Models Covered

Sterndrive

Models Covered	Serial Number
QSD 2.8 Sterndrive 170 HP	88300400 - 88304999
QSD 2.8 Sterndrive 200 HP	88305400 - 88309999
QSD 2.8 Sterndrive 230 HP	88310400 - 88314999
QSD 4.2 Sterndrive 270 HP	88401000 - 88404999
QSD 4.2 Sterndrive 320 HP	88406000 - 88415999
QSD 4.2 Sterndrive 350 HP	88417000 - 88419999

Inboard

Models Covered	Serial Number
QSD 2.8 Inboard 170 HP	88300000 - 88300399
QSD 2.8 Inboard 200 HP	88305000 - 88305399
QSD 2.8 Inboard 230 HP	88310000 - 88310399
QSD 4.2 Inboard 270 HP	88400000 - 88400999
QSD 4.2 Inboard 320 HP	88405000 - 88405999
QSD 4.2 Inboard 350 HP	88416000 - 88416999

Notice To Users Of This Manual

Throughout this publication, dangers, warnings, cautions, and notices, (accompanied by the International HAZARD Symbol ⚠) are used to alert the mechanic to special instructions concerning a particular service or operation that may be hazardous if performed incorrectly or carelessly. These safety alerts follow ANSI standard Z535.6-2006 for product safety information in product manuals, instructions, and other collateral materials. **OBSERVE THEM CAREFULLY!**

These safety alerts alone cannot eliminate the hazards that they signal. Strict compliance to these special instructions when performing the service, plus common sense operation, are major accident prevention measures.

⚠ DANGER
Indicates a hazardous situation which, if not avoided, will result in death or serious injury.

⚠ WARNING
Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION
Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE
Indicates a situation which, if not avoided, could result in engine or major component failure.

IMPORTANT: Identifies information essential to the successful completion of the task.

NOTE: Indicates information that helps in the understanding of a particular step or action.

This manual has been written and published by the Service Department of Cummins MerCruiser Diesel to aid our dealers' mechanics and company service personnel when servicing the products described herein. We reserve the right to make changes to this manual without prior notification.

Mercury, Mercury Marine, MerCruiser, Mercury MerCruiser, Mercury Racing, Mercury Precision Parts, Mercury Propellers, Mariner, Quicksilver, #1 On The Water, Alpha, Bravo, Pro Max, OptiMax, Sport-Jet, K-Planes, MerCathode, RideGuide, SmartCraft, Zero Effort, M with Waves logo, Mercury with Waves logo, and SmartCraft logo are all registered trademarks of Brunswick Corporation. Mercury Product Protection logo is a registered service mark of Brunswick Corporation.

It is assumed that these personnel are familiar with marine product servicing procedures. Furthermore, it is assumed that they have been trained in the recommended service procedures of Cummins MerCruiser Diesel Power Products, including the use of mechanics' common hand tools and the special Cummins MerCruiser Diesel or recommended tools from other suppliers.

We could not possibly know of and advise the marine trade of all conceivable procedures and of the possible hazards and/or results of each method. Therefore, anyone who uses a service procedure and/or tool, which is not recommended by the manufacturer, first must completely satisfy himself that neither his nor the products safety will be endangered.

All information, illustrations and specifications contained in this manual are based on the latest product information available at the time of publication. As required, revisions to this manual will be sent to all dealers contracted by us to sell and/or service these products.

Refer to dealer service bulletins, operation maintenance and warranty manuals and installation manuals for other pertinent information concerning the products described in this manual.

Work Precautions

It should be kept in mind, while working on the product, that the electrical systems are capable of violent and damaging short circuits or severe electrical shocks. When performing any work where electrical terminals could possibly be grounded or touched by the mechanic, the battery cables should be disconnected at the battery.

Any time the intake or exhaust openings are exposed during service they should be covered to protect against accidental entrance of foreign material which could enter the cylinders and cause extensive internal damage when the engine is started.

It is important to note, during any maintenance procedure replacement fasteners must have the same measurements and strength as those removed. Numbers on the heads of the metric bolts and on the surfaces of metric nuts indicate their strength. American bolts use radial lines for this purpose, while most American nuts do not have strength markings. Mismatched or incorrect fasteners can result in damage or malfunction, or possibly personal injury. Therefore, fasteners removed should be saved for reuse in the same locations whenever possible. Where the fasteners are not satisfactory for reuse, care should be taken to select a replacement that matches the original.

Personnel should not work on or under an engine that is suspended. Engines should be attached to work stands, or lowered to ground as soon as possible.

Replacement Parts

Use of parts other than the recommended service replacement parts, will void the warranty on those parts that are damaged as a result.

⚠ WARNING

Avoid fire or explosion hazard. Electrical, ignition, and fuel system components on Mercury Marine products comply with federal and international standards to minimize risk of fire or explosion. Do not use replacement electrical or fuel system components that do not comply with these standards. When servicing the electrical and fuel systems, properly install and tighten all components.

Cleanliness And Care Of Product

A Cummins MerCruiser Diesel Power Product is a combination of many machined, honed, polished and lapped surfaces with tolerances that are measured in the thousands of a mm/in. When any product component is serviced, care and cleanliness are important. Throughout this manual, it should be understood that proper cleaning and protection of machined surfaces and friction areas is a part of the repair procedure. This is considered standard shop practice even if not specifically stated.

Whenever components are removed for service, they should be retained in order. At the time of installation, they should be installed in the same locations and with the same mating surfaces as when removed.

Manual Outline

Important Information

Section 1A - General Information

Table of Contents

Introduction

This comprehensive overhaul and repair manual is designed as a service guide for the MerCruiser and Cummins MerCruiser Diesel models listed earlier. It provides specific information, including procedures for disassembly, inspection, assembly and adjustment, to enable dealers and service mechanics to repair these products. Before attempting repairs, read through the procedures to understand the methods and tools used and the cautions and warnings required for safety.

How To Use This Manual

This manual is divided into sections, which represent major components and systems.

Some sections are further divided into parts that more fully describe the component.

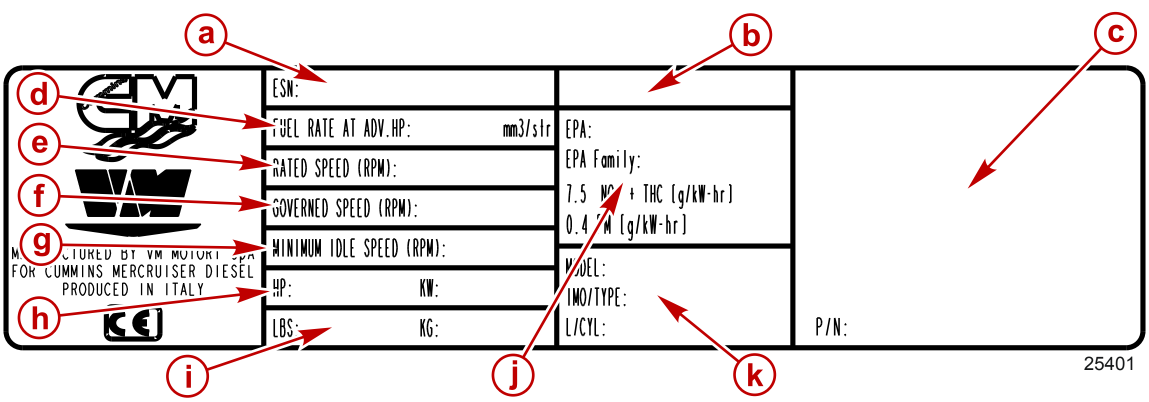
Refer to the **Service Manual Outline** following **Models Covered** in this manual for section titles.

Engine Serial Number and Decal Locations

Engine Dataplate

A tamper-resistant engine data plate is affixed to the engine at the time of manufacture by Cummins MerCruiser Diesel. It contains important exhaust gas emissions information. Please note that the engine data plate will not affect the fit, function, or performance of the engine and neither boatbuilders nor dealers may remove the engine data plate or the engine component it is affixed to before sale. If modifications are necessary or the engine data plate is damaged contact Cummins MerCruiser Diesel about the availability of a replacement.

The owner or operator is not to modify the engine in any manner that would alter the horsepower or allow exhaust gas emission levels to exceed their predetermined factory specifications.

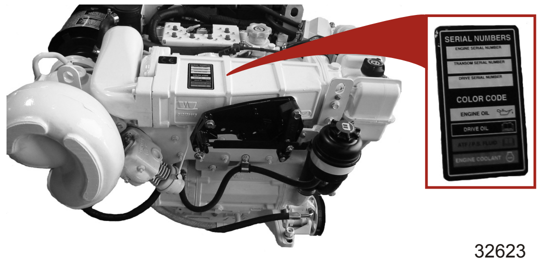


Typical engine dataplate

- **a -** Engine serial number
- **b -** Cummins MerCruiser Diesel model information
- **c -** Emissions certification information
- **d -** Fuel rate
- **e -** Rated operation engine speed
- **f -** Governed engine speed
- **g -** Minimum idle speed
- **h -** Engine power rating
- **i -** Engine weight
- **j -** Emissions data
- **k -** Manufacturer model number, IMO type, liters per cylinder

Serial Number Decal

The serial number decal is located on top of the engine on the aft end of the intercooler.



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Serial number and maintenance color code decal

Operation—Duty Cycle

Duty Cycle Rating

IMPORTANT: Damage caused by improper application or failure to operate the power package within the specified operating parameters will not be covered by the Cummins MerCruiser Diesel Limited Warranty.

The boat manufacturer or the installing dealer is responsible for ensuring that the power package is applied in accordance with recommendations indicated in the appropriate Cummins MerCruiser Diesel applications manual. In all cases, the power package must be equipped with a gear ratio and propeller that allows the engine to operate at wide open throttle (WOT) at the rated engine RPM. The power package must also be applied Use of Cummins MerCruiser Diesel engines in applications other than those indicated by the following information or the appropriate application manual is not approved.

High Output Rating

High Output Rating applies to variable load applications where full power is limited to one (1) hour out of every eight (8) hours of operation. Reduced load operation occurs when engine RPM is at least 200 RPM below the engine's maximum rated RPM for applications rated at or below 3000 RPM and at least 400 RPM below the engine's maximum rated RPM for applications rated above 3000 RPM. This rating is for pleasure (non-revenue generating) applications that operate 500 hours or less per year.

Engine Break-In

20-Hour Break-In Period

IMPORTANT: The first 20 hours of operation are a break-in period for the engine. Correct break-in is essential to obtain minimum oil consumption and maximum engine performance. During this break-in period, observe the following rules:

- Do not operate below 1500 RPM for extended periods of time during the first 10 hours. Advance the throttle above 1500 RPM as soon as conditions permit safe operation.
- Do not consistently operate at one speed for extended periods.
- Do not exceed 3/4 throttle during the first 10 hours, during the next 10 hours do not operate at full throttle for more than five minutes at a time.
- Do not accelerate at full-throttle from idle speed.
- Do not operate at full throttle until the engine reaches normal operating temperature.
- High oil consumption is normal during the break-in period. Frequently check the engine oil level.

After the 20-Hour Break-In Period

To help extend the life of your power package, Cummins MerCruiser Diesel recommends:

- Changing the engine oil and filter, and the transmission fluid on inboard models, at the interval indicated in the **Maintenance Schedule**.
- Using a propeller that allows the engine to operate at the rated engine RPM when at full throttle with a maximum boat load.
- Operating at 3/4 throttle or lower. See the duty cycle information listed in **Section 1A: Operation—Duty Cycle**.

Important Information

Section 1B - Maintenance

1
B

Table of Contents

Engine Specifications

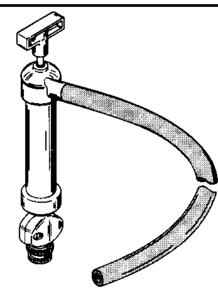
Description	Specifications	
	QSD 2.8	QSD 4.2
Rated engine RPM (**Conditions Affecting Operation —Propeller Selection** for additional information)	For complete, specific engine performance data refer to the Cummins MerCruiser Diesel Performance Curves & Datasheeets at www.cmdmarine.com	
Engine type	In-line 4–cylinder diesel	In-line 6–cylinder diesel
Displacement	2.8 liter (169 cid)	4.2 liter (256 cid)
Firing order	1-3-4-2	1-5-3-6-2-4
Bore	94 mm (3.700 in.)	
Stroke	100 mm (3.937 in.)	
Compression ratio	17:1	
Valve clearance	Hydraulic	
Maximum pressure difference between cylinders	500 kPa (72 PSI)	
Idle RPM in neutral (engine at normal operating temperature)	700	600
Oil pressure at idle	2.4 bar [240 kPa] (35 PSI)	2.1 bar [210 kPa] (30 PSI)
Oil pressure at 3800 RPM	6.2 bar [620 kPa] (87 PSI)	6.6 bar [660 kPa] (93 PSI)
Oil temperature	100-110° C (212-230° F)	
Thermostat (water)	83° C (181° F)	89° C (192° F)
Thermostat (oil)	95° C (203° F)	87° C (187° F)
Coolant temperature	80–85° C (176–185° F)	
Electrical system	12-volt negative (–) ground	
Alternator rating	1540 W, 14 V, 110 A	
Recommended battery rating	750 CCA, 950 MCA, or 180 Ahm	
Starter	12 V, 2.4 kW	

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
	Fleetguard Compleat with DCA4, Fleetguard Part Number CC2825	Closed cooling system	Obtain Locally
19	Perfect Seal	Drain plug or fitting threads	92-34227 1
25	Liquid Neoprene	All electrical connections	92- 25711 3
28	Dexron III Automatic Transmission Fluid	Power-assisted steering system	Obtain Locally
34	Special Lubricant 101	Steering cable grease fitting	92-802865Q02
		Steering cable	
		Propeller shaft	
		Propeller shaft splines	
42	U-joint and Gimbal Bearing Grease	Gimbal bearing grease insert	92-802870A1
		Transom end grease fitting, engine end grease fitting, driveshaft grease fittings	

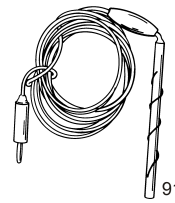
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Transmission filter element O-ring	Obtain Locally
		Water-separating fuel filter sealing ring	
		Throttle cable pivot points and guide contact surfaces	
		Shift cable pivot points and guide contact surfaces	
87	High Performance Gear Lube	Gear lube monitor	92-858064K01
91	Engine Coupler Spline Grease	U-joint shaft splines and O-rings	92-802869A1
		Engine coupler and shaft splines	
94	Anti-Corrosion Grease	Propeller shaft	92-802867Q 1
		Propeller shaft splines	
95	2-4-C Marine Lubricant with Teflon	Propeller shaft	92-802859A1
		Propeller shaft splines	
114	Power Trim and Steering Fluid	Power trim pump	92-858074K01
		Power-assisted steering pump	
121	15W40 4-cycle Diesel Engine Oil	Oil filter O-rings	92-858042K01
123	Marine Engine Coolant (Only available in Europe)	Closed cooling system	92-813054A2

Special Tools

Crankcase oil pump	91-90265A 5
 11591	Aids in the removal of engine oil without draining the crankcase.

Dual Water Pick-up Flush Gearcase Seal Kit	91-881150K 1
 9194	Blocks off the front water inlet holes on the dual water inlet gearcases.

Side Water Pickup Flushing Device	91-44357Q 2
 9192	Attaches to the water intakes; provides a fresh water connection when flushing the cooling system or operating the engine.

Reference Electrode	91-76675T 1
 9188	Senses and electrical current in the water when testing the MerCathode system. Use to check hull potential.

Propeller Nut Tool	91-805457T 1
 10677	Aids in the removal and installation of the front propeller nut.

Tools

Description	Part Number
Water Supply Hose Adapter (to Water Inlet Fitting)	Obtain locally
Typical hand-operated grease gun	

Approved Paints

The following approved paints are acceptable for refinishing and touch-up.

Description	Part Number
Marine Cloud White (CMD part number: 40918660)	Obtain locally
Mercury Light Gray Primer	92-80287852
Mercury Phantom Black	92-802878Q1

Capacities

NOTE: All capacities are approximate fluid measures.

Engine

IMPORTANT: You may need to adjust oil levels depending on the installation angle and cooling systems (heat exchanger and fluid lines).

Always use the dipstick to determine the exact quantity of oil or fluid required.

QSD 2.8

All models	Capacity Liters (U.S. qts)	Fluid Type	Part Number
Engine oil (with filter)	8.9 (9.4)	15W40 4-cycle Diesel Engine Oil	92-858042K01
Closed cooling system	11 (11.6)	Marine Engine Coolant (Only available in Europe)	92-813054A2
		Fleetguard Compleat with DCA4 Fleetguard Part Number: CC2825 Container size:3-3/4 liters, 1 U.S. gallon	Obtain locally

QSD 4.2

All models	Capacity Liters (U.S. qts)	Fluid Type	Part Number
Engine oil (with filter)	13.8 (14.6)	15W40 4-cycle Diesel Engine Oil	92-858042K01
Closed cooling system	17.25 (18.2)	Marine Engine Coolant (Only available in Europe)	92-813054A2
		Fleetguard Compleat with DCA4 Fleetguard part number: CC2825 Container size:3-3/4 liters, 1 U.S. gallon	Obtain locally

Sterndrive

NOTE: Oil capacity includes gear lube monitor.

BRAVO SERIAL NUMBERS BELOW 0W240000

Models	Capacity	Fluid Type
Bravo One	2602 ml (88 fl. oz.)	High Performance Gear Lubricant
Bravo Two	3076 ml (104 fl. oz.)	
Bravo Three	2839 ml (96 fl. oz.)	

BRAVO SERIAL NUMBERS ABOVE 0W240000

Models	Capacity	Fluid Type
Bravo One	2736 ml (92½ fl. oz.)	High Performance Gear Lubricant
Bravo Two	3209 ml (108½ fl. oz.)	
Bravo Three	2972 ml (100½ fl. oz.)	

Transmission

IMPORTANT: It may be necessary to adjust oil levels depending on installation angle and cooling systems (heat exchanger and fluid lines).

NOTE: Always use the dipstick to determine the exact quantity of oil or fluid required.

Manufacturer	Model	Capacity	Fluid Type
ZF Marine (Hurth)	63A	4.5 liters (4 ¾ U.S. qts.)	Dexron III Automatic Transmission Fluid
	63IV	4.9 liters (5 ¼ U.S. qts.)	
Technodrive TwinDisc	485-A	2.6 liters (2 ½ U.S. qts.)	SAE 20W-40 or SAE 15W-40 engine oil

Maintenance Intervals

NOTE: Refer to appropriate Mercury MerCruiser Sterndrive Service Manual for information and procedures on Sterndrive Maintenance.

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

Maintenance intervals and the corresponding tasks, as shown in this schedule or found in a previous schedule, are based on an average boating application and environment. However, factors such as individual operating habits and personal maintenance preferences can impact the suggested intervals. In consideration of these factors, Cummins MerCruiser Diesel has adjusted some maintenance intervals and corresponding tasks. In some cases, more tasks are scheduled to be performed in a single visit to the servicing facility. Therefore, the boat owner and servicing dealer should discuss the current Maintenance Schedule and develop appropriate maintenance intervals to coincide with individual operating habits, operating environments, and maintenance requirements.

Always disconnect battery cables from the battery before working around electrical system components to prevent injury to yourself and damage to the electrical system should a wire be accidentally shorted.

Maintenance Schedule—Sterndrive Models

Routine Maintenance

***NOTE:** Perform only the maintenance tasks that apply to your particular power package.*

Task Interval	Maintenance to Be Performed
Each day start	• Check the engine oil level. (You may extend this interval based on operator experience with the product.) • Check the engine coolant level. • Check the power-assisted steering fluid level. • Check the sterndrive gear lube level in the gear lube monitor.
Each day end	• If operating in saltwater, brackish water, or polluted water, flush the seawater section of the cooling system after each use. • Drain any water from the primary fuel filter after each use. (Drain all water from both fuel filters if operating in freezing temperatures.)
Weekly	• Drain any water from the fuel filters. • Check the trim pump fluid level. • Check the seawater inlets for debris or marine growth. • Check and clean the seawater strainer. • Inspect the sterndrive anodes and replace if eroded 50% or more.
Every two months	• Check the battery connections and fluid level. • Lubricate the propeller shaft and torque the propeller nut (If operating only in freshwater, you may extend this maintenance to every four months). • Treat the engine surfaces with Corrosion Guard if operating in saltwater, brackish water, or polluted waters. • Inspect the air filter. (Every two months or every 50 hours, whichever occurs first.) • Inspect the engine anodes and replace if eroded 50% or more. • Ensure that the gauges and the wiring connections are secure and clean the gauges. (Every two months or every 50 hours, whichever occurs first. If operating in saltwater, reduce the interval to every 25 hours or 30 days, whichever occurs first.)

Scheduled Maintenance

***NOTE:** Perform only the maintenance tasks that apply to your particular power package.*

Task Interval	Maintenance to Be Performed
After first 25 hours and not to exceed 30 hours	• Change the engine oil and filter.
Annually	• Touch up the power package with paint and spray with Corrosion Guard.

Task Interval	Maintenance to Be Performed
Every 100 hours or annually (whichever occurs first)	• Change the engine oil and filter. • Change the sterndrive gear lube. • Torque the gimbal ring U-bolt locknuts. • Replace the fuel filters. • Check the steering system and the remote control for loose, missing, or damaged parts. Lubricate the cables and linkages. • Inspect and lubricate the sterndrive U-joint splines. Inspect the bellows, the exhaust tube, and check the clamps. • Lubricate the gimbal bearing and engine coupler (Lubricate the engine coupler every 50 hours if operated at idle for prolonged periods of time). • Check the continuity circuit for loose or damaged connections. If equipped with MerCathode, test the unit output. • Check the engine alignment. • Torque the engine mounts. • Check the electrical system for loose, damaged, or corroded fasteners. • On driveshaft extension models, lubricate the drive shaft U-joints, transom end (tailstock) bearings, and engine end (output) bearings. • Inspect the condition and tension of the belts. • Inspect the cooling system and the exhaust system for damage or leaks. Check the hose clamps for tightness. • Disassemble and inspect the seawater pump and replace worn components. • Clean the seawater section of the closed cooling system. Clean, inspect, and test the pressure cap. Check the anodes and replace if eroded 50% or more. • Replace the air filter.
Every 2 years	• Replace the engine coolant.
Every 500 hours or 5 years (whichever occurs first)	• Clean the aftercooler core.
Every 1000 hours or 5 years (whichever occurs first)	• Clean the fuel tank.

Maintenance Schedule—Inboard Models

Routine Maintenance

***NOTE:** Perform only the maintenance tasks that apply to your particular power package.*

Task Interval	Maintenance to Be Performed
Each day start	• Check the engine oil level. (You may extend this interval based on operator experience with the product.) • Check the engine coolant level. • Check the transmission fluid level.
Each day end	• If operating in saltwater, brackish water, or polluted water, flush the seawater section of the cooling system after each use. • Drain any water from the primary fuel filter after each use. (Drain all water from both fuel filters if operating in freezing temperatures.)
Weekly	• Drain any water from the fuel filters. • Check the seawater inlets for debris or marine growth. • Check and clean the seawater strainer.

Task Interval	Maintenance to Be Performed
Every two months	• Check the battery connections and fluid level. • Treat the engine surfaces with Corrosion Guard if operating in saltwater, brackish water, or polluted waters. • Inspect the air filter. (Every two months or every 50 hours, whichever occurs first.) • Inspect the engine anodes and replace if eroded 50% or more. • Ensure that the gauges and the wiring connections are secure and clean the gauges. (Every two months or every 50 hours, whichever occurs first. If operating in saltwater, reduce the interval to every 25 hours or 30 days, whichever occurs first.)

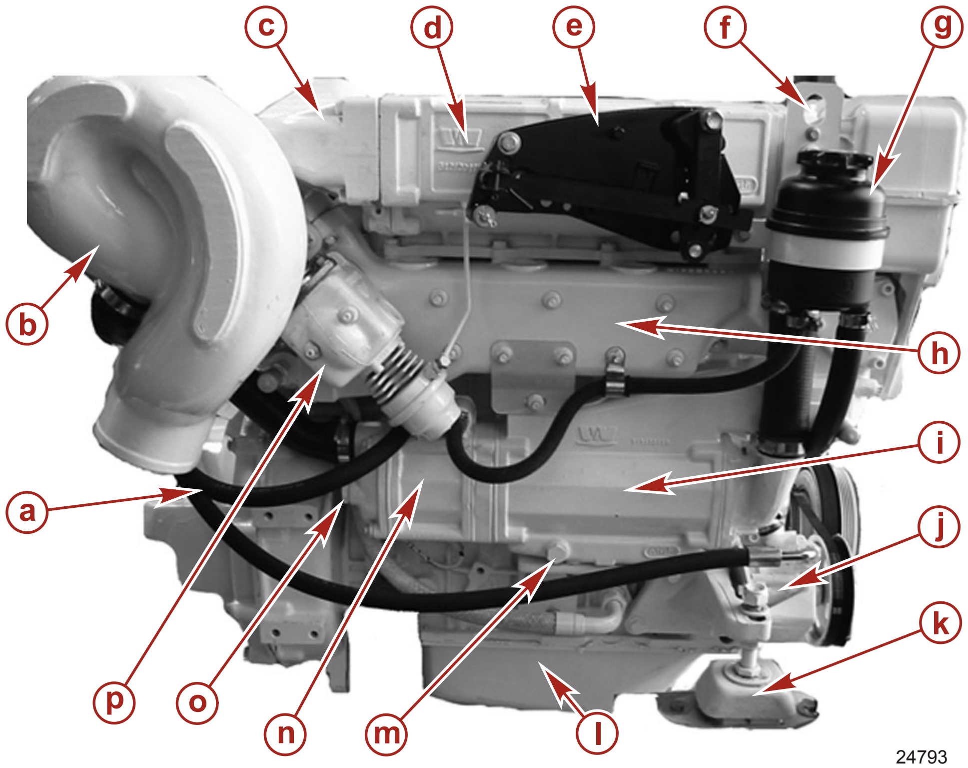
Scheduled Maintenance

NOTE: Perform only the maintenance tasks that apply to your particular power package.

Task Interval	Maintenance to Be Performed
After first 25 hours and not to exceed 30 hours	• Change the engine oil and filter. • Change the transmission fluid.
Annually	• Touch up the power package with paint and spray with Corrosion Guard.
Every 100 hours or annually (whichever occurs first)	• Change the engine oil and filter. • Change the transmission fluid. • Replace the fuel filters. • Check the steering system and the remote control for loose, missing, or damaged parts. Lubricate the cables and linkages. • Torque the engine mounts. • Check the electrical system for loose, damaged, or corroded fasteners. • Inspect the condition and tension of the belts. • Inspect the cooling system and the exhaust system for damage or leaks. Check the hose clamps for tightness. • Disassemble and inspect the seawater pump and replace worn components. • Clean the seawater section of the closed cooling system. Clean, inspect, and test the pressure cap. Check the anodes and replace if eroded 50% or more. • Replace the air filter.
Every 2 years	• Replace the engine coolant.
Every 500 hours or 5 years (whichever occurs first)	• Clean the aftercooler core.
Every 1000 hours or 5 years (whichever occurs first)	• Clean the fuel tank.
According to the OEM	• Check the engine-to-propeller shaft alignment.

