with Engine Alignment section.

Engine Alignment

NOTE! Correct engine alignment is essential to long engine drive-train life. The front engine mounts may need adjustment UP or DOWN to produce correct engine alignment. Use Alignment Tool, Volvo Penta P/N 3851083-0, with Universal Handle, Volvo Penta P/N 3850609-31, to check engine alignment.



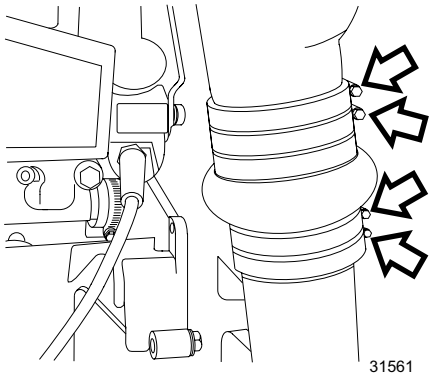
1. Slide alignment tool through driveshaft gimbal bearing. The alignment tool must slide through the gimbal bearing and into engine coupler with ease. If the alignment tool binds going into engine coupler, make sure the gimbal bearing is properly aligned. If gimbal bearing alignment is correct, the front engine mounts must be adjusted either UP or DOWN, as required, until alignment tool slides easily in and out of engine coupler.



2. To change engine height, tighten or loosen nuts (1) and (2) as required. See respective engine section, Front Mount Height Adjustment.
3. After correct alignment has been made, the front mount(s) must be tightened to maintain alignment.
   - While holding one nut with an open-end wrench, tighten the second adjusting nut to 100-120 ft. lb. (136-163 N•m).

Connect Exhaust Hose

Push lower hoses up onto intermediate exhaust pipes.



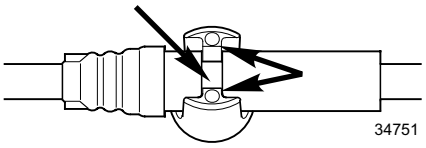
Position and tighten all hose clamps securely between ribs of exhaust hose(s) as shown.

⚠ **Caution!**

DO NOT install hose clamps in expanded area of hose(s). Cooling will be restricted and engine damage will occur.

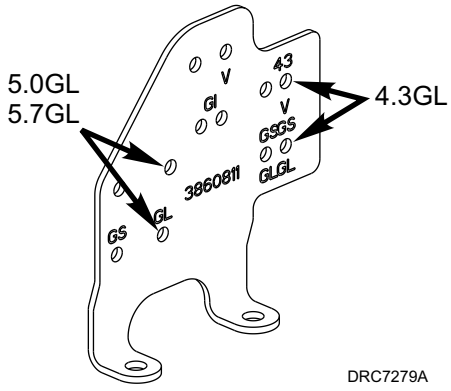
Connect Throttle Cable

NOTE! Position remote control handle in NEUTRAL, propeller should rotate freely. Turn propeller shaft and shift into the forward gear detent position, then pull handle HALFWAY BACK towards NEUTRAL. This positions the control for proper throttle adjustment. Failure to follow this procedure can result in "hard shifting" into gear.

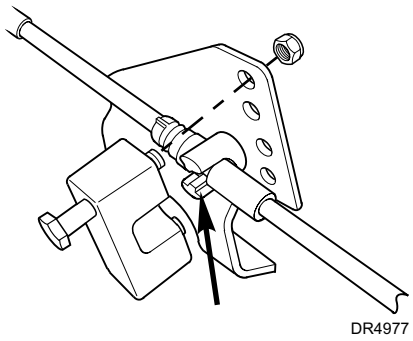


1. Align internal bosses of trunnion with throttle cable groove. Press trunnion on throttle cable until seated.

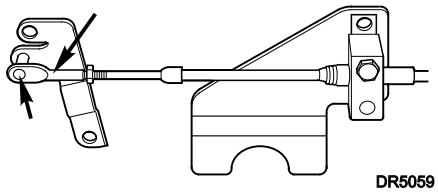
Carbureted Models Only



2. 4.3GL and Models: The engine throttle cable anchor block bracket has several sets of anchor block holes. The sets of holes marked with a "V" are used for Volvo Penta engines. The set of holes marked "43" are for 4.3 GL models. Holes marked GL are for all 5.0 and 5.7 Liter, carburetor models.

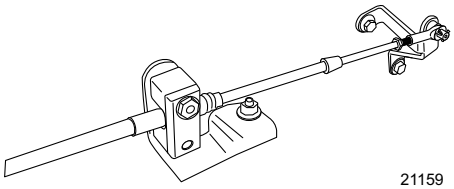


3. Install open end of trunnion in anchor block. Install screw in anchor block and position throttle cable assembly in selected set of holes. Nut must be against the anchor bracket, tighten it securely.



4. Throttle arm connector must have a minimum of 9 full turns or 1/4 in. (6 mm) of throttle cable thread engagement. Install throttle arm connector onto the throttle cable. Pull connector forward to remove all end play from throttle cable, then turn the connector in until hole aligns with the throttle arm stud.

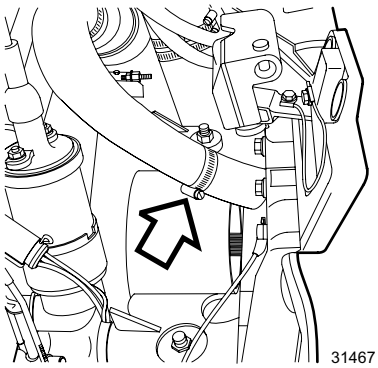
NOTE! If throttle arm connector hole cannot be adjusted to align with the throttle arm, check for proper cable installation in the remote control box.



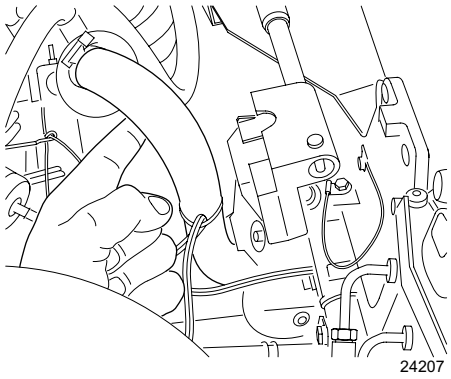
5. Install connector onto throttle arm. Install washer and cotter pin, and spread cotter pin prongs. Tighten jam nut against connector.

For throttle and shift cable adjustment procedures, See “Installation of Shift and Throttle Cables” on page 195.

Connect Water Hose



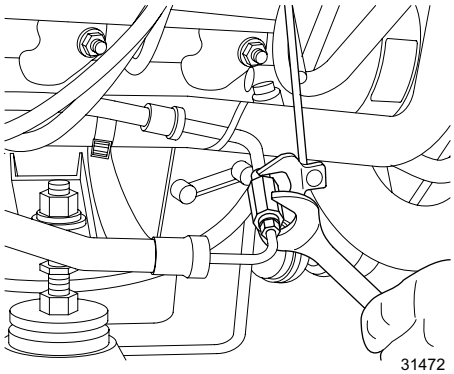
1. Slide hose clamp onto water inlet hose. Lightly lubricate inside of water inlet hose and push hose onto water inlet tube.