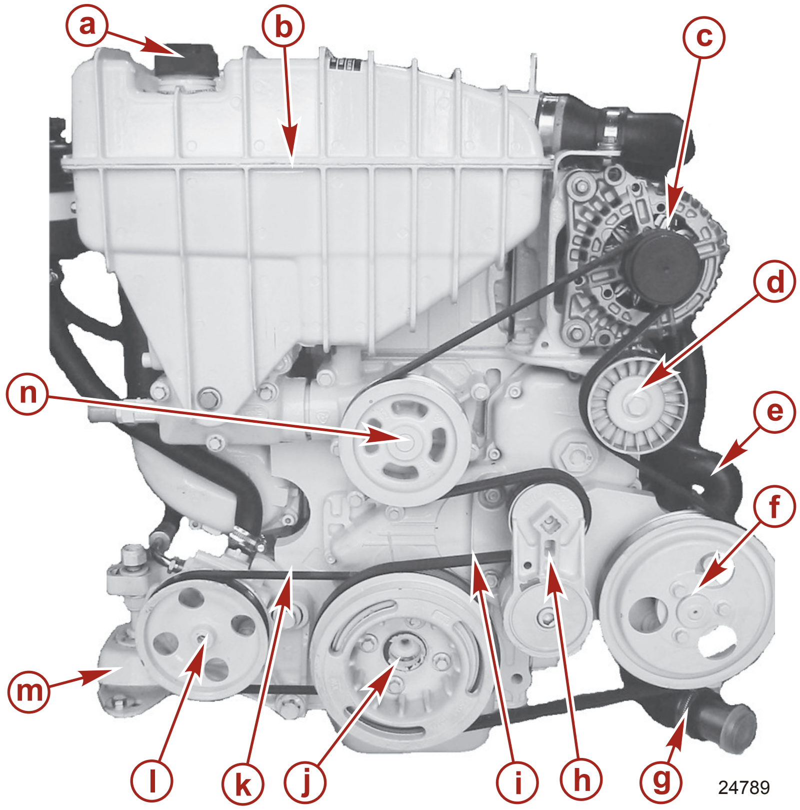
2.8 Engine External Views

Starboard Side View



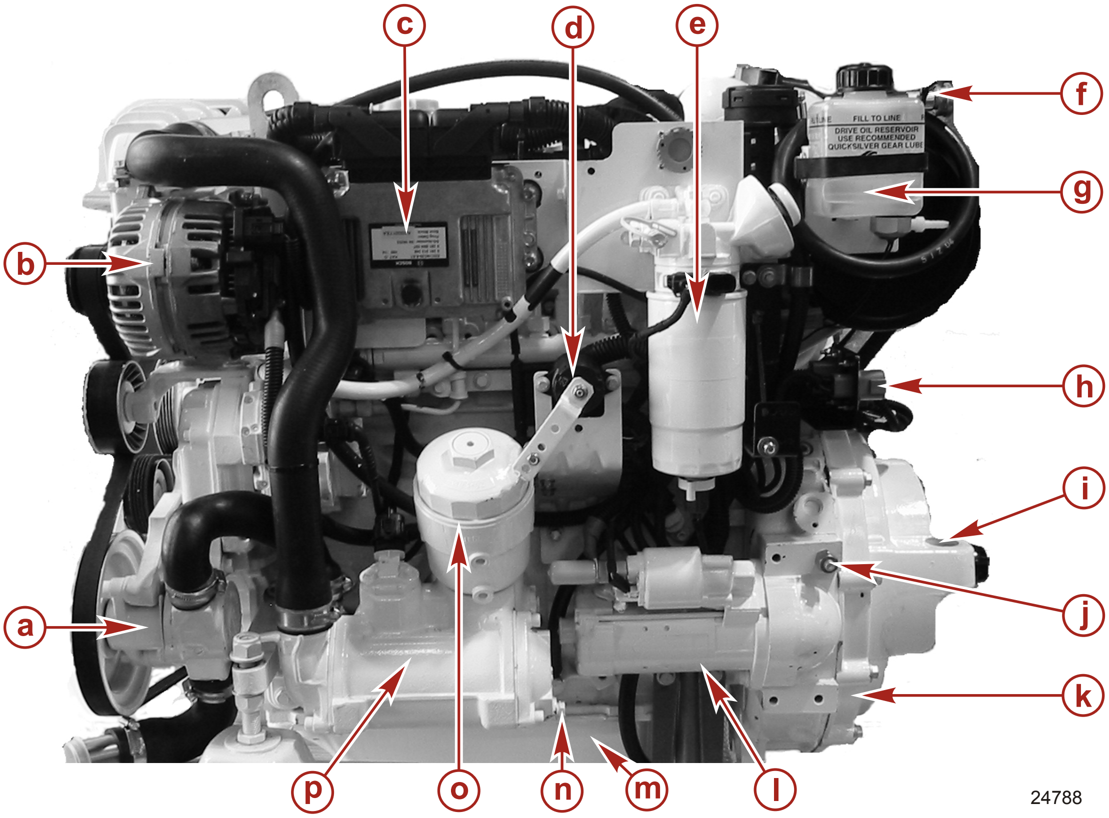
- **a -** Power-assisted steering hoses (connected for shipment)
- **b -** Sterndrive exhaust riser (or inboard exhaust, not shown)
- **c -** Aftercooler air duct
- **d -** Aftercooler
- **e -** Shift plate
- **f -** Front engine lifting eye
- **g -** Power-assisted steering fluid reservoir
- **h -** Intake and exhaust manifold
- **i -** Heat exchanger
- **j -** Power-assisted steering pump
- **k -** Front engine mount
- **l -** Oil pan
- **m -** Coolant drain
- **n -** Fluid cooler
- **o -** Seawater drain and sacrificial anode
- **p -** Wastegate

Front View



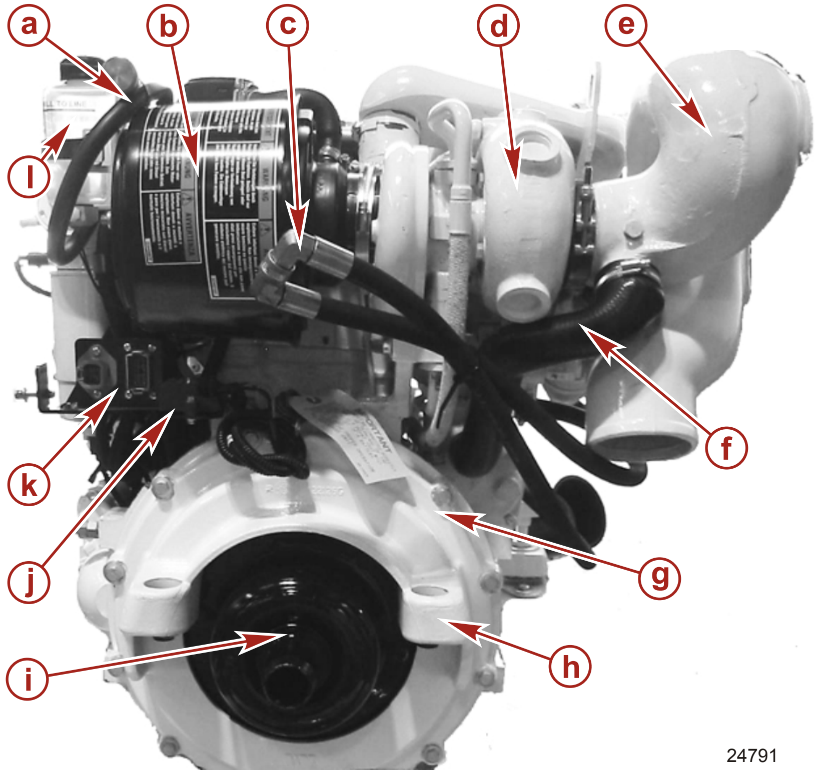
- **a -** Pressure cap
- **b -** Coolant expansion tank and reservoir
- **c -** Alternator
- **d -** Idler pulley
- **e -** Seawater pump outlet hose
- **f -** Seawater pump
- **g -** Seawater pump inlet hose
- **h -** Tensioner
- **i -** Serpentine belt
- **j -** Crankshaft balancer and pulley
- **k -** Power-assisted steering pump belt
- **l -** Power-assisted steering pump
- **m -** Front engine mount
- **n -** Engine water (coolant) circulating pump

Port Side View



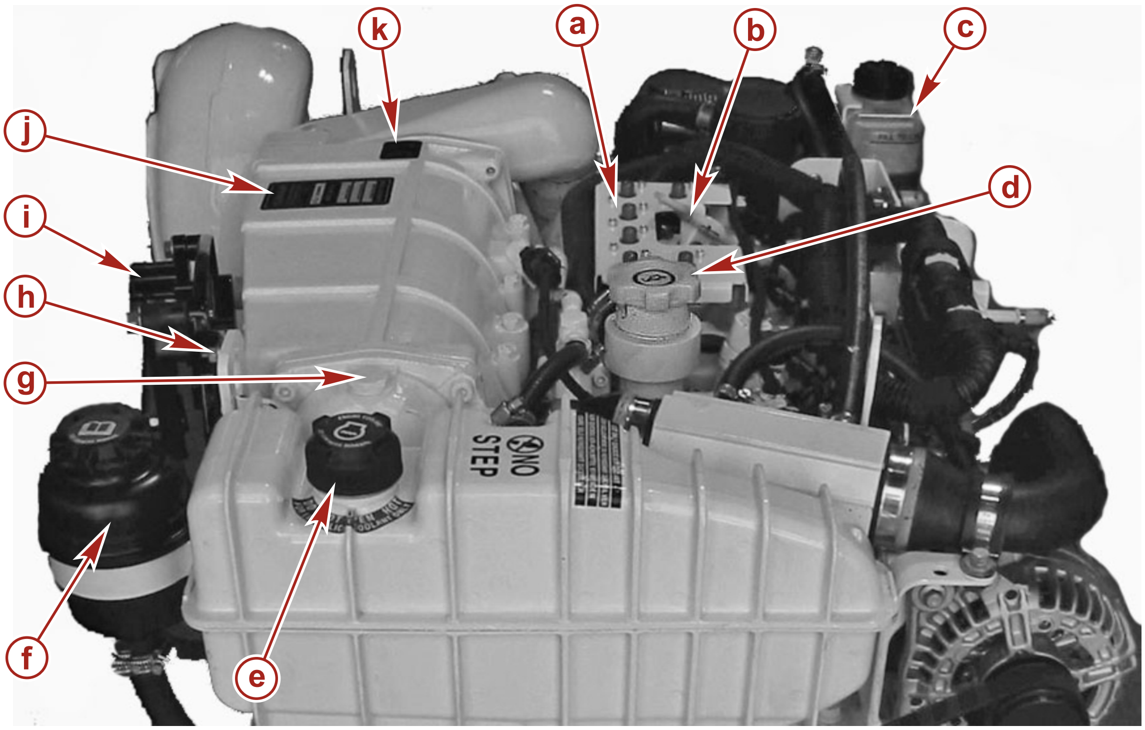
a - Seawater pump
b - Alternator
c - Engine control module (ECM)
d - Throttle position sensor
e - Fuel filter
f - Oil drain hose
g - Gear lube monitor
h - Engine extension harness connector
i - Rear engine mount
j - Ground stud
k - Flywheel housing (rear portion)
l - Starter
m - Oil pan
n - Seawater drain
o - Oil filter
p - Oil cooler

Rear View



- **a -** Oil drain hose
- **b -** Air filter
- **c -** Power-assisted steering hoses, secured for shipping
- **d -** Turbocharger
- **e -** Sterndrive exhaust riser, (inboard exhaust elbow not shown)
- **f -** Seawater overboard hose
- **g -** Flywheel housing (rear portion)
- **h -** Rear engine mount (sterndrive only)
- **i -** Engine coupler with grease fitting
- **j -** MerCathode
- **k -** Engine extension harness connectors
- **l -** Gear lube monitor

Top View



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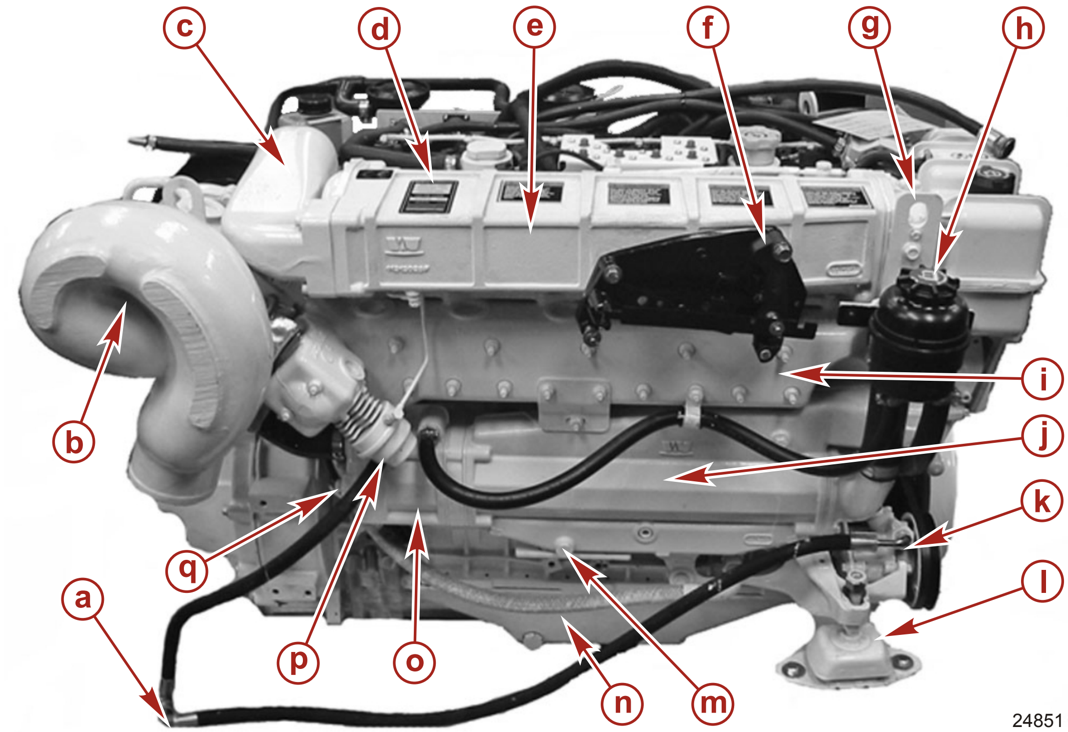
a - Engine circuit breakers
b - Dipstick
c - Gear lube monitor
d - Oil fill cap
e - Coolant pressure cap
f - Power steering reservoir
g - Aftercooler sacrificial anode
h - Front lifting eye
i - Shift plate
j - Serial number decal
k - CE mark

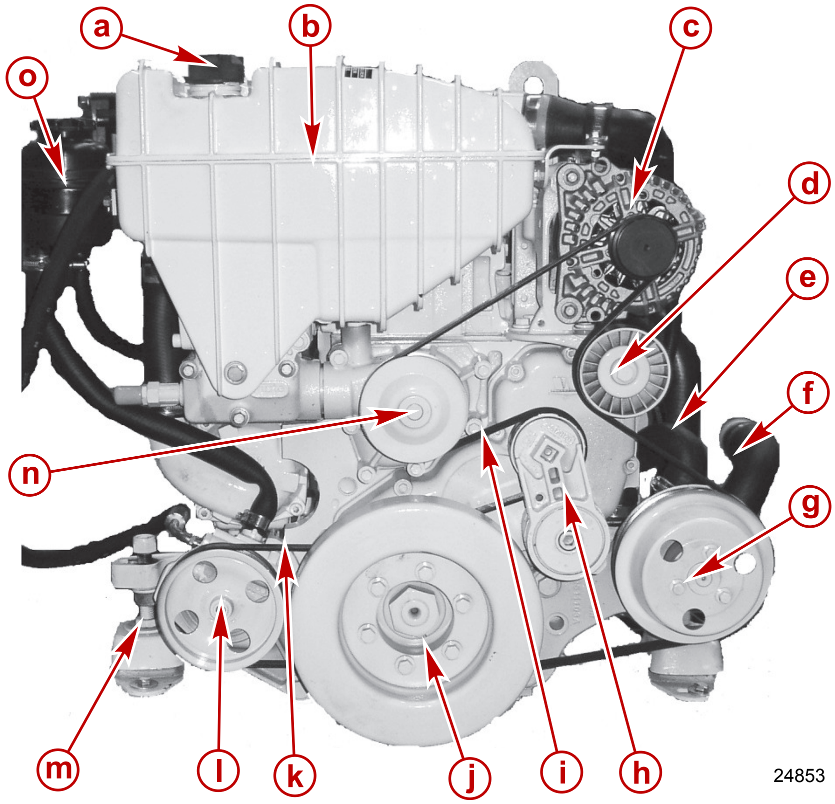
4.2 Engine External Views

Starboard Side View



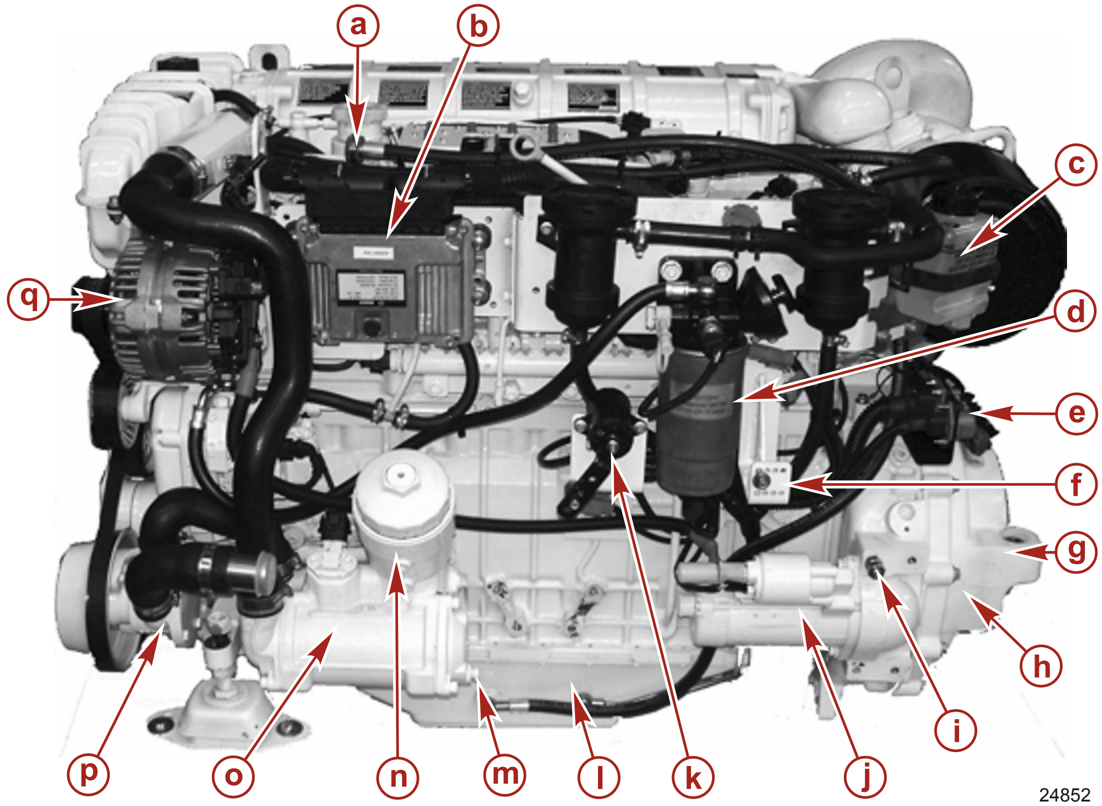
- **a -** Power-assisted steering hoses (connected for shipment)
- **b -** Sterndrive exhaust riser (or inboard exhaust, not shown)
- **c -** Aftercooler air duct
- **d -** Serial number decal
- **e -** Aftercooler
- **f -** Shift plate
- **g -** Front engine lifting eye
- **h -** Power-assisted steering fluid reservoir
- **i -** Intake and exhaust manifold
- **j -** Heat exchanger
- **k -** Power-assisted steering pump
- **l -** Front engine mount
- **m -** Coolant drain
- **n -** Oil pan
- **o -** Fluid cooler
- **p -** Wastegate
- **q -** Seawater drain and sacrificial anode

Front View



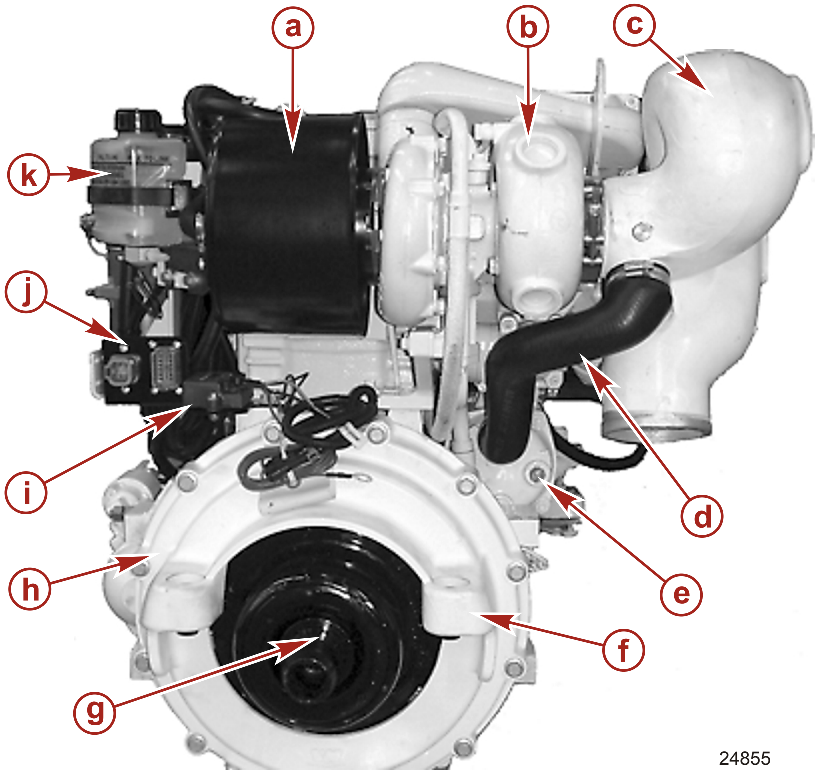
a - Pressure cap
b - Coolant expansion tank and reservoir
c - Alternator
d - Idler pulley
e - Seawater pump outlet hose
f - Seawater pump inlet hose
g - Seawater pump
h - Tensioner
i - Serpentine belt
j - Crankshaft balancer and pulley
k - Power-assisted steering pump belt
l - Power-assisted steering pump
m - Front engine mount
n - Engine water (coolant) circulating pump
o - Power-assisted steering fluid reservoir

Port Side View



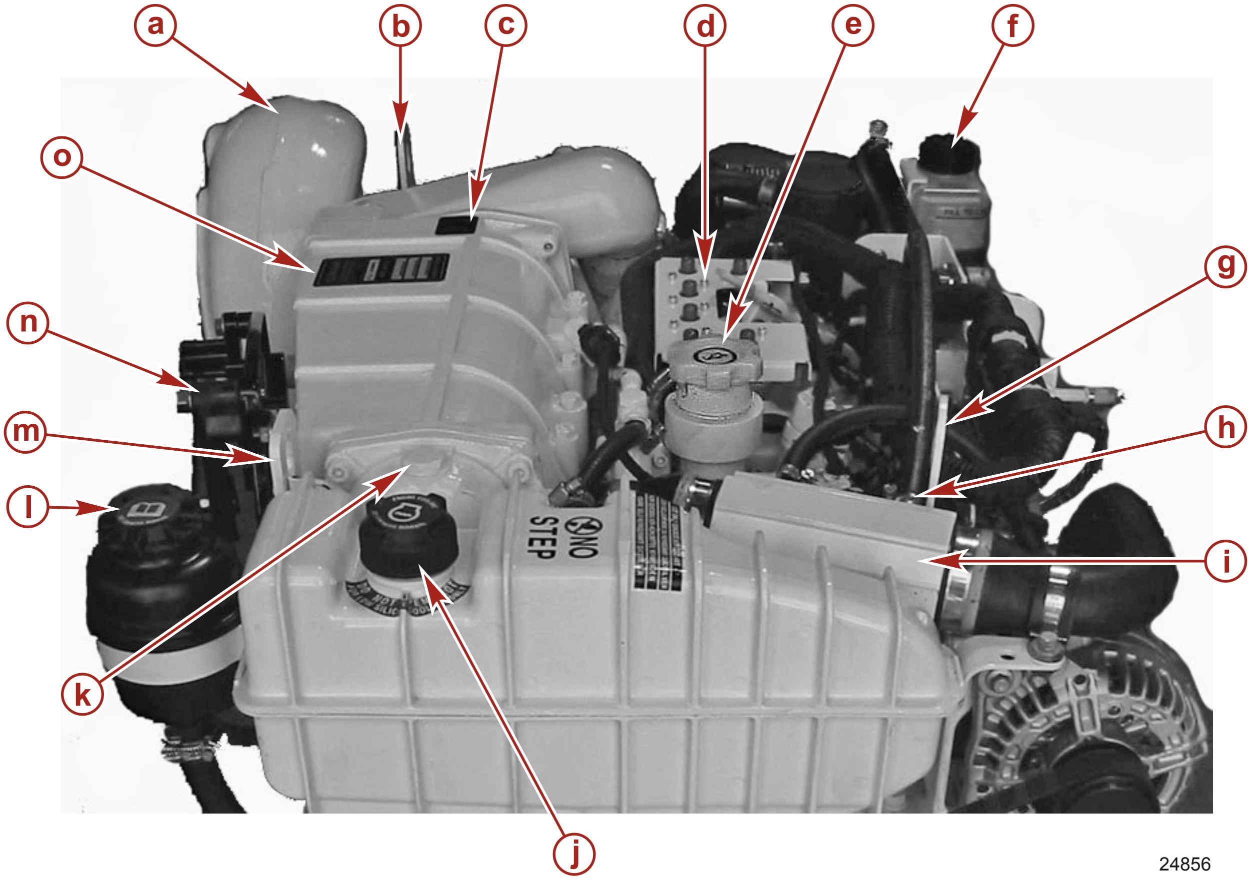
a - Oil drain hose
b - Engine control module (ECM)
c - Gear lube monitor
d - Fuel filter
e - Engine extension harness connector
f - Throttle bracket
g - Rear engine mount (sterndrive only)
h - Flywheel housing (rear portion)
i - Ground stud
j - Starter
k - Throttle position sensor
l - Oil pan
m - Seawater drain
n - Oil filter
o - Oil cooler
p - Seawater pump
q - Alternator

Rear View



a - Air filter
b - Turbocharger
c - Sterndrive exhaust riser, (inboard exhaust elbow not shown)
d - Seawater overboard hose
e - Seawater drain
f - Rear engine mount (sterndrive only)
g - Engine coupler with grease fitting
h - Flywheel housing (rear portion)
i - MerCathode controller
j - Engine extension harness connectors
k - Gear lube monitor

Top View



a - Exhaust elbow
b - Rear lifting eye
c - CE mark
d - Engine circuit breakers
e - Oil fill cap
f - Gear lube monitor
g - Side lifting eye
h - Oil drain hose
i - Fuel cooler
j - Coolant pressure cap
k - Aftercooler sacrificial anode
l - Power-assisted steering reservoir
m - Front lifting eye (use for engine mount adjustment)
n - Shift plate
o - Serial number decal

Engine Oil

Specifications

NOTICE
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

To help obtain optimum engine performance and to provide maximum protection, the engine requires engine oil with a rating of HD-SAE-API CG-4 and CH-4.

We strongly recommend the use of:

Description	Where Used	Part Number
Mercury 4- Cycle 15W40 Marine Engine Oil	Engine crankcase	92-877695K1

This oil is a specially blended 15W40 oil with marine additives for all–temperature operation. It exceeds requirements for API CF-2, CF-4, CG-4 and CH-4 oils.

Other recommended oils:

Description	Where Used	Part Number
Shell Myrina	Engine crankcase	Obtain Locally
Mopar		
Texaco Ursa Super TD		
Wintershall Multi-Rekord		
Veedol Turbostar		
Wintershall Vliva 1		

These oils are approved by Mercury Marine and Marine Power Europe. For all temperature operation use 15W40 oil.

Oil Level—Overfilled

NOTICE

Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

An overfilled engine crankcase or block can cause a fluctuation or drop in oil pressure. The overfull condition results in the engine crankshaft splashing and agitating the oil, causing it to become aerated. The aerated oil causes a loss of engine performance and an increase in crankcase back pressure. An extreme overfill condition could result in large amounts of oil being drawn into the intake.

Checking engine oil level must be done carefully. The oil level must be maintained between the minimum and the maximum oil level mark on the dipstick. To ensure that you are not getting a false reading, observe the following before checking the oil level.

- If the boat is in the water, ensure that the boat is at rest.
- If the boat is on a trailer, raise or lower the bow until the boat is sitting as it does at rest in the water.
- Allow five minutes for the oil to drain into the oil pan if the engine has just been operated or oil has just been added.

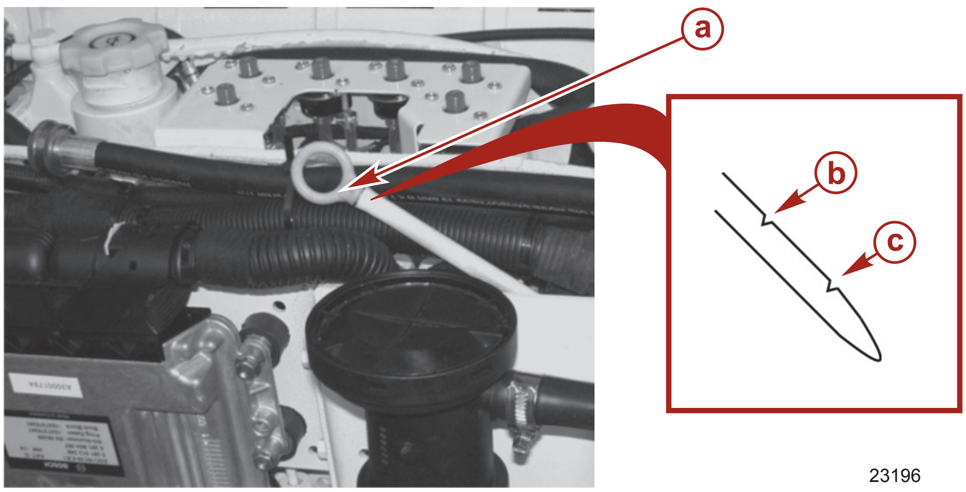
Checking

IMPORTANT: Engine crankcase oil must be checked at intervals specified in Maintenance Schedules. It is normal for an engine to use a certain amount of oil in the process of lubricating and cooling the engine. The amount of oil consumed depends greatly upon engine speed, with consumption being highest at wide open throttle and decreasing substantially as engine speed is reduced.

NOTICE

With the engine running, the crankshaft journals or rod journals may strike and break the dipstick, resulting in damage to internal engine components. Stop the engine completely before removing or inserting the dipstick.

1. To check the engine oil level during operation, stop the engine and allow five minutes for the oil to drain into the pan.
2. Remove the dipstick. Wipe clean and reinstall into the dipstick tube.
3. Remove the dipstick and observe the oil level. The oil level must be between the marks on the dipstick. If necessary, add oil. See **Filling**.



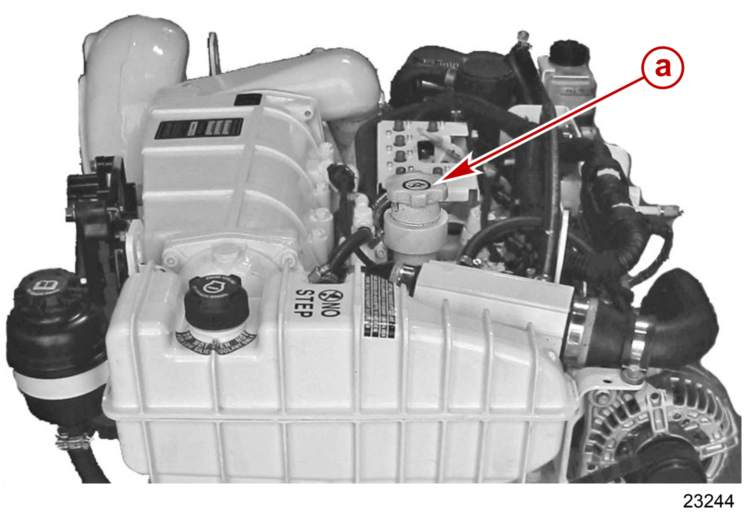
Typical

a - Dipstick
b - Maximum mark
c - Minimum mark

Filling

IMPORTANT: Do not overfill the engine with oil.

1. Remove the oil fill cap.



Typical

a - Oil fill cap

2. Add the specified oil to bring the oil level up to, but not over, the maximum mark on the dipstick.

2.8	Capacity Liters (U.S. qts)	Fluid Type
Engine Oil (With Filter)	8.9 liter (9.4 U.S. qts)	4-Cycle 15W40 Marine Engine Oil

4.2	Capacity Liters (U.S. qts)	Fluid Type
Engine Oil (With Filter)	13.8 liter (14.6 U.S. qts)	4-Cycle 15W40 Marine Engine Oil

IMPORTANT: When refilling the engine with oil always use the dipstick to determine how much oil is required.