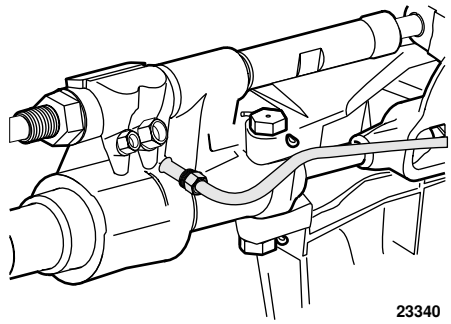
2. If inlet hose is not installed properly, underside of hose may collapse. Check underside of hose for proper installation and adjust hose as required. Tighten hose clamp securely.

NOTE! Failure to install water inlet hose correctly can result in powerhead damage from blockage of water circulation.

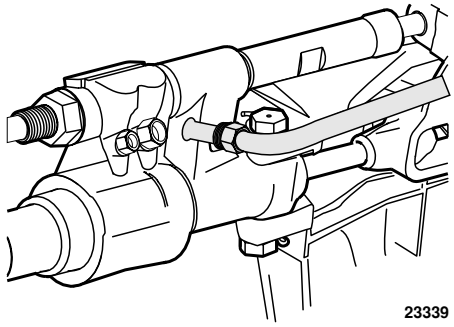
Connect Power Steering Lines



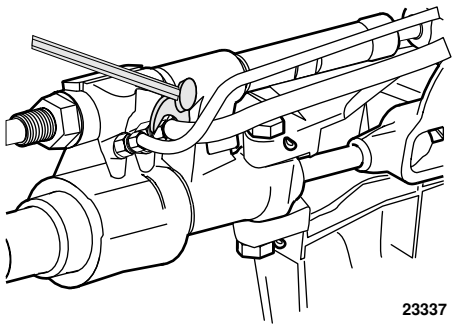
1. Remove tape or protective cover from small hydraulic hose fitting (or unscrew steering line connector) and small steering cylinder opening.



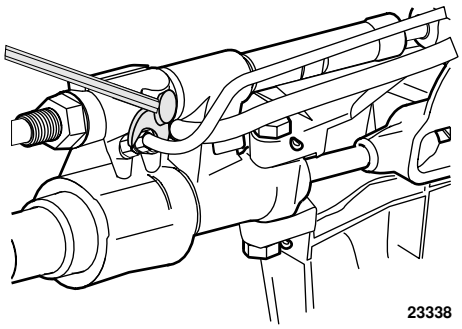
2. Install small hose fitting into steering cylinder.



3. Install large hose fitting into steering cylinder.

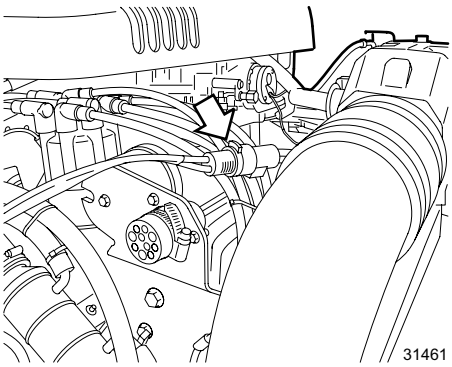


4. Tighten small hose fitting to 10-12 ft. lb. (14-16 N•m).

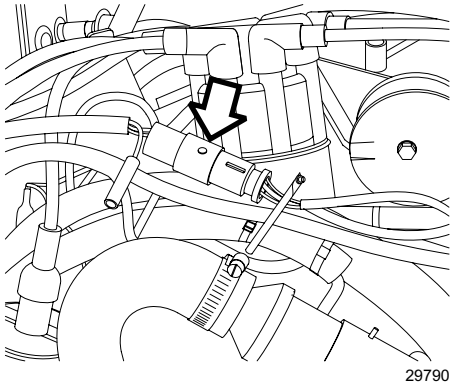


5. Tighten large hose fitting to 15-17 ft.lb. (20-23 N•m).

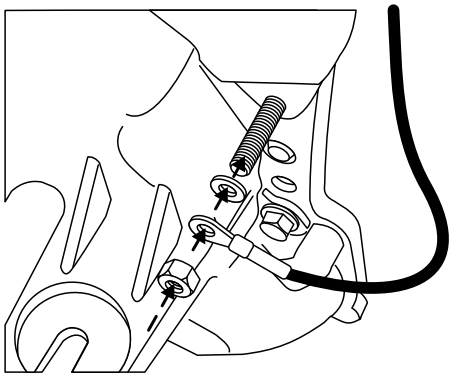
Connect Electrical Cables



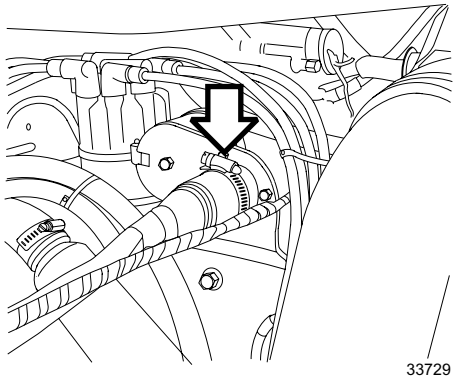
6. Connect plastic two-wire plug of engine harness to two-wire receptacle of trim/tilt motor. Connectors should lock together. Route trim/tilt cable behind shift bracket.

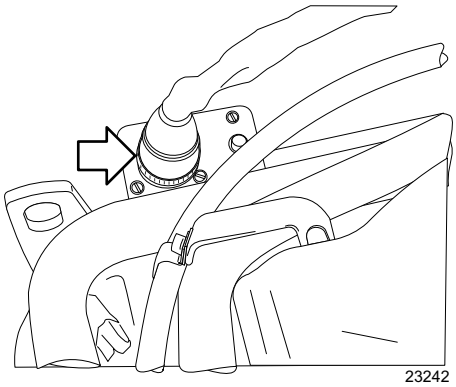


7. Connect rubber two-wire trim/tilt sender plug to two-wire receptacle of instrument harness. Secure connectors with wire retainer and cable with a tie strap.



8. Connect ground wires from boat battery, and transom sheld to the engine grounding stud.





9. Route the instrument cable plug to join engine cable receptacle on engine.

⚠ **Warning!**

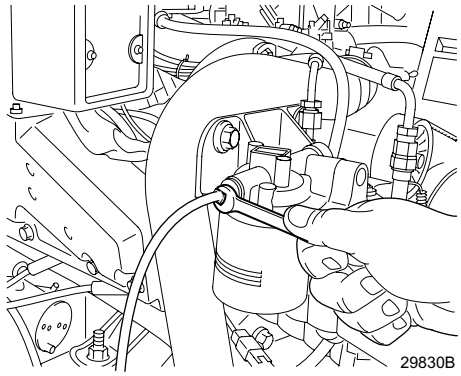
Ensure cable is routed to prevent cutting or chafing on any sharp or hot object. This could result in an electrical short, and contribute to fire and explosion in the engine compartment.

10. Apply a light coat of Volvo Penta Grease grease around large engine plug.
11. Slide hose clamp over large engine receptacle. Align the two large terminals on plug and receptacle and press together. Slide hose clamp over receptacle and tighten securely.
12. **All switches must be in the "OFF" position prior to connecting battery cables to the battery.** Be sure polarity is observed; positive (+) cable to the positive terminal, and negative (-) cable to the negative terminal.

⚠ **Warning!**

Route all hoses and wires at least 1" (25 mm) away from the exhaust pipe or exhaust elbows. Under no circumstances should these items be allowed to come into contact with the exhaust pipe or exhaust elbows.

Connect Fuel Supply

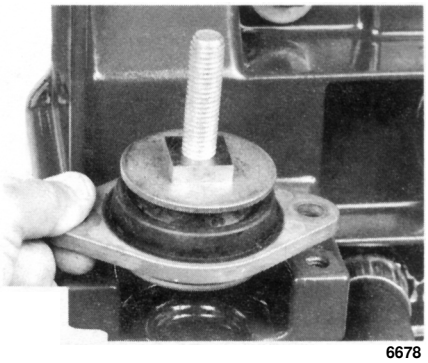


13. Attach boat's fuel supply hose to fuel filter canister. On EFI models connect to the Fuel Cell. Tighten connection securely. Check for fuel leaks when testing engine, and repair any leaks that might occur.

Rear Engine Mounts

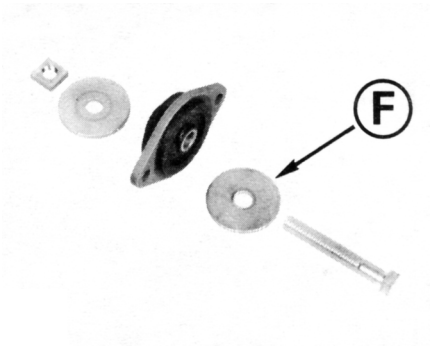
Removal

1. Remove engine See "Engine Removal" on page 139.


6678

2. Unscrew two screws and washers, then lift mount assembly off transom plate.

Disassembly



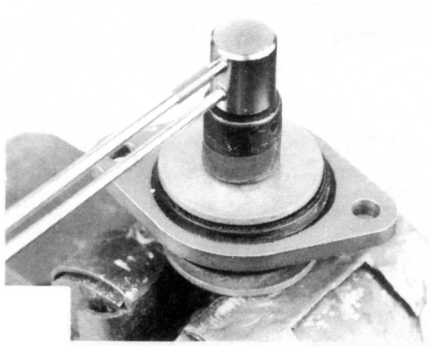
16348

1. Hold square nut and remove screw. Mount assembly will break down into components shown. Pay particular attention to the two mount washers; their thickness, shape (concave or flat), and position in the assembly (above or below the rubber mount).

Assembly

1. Slide lower washer onto mount bolt; make sure you choose the correct washer (as determined during the mount disassembly) for this position. Insert bolt into bottom (flat) side of rubber mount assembly, and install remaining washer and square nut. Do not tighten nut at this time.

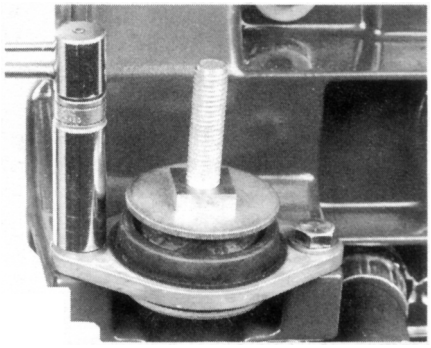
NOTE! If top and bottom washers are not installed in their original positions, mount may transmit excessive engine vibrations into boat and cause undesirable operating conditions.


6680

2. Turn mount assembly upside down and clamp square nut in vise. Rotate rubber mount until mounting holes are positioned at 90° to any side of square nut. Hold mount in this position and tighten center bolt to 44-52 ft. lb. (60-71 N•m).

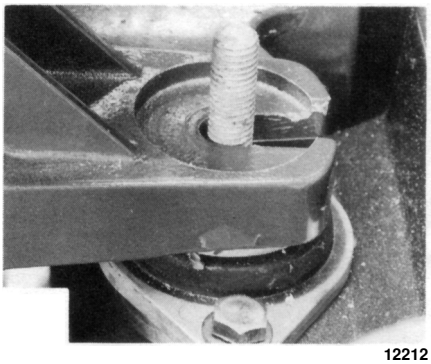
NOTE! If 90° relationship between nut and mounting holes is not maintained, slot of engine mount pad cannot engage rear mount during installation.

Installation



6677

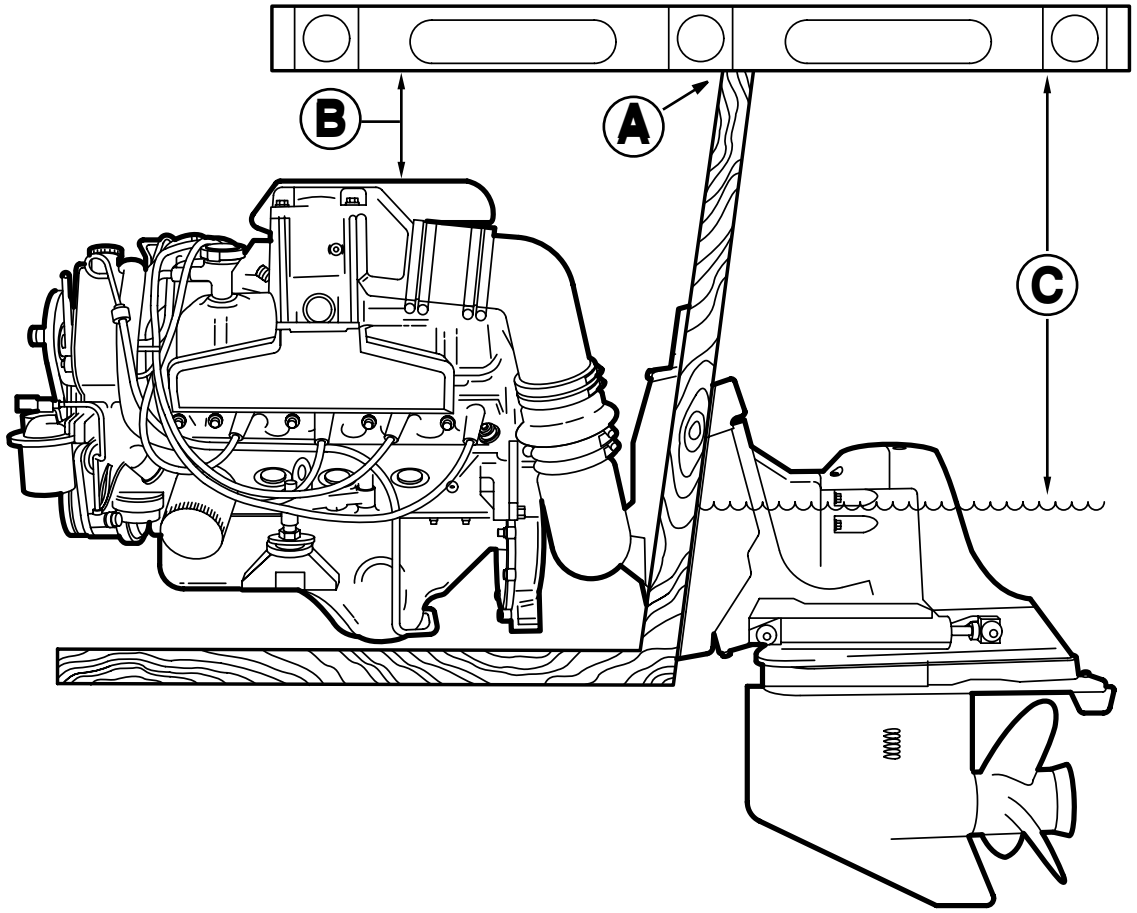
1. Place mount assembly on transom plate. Install two screws and washers, and tighten them to 20-25 ft. lb. (27-34 N•m).