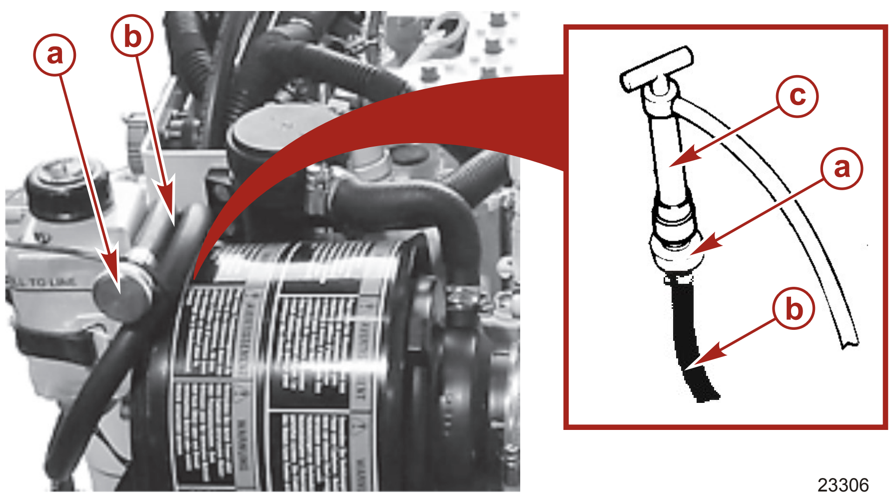
3. Install the oil fill cap.

Changing Oil and Filter

See the **Maintenance Schedule** for the change interval. You should change the engine oil before placing the boat in storage.

IMPORTANT: Change the engine oil when the engine is warm from operation. Warm oil flows more freely, carrying away more impurities. Use only recommended engine oil. See Specifications.

1. Start the engine and allow it to warm up to normal operating temperature.
2. Stop the engine and allow some time for the oil to drain into the oil pan (approximately five minutes).
3. Remove the fitting from the end of crankcase oil drain hose.
4. Install the crankcase oil pump (order separately) onto the threaded fitting of the oil drain hose.



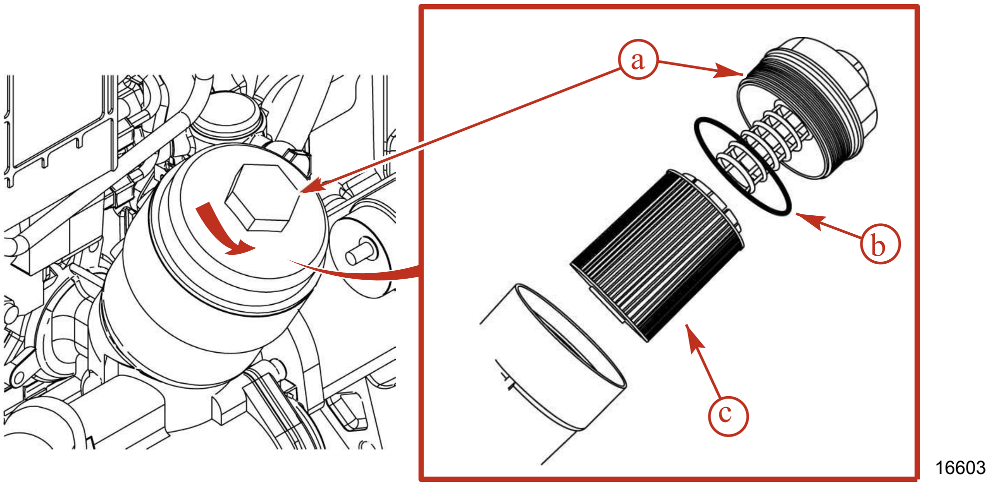
Typical

a - Threaded fitting
b - Oil drain hose
c - Crankcase oil pump

Crankcase oil pump	91-90265A 5

5. Pump the oil out of the crankcase into the drain pan.
6. Contain and dispose of the oil or oil waste as directed by local authorities.
7. Remove the crankcase oil pump and install the crankcase oil drain hose fitting when the crankcase is empty. Tighten securely.

8. Install the oil dipstick.
9. Place a suitable container under the oil filter housing to contain any oil leakage that may occur. Use an appropriate socket to loosen the oil filter top piece.
10. Remove the top piece and cartridge type oil filter.
11. Disconnect and discard the old filter element. Discard the old O-ring from the top piece.



Typical

a - Top piece
b - O-ring
c - Filter element

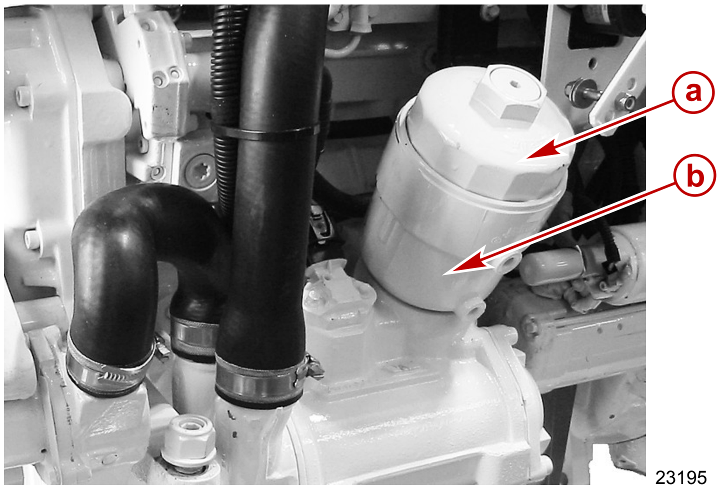
12. Install the new O-ring. Apply lubricant to the O-ring.

Tube Ref No.	Description	Where Used	Part No.
121	15W40 4-cycle Diesel Engine Oil	Oil filter O-rings	92-858042K01

13. Push the filter element onto the top piece until it is locked. Listen for a click.
14. Install the top piece with the new filter element into the oil filter housing.

IMPORTANT: Overtightening the top piece will cause deformation resulting in oil leakage.

15. Turn the oil filter top piece until the sealing surface contacts the housing. Torque the top piece using an appropriate socket.



a - Top piece **b -** Oil filter housing

Description	Nm	lb. in.	lb. ft.
Oil filter top piece	25	–	18

16. Remove the oil fill cap and refill the engine with new oil. See **Filling**.

IMPORTANT: When refilling the engine with oil, always use the dipstick to determine how much oil is required.

17. Start the engine and check for leaks.

Sterndrive Gear Lube

NOTICE

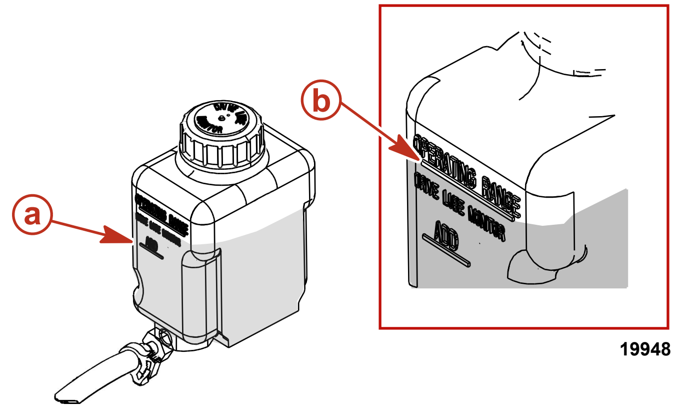
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

Checking

NOTE: *The gear lube level will fluctuate during operation. The gear lube level should be checked with the engine cold, before starting.*

1. Check the gear lube monitor to determine the gear lube level. Keep the gear lube level within the recommended operating range.

2. IF the gear lube level is low, see **Filling**.



Gear lube level shown is at the correct operating range

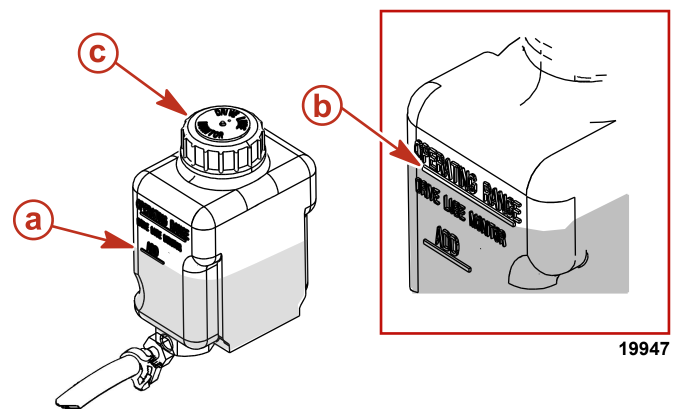
a - "ADD" mark
b - "OPERATING RANGE" mark

IMPORTANT: If any water is visible at the bottom of the gear lube monitor or appears at the fill and drain plug hole, or if the gear lube appears discolored, locate and repair the leak immediately. ***Refer to the appropriate Mercury MerCruiser Sterndrive Service Manual.***

Filling

NOTE: If more than 59 ml (2 fl. oz.) of High Performance Gear Lube is required to fill the gear lube monitor, a seal may be leaking. Damage to the sterndrive may occur due to lack of lubrication. Refer to the appropriate Mercury MerCruiser Sterndrive Service Manual.

1. Remove the gear lube monitor cap.
2. Fill the gear lube monitor with the specified gear lube so that the gear lube level is in the operating range. Do not overfill.



Gear lube monitor

a - Gear lube level at the "ADD" mark
b - Gear lube level at the "OPERATING RANGE" mark
c - Gear lube monitor cap

Tube Ref No.	Description	Where Used	Part No.
87	High Performance Gear Lube	Gear lube monitor	92-858064K01

3. Ensure that the rubber gasket is inside the gear lube monitor cap and install the cap. Do not overtighten.

NOTE: When filling the entire sterndrive, see ***Changing****.*

Changing

Refer to the appropriate Mercury MerCruiser Sterndrive Service Manual.

ZF Marine Transmission Fluid

Checking

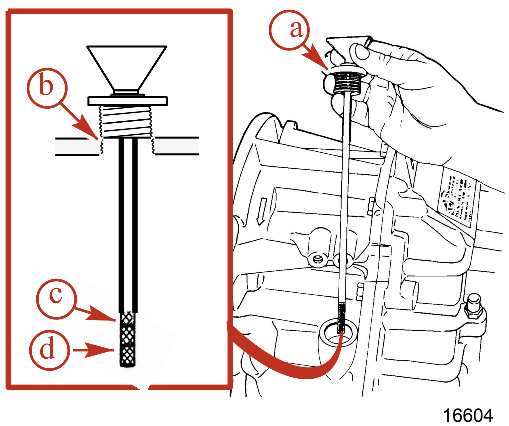
1. Remove the dipstick.

IMPORTANT: When checking the fluid level, rest the dipstick on top of the threaded housing hole. Do not screw the dipstick into the threaded housing hole.

2. Check the fluid level as indicated on the dipstick with the dipstick resting on the top of the threaded hole.

NOTE: The fluid level may be somewhat over the maximum mark, as some of the fluid from the transmission fluid cooler and hoses may have drained back into the transmission.

3. If the fluid level is low, add transmission fluid to bring the level up to the maximum mark on the dipstick.



a - Dipstick
b - Threaded hole
c - Maximum fluid level
d - Minimum fluid level

IMPORTANT: To accurately check the fluid level, the engine must be operated at 1500 RPM for two minutes immediately before checking the level.

4. Start the engine and operate at 1500 RPM for two minutes to fill all the hydraulic circuits.
5. Stop the engine and quickly check the fluid level with the dipstick resting on the top of the threaded hole.
6. If the fluid level is low, add transmission fluid to bring the level up to the maximum mark on the dipstick. See **Filling**.

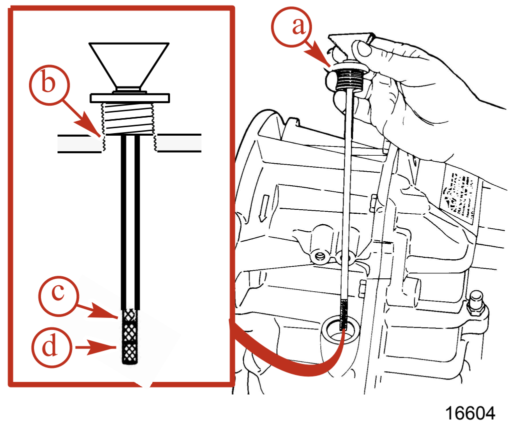
NOTE: If the transmission fluid level was extremely low, see ***Troubleshooting****.*

7. Install the dipstick.

Filling

1. If necessary, add the specified automatic transmission fluid through the dipstick threaded hole to bring the level up to the maximum mark on the dipstick.

IMPORTANT: Use only the specified automatic transmission fluid (ATF).



a - Dipstick
b - Threaded hole
c - Maximum fluid level
d - Minimum fluid level

NOTE: Always use the dipstick to determine the quantity of oil or fluid required.

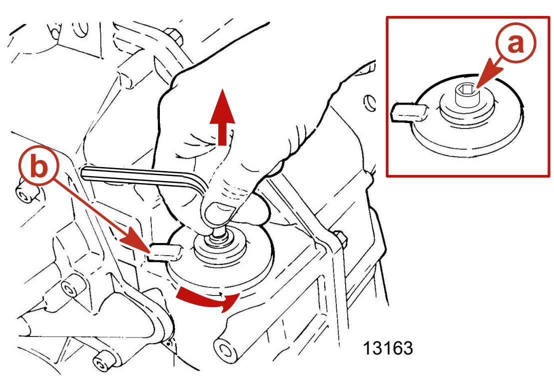
NOTE: Capacities are for the transmission only and do not include the fluid cooler or fluid cooler hose capacities.

<table>
<tr><th>Model</th><th>Capacity</th><th>Fluid type</th><th>Part Number</th></tr>
<tr><td>ZF Marine 63A</td><td>4 liters (4.2 US qt)</td><td rowspan="2">Dexron III Automatic Transmission Fluid or Equivalent</td><td rowspan="2">Obtain locally</td></tr>
<tr><td>ZF Marine 63IV</td><td>4.4 liters (4.6 US qt)</td></tr>
</table>

2. Install the dipstick.
3. Check the fluid level. See **Checking**.

Changing

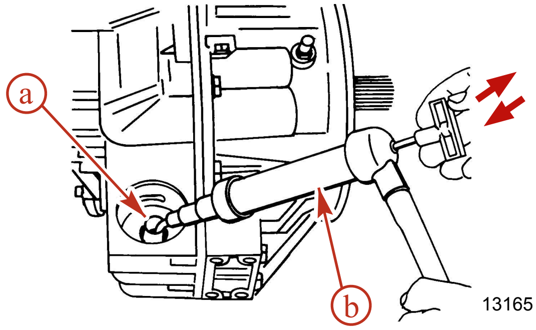
1. Clean the exterior of the transmission around the fluid filter assembly.
2. Use a 6 mm Allen wrench and remove the fluid filter assembly by turning the assembly nut counterclockwise and pulling at the same time.



a - Assembly nut
b - Fluid filter assembly

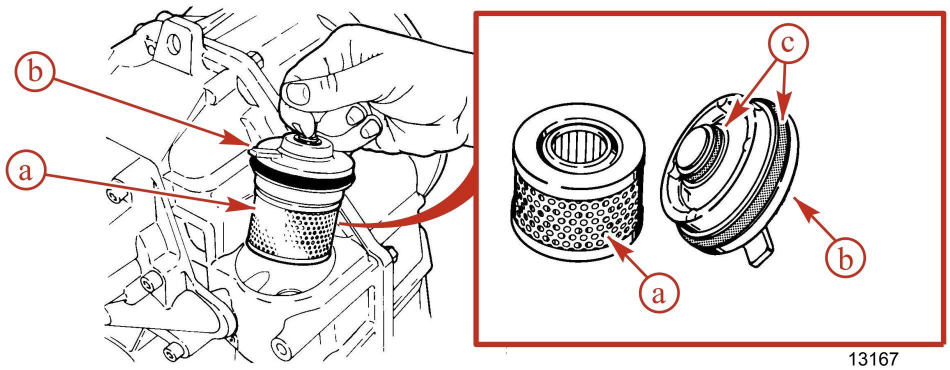
3. Push the hose of a suction pump through the suction pipe and down to the bottom of the housing.

4. Pump the fluid from the housing into a suitable container. Dispose of the fluid properly.



a - Suction pipe
b - Suction pump

5. Remove and discard the filter element and the O-rings.
6. Coat the new O-rings with transmission fluid.
7. Install the new O-rings and filter element.

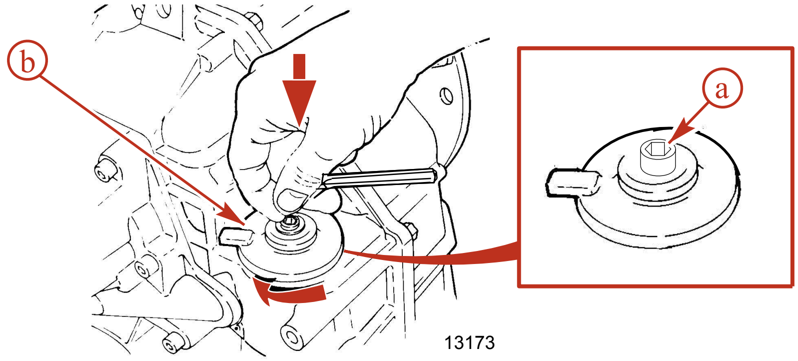


a - Filter element
b - Cover
c - O-rings

NOTICE
Improper installation of the transmission fluid filter assembly may cause the fluid to foam or leak out, resulting in decreased efficiency and damage to the transmission. Properly seat the transmission fluid filter during installation.

8. Install the fluid filter assembly in the transmission cavity by turning clockwise and pushing at the same time.

9. Using a 6 mm Allen wrench, turn the filter assembly nut clockwise to tighten. Torque the nut.



a - Assembly nut **b -** Fluid filter assembly

Description	Nm	lb. in.	lb. ft.
Filter assembly nut	5-8	48-72	

10. Fill the transmission to the proper level with the specified fluid. See **Filling**.

Technodrive Transmission Fluid

Checking

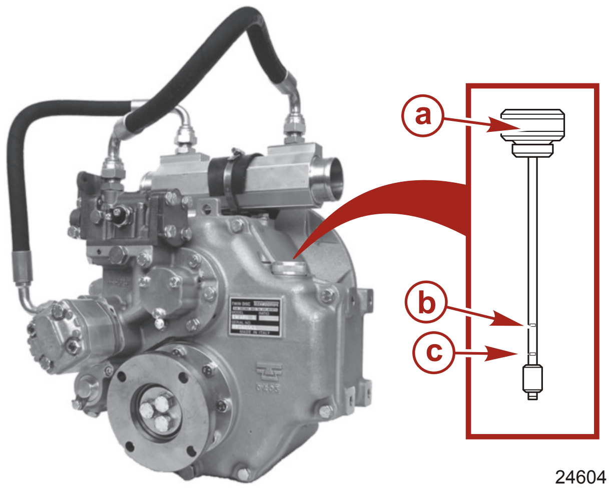
1. Remove the dipstick.

IMPORTANT: When checking the fluid level, rest the dipstick on top of the threaded housing hole. Do not screw the dipstick onto the threaded housing hole.

2. Check the fluid level as indicated on the dipstick with the dipstick resting on the top of the threaded hole.

NOTE: *The fluid level may be somewhat over the maximum mark, as some of the fluid from the transmission fluid cooler and hoses can drain back into the transmission.*

3. If the fluid level is low, add transmission fluid to bring the level up to the maximum mark on the dipstick.



a - Dipstick
b - Maximum fluid level
c - Minimum fluid level

IMPORTANT: To accurately check the fluid level, the engine must be operated at 1500 RPM for two minutes immediately before checking the level.

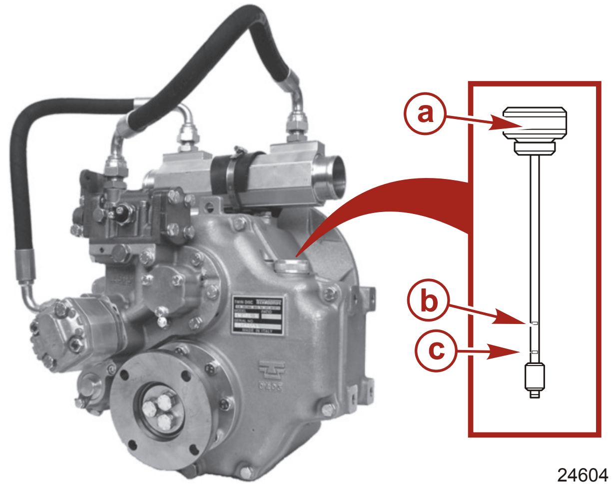
4. Start the engine and operate at 1500 RPM for two minutes to fill all the hydraulic circuits.
5. Stop the engine and quickly check the fluid level with the dipstick resting on the top of the threaded hole.
6. If the fluid level is low, add transmission fluid to bring the level up to the maximum mark on the dipstick. See **Filling**.

*NOTE: If the transmission fluid level was extremely low, see **Troubleshooting**.*

7. Install the dipstick.

Filling

1. If necessary, add specified transmission fluid through the dipstick threaded hole to bring the level up to the maximum mark on the dipstick.



a - Dipstick
b - Maximum fluid level
c - Minimum fluid level

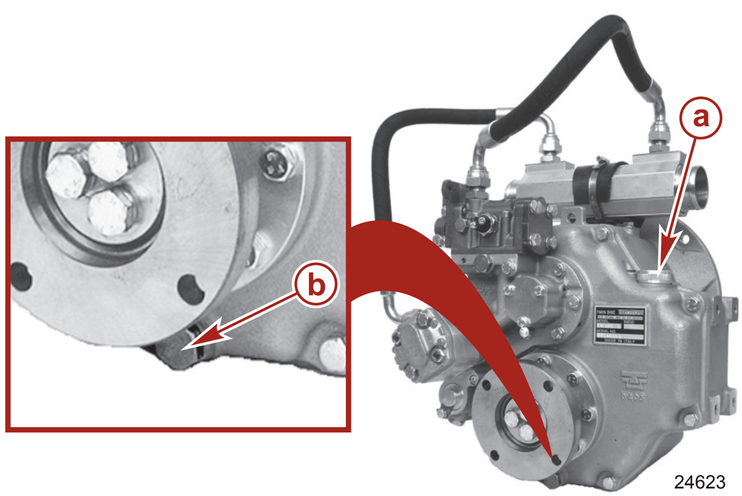
NOTE: Always use the dipstick to determine the quantity of oil or fluid required.

Model	Capacity	Fluid type	Part Number
Technodrive 485A	2.6 liters (2 ½ US qt)	SAE 20W - 40 or SAE 15W - 40 engine oil	Obtain Locally

2. Install the dipstick.
3. Check the fluid level. See **Checking**.

Changing

1. Remove the fill cap and dipstick.
2. Remove the transmission fluid drain plug and drain the transmission into a suitable container.



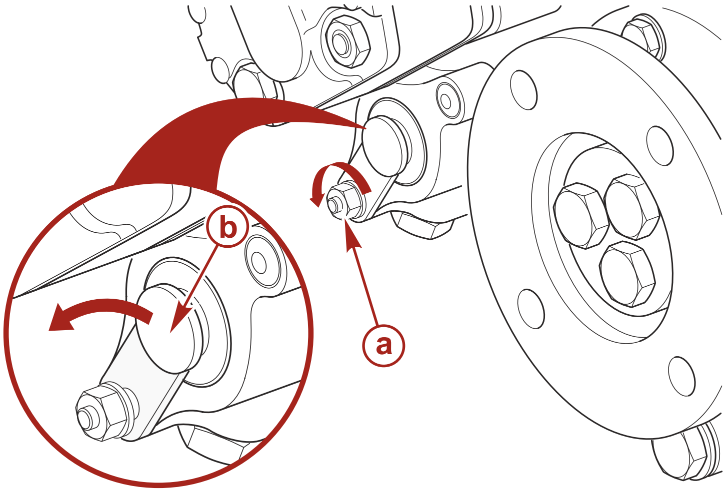
a - Fill cap and dipstick
b - Drain plug

3. Contain and dispose of the oil or oil waste as directed by local authorities.
4. Reinstall the transmission fluid drain plug.

5. Torque the drain plug.

Description	Nm	lb. in.	lb. ft.
Transmission fluid drain plug	17	–	12.5

6. Clean the exterior of the transmission around the fluid filter assembly.
7. Loosen the assembly nut then rotate the securing tab in the direction shown.



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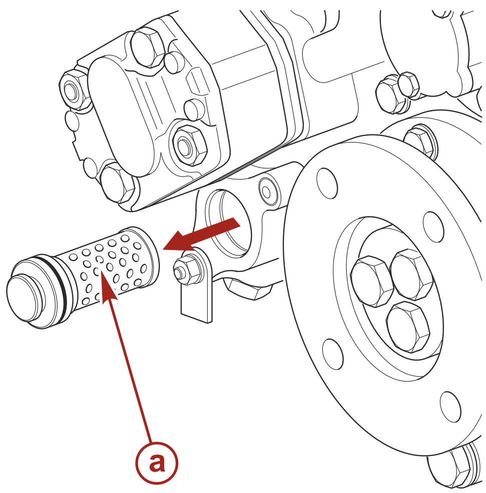
a - Assembly nut
b - Securing tab

8. Remove the filter element.



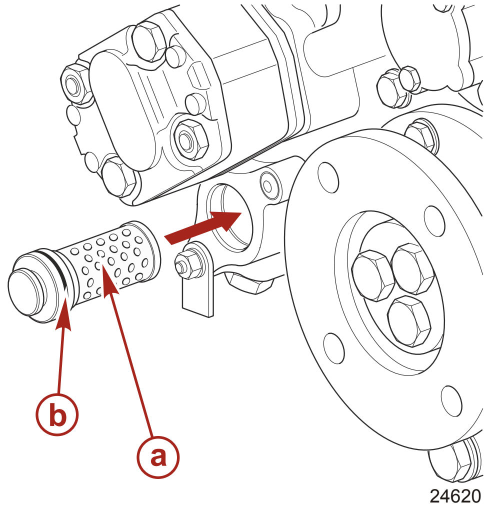
24618

a - Filter element

9. Clean the filter element using a suitable cleaning solvent.
10. Lubricate the O-rings.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Transmission filter element O-ring	Obtain Locally

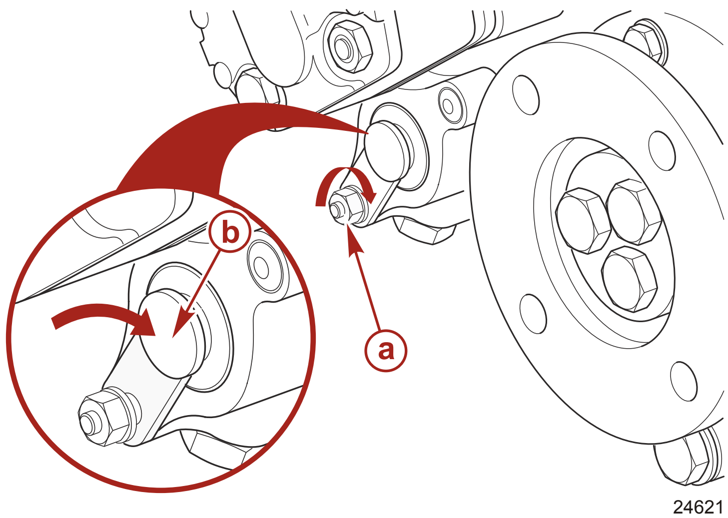
11. Reinstall the filter element.



a - Filter element **b -** O-ring

NOTICE
Improper installation of the transmission fluid filter assembly may cause the fluid to foam or leak out, resulting in decreased efficiency and damage to the transmission. Properly seat the transmission fluid filter during installation.

12. Replace the securing tab over the filter assembly by turning it clockwise.
13. Tighten the assembly nut. Torque the nut.



a - Assembly nut
b - Securing tab

Description	Nm	lb. in.	lb. ft.
Assembly nut	5-8	48-72	–

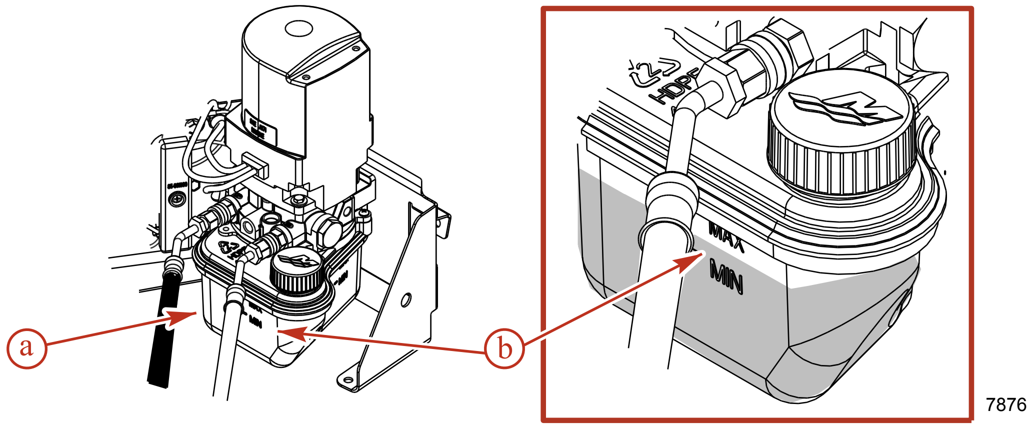
14. Fill the transmission to the proper level with the specified fluid. See **Filling**.

Power Trim Fluid

Checking

IMPORTANT: Check the fluid level with the sterndrive in the full down (in) position only.

1. Place the sterndrive in full down (in) position.
2. Observe the fluid level. The fluid level must be between the "MIN" and "MAX" lines on the reservoir.



a - Reservoir **b -** "MIN" and "MAX" lines

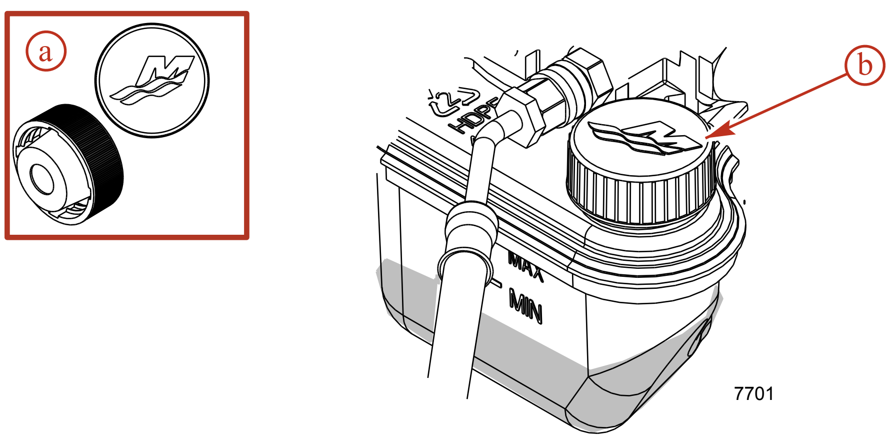
3. Fill as necessary with the specified fluid. See **Filling**.