12212

2. Install engine See “Engine Installation” on page 145. Make sure mount pad slot engages square nut. Install both flat washers and locknuts, then tighten locknuts to 28-30 ft. lb. (38-41 N•m).

Determining Minimum Engine Height



1. To determine minimum engine height, use a level (A) placed on top of the transom, measure from bottom of level to top of elbow (B) and record distance.
2. Measure from bottom of level to static water line (C) and record distance.
3. Subtract dimension (B) from dimension (C) and record result. See engine height requirements below:
   - Measurement (B) minus (C) should not be less than 14 in. (35.6 cm).
4. When engine installations do not meet these specifications, an exhaust elbow high-rise kit must be installed.

NOTE! An installation that permits water to enter the engine through the exhaust manifolds) will not be covered by warranty, unless damage is due to defective part(s).

Safety Section

Part A

Part B

Part A - Marine Products and safety of People Who Use Them

Enjoyable boating is the goal of people who design and build marine products. To reach this goal, manufacturers are careful to make sure...

- Product User is informed. . .
- Products are safe and reliable. . .

It's up to you, the People who. . .

- Install accessories. . .
- Service and Maintain the boat. . .
- Service and maintain the sterndrive. . .

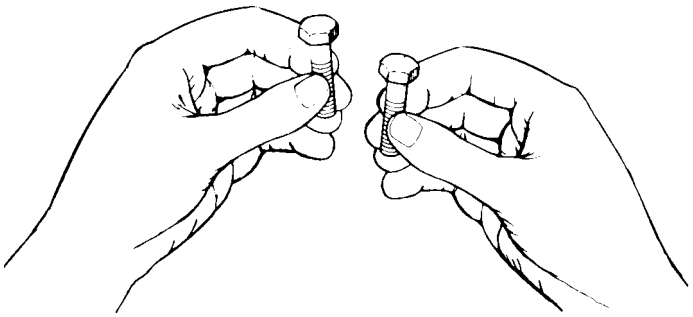
. . . to keep the products safe and reliable.

This section talks about safe boating and how you can help keep it safe. Some things you may know . . . but others you may not.

First!

A word about fasteners . . . plain . . . special . . . all screws, nuts, washers and bolts.

Do Not Substitute Fasteners



They look the same, but . . . are they?

The Same Size?
The Same Strength?
The Same Material?
The Same Type?
Standard or Metric Thread?

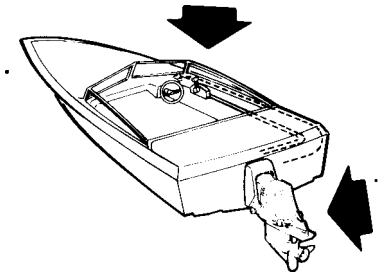
Don't substitute unless you know they are the same in all characteristics.

Second!

- Special locking screws and nuts are often used to attach steering, and remote control components to the sterndrive.
- When you remove any part from the sterndrive, keep track of special screws and nuts. Don't mix with other parts
- When reassembling the sterndrive, use only the special screws and nuts intended to hold steering, and control cables, plus related parts.
- Service with parts of known quality that meet Marine Industry (BIA/ABYC) Standard.

Sterndrive Shift System

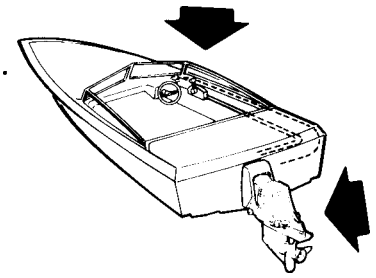
The Shift System starts
here at the remote control lever. . .



. . . and ends here at the propeller.

What's Most Important?

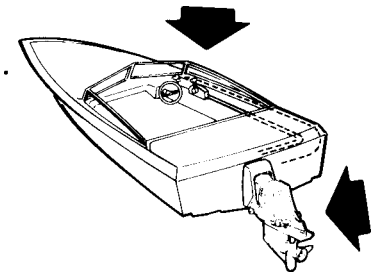
When the control lever is in Forward,
Neutral or Reverse position . .



. . . Shift mechanism must match
control lever position.

What Could Happen?

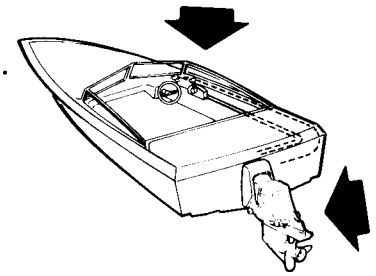
- **If . . . Neutral**



Forward or Reverse

. . . Propeller is still powered (turning) unknown to operator, or engine will start in gear, boat will move unexpectedly.

- **If . . . Forward**



Reverse

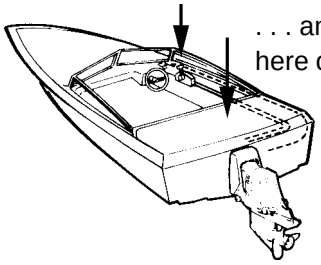
. . . boat will move opposite to direction intended by operator.

How Can Loss of Shift Control be Minimized? In pre-delivery inspection and when servicing . . .

- Read, understand and follow manufacturers instructions.
- Closely follow the warnings marked with ⚠ . . .
- Assemble parts and make adjustments carefully . . .
- Test your work. Don't guess. Make sure propeller does what the operator wants and nothing else.

Sterndrive Throttle Control System

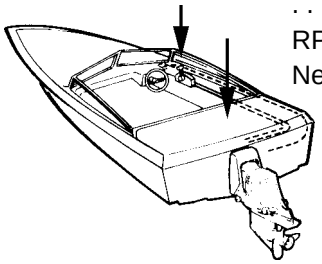
The throttle Control System starts here and the remote control lever . . .



. . . and ends here on the engine.

What's Most Important?

When the control lever is moved from Forward (or Reverse) to Neutral . . .



. . . engine speed must slow to idle RPM and allow operator to shift into Neutral.

Operator must be able to stop propeller.

What Could Happen?

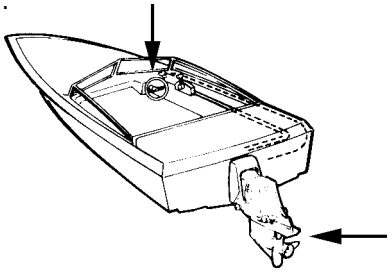
If operator cannot slow the engine to idle RPM and shift into neutral, (stop propeller), operator could panic and lose control of boat.

How Can Loss of Throttle Control be Minimized? In pre-delivery inspection and when servicing . . .

- Read, understand, and follow manufacturers instructions.
- Closely follow the warnings marked with ⚠ . . .
- Assemble parts and make adjustments carefully . . .
- Test your work. Don't guess. Make sure engine throttle response is smooth.
- Make sure full throttle operating RPM can be reached so operator won't overload engine

Sterndrive Steering System

The Steering System starts here at the helm . . .



. . . and ends here at the propeller on the sterndrive

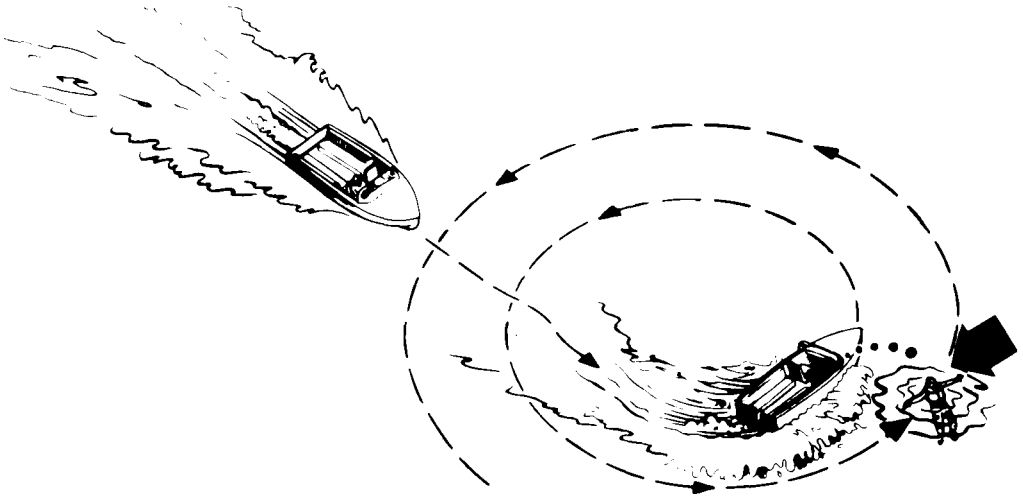
What's Most Important?

The Steering System . . .

- must be installed properly
- must be adjusted properly
- must be lubricated

What Could Happen?

- . . . if steering system comes apart, boat would turn suddenly and circle . . . passengers and/or operator may be thrown into water and could be hit.



- . . . if steering jams, operator may not be able to avoid obstacles. Operator could panic.
- . . . if steering is loose, operator may not be able to maintain a true course, and could result in loss of boat control.

How Can Loss of Steering Control be Minimized?

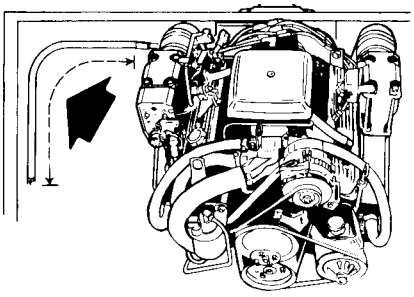
In pre-delivery inspection and when servicing

- use steering components which meet marine industry (BIA/ABYC) standards . . .
- Read, understand, and follow manufacturer's instructions.
- Assemble parts and make adjustments carefully . . .
- Closely follow the warnings marked with ⚠ . . .
- Keep parts moving freely . . . lubricate parts as soon as shown in manuals
- Use bolts, nuts, and washers supplied with steering attachment kits

When power assisted or mechanical steering systems are used, check to uncover possible trouble!

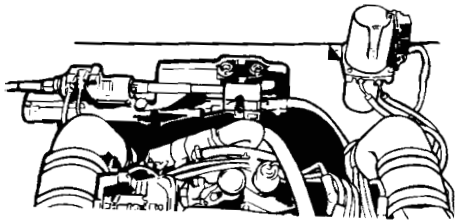
- Cable housing in this area must not be restricted

Why? Unit may go to full turn without turning steering wheel (Power assist models)

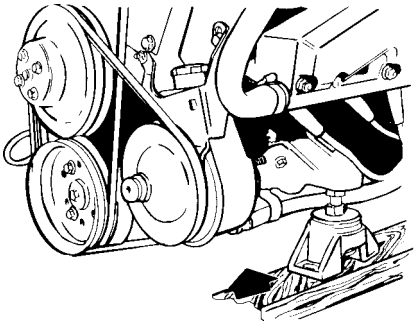


- Steering components must not bind

Why? Possible jamming of steering system.



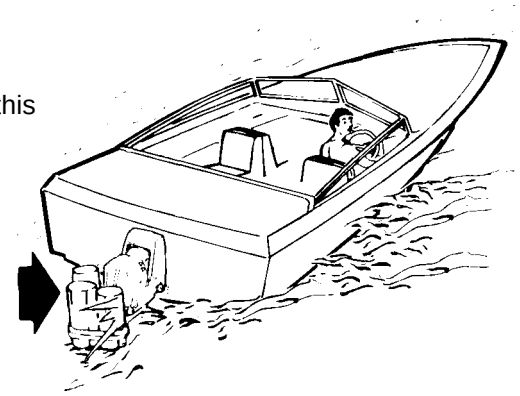
Power steering parts and push/pull cable must be free to move in order to actuate power steering valve when operator turns steering wheel

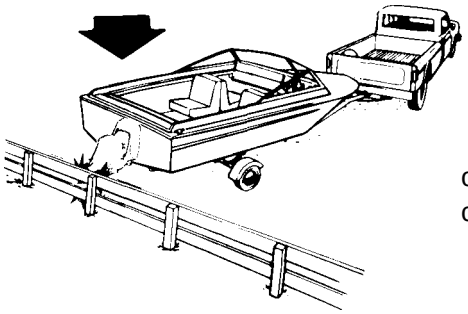


Engine stringer must not interfere with power steering pump and pulley

Maintain proper belt tension.