Tube Ref No.	Description	Where Used	Part No.
114	Power Trim and Steering Fluid	Power trim pump	92-858074K01

Filling

1. If the fluid level is below the "MIN" line, the specified fluid must be added.
2. Remove the fill cap from the reservoir.

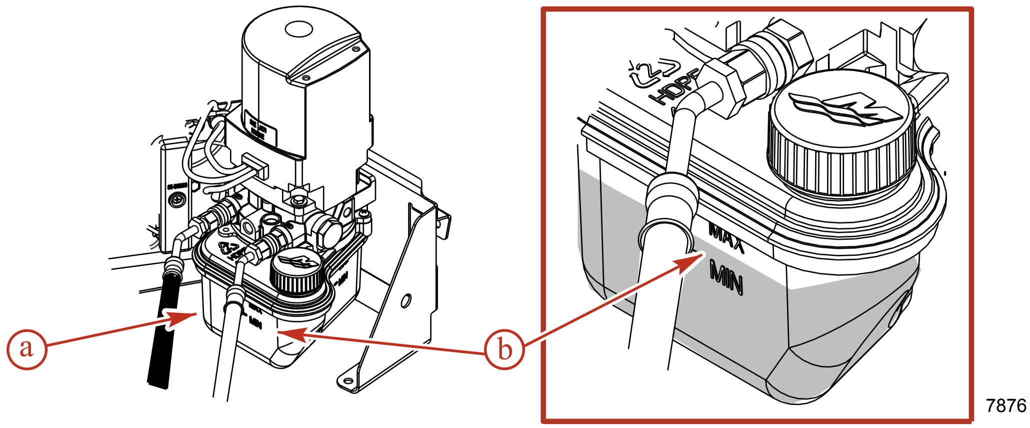
NOTE: The fill cap is vented.



Power trim pump reservoir shows the fluid level is below "MIN" line

a - Fill cap assembly **b -** Fill cap installed

3. Add the specified fluid to bring the fluid level to within the "MIN" and "MAX" lines on the reservoir.



a - Reservoir

b - "MIN" and "MAX" lines

Tube Ref No.	Description	Where Used	Part No.
114	Power Trim and Steering Fluid	Power trim pump	92-858074K01

4. Install the fill cap.

Changing

Power trim fluid does not require changing unless it becomes contaminated with water or debris.

1. Remove the contaminated power trim fluid from the power trim pump reservoir.
2. Fill the power trim pump reservoir to the proper level with the appropriate power trim fluid. See **Filling.**
3. Raise and lower the sterndrive 6 to 10 times to cycle the power trim fluid, and to purge contaminants from the system.
4. Repeat steps two and three until the power trim fluid is no longer contaminated.

Power-Assisted Steering Fluid

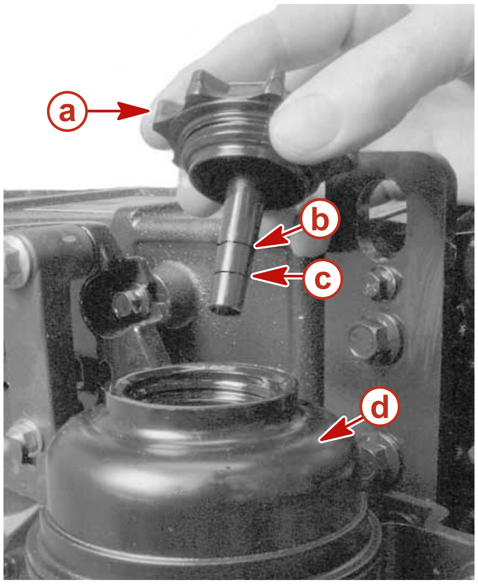
IMPORTANT: Use only Quicksilver Power Trim and Steering Fluid or Dexron III automatic transmission fluid (ATF) in the power-assisted steering system.

IMPORTANT: Running the pump dry will damage the pump. Always check steering fluid levels before operating the boat.

Checking

1. Center the sterndrive and stop the engine.

2. Remove the fill cap and dipstick from the fluid reservoir and observe the level.
   a. The proper fluid level with the engine cold should be between the full cold mark and the end of the dipstick.
   b. With the engine at normal operating temperature the fluid level should be between the full hot and full cold marks.



a - Fill cap and dipstick
b - Full hot mark
c - Full cold mark
d - Fluid reservoir

IMPORTANT: If fluid is not visible in the fluid reservoir, determine the cause and correct.

Filling

1. Remove the fill cap and dipstick and observe the fluid level.
2. Add the specified fluid to bring the fluid level up to the proper level.

Tube Ref No.	Description	Where Used	Part No.
114	Power Trim and Steering Fluid	Power-assisted steering pump	92-858074K01

Tube Ref No.	Description	Where Used	Part No.
28	Dexron III Automatic Transmission Fluid	Power-assisted steering system	Obtain Locally

3. Install the fill cap and dipstick.

Changing

Power-assisted steering fluid does not require changing unless it becomes contaminated. See the section titled **Power-Assisted Steering System**.

Closed Cooling System

Coolant Requirement

NOTICE

Using propylene glycol antifreeze in the closed cooling system can damage the cooling system or the engine. Fill the closed cooling system with an ethylene glycol antifreeze solution suitable to the lowest temperature to which the engine will be exposed.

Diesel engines are high-compression engines and create higher engine operating temperatures than gasoline engines. The closed cooling system and engine must remain as clean as possible to provide adequate engine cooling. Adequate engine cooling can be assured by using the proper antifreeze, water, additives and inhibitors. Cummins MerCruiser Diesel recommends that the closed cooled section of the closed cooling system be filled with a low-silicate formula of ethylene glycol coolant (antifreeze) in solution with deionized water. A low-silicate formula prevents coolant separation, that causes a silicate gelatin to form. This gelatin will block engine and heat exchanger passages causing the engine to overheat.

The coolant (antifreeze), if not premixed, should be mixed with deionized water before being added to the closed cooling system. Common tap water or softened water contains minerals that can leave deposits in the system reducing the efficiency of the cooling system. The addition of proper additives and inhibitors to approved coolant solutions will form a protective film on internal passages and protect against internal corrosion of the cooling system.

The closed cooled section of the closed cooling system should remain filled with an approved coolant (antifreeze) solution year round. Do not drain the closed cooled section for storage; that will promote rusting of the internal surfaces. If the engine will be exposed to freezing temperatures, ensure that the closed cooled section is filled with a properly mixed coolant (antifreeze) solution that will protect the engine and the closed cooling system at the lowest temperature to which they will be exposed.

NOTE: *The coolant (antifreeze) used in these marine engines must be a low-silicate ethylene glycol, containing special additives and deionized, purified water. Using other types of engine coolant may cause fouling of the heat exchangers and overheating of the engine. Do not combine different types of coolants without knowing that they are compatible. If your are unsure refer to the coolant manufacturer's instructions.*

Some approved types of antifreeze-coolants are listed in the following table.

Description	Availability	Part Number
Marine Engine Coolant Quantity: 3 3/4 liters (1 U.S. Gallon)	Europe only	92-813054A2
Fleetguard Compleat with DCA4 Quantity: 3 3/4 liters (1 US Gallon)	Worldwide	Fleetguard Part Number: CC2825

See **Maintenance Schedules** for change intervals.

See **Specifications** for quantity of coolant (antifreeze) required.

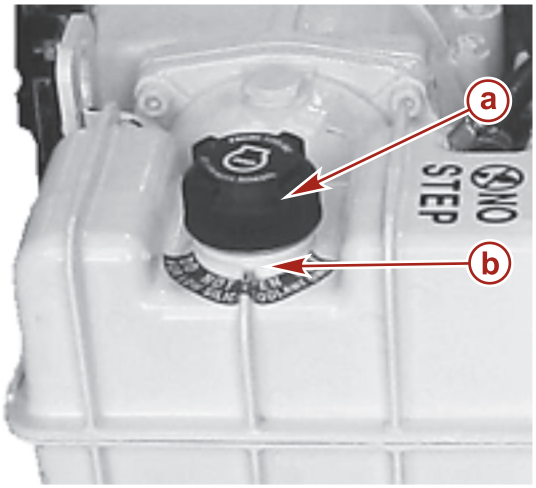
Checking

⚠ CAUTION

A sudden loss of pressure can cause hot coolant to boil and discharge violently resulting in serious injury from burns. Allow the engine to cool down before removing the coolant pressure cap.

IMPORTANT: Check engine coolant before starting the engine.

1. Allow the engine to cool.
2. Remove the pressure cap from the coolant expansion tank and observe the coolant level.
3. The coolant level in the coolant expansion tank should be within 25 mm (1 in.) of the bottom of the filler neck or between the upper and lower marks, if marked.



23248

a - Pressure cap
b - Bottom of filler neck

4. *If the coolant level is correct*, install the pressure cap.
5. *If the coolant level is low*, do the following.
   a. Check the coolant system for malfunction. Refer to **Section 6A**.
   b. Add the specified coolant. See **Filling the Closed Cooling System** .
   c. Install the pressure cap.

Draining the Closed Cooling System

NOTICE
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

NOTE: For instructions on draining the seawater section, see ***Draining the Seawater System****.*

IMPORTANT: Observe the following points.

- Ensure that the engine is as level as possible to promote complete draining of the cooling system.
- The closed cooled section must be filled year-round with the required coolant. If the engine will be exposed to freezing temperatures, ensure that the closed cooled section is filled with a solution of ethylene glycol antifreeze and properly–mixed water that will protect the engine at the lowest temperature to which it will be exposed.
- Do not use propylene glycol antifreeze in the closed cooled section of the engine.

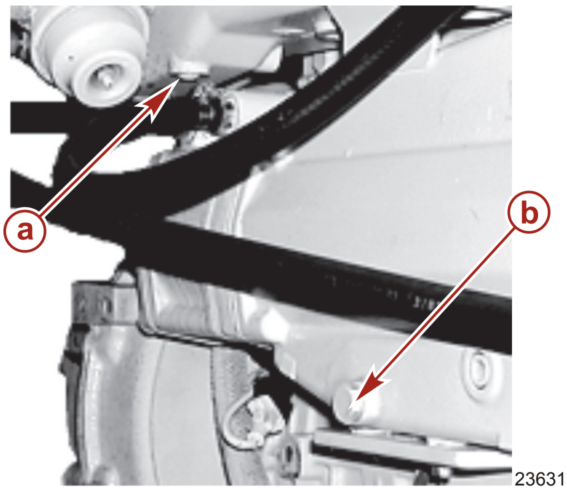
⚠ CAUTION

A sudden loss of pressure can cause hot coolant to boil and discharge violently resulting in serious injury from burns. Allow the engine to cool down before removing the coolant pressure cap.

1. Allow the engine to cool.
2. Remove the pressure cap from the expansion tank and coolant reservoir.

NOTE: Drain coolant into a suitable container. Dispose of old coolant properly.

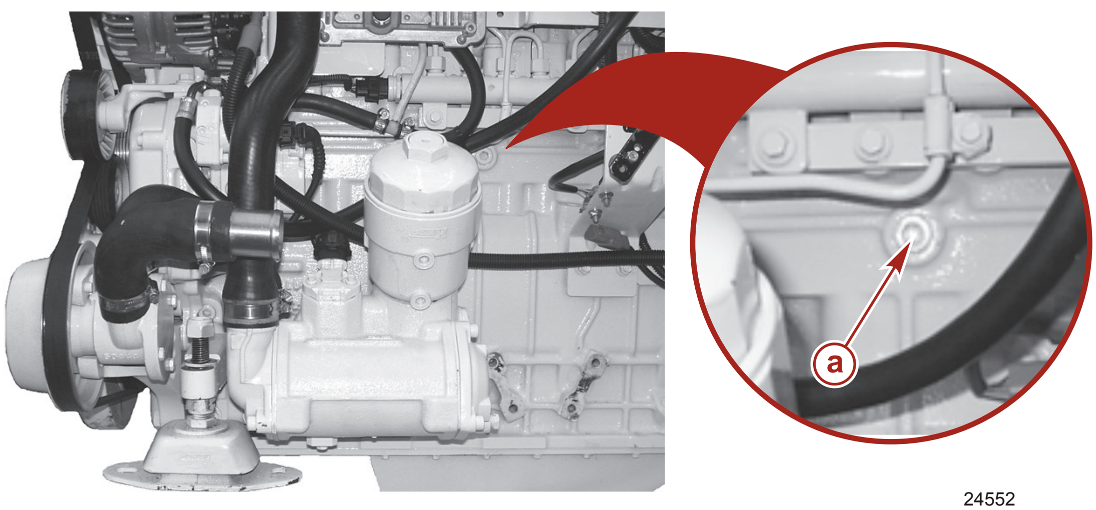
3. Remove the intake and exhaust manifold drain plug.
4. Remove the heat exchanger drain plug.



4.2 shown, 2.8 similar

a - Intake and exhaust manifold drain plug
b - Fluid cooler drain plug

5. Open the engine block drain plug.



4.2 shown, 2.8 similar

a - Engine block drain plug

6. After the coolant has drained completely, install the intake and exhaust manifold drain plug, the heat exchanger drain plug, and the engine block drain plug. Tighten all drain plugs securely.

7. If required, clean the closed cooling system. See **Cleaning the Closed Cooling System**.
8. Fill the system with the specified coolant. See **Filling**.

Cleaning the Closed Cooling System

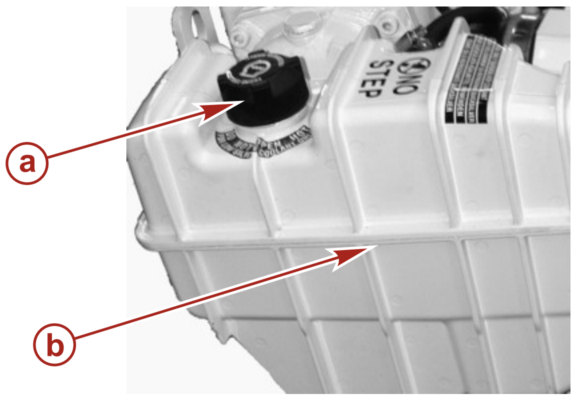
The closed cooling section of the cooling system should be cleaned at least once every two years or whenever decreased cooling efficiency is experienced.

Use a high-grade automotive cooling system cleaner to remove closed cooling system deposits. Follow the manufacturer's instructions.

If the closed cooling section is extremely dirty, use a pressure flushing device to flush out any remaining deposits. Flushing should be done in the direction opposite normal coolant flow to allow water to get behind deposits and force them out. For proper hookup and flushing procedures refer to the instructions that accompany the flushing device.

Filling the Closed Cooling System

1. Remove the pressure cap.



23302

a - Pressure cap **b -** Coolant expansion tank

IMPORTANT: Use only the specified coolant.

2. If the coolant is being replaced or the level is low, slowly add the specified coolant to the level indicated in the table.

Coolant level in expansion tank	
All models	Within 25 mm (1 in.) of the bottom of the filler neck, or between the upper and lower marks, if marked

Tube Ref No.	Description	Where Used	Part No.
123	Marine Engine Coolant (Only available in Europe)	Closed cooling system	92-813054A2
	Fleetguard Compleat with DCA4, Fleetguard Part Number CC2825	Closed cooling system	Obtain Locally

NOTICE

Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

3. Ensure that the seawater pickup pump is supplied cooling water.

4. Do not install the pressure cap. Start and operate the engine at fast idle (1500–1800 RPM). Add coolant if necessary to maintain the coolant at the level specified previously.

IMPORTANT: When installing the pressure cap, be sure to tighten it securely to avoid coolant loss.

5. Install the pressure cap after the engine has reached normal operating temperature (with the thermostat fully open) and the coolant level remains constant.
6. Test the engine operation. Observe the temperature gauge and check the engine for coolant leaks. If the temperature gauge indicates the presence of excessive temperature or coolant is leaking, stop the engine immediately and inspect for the cause.
7. After the first operation, allow the engine to cool.
8. Remove the pressure cap and add the specified coolant to the level indicated in the table.

Coolant level in expansion tank	
All models	Within 25 mm (1 in.) of the bottom of the filler neck, or between the upper and lower marks, if marked

9. Install and securely tighten the pressure cap.

Battery

NOTE: Refer to the manufacturer's instructions.

1. Ensure that the battery connections are secure.
2. Check the fluid level.

Fuel System

General Information

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

⚠ WARNING

Fuel leakage is a fire or explosion hazard, which can cause serious injury or death. Periodically inspect all fuel system components for leaks, softening, hardening, swelling, or corrosion, particularly after storage. Any sign of leakage or deterioration requires replacement before further engine operation.

⚠ WARNING

Failure to comply with regulations can result in injury from fire or explosion. Electrical system components on this engine are not rated as external ignition–protected (EIP). Do not store or use gasoline on boats equipped with these engines, unless provisions have been made to exclude gasoline vapors from the engine compartment (REF: 33 CFR).

IMPORTANT: Use of improper or water-contaminated diesel fuel can cause serious engine damage. Use of improper fuel is considered misuse of the engine, and the resulting damage will not be covered by warranty.

⚠ WARNING

This engine requires diesel fuel. Mixing gasoline, gasohol, or alcohol and diesel fuel can cause serious injury or death due to fire or explosion. Never mix gasoline, gasohol, or alcohol with diesel fuel.

Grade 2-D diesel fuel is required. It must meet ASTM Standards D975 (or fuel rated Diesel DIN 51601), and have a minimum cetane rating of 45. The cetane number is a measure of the ignition quality of diesel fuel. Increasing the cetane number will not improve overall engine performance, but it may be necessary to raise the cetane rating for low-temperature or high-altitude use. A lower cetane number could cause hard starting and slower warm-up and could increase engine noise and exhaust emissions.

NOTE: *If your engine suddenly becomes noisy after a fill-up, you may have received substandard fuel with a low cetane rating.*

The maximum sulphur content of Grade 2-D diesel fuel is rated at 0.50% by weight (ASTM). Limits may vary outside of the United States. On intermittent-use engines, diesel fuel with a high sulphur content will greatly increase the following problems:

- Corrosion on metal parts.
- Deterioration of elastomer and plastic parts.
- Corrosion, extensive damage, and excessive wear of internal engine parts, particularly bearings.
- Difficulty in starting and operating the engine.

Diesel Fuel in Cold Weather

Unaltered diesel fuels thicken and gel in cold temperatures unless they are treated. Virtually all diesel fuels are climatized to allow their use in a particular region for that time of the year. If it becomes necessary to treat the diesel fuel further, it is the owner's and operator's responsibility to add a commercial standard brand anti-gel diesel fuel additive according to product directions.

Water-Separating Fuel Filter

⚠ WARNING

Fuel is flammable and explosive. Ensure the key switch is off and the lanyard is positioned so that the engine cannot start. Do not smoke or allow sources of spark or open flame in the area while servicing. Keep the work area well ventilated and avoid prolonged exposure to vapors. Always check for leaks before attempting to start the engine and wipe up any spilled fuel immediately.

NOTICE

Water entering the fuel injection system will cause corrosion and rusting of the injectors and other components, disabling the fuel injection system. Check daily for water in the water-separating fuel filter and have the engine inspected immediately if there is evidence of water in the fuel system.

IMPORTANT: Use a suitable container to collect fuel. Clean up any spills immediately and dispose of fuel in a safe manner in accordance with all local, federal, and international regulations.

The engine-mounted water-separating fuel filter is equipped with a water-in-fuel (WIF) sensor. A fault code will be set in the ECM if the WIF sensor detects water in the fuel. Depending upon the boat instrumentation package, this information may also be displayed on SmartCraft System series master gauges. Replace the fuel filter at the intervals specified in the maintenance schedule or whenever water is detected in the fuel, whichever occurs first.

See **Maintenance Schedule**.

See **Section 4C, Instrumentation**.

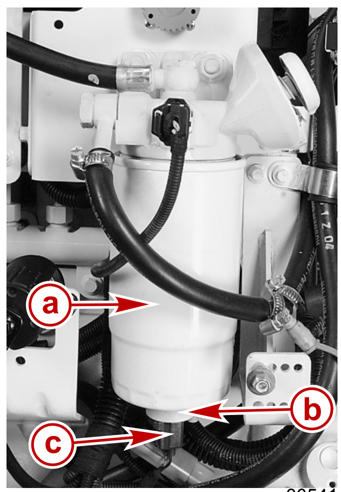
Draining

The engine-mounted water-separating fuel filter can be drained of water and small dirt particles by opening the drain cap on the bottom of the filter.

NOTE: *To ensure complete drainage in warm weather, drain the filter before starting daily operations. In cold weather, where there is a possibility that the condensed water will freeze, drain the filter shortly after the end of daily operations.*

NOTE: *Place a suitable container under the fuel filter to catch contaminated fuel or water and dispose of it properly.*

1. Place a container under the drain cap on the filter.
2. Open the drain by turning the drain cap counterclockwise (as viewed from the bottom of the filter) until fuel starts to drain. Do not remove the drain cap.



30541

a - Filter
b - Drain cap
c - WIF sensor wire connection

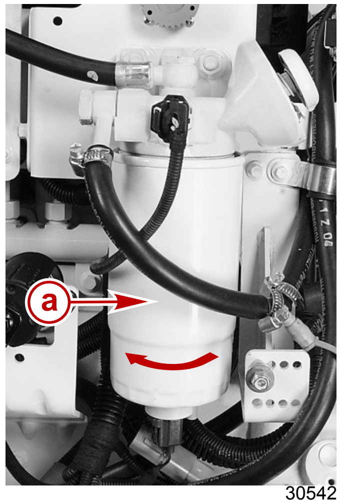
3. Drain until the fuel is clear in appearance.
4. Close the drain cap by turning it clockwise. Tighten it securely.
5. Fill the fuel filter. See **Filling**.

Replacing

⚠ WARNING
Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

IMPORTANT: The element cannot be cleaned and reused. It must be replaced.

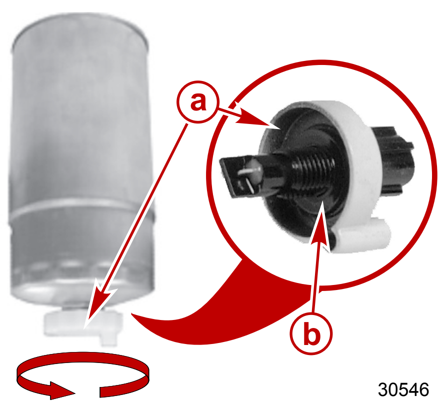
1. Disconnect both battery cables from the battery.
2. Disconnect the Water in Fuel (WIF) sensor wires, if equipped.
3. Remove the water-separating fuel filter and sealing ring from the mounting bracket. Do not use a filter wrench.



a - Water-separating fuel filter

NOTE: *Retain and reuse the existing WIF sensor (filter drain). Replace the O-ring on the WIF sensor (filter drain).*

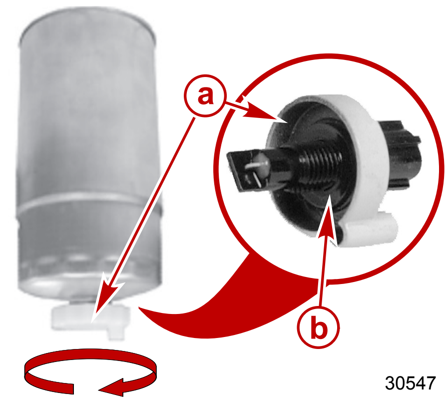
4. Remove the WIF sensor and O-ring seal from the bottom of the existing fuel filter. Note the position of the O-ring seal.



a - WIF sensor
b - O-ring seal

5. Discard the used filter and O-ring seal as defined by local authorities.

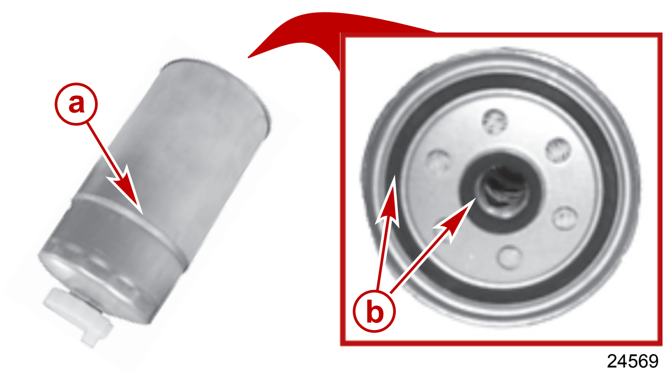
6. Install the WIF sensor with a new O-ring on the new water-separating fuel filter.



a - WIF sensor
b - O-ring seal

Description	Nm	lb–in.	lb–ft
Water in fuel sensor (filter drain)	2.5	–	22

7. Lubricate the fuel filter seals.

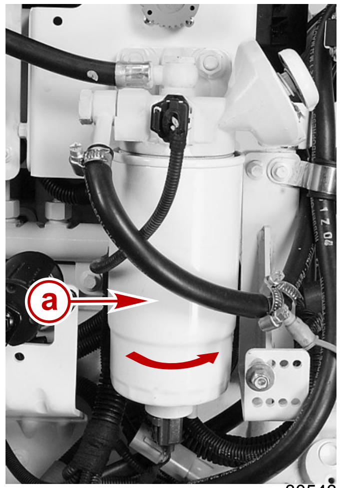


Typical

a - Water-separating fuel filter
b - Seals

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Water-separating fuel filter sealing ring	Obtain Locally

8. Align the filter to the bracket. Tighten the filter by hand in the direction shown to secure the filter to the bracket. Do not use a filter wrench.



a - Water-separating fuel filter

9. Ensure that the drain cap is securely tightened.
10. Connect the WIF sensor wires.
11. Fill the water-separating fuel filter with fuel. See **Filling**.
12. Check the filter and drain cap for fuel leaks.
13. Connect the battery cables.
14. Start and operate the engine. Check the filter connection for fuel leaks. If leaks exist, recheck filter installation. If leaks continue, stop the engine immediately and contact your Cummins MerCruiser Diesel Authorized Repair Facility.

Filling

A type of hand pump and primer plunger is located on the fuel filter bracket. Use it to:

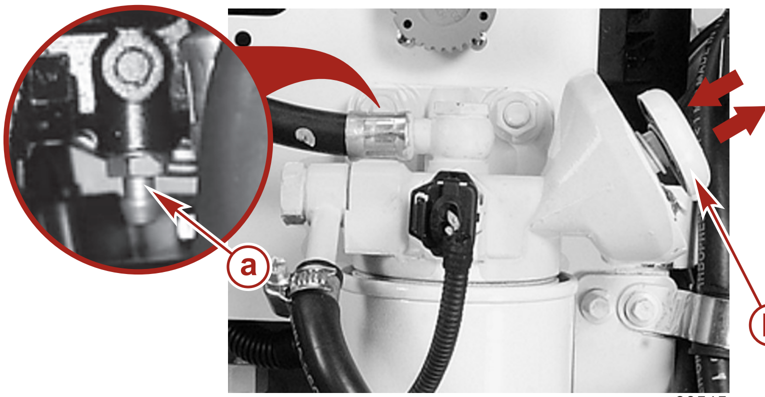
- Refill the fuel filter when draining or changing the filter.
- Refill the fuel system on the engine if the system was run dry.
- Prime the fuel system if the engine has not been run for an extended period.

IMPORTANT: To ensure that unfiltered fuel does not get into the fuel system, use only the hand pump and primer plunger to fill the fuel filter.

NOTE: Follow this procedure after installing a new filter or if the fuel has been drained from the filter while checking for water.

1. Loosen the air vent (bleed) screw on the fuel filter bracket.

2. Move the primer plunger up and down repeatedly. The filter is full when an air-free stream of fuel flows from the air vent screw.



30545

a - Air vent screw
b - Primer plunger

3. Securely tighten the air vent screw.

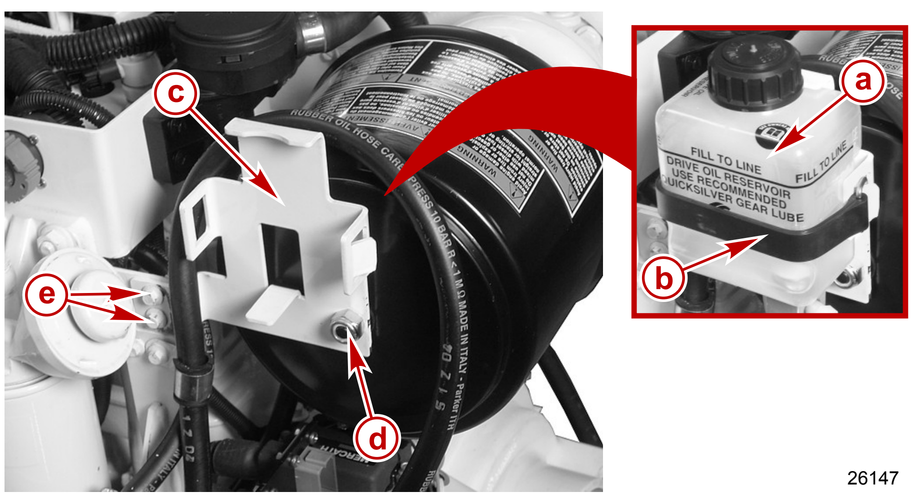
2.8 Air Filter

Removal

IMPORTANT: Keep gear lube monitor bottle in an upright position to prevent fluid from spilling.

NOTE: It is not necessary to drain the gear lube monitor to perform this procedure.

1. Remove the gear lube monitor retaining strap and remove the gear lube monitor from the bracket and set aside.
2. Remove the air filter cover retaining nut from the gear lube monitor bracket on the air filter.
3. Remove the gear lube monitor bracket.



26147

a - Gear lube monitor
b - Gear lube monitor retaining strap
c - Gear lube monitor bracket
d - Air filter cover retaining nut
e - Gear lube monitor bracket retaining bolts

4. Remove the air filter cover.

NOTE: It is not necessary to remove the air filter bracket mounted on the turbocharger inlet.

5. Remove the air filter cartridge from the air filter bracket mounted on the turbocharger inlet.

12618

Shown removed from the engine for clarity only

a - Air filter cartridge **b -** Air filter bracket

Inspection

1. The air filter cannot be cleaned. Replace the air filter if it is dirty or contaminated.
2. Replace the air filter if the foam element is deteriorated or torn.
3. Replace the air filter at the recommended interval. See **Maintenance Schedules** for the replacement interval under normal conditions.