- Check for damaged parts . . . impacts to the sterndrive like this





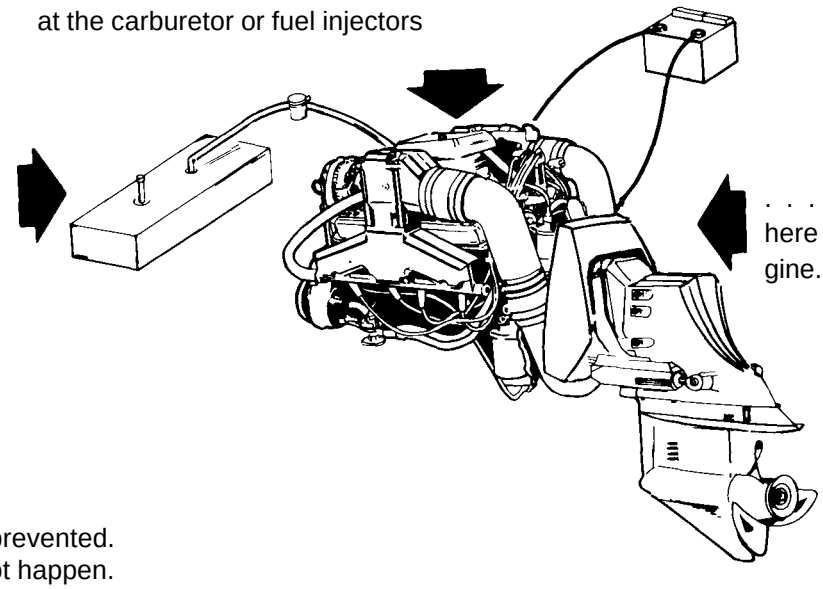
or this . . . or ? ? ?
can put stress on steering components. Look for . . .

- Cracked parts
- Bent parts
- Loose fasteners

Replace damaged parts. If weakened, parts could fail later . . . on the water . . . when least expected.

The electrical System begins here at the battery . . .

. . . and ends here at the carburetor or fuel injectors



The fuel system starts here at the fuel tank . . .

. . . and ends here on the engine.

What's Important?

- Fuel leakage must be prevented.
- Electric sparks must not happen.

What Could Happen?

Gasoline can explode and/ or burn easily:

- When boating, fuel leaking in the engine compartment could be ignited by a spark from a loose wire connection, or a damaged or deteriorated electrical component.

How Can Fire and Explosion Be Minimized?

- Read, understand and follow manufacturers instructions.
- Closely follow the warnings marked with ⚠ . . .
- Do not substitute fuel or electrical parts with other parts which may look the same. These parts are designed and manufactured to meet special U. S. Coast Guard safety regulations to prevent fire and explosion.

If you work on marine engines, you must understand these U.S. Coast Guard requirements. If you don't have them, write to . . .

- - - - - - - - -
- - - - - - - - -
- - - - - - - - -

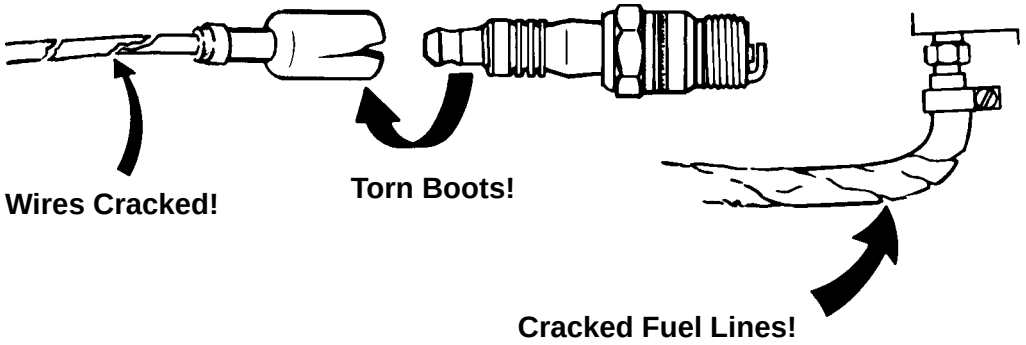
National Technical Information Service
Springfield, Virginia 22161

. . . and ask for copies of:

(1) Electrical System Compliance Guideline (AD/A-049-638)
(2) Fuel System Compliance Guideline (AD/A-047-767)
These are concise guidelines - easy to read and understand. They explain what must be done to prevent fire and explosions.

- Always use replacement parts specified by the manufacturer. They meet the U.S. Coast Guard requirements. Most automotive parts do not, especially electrical components that must meet ignition protection requirements of the U.S. Coast Guard regulations.

- When nonmetallic parts look to be in poor shape . . . replace them!

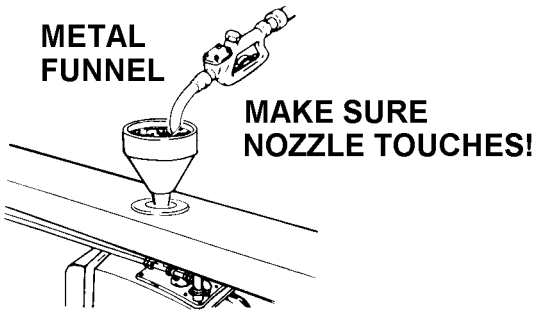


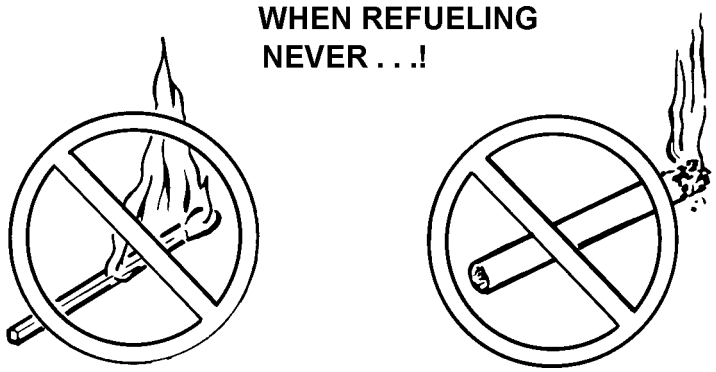
Using parts which meet U.S. Coast guard requirements is only half the job. The other half is your job . . .

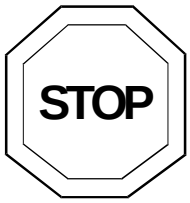
It's time for replacement BEFORE sparks and/or fuel leaks occur.

- Replace parts carefully. Make sure nuts and bolts are tight especially when they anchor electrical wires (to prevent sparking). If lock washers are specified - use them. No short cuts or missing parts with either of these CRITICAL safety related systems.

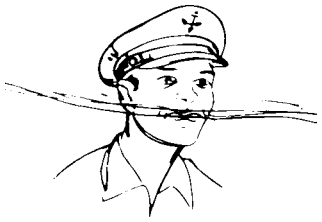
- When refueling, always ground fuel nozzle to the inlet fitting on the boat to prevent the buildup of electrostatic sparks. If you use a funnel, make sure it's metal and ground the fuel nozzle to the funnel.