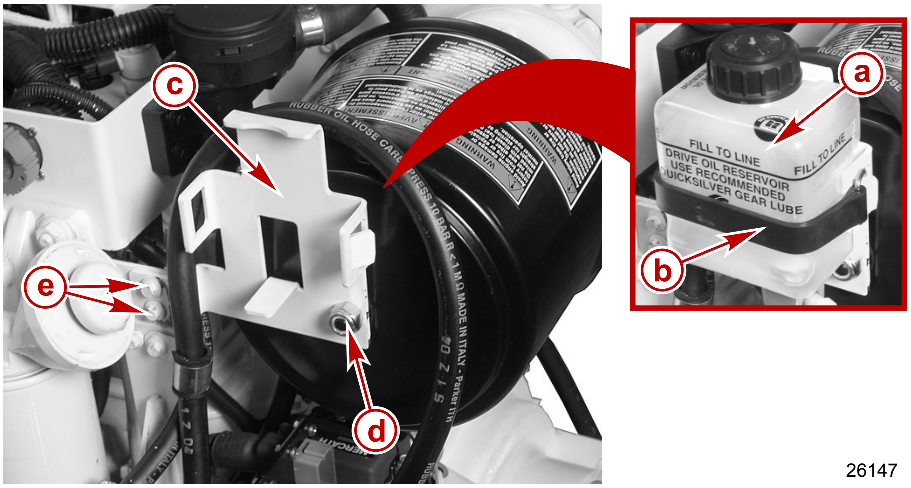
Installation

IMPORTANT: Treatment such as partial oil saturation is not required and is not recommended on the foam element before use. The foam element must be clean and dry for proper filtration.

1. Install the air filter cartridge onto the air filter bracket.
2. Install the air filter cover, gear lube monitor bracket, and nuts.
3. Torque the air filter cover retaining nut and gear lube monitor bracket nuts.

Description	Nm	lb. in.	lb. ft.
Air filter cover retaining nut	10.8	95	
Gear lube monitor bracket nuts	11		8

4. Install the gear lube monitor in the bracket and hold in place with the retaining strap.



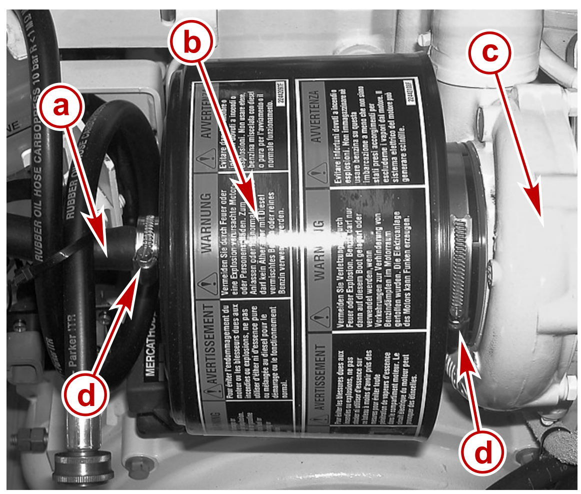
26147

a - Gear lube monitor
b - Gear lube monitor retaining strap
c - Gear lube monitor bracket
d - Air filter cover retaining nut
e - Gear lube monitor bracket retaining bolts

4.2 Air Filter

Removal

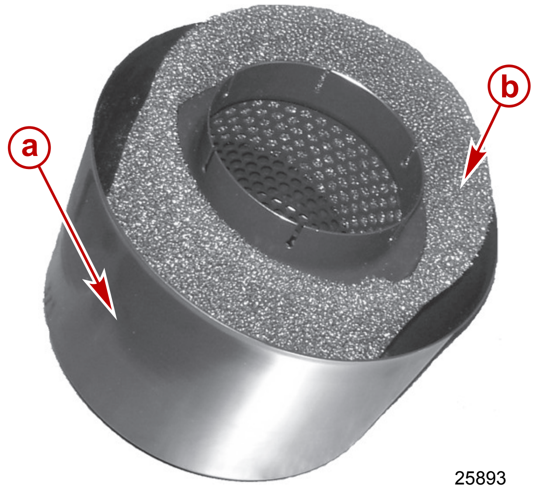
1. Loosen the clamp and remove the oil separator vent hose.
2. Loosen the clamp and remove the air filter housing from the turbocharger inlet.



25881

a - Oil separator vent hose
b - Air filter housing
c - Turbocharger
d - Clamp

3. Remove the air filter element from the air filter housing



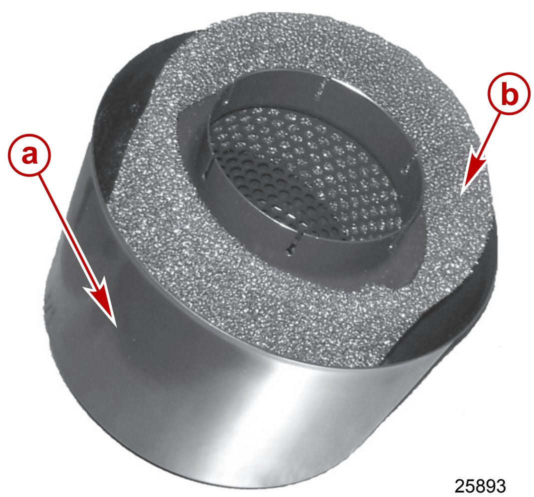
a - Air filter housing	**b -** Air filter element

Inspection

1. The air filter cannot be cleaned. Replace the air filter if it is dirty or contaminated.
2. Replace the air filter if the foam element is deteriorated or torn.
3. Replace the air filter at the recommended interval. See **Maintenance Schedules** for the replacement interval under normal conditions.

Installation

1. Slide the filter element into the air filter housing. Ensure that the element is seated fully into the air filter housing.



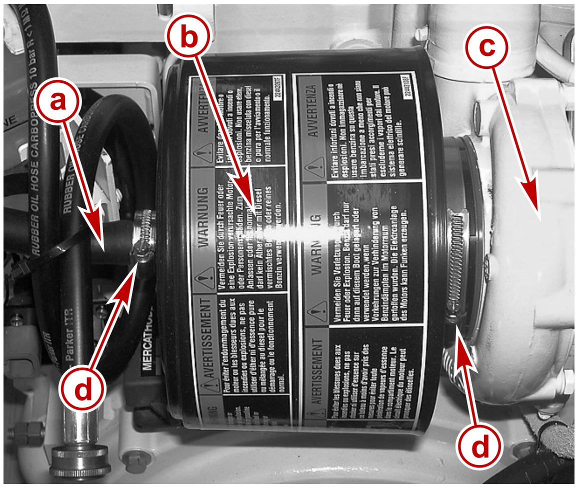
a - Air filter housing	**b -** Air filter element

***NOTE:** The warning labels on the air filter housing must be visible after the air filter housing is installed.*

2. Install the air filter housing on to the turbocharger inlet.
3. Torque the air filter housing clamp.

Description	Nm	lb. in.	lb. ft.
Air filter housing clamp	3.4–6.8	30–60	

4. Install the oil separator vent house. Tighten the oil separator vent hose clamp securely.



25881

a - Oil separator vent hose
b - Air filter housing
c - Turbocharger
d - Clamp

Seawater System

Draining the Seawater System

⚠ CAUTION

Water can enter the bilge when the drain system is open, damaging the engine or causing the boat to sink. Remove the boat from the water or close the seacock, disconnect and plug the seawater inlet hose, and ensure the bilge pump is operational before draining. Do not operate the engine with the drain system open.

IMPORTANT: The engine must be as level as possible to ensure complete draining of the cooling system.

Drain the seawater system of the power package before cold weather (freezing temperature), seasonal storage, or extended storage.

IMPORTANT: The boat must not be operating during this procedure.

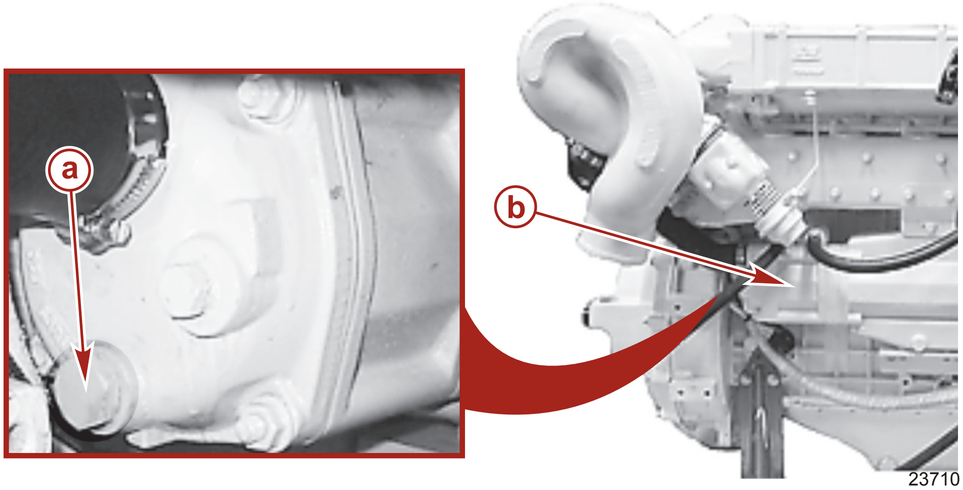
⚠ CAUTION

Water can enter the bilge when the drain system is open, damaging the engine or causing the boat to sink. Remove the boat from the water or close the seacock, disconnect and plug the seawater inlet hose, and ensure the bilge pump is operational before draining. Do not operate the engine with the drain system open.

1. Remove the boat from the water if possible.
2. **If the boat is to remain in the water**, turn on the bilge pump, close the seacock (if equipped), or disconnect and plug the seawater inlet hose.
3. Make the engine as level as possible to ensure complete draining of the seawater system.

NOTE: The anode assembly on the back of the fluid cooler can be used as a drain plug.

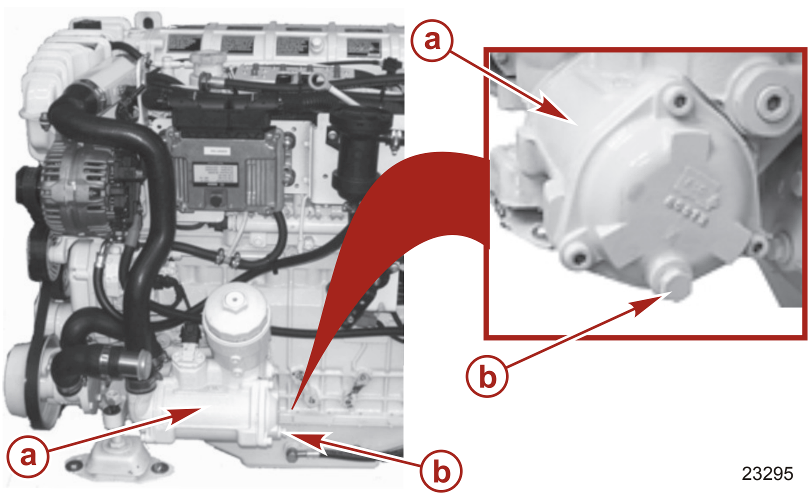
4. Remove the drain plug from the aft end cover of the fluid cooler.



Typical engine

a - Anode assembly drain plug **b -** Fluid cooler

5. Remove the drain plug, or fitting (if equipped), from the aft end cover of the engine oil cooler.

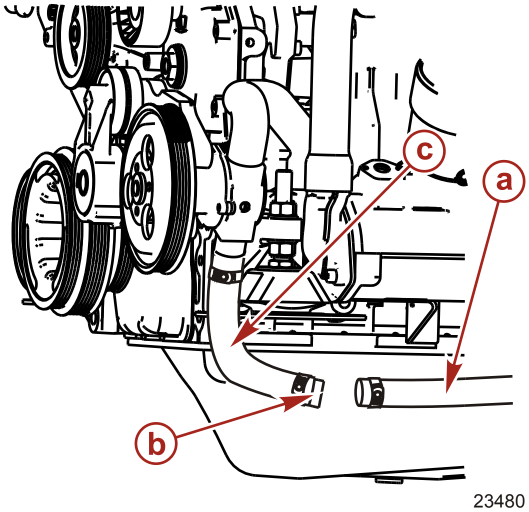


Typical engine

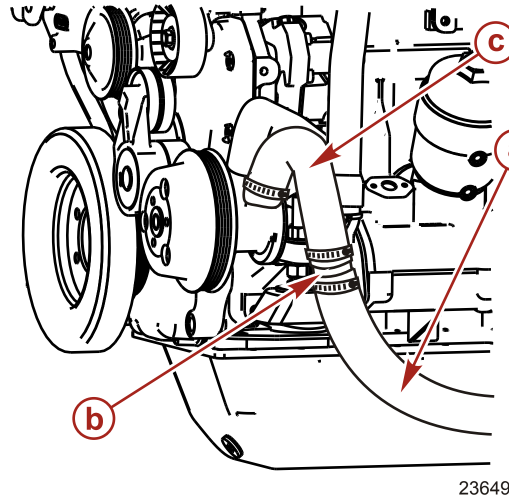
a - Engine oil cooler **b -** Drain plug, or fitting if equipped

NOTE: *In the following steps, the hoses may require lowering or bending to allow seawater to drain completely.*

6. Disconnect the seawater inlet hose from the connector on the seawater pump hose and drain.



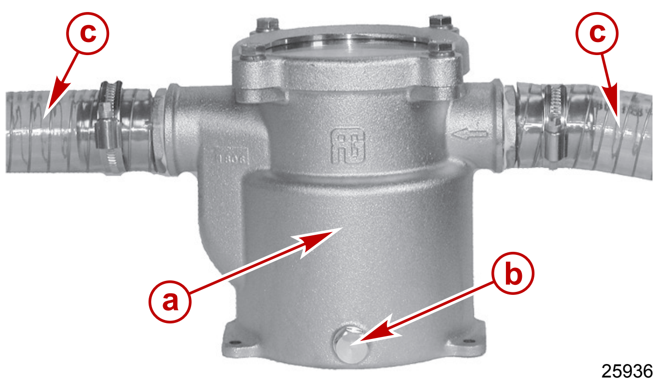
2.8



4.2

a - Seawater inlet hose
b - Connector
c - Seawater pump hose

7. Repeatedly clean out the drain holes using a stiff piece of wire until the seawater section is completely drained.
8. **On models equipped with a seawater strainer**, remove the hose at the seawater strainer and drain the hose completely. Drain and empty the seawater strainer. Reconnect the hose and tighten the hose clamps securely. Install the sealing washer and drain plug.



a - Seawater strainer
b - Sealing washer and drain plug
c - Hose

9. After the seawater has completely drained, apply sealant to the threads of the drain plugs or fittings (if equipped). Install and tighten the drain plugs or fittings securely.

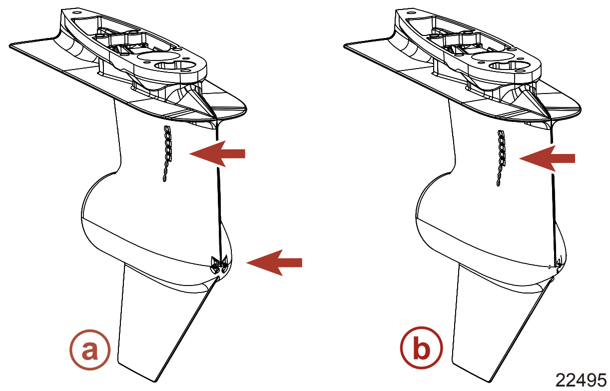
Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Drain plug or fitting threads	92-34227 1

10. Reconnect the hoses. Tighten the hose clamps securely.

Sterndrive Water Inlets Check

1. Obtain a piece of wire the appropriate size to insert into the water inlets holes.

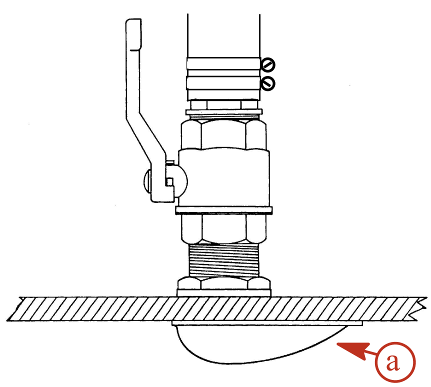
2. Insert the wire in and out of the sterndrive water inlets to ensure that they are open and to remove debris or marine growth. Do not scrape the sterndrive paint.
3. Remove the wire from the sterndrive and retain for periodic water inlet checks.



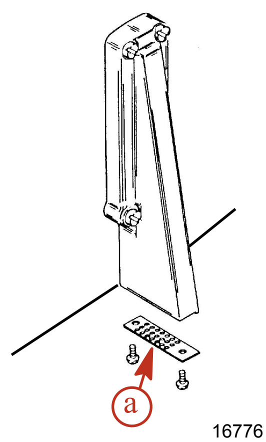
a - Dual water pickup water inlets **b -** Side pickup water inlets

Checking the Seawater Pickups

1. Ensure that the water inlet holes for the seawater pickup are clean and not obstructed.



Typical through-hull seawater pickup



Typical through-transom seawater pickup

a - Water inlet holes

Cleaning the Seawater Strainer, if Equipped

NOTICE
An open seawater strainer or seacock during some service or maintenance procedures can introduce water into the boat, causing damage or sinking the boat. Always close the water supply from the seawater pump, water inlet, or seacock when performing service or maintenance on the cooling system.

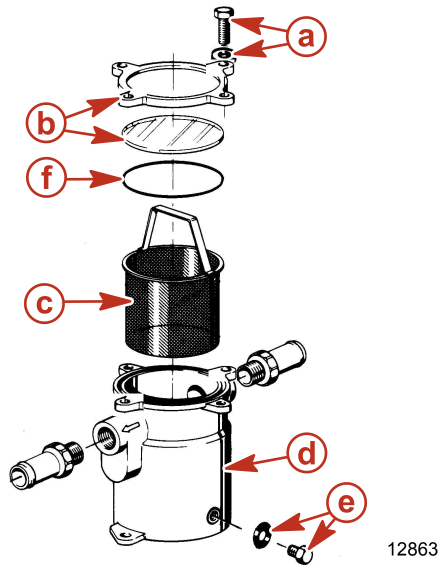
1. With the engine off, close the seacock, if equipped, or remove and plug the seawater inlet hose.
2. Remove the screws, washers, and cover.
3. Remove the strainer, drain plug, and sealing washer.
4. Clean all the debris from the strainer housing. Flush both the strainer and housing with clean water.
5. Check the cover gasket and replace when damaged or if it leaks.

6. Reinstall the strainer, drain plug, and sealing washer.

⚠ CAUTION

Seawater leaking from the seawater strainer could cause excess water in the bilge, damaging the engine or causing the boat to sink. Do not overtighten the cover screws, or the cover may warp and introduce seawater into the bilge.

7. Install the seal and cover using the screws and washers. Do not overtighten the cover screws.



a - Screws and washers
b - Cover with glass
c - Strainer
d - Housing
e - Drain plug and sealing washer
f - Seal

8. Open the seacock, if equipped, or remove the plug and reconnect the seawater inlet hose.
9. Upon first starting the engine, check for leaks or air in the system that would indicate an external leak.

Flushing the Seawater System—Sterndrive Models

Flushing the seawater system with fresh water is needed only for applications operating in saltwater, brackish water, polluted water, or water with a high mineral content to avoid salt or silt buildup. For best results we recommend flushing the seawater system after each outing. After each operation in saltwater and before storage, the seawater cooling system must be flushed.

WITH THE BOAT OUT OF THE WATER

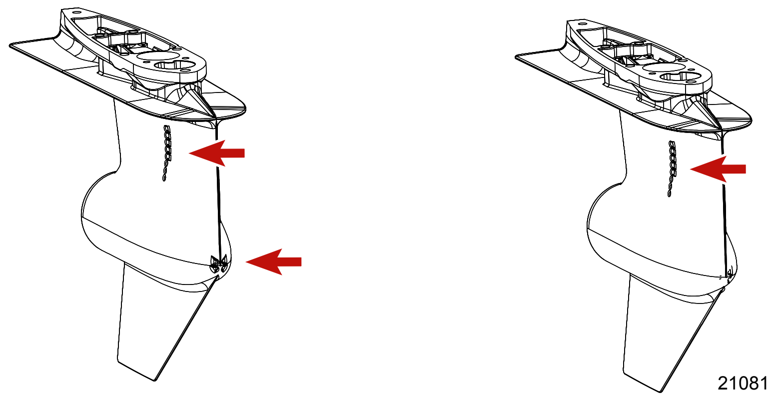
1. Lower the sterndrive to the full down (in) position.

⚠ WARNING

Rotating propellers can cause serious injury or death. Never operate the boat out of the water with a propeller installed. Before installing or removing a propeller, place the drive unit in neutral and engage the lanyard stop switch to prevent the engine from starting. Place a block of wood between the propeller blade and the anti-ventilation plate.

2. Remove the propeller. See **Propellers**.

3. Install the appropriate flushing attachment over the water inlet holes in the gear housing.

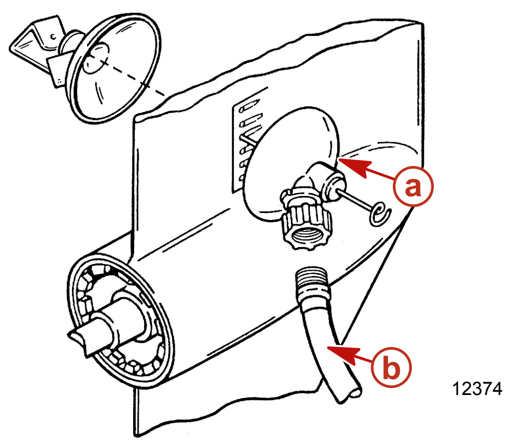


Dual water pickup **Side pickup**

Dual Water Pick-up Flush Gearcase Seal Kit	91-881150K 1

Side Water Pickup Flushing Device	91-44357Q 2

4. Connect a flushing hose from a water tap to the flushing attachment.

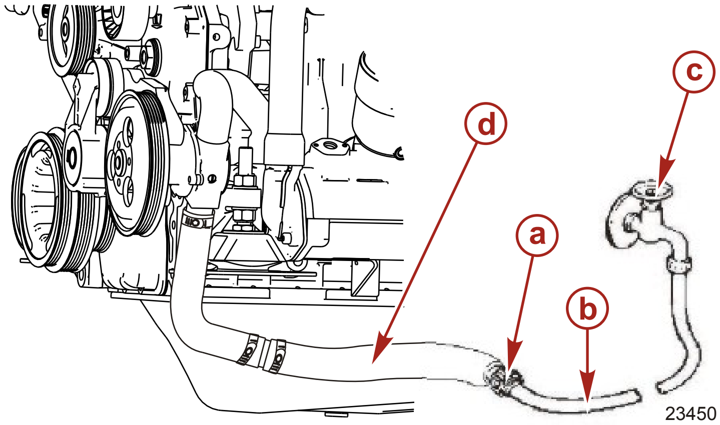


Typical

a - Flushing attachment
b - Hose

IMPORTANT: Engines with the sterndrive water inlet blocked off at the gimbal housing and using a through-hull or through-transom water inlet need a supply of cooling water available to both the sterndrive and to the engine during operation.

5. **If your power package uses a through-hull or through-transom pickup**, connect a second flushing hose from a water tap to the seawater inlet hose connected to the seawater pump inlet using an appropriate adapter.



2.8 shown, 4.2 similar

a - Adapter
b - Flushing hose
c - Water tap
d - Seawater inlet hose

6. Partially open the water source to about 1/2 maximum. Do not use full water pressure.
7. Place the remote control in neutral, idle speed position and start the engine.

NOTICE
Operating the engine out of the water at high speeds creates suction, which can collapse the water supply hose and overheat the engine. Do not operate the engine above 1400 RPM out of the water and without sufficient cooling water supply.

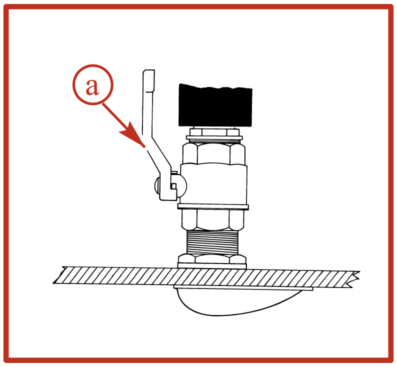
8. Operate the engine at idle speed in neutral for about ten minutes or until the discharge water is clear.
9. Observe the water temperature gauge to ensure that the engine is operating in the normal range.
10. Stop the engine.
11. Shut off the water tap.
12. Remove the sterndrive flushing attachment.
13. **If your power package uses a through-hull pickup**,
    a. Remove the adapter from the seawater pump inlet hose connection.
    b. Reconnect the seawater inlet hose. Tighten the hose clamps securely.

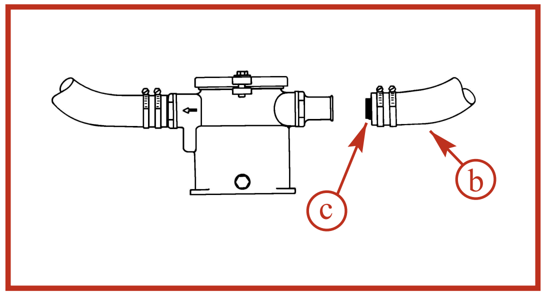
WITH THE BOAT IN THE WATER

NOTICE

Disconnecting the seawater inlet hose will cause water to enter the bilge resulting in engine damage. Close the seacock before disconnecting the seawater inlet hose. Plug the seawater inlet hose immediately after disconnecting it.

1. Close the seacock, if equipped, or disconnect and plug the seawater inlet hose.

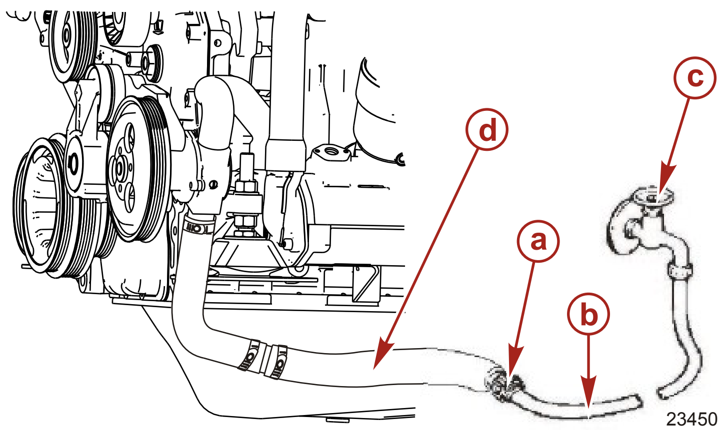




13171

a - Seacock
b - Seawater inlet hose
c - Plug

2. Using an appropriate adapter, connect a flushing hose from a water tap to the seawater inlet hose connected to the seawater pump inlet.



2.8 shown, 4.2 similar

a - Adapter
b - Flushing hose
c - Water tap
d - Seawater inlet hose

3. Lower the sterndrive to the full down (in) position.
4. Partially open the water source to about 1/2 maximum. Do not use full water pressure.

5. Place the remote control in neutral, idle speed position and start the engine.

NOTICE

Operating the engine out of the water at high speeds creates suction, which can collapse the water supply hose and overheat the engine. Do not operate the engine above 1400 RPM out of the water and without sufficient cooling water supply.

6. Operate the engine at idle speed in neutral for about ten minutes or until the discharge water is clear.
7. Observe the water temperature gauge to ensure that the engine is operating in the normal range.
8. Stop the engine.
9. Shut off the water tap.
10. Remove the adapter from the seawater pump inlet hose connection.
11. Do not open the seacock or reconnect the water inlet hose at this time to prevent water from siphoning into the boat or engine.
12. Place an appropriate tag on the key switch stating that the seacock must be opened or the seawater inlet hose must be reconnected before operating the engine.

Flushing the Seawater System—Inboard Models

Flushing the seawater system with fresh water is needed only for applications operating in saltwater, brackish water, polluted water, or water with a high mineral content to avoid salt or silt buildup. For best results we recommend flushing the seawater system after each outing. After each operation in saltwater and before storage, the seawater cooling system must be flushed.

WITH THE BOAT OUT OF THE WATER

NOTICE

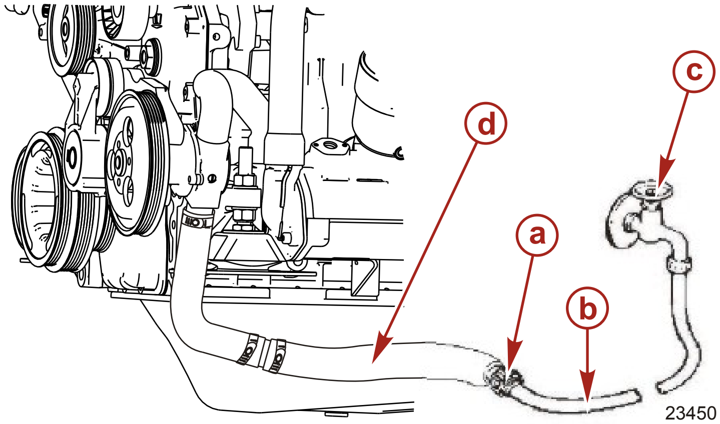
Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

⚠ WARNING

Rotating propellers can cause serious injury or death. Never operate the boat out of the water with a propeller installed. Before installing or removing a propeller, place the drive unit in neutral and engage the lanyard stop switch to prevent the engine from starting. Place a block of wood between the propeller blade and the anti-ventilation plate.

1. Remove the propeller. Refer to the boat manufacturer's instructions.
2. Disconnect the seawater inlet hose from the seawater pickup pump connection.

3. Using an suitable adapter, connect a flushing hose from a water tap to the seawater inlet hose connected to the seawater pump inlet.



2.8 shown, 4.2 similar

a - Adapter
b - Flushing hose
c - Water tap
d - Seawater inlet hose

4. Partially open the water source to about 1/2 maximum. Do not use full water pressure.
5. Place the remote control in the neutral, idle speed position and start the engine.

NOTICE
Operating the engine out of the water at high speeds creates suction, which can collapse the water supply hose and overheat the engine. Do not operate the engine above 1400 RPM out of the water and without sufficient cooling water supply.

6. Operate the engine at idle speed in neutral for about 10 minutes, or until the discharge water is clear.
7. Observe the water temperature gauge to ensure that the engine is operating in the normal range.
8. Stop the engine.
9. Shut off the water tap.
10. Remove the adapter from the seawater pump inlet hose connection.
11. Reconnect the seawater inlet hose. Tighten the hose clamps securely.

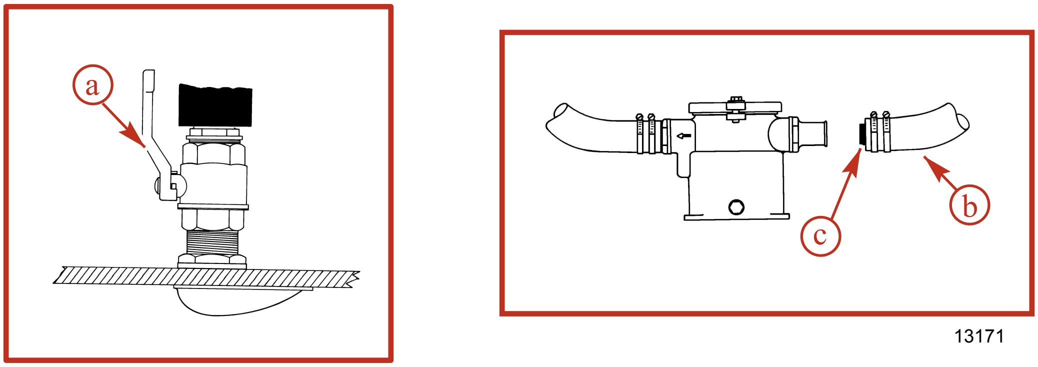
WITH THE BOAT IN THE WATER

NOTICE
Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

NOTICE

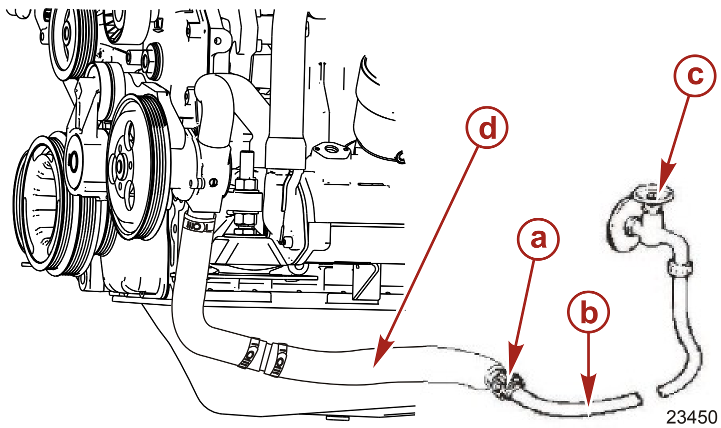
Flushing the engine with the boat in the water can cause seawater to flow into the engine, resulting in engine damage. Close the seacock before flushing the engine. Keep the seacock closed until starting the engine.

1. Close the seacock (if equipped) or disconnect and plug the seawater inlet hose.



a - Seacock
b - Seawater inlet hose
c - Plug

2. Using an suitable adapter, connect a flushing hose from a water tap to the seawater inlet hose connected to the seawater pump inlet.



2.8 shown, 4.2 similar

a - Adapter
b - Flushing hose
c - Water tap
d - Seawater inlet hose

3. Partially open the water source to about 1/2 maximum. Do not use full water pressure.
4. Place the remote control in the neutral, idle speed position and start the engine.

NOTICE

Operating the engine out of the water at high speeds creates suction, which can collapse the water supply hose and overheat the engine. Do not operate the engine above 1400 RPM out of the water and without sufficient cooling water supply.

5. Operate the engine at idle speed in neutral for about 10 minutes, or until the discharge water is clear.
6. Observe the water temperature gauge to ensure that the engine is operating in the normal range.
7. Stop the engine.

8. Shut off the water tap.
9. Remove the adapter from the seawater pump inlet hose connection.
10. To prevent water from siphoning into the boat or engine, do not open the seacock or reconnect the water inlet hose at this time.
11. Place an appropriate tag on the key switch stating that the seacock must be opened or the seawater inlet hose must be reconnected before operating the engine.

Engine Seawater Pump Inspection

Remove and inspect the engine seawater pump at the interval specified in the **Maintenance Schedule**. Refer to **Section 6—Cooling Systems** for seawater pump removal and inspection.

Corrosion Protection

General Information

Whenever two or more dissimilar metals (such as those found on this power package) are submerged in a conductive solution (such as saltwater, polluted water, or water with a high mineral content;) a chemical reaction takes place causing electrical current to flow between metals. The electrical current flow causes the metal that is most chemically active, or anodic, to erode. This erosion is known as *galvanic corrosion* and, if it is not controlled, it will eventually require the replacement of power package components exposed to water.

To help control the effects of galvanic corrosion, Cummins MerCruiser Diesel power packages come with several sacrificial anodes and other corrosion protection devices. For a more comprehensive explanation of corrosion and corrosion protection refer to the **Marine Corrosion Protection Guide**.

IMPORTANT: Replace sacrificial anodes if they are eroded 50% or more. Avoid the use of anodes from another manufacturer.

Engine Corrosion Protection Components

This engine is equipped with a sacrificial anode located on top of the aftercooler end cover to assist in protecting the engine and the seawater cooling system from corrosion. It also contains a second sacrificial anode assembly on the stern end of the fluid cooler.

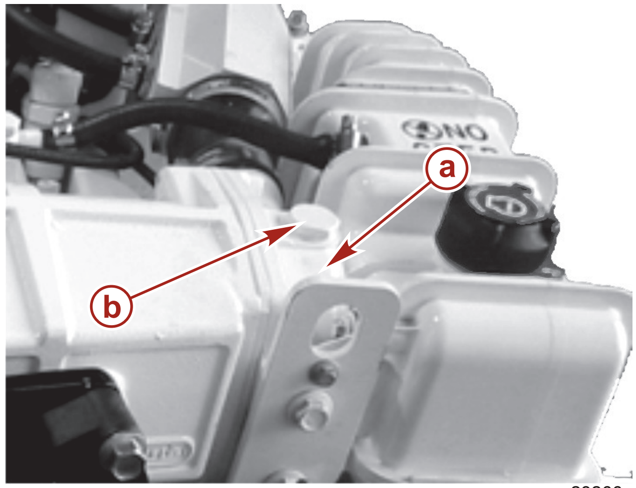
REMOVAL

1. Allow the engine to cool.

NOTICE
Failure to close the seawater inlet or seacock when removing or replacing the anode plugs can lead to water damage. Close the seacock or remove and plug the seawater inlet hose to prevent water from entering the anode plug holes.

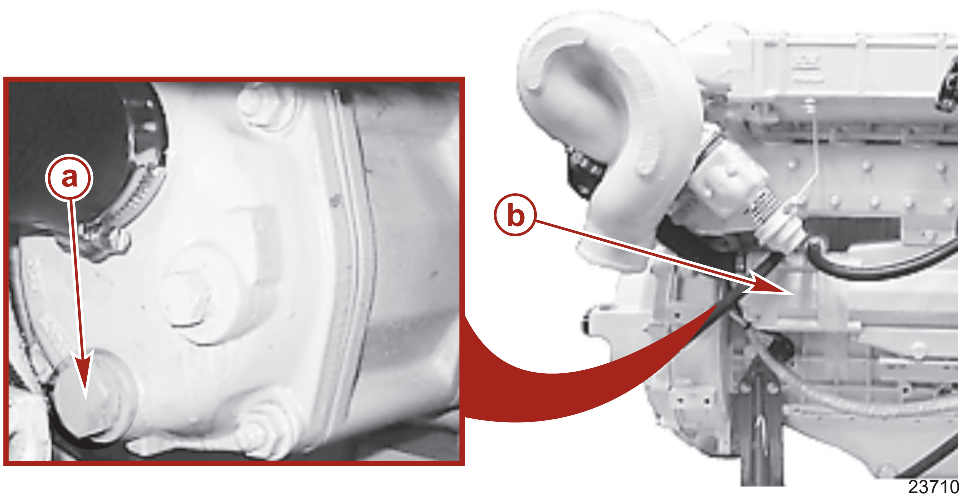
2. With the engine off, close the seacock, if equipped, or remove and plug the seawater inlet hose.
3. Drain the seawater system. See **Draining the Seawater System** .

4. Remove the anode assembly (anode plug and the sacrificial anode) from the top of the aftercooler end cover.



a - Aftercooler end cover **b -** Anode assembly

5. Remove the anode assembly (anode plug and the sacrificial anode) from the aft end of the fluid cooler.



Typical engine

a - Anode assembly **b -** Fluid cooler

CLEANING AND INSPECTION

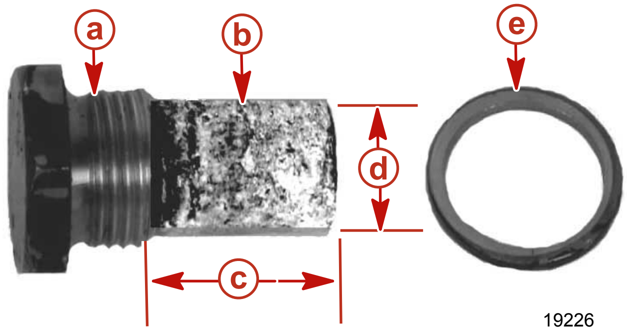
Inspection and replacement interval will vary according to the condition of the seawater and the mode of engine operation.

NOTE: *Using sandpaper, fiber brush, or cleaning pad, remove the deposits from the surface of the anode before trying to determine the amount of erosion. Do not use a mild steel brush, which might leave deposits that could accelerate corrosion.*

1. Remove the deposits.

2. Inspect and measure the anode. Compare the measurements to the specifications for a new sacrificial anode and replace the anode assembly when deteriorated 50%.

NOTE: Sacrificial anodes are available only as an assembly. Replace both the plug and anode as a unit.



Anode assembly

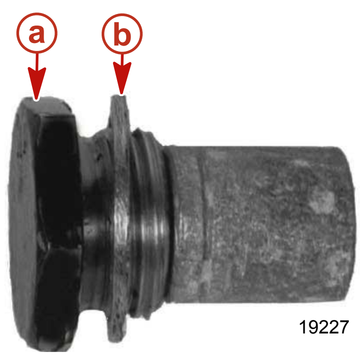
a - Anode plug
b - Sacrificial anode
c - Length
d - Diameter
e - Sealing washer

Sacrificial anode measurements (new)	
Length	19 mm (3/4 in.)
Diameter	16 mm (5/8 in.)

3. Discard the sealing washer.

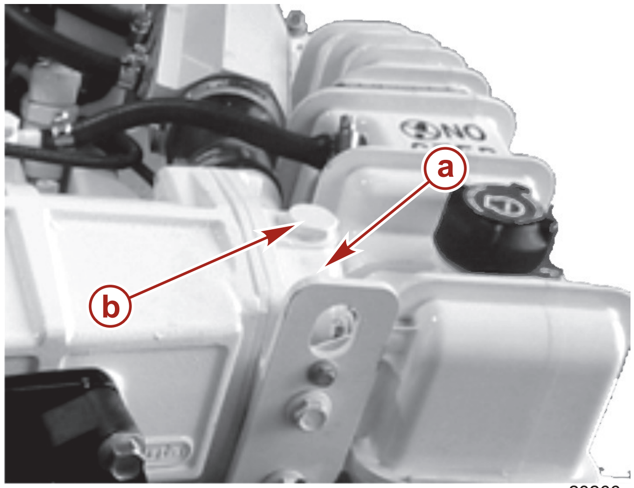
INSTALLATION

1. Install a new sealing washer on the anode assembly (anode plug with the sacrificial anode).



a - Anode assembly
b - Sealing washer

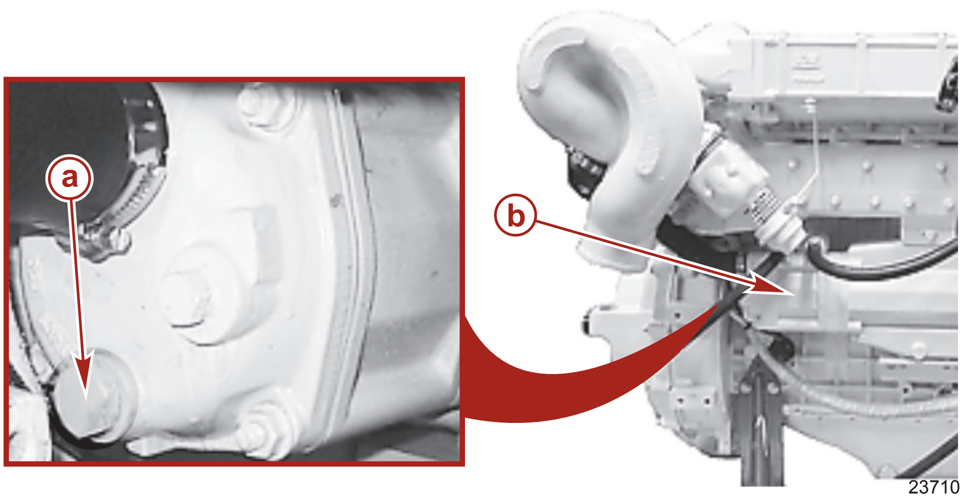
2. Install the anode assembly and washer into the aftercooler end cover. Tighten securely.



a - Aftercooler end cover

b - Anode assembly

3. Install the anode assembly and washer into the aft end of the fluid cooler. Tighten securely.



Typical engine

a - Anode assembly

b - Fluid cooler

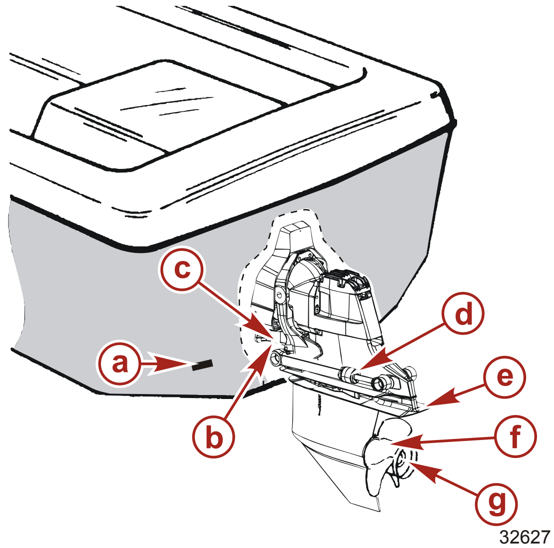
4. Unplug and connect the seawater inlet hose, or open the seacock if equipped.

NOTICE
Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

5. Ensure that the seawater pickup pump is supplied cooling water.
6. Start the engine and check for leaks

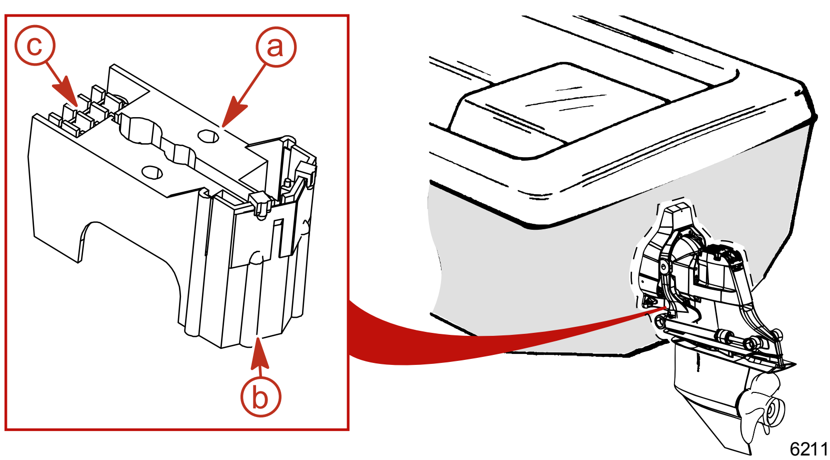
Sterndrive Corrosion Protection Components

To help control the effects of galvanic corrosion, Cummins MerCruiser Diesel sterndrives come with several sacrificial anodes and other corrosion protection devices. For a more comprehensive explanation of corrosion and corrosion protection refer to the **Marine Corrosion Protection Guide** .



a - Anode kit
b - Ventilation plate anode
c - MerCathode System
d - Trim cylinder anodes
e - Gearcase anodic plate
f - Bearing carrier anodes
g - Propshaft Anode (Bravo III standard)

NOTICE
Washing the MerCathode assembly can damage components and lead to rapid corrosion. Do not use any cleaning equipment such as brushes or high-pressure washers to clean the MerCathode assembly.

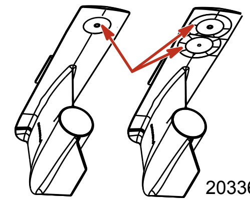
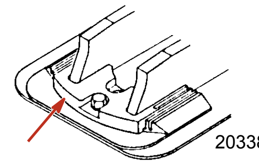
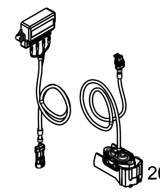
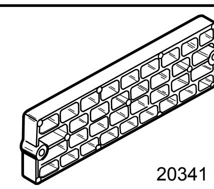
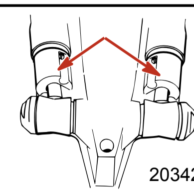
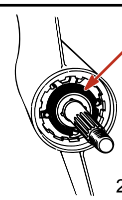
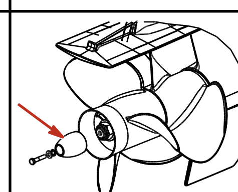


a - MerCathode reference electrode
b - Do not paint
c - Do not pressure wash

IMPORTANT: Replace sacrificial anodes if they are eroded 50% or more.

The following sacrificial anodes are installed at different locations on your power package. These anodes help protect against galvanic corrosion by sacrificing its metal to be slowly eroded instead of the metal components on the power package.

MerCathode System - The electrode assembly replaces the anodic block. The system should be tested to ensure adequate output. The test should be performed where boat is moored, using Quicksilver Reference Electrode and Test Meter. Contact your Cummins MerCruiser Diesel Authorized Repair Facility.

Description	Location	Figure
Gearcase anodic plate	Mounted on the underside of the lower gearcase.	 20336
Ventilation plate anode	Mounted on the front of the gearcase.	 20338
MerCathode System	The MerCathode electrode is mounted to the underside of the gimbal housing. The MerCathode controller is mounted on the engine or on the boat transom. The controller harness connects to the electrode harness.	 20340
Anode kit (if equipped)	Mounted to the boat transom.	 20341
Trim cylinder anodes	Mounted on each of the trim cylinders.	 20342
Bearing carrier anode (Bravo One)	Located in front of the propeller, between the front side of the propeller and the gear housing.	 20343
Prop shaft anode (Bravo Three)	Located behind the aft propeller.	 20344

In addition to the corrosion protection devices, take the following steps to inhibit corrosion.

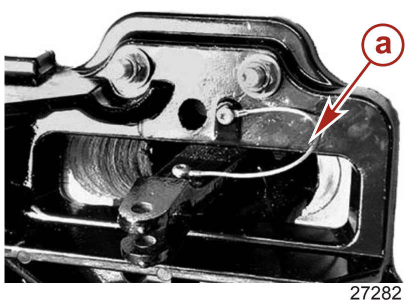
1. Paint the power package. See **Painting Your Power Package**.

2. Annually spray the power package components on the inside of the boat with Corrosion Guard to protect the finish from dulling and corrosion. You may also spray external power package components.
3. Keep all lubrication points, especially the steering system, shift and throttle linkages, well lubricated.
4. Flush the cooling system periodically, preferably after each use.

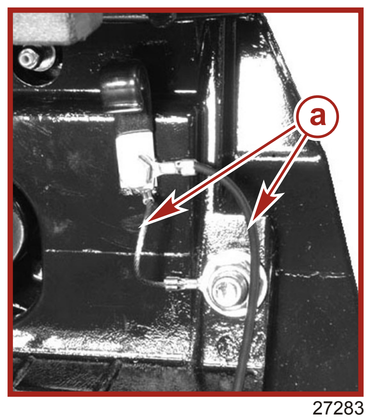
Continuity Circuit—Bravo Sterndrive

The transom assembly and sterndrive have ground-circuit wires to ensure good electrical continuity between the engine, transom assembly, and sterndrive components. Good continuity to a ground is essential for the anode and MerCathode system to function effectively.

1. Inspect the steering lever ground wire for loose connections, broken connectors, or frayed wiring.
2. Inspect the inner transom plate ground wire for loose connections, broken connectors, or frayed wiring.



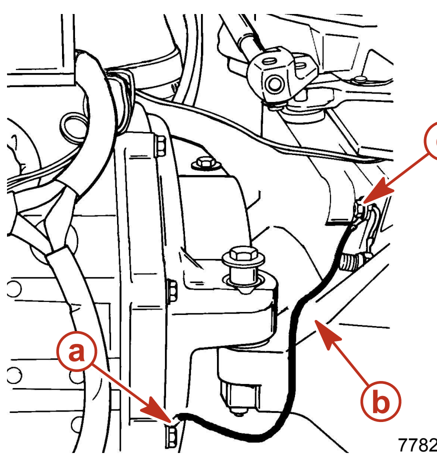
Steering lever continuity wire



Transom plate continuity wires

a - Continuity wire

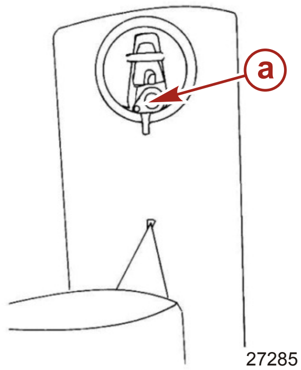
3. Inspect the flywheel housing grounding stud and ground wire, and the inner transom plate grounding screw for loose connections, broken connectors, or frayed wiring.



Typical

a - Flywheel housing screw or grounding stud
b - Continuity circuit (ground) wire
c - Inner transom plate grounding screw

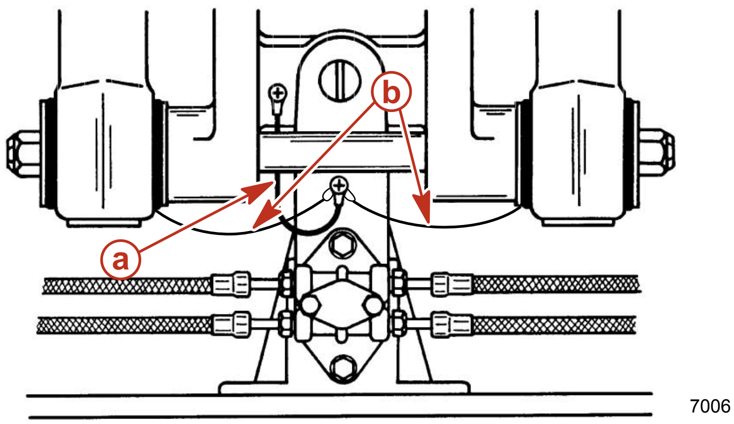
4. Inspect the driveshaft housing–to–gear housing ground plate inside the anode cavity for a loose or faulty connection.



Sterndrive anodic plate cavity

a - Ground plate (inside anode cavity)

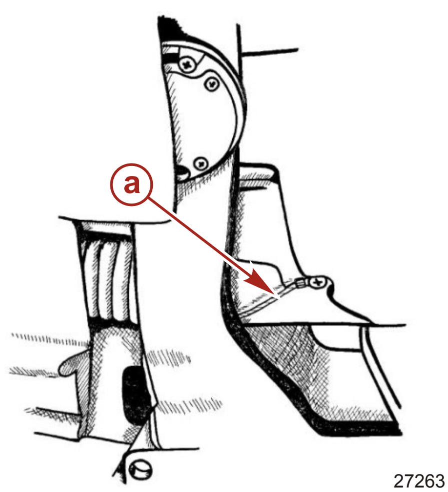
5. Inspect the gimbal housing ground wires for loose connections, broken connectors, or frayed wiring.



a - Gimbal housing–to–gimbal ring ground wire

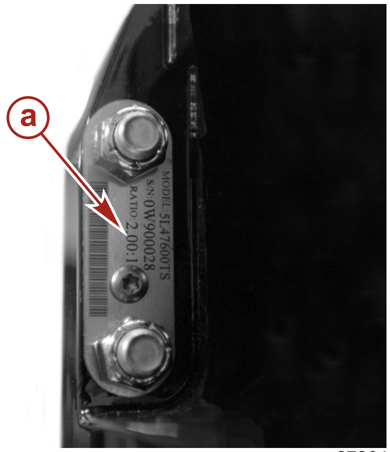
b - Gimbal housing–to–trim cylinder ground wires

6. Inspect the gimbal ring ground wire for loose connections, broken connectors, or frayed wiring.



a - Gimbal ring-to-bell housing ground wire

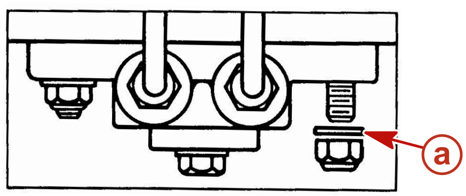
7. Inspect the sterndrive ground plate for loose or broken connections.



27264

a - Sterndrive-to-bell housing ground plate

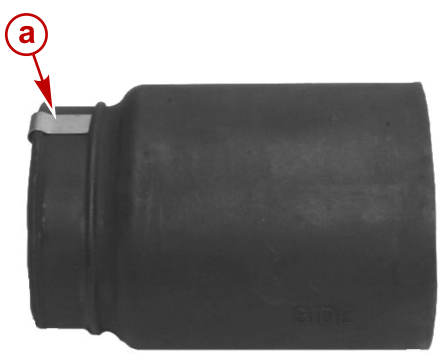
8. Inspect the continuity washers under the hydraulic manifold block fasteners for a loose or faulty connection .



9957

a - Continuity washers

9. Inspect the sterndrive U-joint bellows ground clips and exhaust tube ground clip for loose or faulty connections.



19627

Exhaust tube ground clip shown, U-joint bellows ground clips similar

a - Exhaust tube ground clip

MerCathode

If the boat is equipped with a Quicksilver MerCathode system, the system should be tested to ensure that it is providing adequate output to protect the underwater metal parts on the boat. The test should be made where the boat is moored, using a Quicksilver Reference Electrode and Test Meter.

Reference Electrode	91-76675T 1

Refer to the appropriate Mercury MerCruiser Sterndrive Service Manual for testing procedures.

Boat Bottom Care

To achieve maximum performance and fuel economy, the boat bottom must be kept clean. Accumulation of marine growth or other foreign matter can greatly reduce boat speed and increase fuel consumption. To ensure best performance and efficiency, periodically clean the boat bottom in accordance with manufacturer's recommendations.

In some areas, it may be advisable to paint the bottom to help prevent marine growth. Refer to the following information for special notes about the use of anti-fouling paints.

Painting Your Power Package

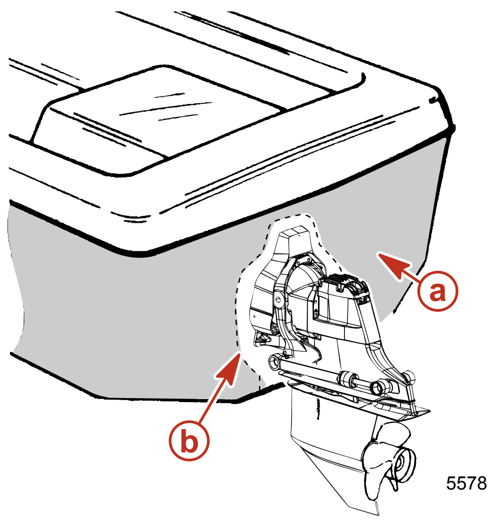
IMPORTANT: Corrosion damage that results from the improper application of anti-fouling paint will not be covered by the limited warranty.

1. **Painting the boat hull or transom**: you may apply anti-fouling paint to the boat hull and transom. However, observe the following:

IMPORTANT: Do not paint anodes or MerCathode System reference electrode and anode. Paint will render them ineffective as inhibitors of galvanic corrosion.

IMPORTANT: If anti-fouling protection is required for the boat hull or transom, you can use copper-based or tin-based paints where not prohibited by law. If using copper-based or tin-based anti-fouling paints, observe the following:

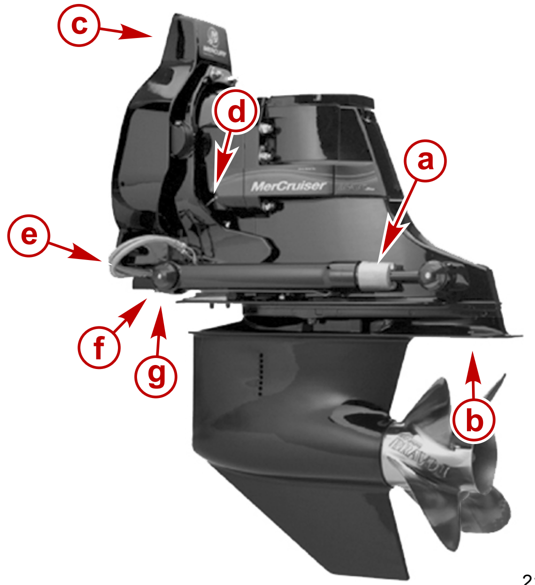
- Avoid any electrical interconnection between the paint and the Mercury MerCruiser product, anodic blocks, or MerCathode system by allowing a minimum of 40 mm (1-1/2 in.) unpainted area on the transom of the boat around these items.



a - Painted boat transom   **b -** Unpainted Area on Transom

2. **Painting the sterndrive unit or transom assembly**: The sterndrive unit and transom assembly should be painted with a good-quality marine paint or an anti-fouling paint that does not contain copper, tin, or any other material that could conduct electrical current. Do not paint drain holes, anodes, MerCathode system, or items specified by the boat manufacturer.

Sterndrive Surface Care



Standard Bravo sterndrive

- **a -** Sacrificial trim cylinder anode
- **b -** Sacrificial anodic plate
- **c -** Steering lever ground wire
- **d -** Ground wire between the gimbal ring and bell housing
- **e -** Stainless steel hoses
- **f -** Ground wire between the gimbal housing and trim cylinder
- **g -** Ground wire between the gimbal ring and gimbal housing

We recommend the following maintenance tasks and comments to help keep your sterndrive corrosion-free:

- Maintain a complete paint covering on the sterndrive.
- Check the finish regularly. Prime and paint nicks and scratches using Mercury enamel paint and touch up paint. Use only tin–based anti–fouling paint or its equivalent on or near aluminum surfaces below the waterline.
- If bare metal is showing, apply 2 coats of paint.

Description	Where used	Part number
Mercury Phantom Black	Bare metal	92- 802878-1

- Coat all electrical connections with sealant.

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	All electrical connections	92- 25711 3

- Inspect the sacrificial trim tab or anode plate, if equipped, at regular intervals and replace it before it erodes by 50%. If a stainless steel propeller is installed, additional anodes or a MerCathode System will be required.
- Inspect the propeller shaft for fishing line, which can cause corrosion on a stainless steel shaft.
- Remove the propeller at least every 60 days and lubricate the propeller shaft.
- Do not use lubricants containing graphite on or near the aluminum in saltwater.
- Do not paint trim tabs or the mounting surface.