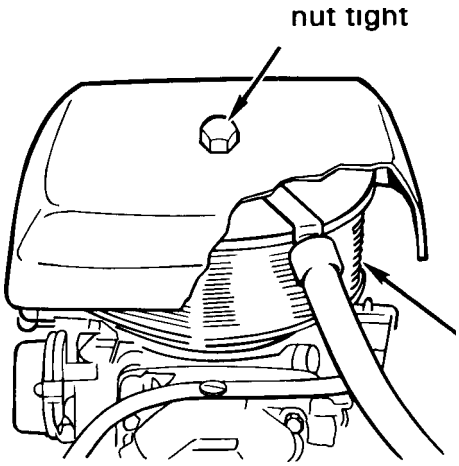
- If you smell gasoline in the engine compartment . . . find its source and stop the leakage.



- Follow "Starting Procedure" outlined in the operator's manual.

  Always make sure there are no gasoline fumes in the engine compartment before starting the engine. Open the compartment and use your nose. Don't gamble.

- **Backfire flame arrestor** must be in place and securely attached to the air intake.



Do not alter the backfire flame arrestor.

If loose, damaged, or altered, an engine "backfire" may pass through the flame arrestor assembly into the engine compartment. If fumes are present in compartment, fire and explosion could result.

Summing Up

Now you know some things that can take the joy out of enjoyable boating.

No doubt about it . . . it takes time!

- Reading and understanding instructions.
- Reading and understanding warnings marked with  . . .
- Putting parts together correctly . . .
- Making correct adjustments . . .
- Testing you work.

and making sure

- Worn or damaged parts are replaced,
- Replaced parts are like originals . . . in every way.
- Customer is told of things which need attention . . .

But do you really want the alternative?

Part B - Marine Products and Safety of People* Who Fix Them

Part A talked about safe boating and how you, the mechanic, can help keep it safe for the boater. But what about you? Mechanics can be hurt while . . .

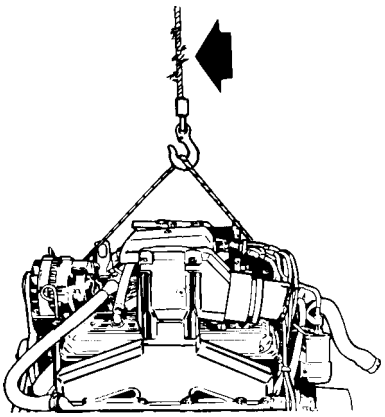
- Servicing boats
- Servicing sterndrives
- Troubleshooting problems
- Testing their work

Some items you'll know . . . others you may not.

When Lifting Engines

If hoist is poor shape . . . or too small for the job

- Engine may drop suddenly



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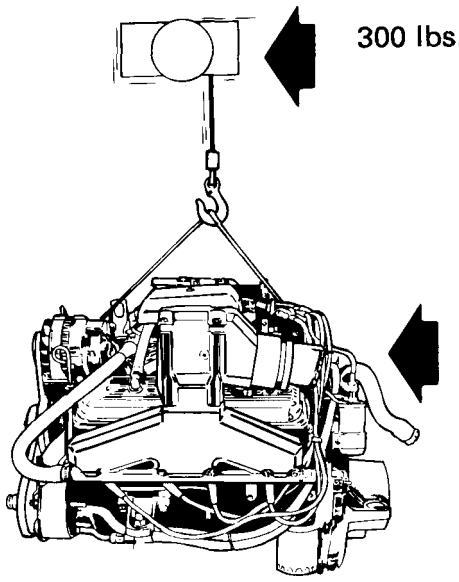


DR3469

- Make sure shop aids have extra capacity — and keep them in good repair!

When Running Engine with Engine Compartment Cover Removed

The engine compartment cover is a guard. When you remove the cover / guard to work on the engine, remember:

- Loose clothing (open shirt sleeves, neckties), long hair, jewelry (rings, watches, bracelets), hands, arms, belts can be caught by moving belts or spinning pulleys
- Handle high voltage ignition components carefully. They can shock you and may cause you to recoil into moving parts.

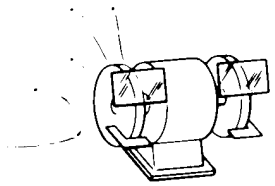
Two people working together on a running engine must look out for each other. Never, ever, hit the key to start the engine before signalling to your partner. (He may be leaning over the engine with his hands on a belt, or a "hot" electrical part, near the propeller, etc.)

*Mechanics, technicians, backyard do-it-yourselfers.

- Exhaust gasses of running engines contain carbon monoxide. . . you can't see it. . . you can't smell it. . . you can't taste it. . . but it's there whenever an engine runs. . . and it's deadly!

When you smell the other gasses in the exhaust, you are inhaling carbon monoxide. Run engines only in well ventilated areas.

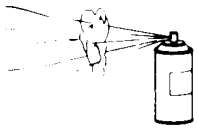
Eyes Need help



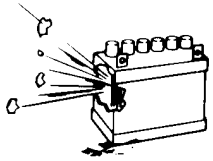
- Grinding

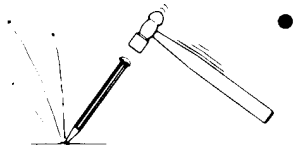
- End of Cables

- Sprayed Cleaners, Paints



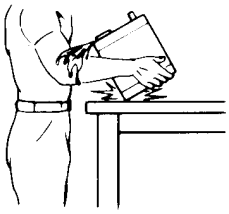
- Acid



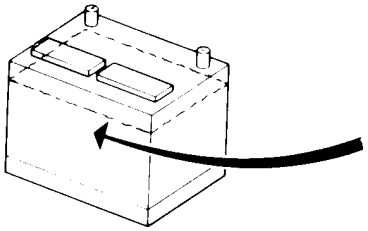


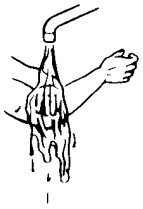
- Chiseling
  (steel on steel)
  (Tip: Use plastic or brass type hammers.
  They don't chip off as easily as steel hammers.)

Handling Lead Acid Batteries

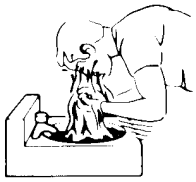


- If spilled or splashed on any part of body..





Wash with lots of water. . .



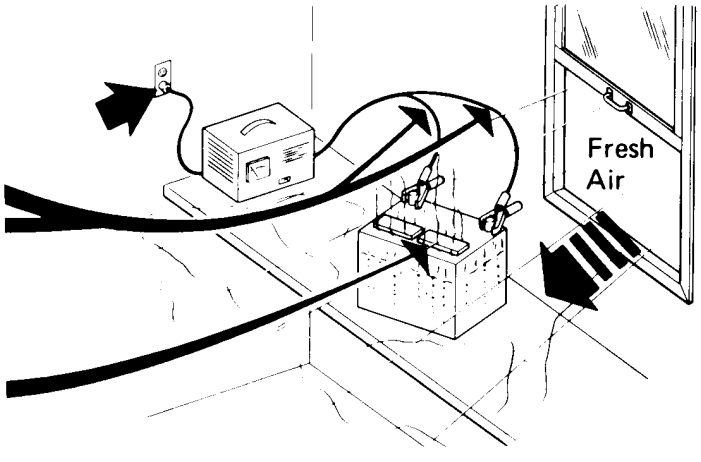
- If solution gets into eyes. . .
  Wash. . . and see a Doctor, fast!