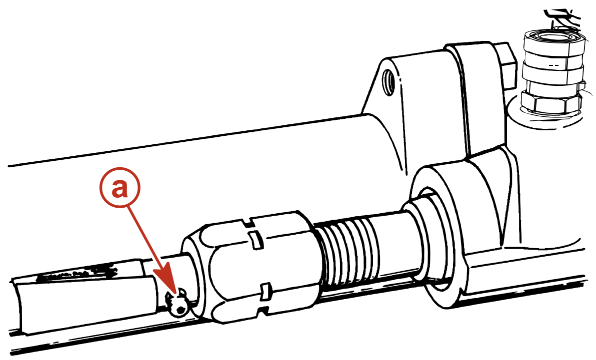
Lubrication

Steering System

> **⚠ WARNING**
>
> **Incorrect cable lubrication can cause hydraulic lock, leading to serious injury or death from loss of boat control. Completely retract the end of the steering cable before applying lubricant.**

NOTE: *If the steering cable does not have a grease fitting, the inner wire of the cable cannot be greased.*

1. **If the steering cable has grease fittings**, turn the steering wheel until the steering cable is fully retracted into the cable housing. Apply approximately three pumps of grease from a typical hand-operated grease gun.

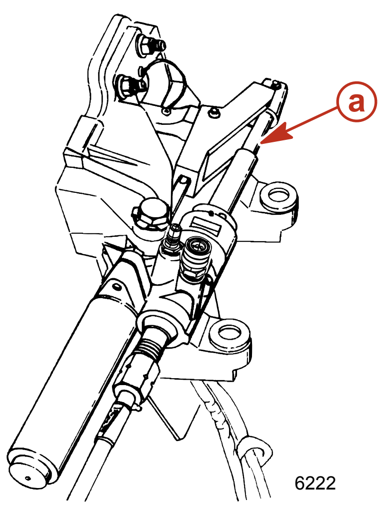


6221

a - Steering cable grease fitting

Tube Ref No.	Description	Where Used	Part No.
34	Special Lubricant 101	Steering cable grease fitting	92-802865Q02

2. Turn the steering wheel until the steering cable is fully extended. Lightly lubricate the exposed part of the cable.

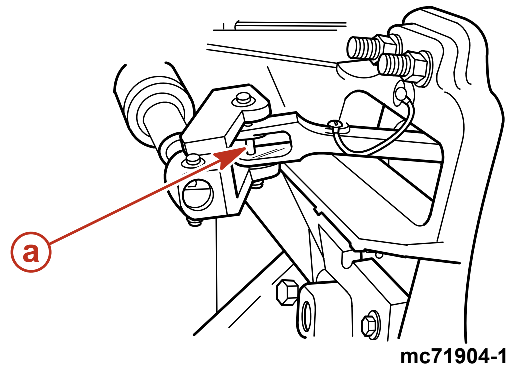


6222

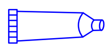
a - Extended steering cable

Tube Ref No.	Description	Where Used	Part No.
34	Special Lubricant 101	Steering cable	92-802865Q02

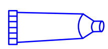
3. Lubricate the steering pin.



a - Steering pin

Tube Ref. No.	Description	Where Used	Part No.
	Synthetic Blend MerCruiser Engine Oil SAE25W-40	Steering pin	92-883725K01

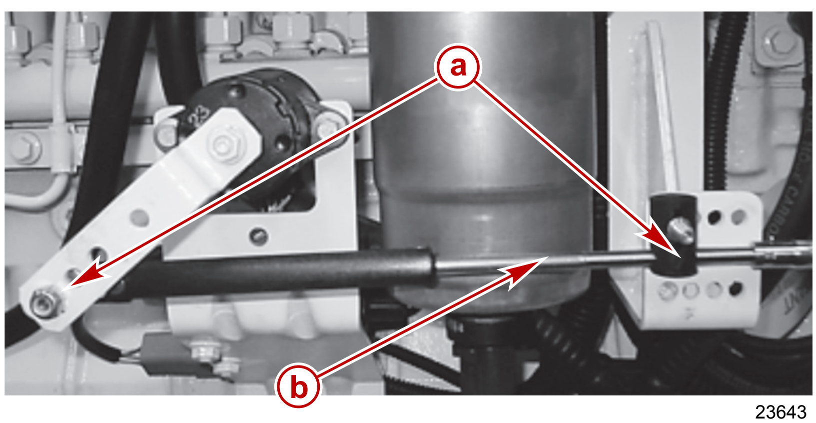
4. On dual engine boats: Lubricate the tie bar pivot points.

Tube Ref. No.	Description	Where Used	Part No.
	Synthetic Blend MerCruiser Engine Oil SAE25W-40	Tie bar pivot points	92-883725K01

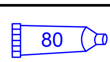
5. Upon first starting the engine, turn the steering wheel several times to starboard and then port to ensure that the steering system operates properly before getting underway.

Throttle Cable

1. Lubricate the pivot points and guide contact surfaces.

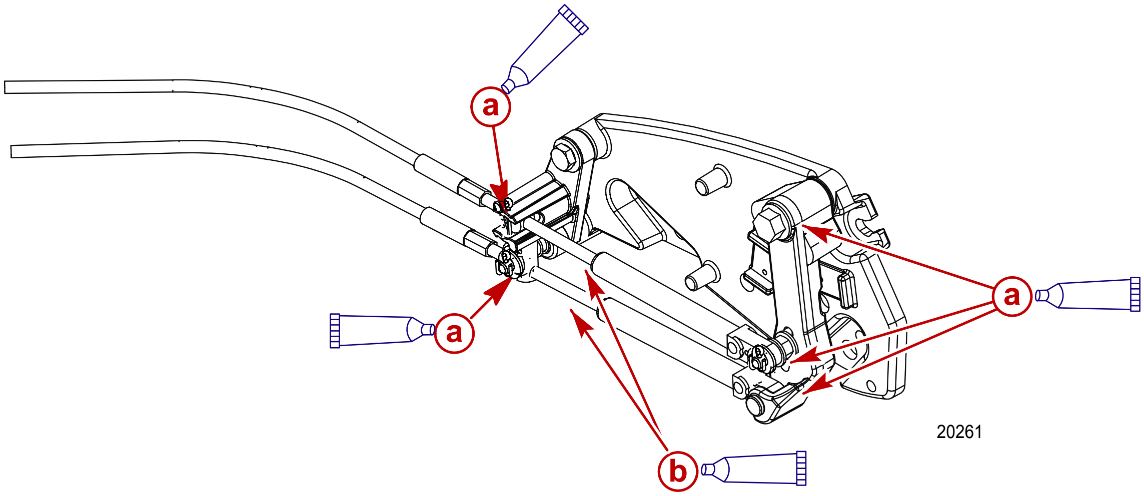


a - Pivot points **b -** Guide contact surfaces

Tube Ref No.	Description	Where Used	Part No.
	SAE Engine Oil 30W	Throttle cable pivot points and guide contact surfaces	Obtain Locally

Shift Cable

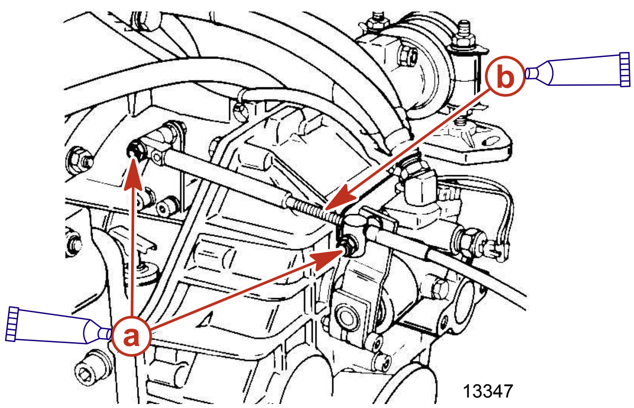
1. Lubricate the pivot points and guide contact surfaces.



Typical sterndrive model shift cable

a - Pivot points **b -** Guide contact surface

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Shift cable pivot points and guide contact surfaces	Obtain Locally



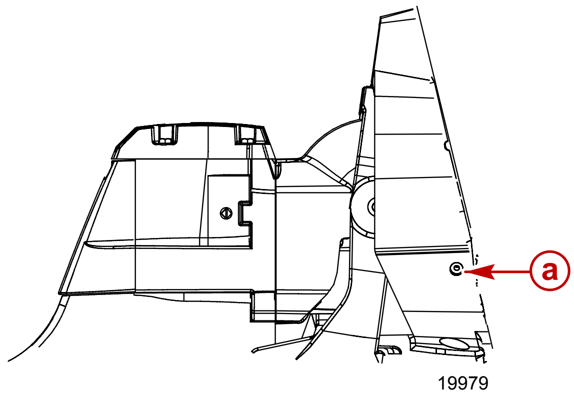
Typical inboard model shift cable and transmission linkage

a - Pivot points **b -** Guide contact surface

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Shift cable pivot points and guide contact surfaces	Obtain Locally

Transom Assembly

1. Lubricate the gimbal bearing by applying approximately 8-10 pumps of grease from a typical hand-operated grease gun.



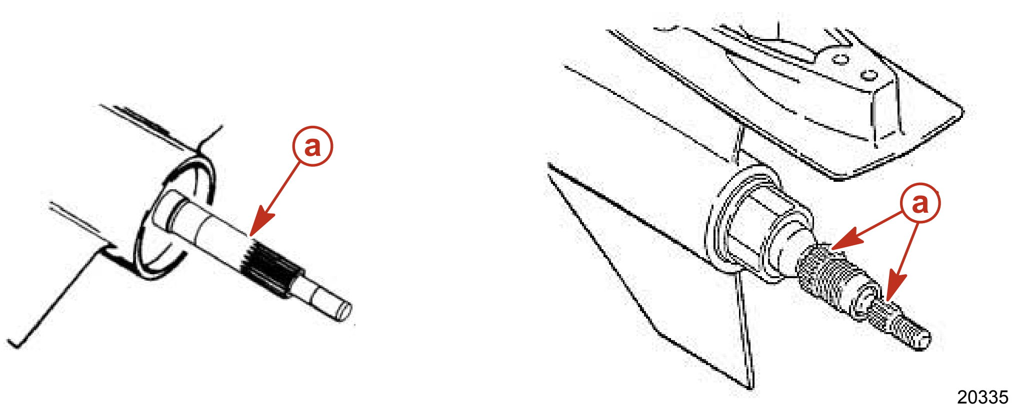
a - Gimbal bearing grease insert

Tube Ref No.	Description	Where Used	Part No.
42	U-joint and Gimbal Bearing Grease	Gimbal bearing grease insert	92-802870A1

Propeller Shaft

NOTE: See ***Propeller Removal****.*

1. Liberally coat the propeller shaft with one of the following lubricants.



a - Propeller shaft

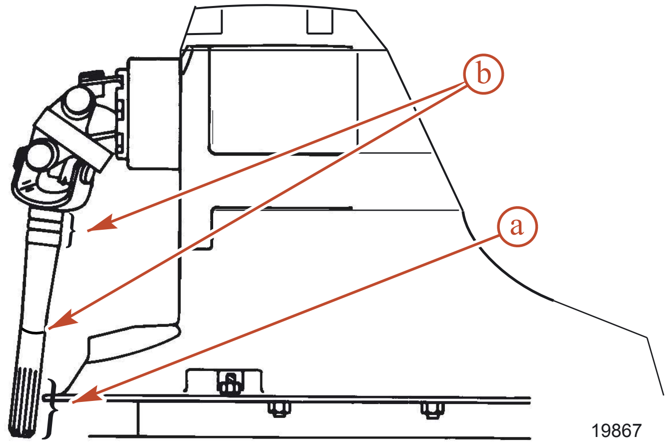
Tube Ref No.	Description	Where Used	Part No.
34	Special Lubricant 101	Propeller shaft	92-802865Q02
94	Anti-Corrosion Grease	Propeller shaft	92-802867Q 1
95	2-4-C Marine Lubricant with Teflon	Propeller shaft	92-802859A1

NOTE: Anti-corrosion grease is for saltwater applications only.

Sterndrive, Bellows, and Engine Alignment

1. Remove the sterndrive. Refer to the appropriate **Mercury MerCruiser Bravo Sterndrive Service Manual** for sterndrive removal and installation.

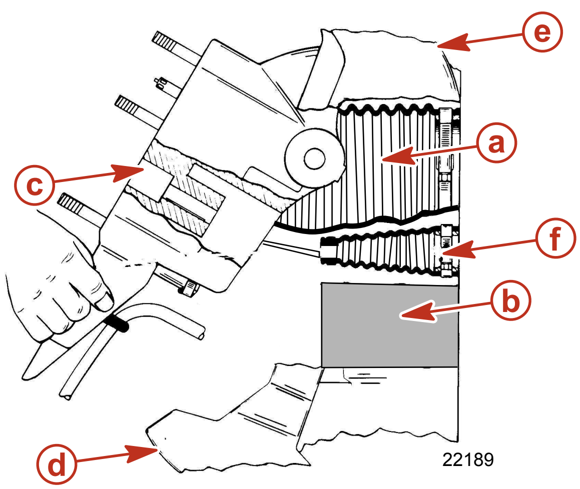
2. Lubricate the U-joint shaft splines and the O-rings.



a - U-joint shaft splines
b - U-joint shaft O-rings

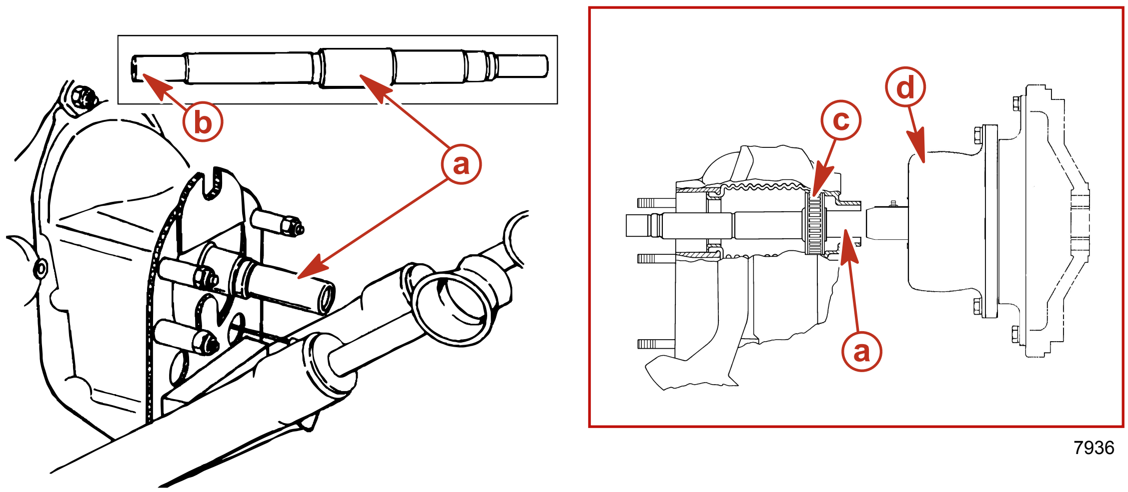
Tube Ref No.	Description	Where Used	Part No.
91	Engine Coupler Spline Grease	U-joint shaft splines and O-rings	92-802869A1

3. Inspect the U-joint bellows for cracks or other signs of deterioration. Ensure that the bellows clamps are tight.
4. Rotate the bell housing in the upward and side-to-side directions to inspect the exhaust tube, shift cable bellows, and clamps.



a - U-joint bellow
b - Exhaust tube
c - Bell housing
d - Gimbal ring
e - Gimbal housing
f - Shift cable bellows

5. Check the engine alignment.



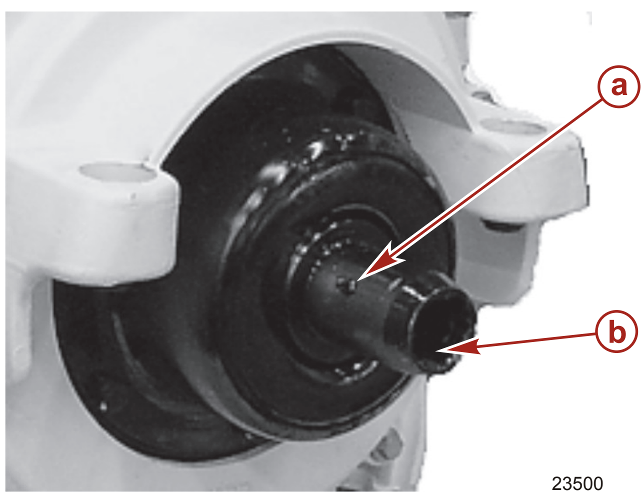
a - Alignment tool
b - End of alignment tool to insert through gimbal housing assembly
c - Gimbal bearing
d - Engine coupler

Engine Coupler

IMPORTANT: These engines are equipped with a sealed engine coupler. The sealed coupler and the shaft splines can be lubricated without removing the sterndrive.

1. Lubricate the engine coupler splines through the grease fitting on the coupler by applying approximately 8-10 pumps of Engine Coupler Spline Grease from a typical hand-operated grease gun.

NOTE: If the boat is operated at idle for prolonged periods of time, the coupler should be lubricated on Bravo models every 50 hours.

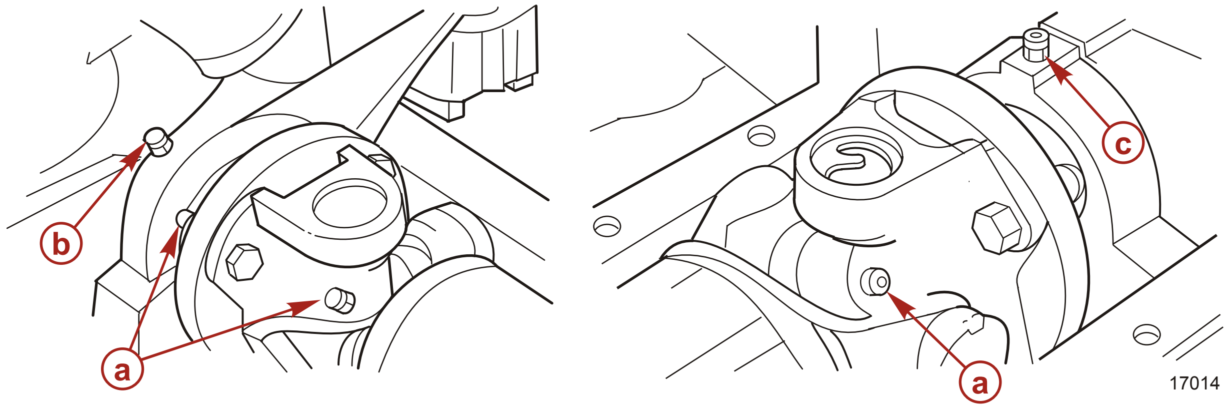


a - Grease fitting　　**b -** Coupler splines

Tube Ref No.	Description	Where Used	Part No.
91	Engine Coupler Spline Grease	Engine coupler and shaft splines	92-802869A1

Driveshaft Extension Models

1. Lubricate the transom end grease fitting and engine end grease fitting by applying approximately 10 - 12 pumps of grease from a typical hand-operated grease gun.
2. Lubricate the driveshaft grease fittings by applying approximately 3 - 4 pumps of grease from a typical hand-operated grease gun.



a - Driveshaft grease fittings
b - Transom end grease fitting
c - Engine end grease fitting

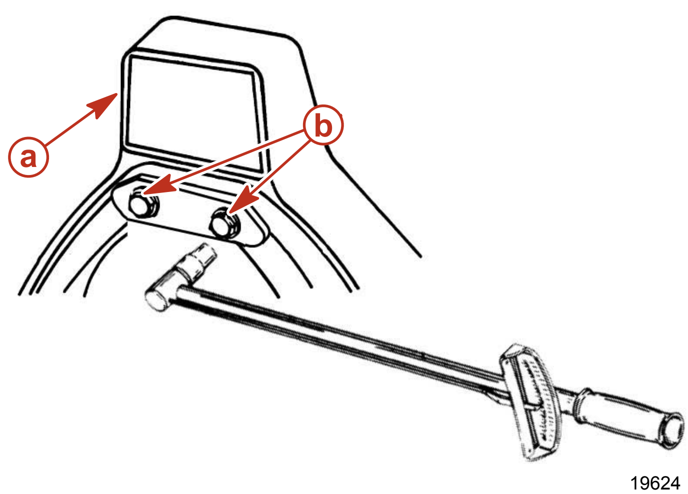
Tube Ref No.	Description	Where Used	Part No.
42	U-joint and Gimbal Bearing Grease	Transom end grease fitting, engine end grease fitting, driveshaft grease fittings	92-802870A1

Maintaining Torques

Gimbal Ring U-bolt Nuts

NOTE: The gimbal ring is a component of the transom assembly.

1. Torque the gimbal ring U-bolt nuts.

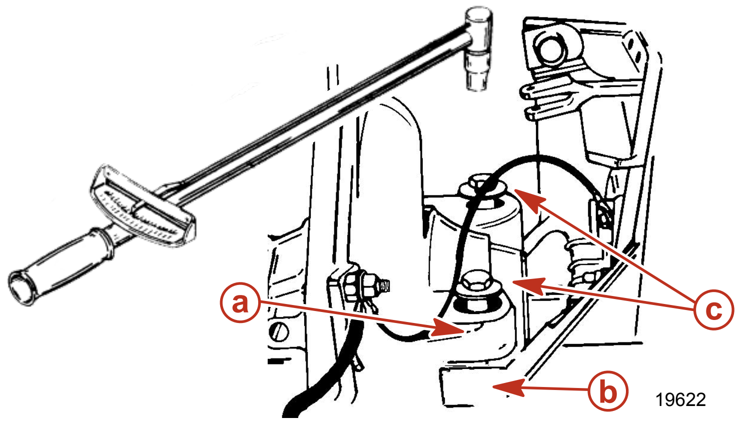


a - Transom assembly
b - Gimbal ring U-bolt nuts

Description	Nm	lb. in.	lb. ft.
Gimbal ring U-bolt nuts for 3/8 in. U-bolt	72		53
Gimbal ring U-bolt nuts for 7/16 in. U-bolt	95		70

Engine Mounts

Loosen the rear engine mount bolts 1 to 1-1/2 turns. Retorque the rear engine mount bolts.



a - Rear engine mount
b - Transom plate mount
c - Rear engine mount bolt

Description	Nm	lb. in.	lb. ft.
Rear engine mounts	51		38

Electrical System

NOTE: Refer to ***Section 4*** *for specific procedures.*

Inspect the entire electrical system for loose, damaged, or corroded fasteners and connectors.

Propellers

Bravo Diesel Sterndrive Propeller Removal

⚠ WARNING

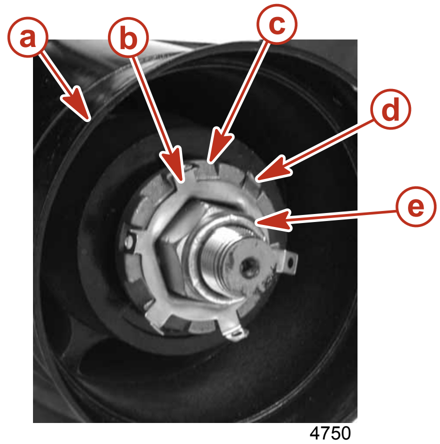
Rotating propellers can cause serious injury or death. Never operate the boat out of the water with a propeller installed. Before installing or removing a propeller, place the drive unit in neutral and engage the lanyard stop switch to prevent the engine from starting. Place a block of wood between the propeller blade and the anti-ventilation plate.

⚠ WARNING

Rotating propellers can cause serious injury or death. Never operate the boat out of the water with a propeller installed. Before installing or removing a propeller, place the drive unit in neutral and engage the lanyard stop switch to prevent the engine from starting. Place a block of wood between the propeller blade and the anti-ventilation plate.

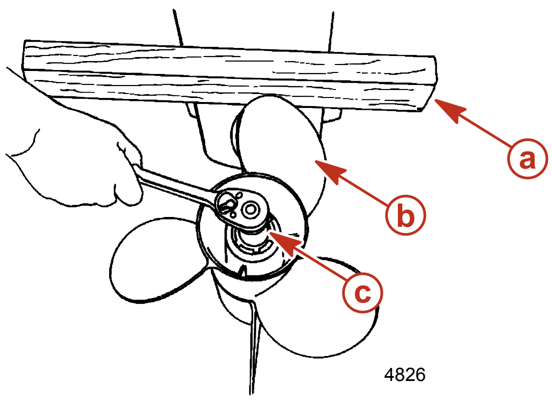
BRAVO ONE MODELS

1. Straighten the bent tabs of the tab washer on the propeller shaft.



a - Prop
b - Tab washer
c - Drive sleeve adapter
d - Tab bent down
e - Propeller nut

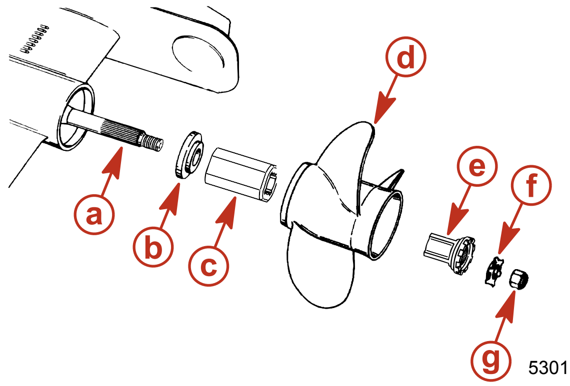
2. Place a block of wood between the propeller blade and the sterndrive's anti-ventilation plate.



a - Wood block
b - Propeller
c - Propeller nut under socket

3. Turn the propeller shaft nut counterclockwise and remove the nut.

4. Slide the propeller and the attaching hardware from the propeller shaft.

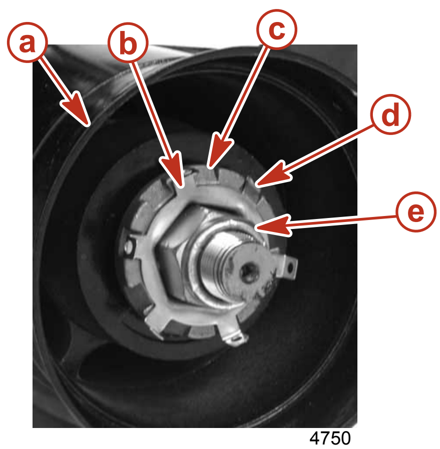


Bravo One models

a - Propeller shaft splines
b - Forward thrust hub
c - Flo-Torque II drive hub
d - Propeller
e - Drive sleeve adapter
f - Tab washer
g - Propeller nut

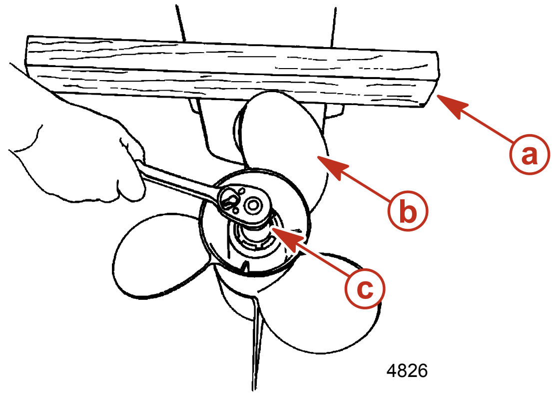
BRAVO TWO MODELS

1. Straighten the bent tabs of the tab washer on the propeller shaft.



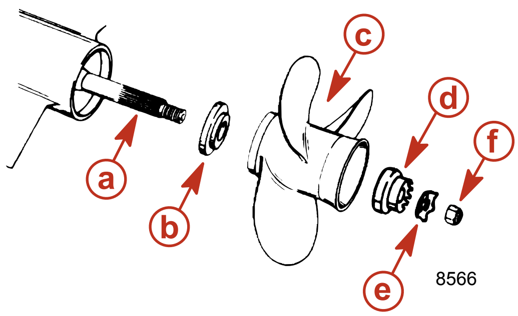
a - Prop
b - Tab washer
c - Drive sleeve adapter
d - Tab bent down
e - Propeller nut

2. Place a block of wood between the propeller blade and the sterndrive's anti-ventilation plate.



a - Wood block
b - Propeller
c - Propeller nut under socket

3. Turn the propeller shaft nut counterclockwise to remove the nut.
4. Slide the propeller and attaching hardware from the propeller shaft.



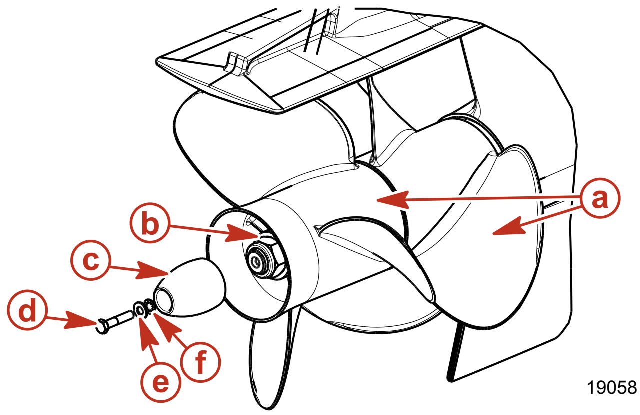
Bravo Two

a - Propeller shaft splines
b - Forward thrust hub
c - Propeller
d - Spline washer
e - Tab washer
f - Propeller nut

BRAVO THREE MODELS

1. Place a block of wood between the propeller blade and the sterndrive's anti-ventilation plate.
2. Remove the bolt and washers securing the propeller shaft anode.

3. Remove the propeller shaft anode.

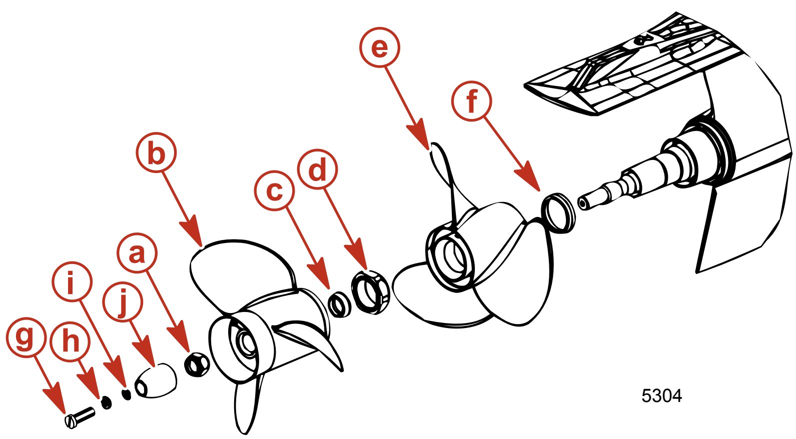


a - Propeller
b - Propeller shaft nut
c - Propeller shaft anode
d - Propeller shaft anode screw
e - Flat washer
f - Star washer

4. Turn the aft propeller shaft nut counterclockwise to remove the nut.
5. Slide the propeller and thrust hub off of the propeller shaft.
6. Using the Propeller Nut Tool, turn the front propeller shaft nut counterclockwise and remove the nut.