Charging Lead Acid Batteries

1 Attach and remove these cables with charger unplugged from 110 volt wall socket. (Prevents shocks if the charger is defective.)

2 Observe correct polarity when connecting these charger leads.

3 Always charge in a well ventilated area. Charging causes acid solution to give off hydrogen gas through the vents in the caps. . . Make sure vents are open. If clogged, pressure inside may build. . . battery may explode.



Battery gas is explosive!
While charging or discharging, remember. . .

No Smoking
No Flames
No Sparks

Never yank cables off battery posts. . . it's a sure way to make lots of sparks. . .surrounded by battery gas

Don't check battery condition by placing metal objects across posts.

You're sure to make sparks and serious burns are possible.

After Charging. . .

- Shut off charger
- Remove charger plug from wall socket

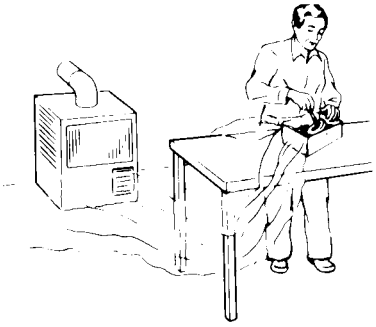
Then. . .

- Take charger cable off battery posts

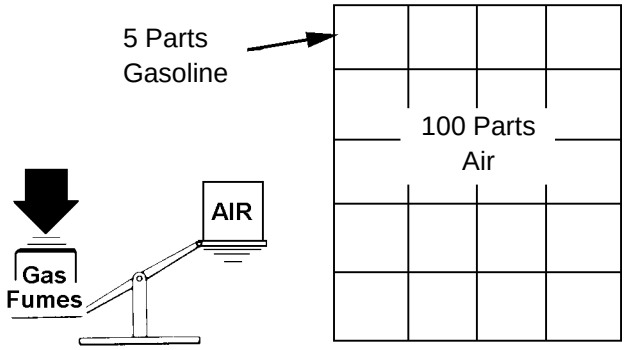
Gasoline! Handle With Care

- When you smell any odor of gasoline, explosion is possible
- Gasoline fumes are heavier than air and will sink to the lowest point in the boat or room, and will stay there. . . waiting

- If the air around you is quiet . . . the pilot light in the heater may ignite the heavy fumes before your nose ever smells the fumes . .



Gasoline explodes easily and violently when mixed with air



What Can you Do?

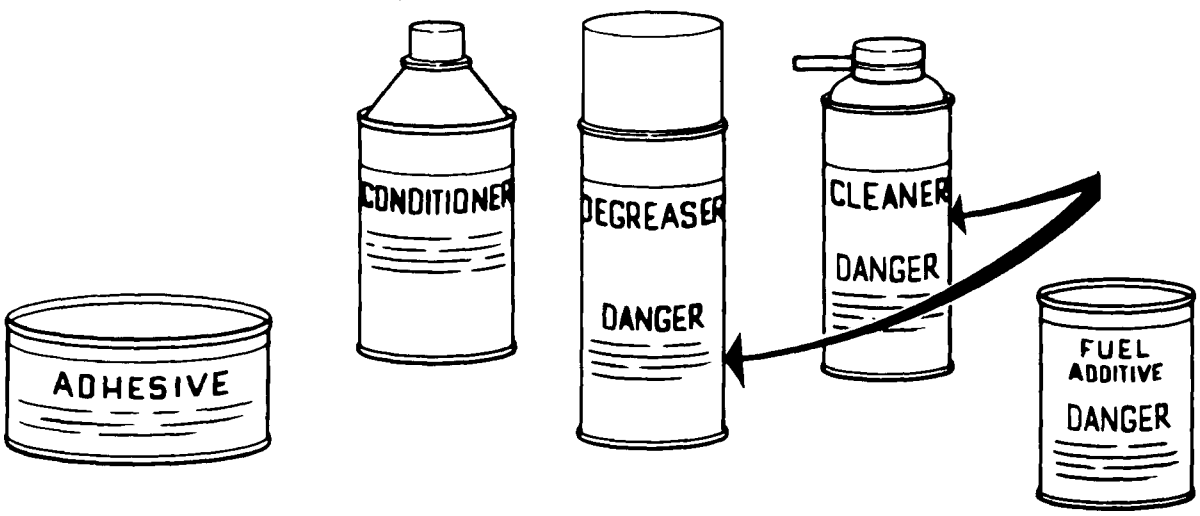
- Store properly . . .
- Fill portable tanks outside boat to prevent spillage in boat
- Use fuel for fuel . . . not for a solvent
- If fumes are smelled (in shop, basement, garage), immediately:
  - Put out open flames, cigarettes, sparking devices
  - Wipe up spill or leak; get towels, rags outside fast
  - Check lowest area for fumes; open doors or windows

Store in sturdy, sealed gas can . . .and . . . keep outside

- Know items in and around repair area which can ignite gasoline fumes . . . Control them if fumes are smelled.
    - Matches, cigarettes, torches, welders
    - Electric motors (with unsealed cases)
    - Electric generators (with unsealed cases)
    - Light switches
    - Appliance pilot lights (furnace, dryer, water heater)
    - ?????????

How many of these are in your area?

Hazardous Products



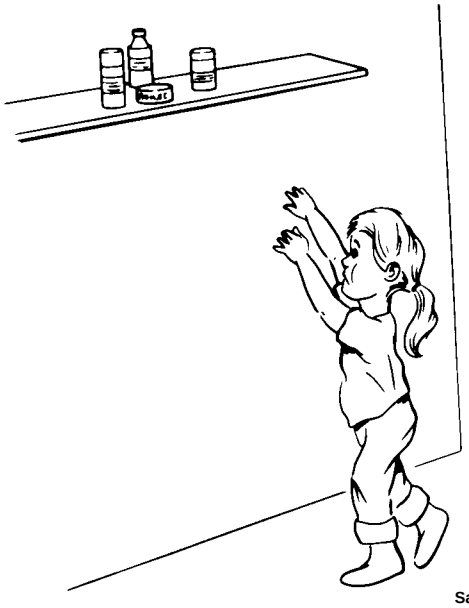
Read the container label. It tells you . . .

- "How, and where, to use,"
- "How to give First Aid," and have "recommended" first aid materials on hand- should an emergency arise
- "How to dispose of can,"

Remember: Little children are very curious and will try to taste everything, so . . .

. . . yummmmmmmmmm

Keep containers away from children



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