Propeller Nut Tool	91-805457T 1

7. Slide the propeller and the thrust hub off the propeller shaft.



Bravo Three

a - Aft propeller nut
b - Aft propeller
c - Aft propeller thrust hub
d - Front propeller nut
e - Front propeller
f - Front propeller thrust hub
g - Propeller shaft anode screw
h - Flat washer
i - Star washer
j - Propeller shaft anode

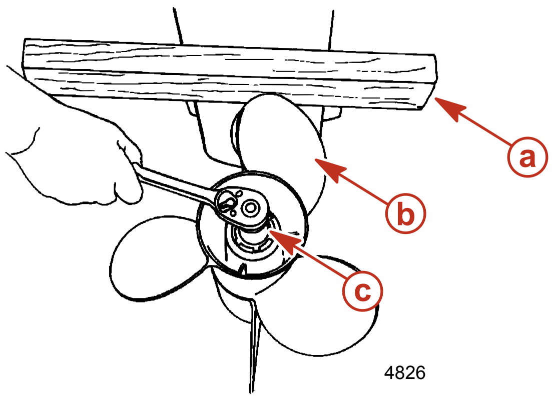
Bravo Diesel Sterndrive Propeller Installation

⚠ WARNING

Rotating propellers can cause serious injury or death. Never operate the boat out of the water with a propeller installed. Before installing or removing a propeller, place the drive unit in neutral and engage the lanyard stop switch to prevent the engine from starting. Place a block of wood between the propeller blade and the anti-ventilation plate.

⚠ WARNING

Rotating propellers can cause serious injury or death. Never operate the boat out of the water with a propeller installed. Before installing or removing a propeller, place the drive unit in neutral and engage the lanyard stop switch to prevent the engine from starting. Place a block of wood between the propeller blade and the anti-ventilation plate.



a - Wood block
b - Propeller
c - Propeller nut under socket

BRAVO ONE MODELS

IMPORTANT: Use a propeller with the correct rotation. The propeller rotation must match the direction of rotation of the propeller shaft.

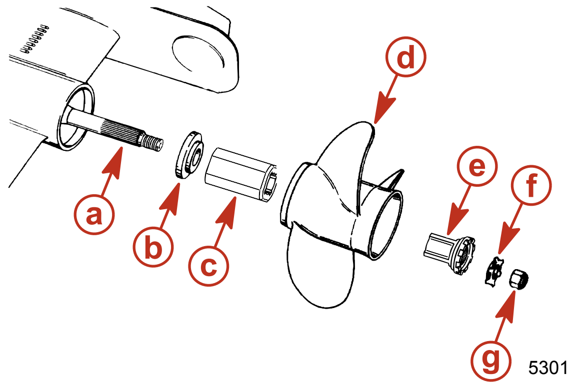
1. Liberally coat the propeller shaft spline with one of the following Quicksilver lubricants.

Tube Ref No.	Description	Where Used	Part No.
34	Special Lubricant 101	Propeller shaft splines	92-802865Q02
94	Anti-Corrosion Grease	Propeller shaft splines	92-802867Q 1
95	2-4-C Marine Lubricant with Teflon	Propeller shaft splines	92-802859A1

NOTE: Anti-corrosion grease is for saltwater applications only.

2. Install the propeller with the attaching hardware as shown.

3. Torque the propeller nut.



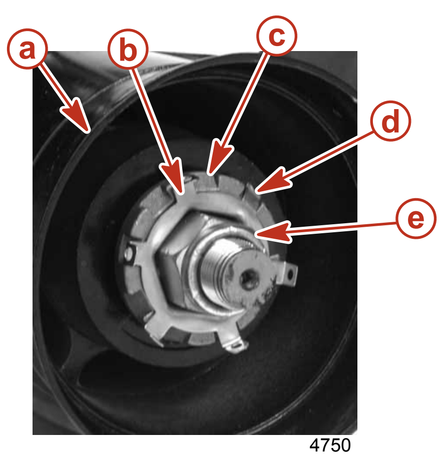
Typical Bravo One model

a - Propeller shaft splines
b - Forward thrust hub
c - Flo-Torque II drive hub
d - Propeller
e - Drive sleeve adapter
f - Tab washer
g - Propeller nut

NOTE: The propeller torque stated is a minimum torque value.

Description	Nm	lb. ft.
Bravo One propeller nut	75	55
	Then align tabs with grooves	

4. **Models equipped with the tab washer**: Continue to tighten the propeller nut until the three tabs on the tab washer align with the grooves on the spline washer.
5. Bend the three tabs down into the grooves.



a - Prop
b - Tab washer
c - Drive sleeve adapter
d - Tab bent down
e - Propeller nut

BRAVO TWO MODELS

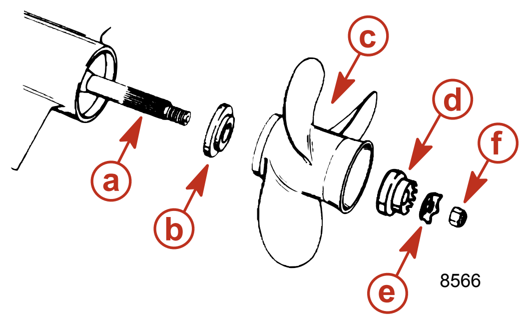
IMPORTANT: Use a propeller with the correct rotation. The propeller rotation must match the direction of rotation of the propeller shaft.

1. Liberally coat the propeller shaft spline with one of the following Quicksilver lubricants.

Tube Ref No.	Description	Where Used	Part No.
34	Special Lubricant 101	Propeller shaft splines	92-802865Q02
94	Anti-Corrosion Grease	Propeller shaft splines	92-802867Q 1
95	2-4-C Marine Lubricant with Teflon	Propeller shaft splines	92-802859A1

NOTE: Anti-corrosion grease is for saltwater applications only.

2. Install the propeller with the attaching hardware as shown.
3. Torque the propeller nut.



Bravo Two

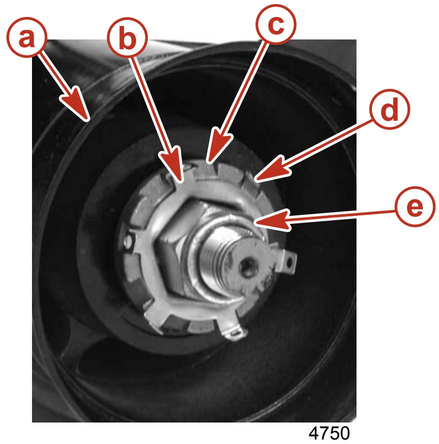
a - Propeller shaft splines
b - Forward thrust hub
c - Propeller
d - Spline washer
e - Tab washer
f - Propeller nut

NOTE: The propeller torque stated is a minimum torque value.

Description	Nm	lb. ft.
Bravo Two propeller nut	81	60
	Then align tabs with groves	

4. Continue to tighten the propeller nut until the three tabs on the tab washer align with the grooves on the spline washer.

5. Bend the three tabs down into the grooves.



a - Prop
b - Tab washer
c - Drive sleeve adapter
d - Tab bent down
e - Propeller nut

BRAVO THREE

1. Liberally coat the propeller shaft spline with one of the following Quicksilver lubricants.

Tube Ref No.	Description	Where Used	Part No.
34	Special Lubricant 101	Propeller shaft splines	92-802865Q02
94	Anti-Corrosion Grease	Propeller shaft splines	92-802867Q 1
95	2-4-C Marine Lubricant with Teflon	Propeller shaft splines	92-802859A1

NOTE: Anti-corrosion grease is for saltwater applications only.

2. Slide the forward thrust hub onto the propeller shaft with the tapered side toward the propeller hub.
3. Align the splines and place the front propeller on the propeller shaft.
4. Install the front propeller locknut and torque using the Propeller Nut Tool.

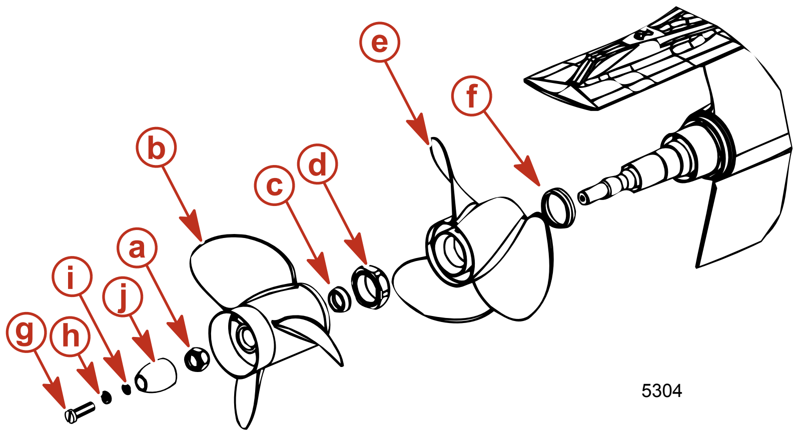
Propeller Nut Tool	91-805457T 1

Description	Nm	lb. ft.
Bravo Three front propeller nut	136	100

5. Slide the rear thrust hub onto the propeller shaft with the tapered side toward the propeller hub.
6. Align the splines and install the rear propeller.
7. Install the propeller nut and torque.

Description	Nm	lb. ft.
Bravo Three rear propeller nut	81	60

8. Install the propeller shaft anode and screw and torque.



Bravo Three

a - Rear propeller nut	**f -** Front propeller thrust hub
b - Rear propeller	**g -** Propeller shaft anode screw
c - Rear propeller thrust hub	**h -** Flat washer
d - Front propeller nut	**i -** Star washer
e - Front propeller	**j -** Propeller shaft anode

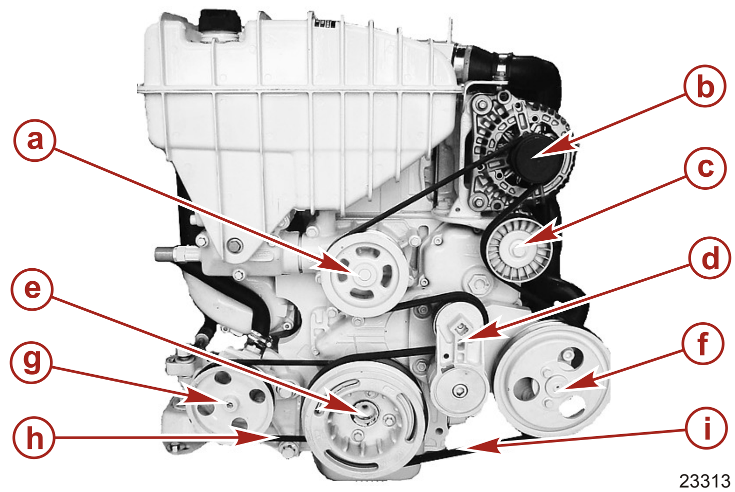
Description	Nm	lb. in.
Propeller shaft anode screw	19	168

Drive Belts

All drive belts must be periodically inspected for tension and condition, such as excessive wear, cracks, fraying, or glazed surfaces.

⚠ WARNING

Inspecting the belts with the engine running may cause serious injury or death. Turn off the engine and remove the ignition key before adjusting tension or inspecting belts.



2.8 shown, 4.2 similar

- **a -** Water circulating pump pulley
- **b -** Alternator pulley
- **c -** Idler
- **d -** Automatic tensioner
- **e -** Crankshaft pulley
- **f -** Seawater pump pulley
- **g -** Power assisted steering pulley
- **h -** Power assisted steering belt
- **i -** Serpentine belt

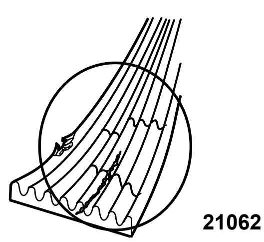
Serpentine Belt

INSPECTION

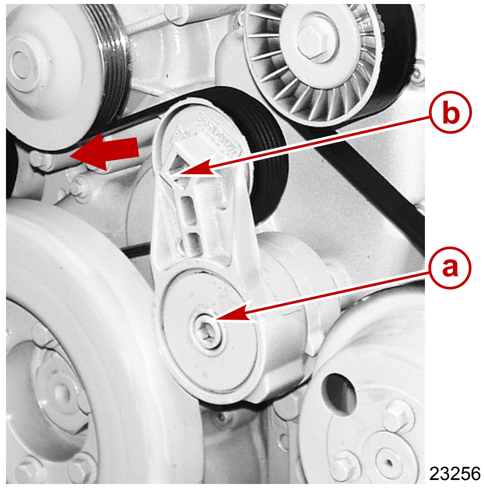
1. Inspect the belt for proper tension and for the following:
   - Excessive wear
   - Cracks

NOTE: Minor, transverse cracks (across the belt width) may be acceptable. Longitudinal cracks (in the direction of belt length) that join transverse cracks are not acceptable.

   - Fraying
   - Glazed surfaces



2. Check the operation of the automatic tensioner and associated components.
   a. Position a suitable tool in the automatic tensioner release slot.
   b. Rotate the automatic tensioner in the direction of the arrow.



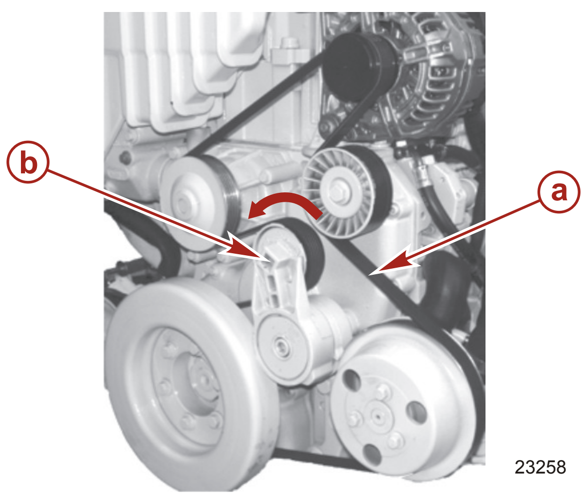
a - Automatic tensioner **b -** Release slot

   c. Release the automatic tensioner and allow it to glide back slowly.
   d. The automatic tensioner must return to the initial position and hold tension on the serpentine belt.

REPLACEMENT

IMPORTANT: If a belt is to be reused, it should be installed in the same direction of rotation as when first used.

1. Position a suitable tool in the automatic tensioner release slot.
2. Rotate the automatic tensioner in the direction of the arrow to remove the tension on the serpentine belt.



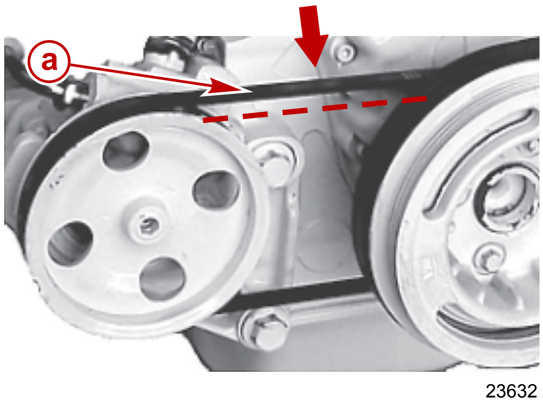
a - Serpentine belt **b -** Release slot

3. Remove the serpentine belt.
4. Replace the serpentine belt.
5. Carefully release the automatic tensioner with the breaker bar, ensuring that the belt stays positioned properly.

Power-Assisted Steering Pump Belt

INSPECTION

1. Inspect the belt for proper tension and for the following:
   - Excessive wear
   - Cracks
   - Fraying
   - Glazed surfaces
2. Replace the belt if worn or damaged. See **Replacement**.
3. Check belt tension by depressing the upper strand of the belt, with moderate hand pressure, at the point shown. The belt must correspond to the specifications in the following table.



2.8 shown, 4.2 similar

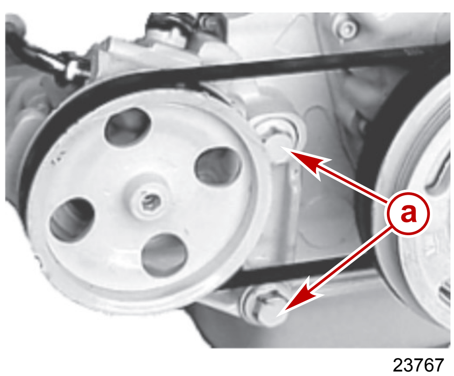
a - Power steering pump belt

Power-assisted steering drive belt tension	
Belt deflection, with moderate hand pressure	5 mm (3/16 in.)

4. Adjust the tension if necessary. See **Adjustment**.

ADJUSTMENT

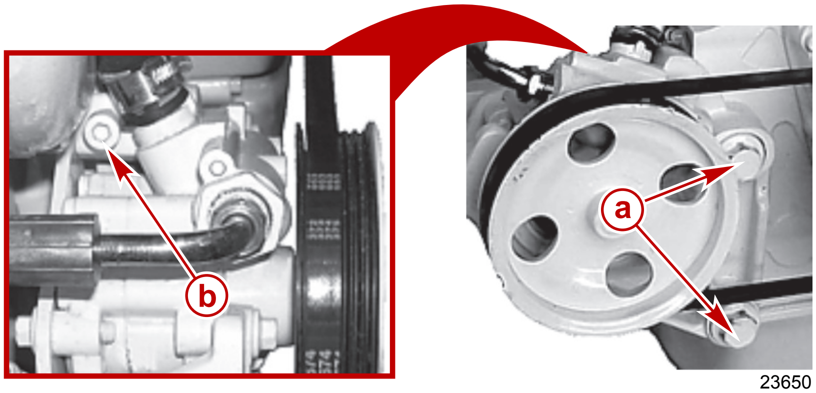
1. Loosen the power-assisted steering pump mounting bolts.



2.8 shown, 4.2 similar

a - Mounting bolts

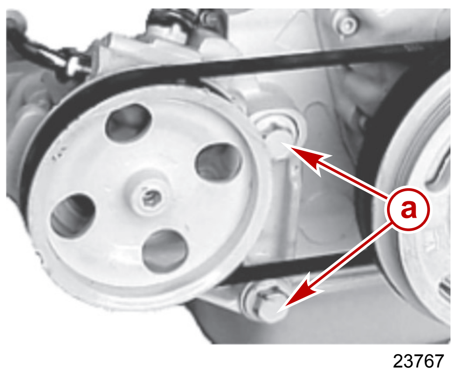
2. Use the adjustment screw to move the power-assisted steering pump to tension the power-assisted steering belt.



a - Mounting bolts **b -** Adjustment screw

Power-assisted steering drive belt tension	
Belt deflection, with moderate hand pressure	5 mm (3/16 in.)

3. Torque the power-assisted steering pump mounting and tensioning flange bolts.



2.8 shown, 4.2 similar

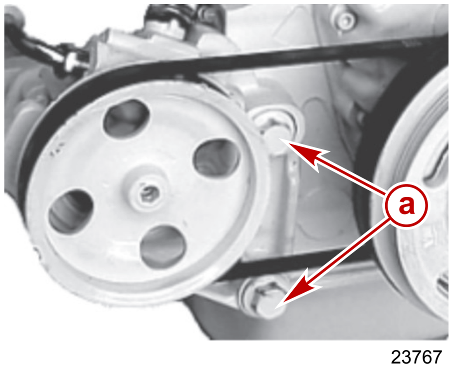
a - Mounting bolts

Description	Nm	lb. in.	lb. ft.
Power-assisted steering pump mounting bolts	21		15

REPLACEMENT

1. Remove the serpentine belt. See **Serpentine Belt**.

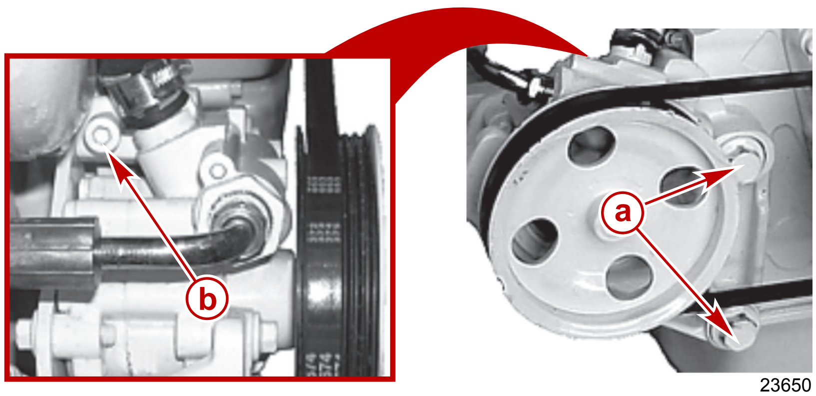
2. Loosen the power-assisted steering pump mounting bolts.



2.8 shown, 4.2 similar

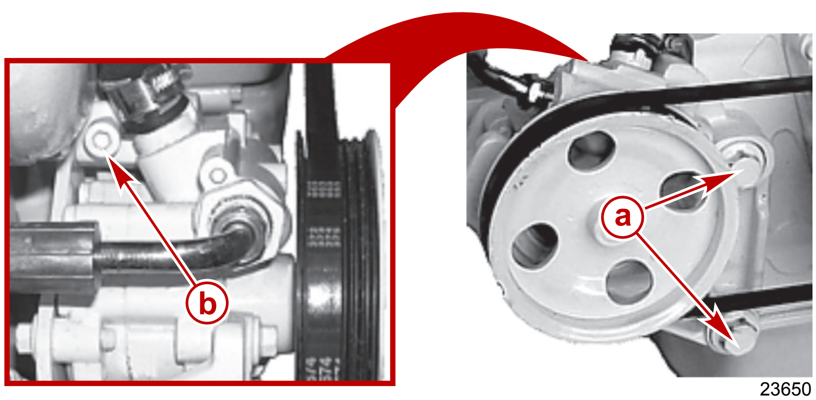
a - Mounting bolts

3. Loosen the existing power-assisted steering pump belt by turning the adjustment screw counterclockwise.



a - Mounting bolts | **b -** Adjustment screw

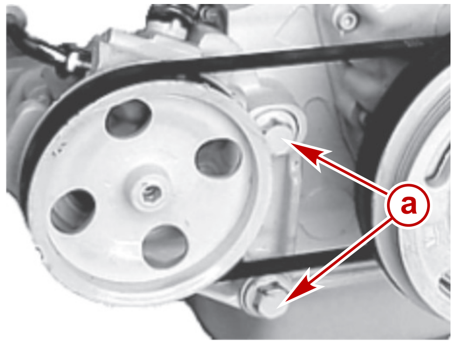
4. Remove the existing power-assisted steering pump belt.
5. Install the new power-assisted steering pump belt.
6. Use the adjustment screw to move the power-assisted steering pump to tension the power-assisted steering belt.



a - Mounting bolts | **b -** Adjustment screw

Power-assisted steering drive belt tension	
Belt deflection, with moderate hand pressure	5 mm (3/16 in.)

7. Torque the power-assisted steering pump mounting and tensioning bolts.



2.8 shown, 4.2 similar

a - Mounting bolts

Description	Nm	lb. in.	lb. ft.
Power-assisted steering pump mounting and tensioning flange bolt	21		15

8. Install the serpentine belt. See **Serpentine Belt**.

Cold Weather (Freezing Temperature), Seasonal Storage, and Extended Storage

IMPORTANT: Damage caused by freezing IS NOT covered by the Cummins MerCruiser Diesel Limited Warranty.

NOTICE
Water trapped in the seawater section of the cooling system can cause corrosion or freeze damage. Drain the seawater section of the cooling system immediately after operation or before any length of storage in cold weather. If the boat is in the water, keep the seacock closed until restarting the engine to prevent water from flowing back into the cooling system. If the boat is not fitted with a seacock, leave the water inlet hose disconnected and plugged.

NOTE: As a precautionary measure, attach a tag to the key switch or steering wheel of the boat reminding the operator to open the seacock or unplug and reconnect the water inlet hose before starting the engine.

You should consider a boat as in storage whenever it is not in operation. The amount of time that the power package is not operated may be for a brief period, such as during a day, overnight, for a season, or for an extended period of time. Certain precautions and procedures must be observed to protect the power package from freeze damage, corrosion damage, or both types of damage during storage.

Freeze damage can happen when water trapped in the seawater cooling system freezes. Exposure to freezing temperatures for even a brief period of time after operating the boat, could result in freeze damage.

Corrosion damage is the result of saltwater, polluted water, or water with a high mineral content trapped in the seawater cooling system. Saltwater should not stay in an engine's cooling system for even brief storage time; drain and flush the seawater cooling system after each outing.

Cold weather operation refers to operating the boat whenever the possibility of freezing temperatures exists. Likewise, cold weather (freezing temperature) storage refers to whenever the boat is not being operated and the possibility of freezing temperatures exists. In such cases, the seawater section of the cooling system must be completely drained immediately after operation.

Seasonal storage refers to when the boat is not being operated for one month or more. The length of time varies depending on the geographic location of the boat in storage. Seasonal storage precautions and procedures include all of the steps for cold weather (freezing temperature) storage and some additional steps that must be taken when storage will last longer than the short time of cold weather (freezing temperature) storage.

Extended storage means storage for a period of time that may last for several seasons or longer. Extended storage precautions and procedures include all of the steps for cold weather (freezing temperature) storage and seasonal storage plus some additional steps.

See the specific procedures in this section related to the conditions and the length of storage for your application.

Cold Weather (Freezing Temperature) Storage

NOTICE
Water trapped in the seawater section of the cooling system can cause corrosion or freeze damage. Drain the seawater section of the cooling system immediately after operation or before any length of storage in cold weather. If the boat is in the water, keep the seacock closed until restarting the engine to prevent water from flowing back into the cooling system. If the boat is not fitted with a seacock, leave the water inlet hose disconnected and plugged.

NOTE: *As a precautionary measure, attach a tag to the key switch or steering wheel of the boat reminding the operator to open the seacock or unplug and reconnect the water inlet hose before starting the engine.*

1. Read all precautions and perform all procedures found in **Draining the Seawater System** and drain the seawater section of the cooling system.
2. Place a caution tag at the helm advising the operator to unplug and connect the water inlet hose or open the seacock, if equipped, before operating the boat.
3. For additional assurance against freezing and corrosion fill the seawater cooling system with a mixture of propylene glycol antifreeze and tap water. See **Seasonal Storage Instructions** in this section.

Preparing Your Power Package for Seasonal or Extended Storage

NOTICE
Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

IMPORTANT: If the boat has already been removed from the water, supply water to the water inlet holes before starting the engine. Follow all warnings and flushing attachment procedures stated in Flushing the Seawater System.

1. Supply cooling water to the water inlet holes or seawater pump inlet.
2. Start the engine and operate until it reaches normal operating temperature.
3. Stop the engine.
4. Change the engine oil and filter.

5. Start the engine and run for about 15 minutes. Check for oil leaks.
6. Flush the seawater cooling system. See **Flushing the Seawater System**.

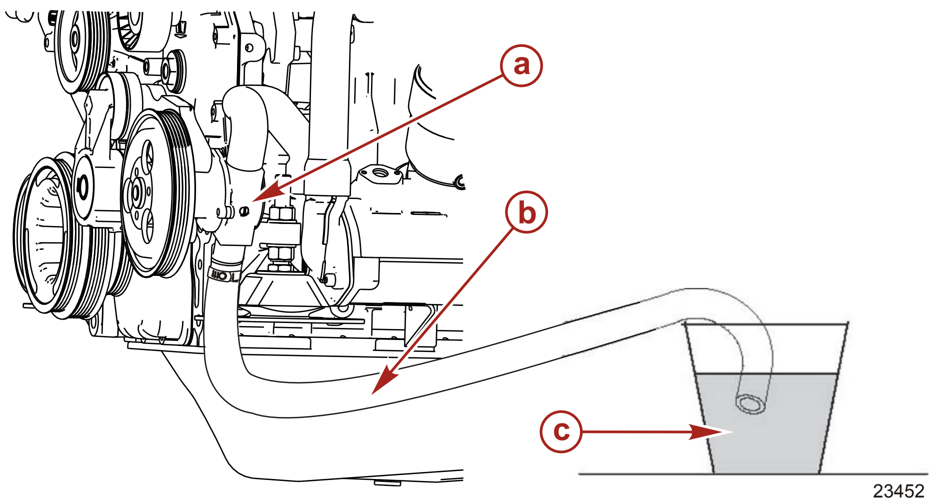
Seasonal Storage Instructions

1. Observe all precautions and perform all procedures found in **Preparing Your Power Package for Seasonal or Extended Storage**.
2. Observe all precautions and perform all procedures found in **Draining the Seawater System** and drain the seawater section of the cooling system.

NOTICE
Water trapped in the seawater section of the cooling system can cause corrosion or freeze damage. Drain the seawater section of the cooling system immediately after operation or before any length of storage in cold weather. If the boat is in the water, keep the seacock closed until restarting the engine to prevent water from flowing back into the cooling system. If the boat is not fitted with a seacock, leave the water inlet hose disconnected and plugged.

IMPORTANT: Cummins MerCruiser Diesel recommends the use of propylene glycol antifreeze in the seawater section of the cooling system for cold weather (freezing temperature), seasonal storage, or extended storage. Make sure that the propylene glycol antifreeze contains a rust inhibitor and is recommended for use in marine engines. Be certain to follow the propylene glycol manufacturer's recommendations.

3. Fill a container with approximately 5.6 liters (6 U.S. quarts) of propylene glycol antifreeze and tap water mixed to manufacturer's recommendation to protect the engine to the lowest temperature to which it will be exposed during cold weather or extended storage.
4. Disconnect the seawater inlet hose from the seawater pump. Using an adapter, if necessary, temporarily connect a hose of appropriate length to the seawater pump and place the other end of the hose into the container of propylene glycol antifreeze and tap water.



Typical

a - Seawater pump
b - Temporary hose
c - Container of propylene glycol antifreeze and tap water

NOTE: Discharge of propylene glycol into the environment may be restricted by law. Dispose of propylene glycol in accordance with federal, state, and local laws and guidelines.

5. Start the engine and operate at idle speed until the antifreeze mixture has been pumped into the engine seawater cooling system.
6. Stop the engine.
7. Remove the temporary hose from the seawater pump.
8. Clean the outside of the engine and repaint required areas with primer and spray paint. After the paint has dried, coat the engine with the specified corrosion-inhibiting oil or equivalent.

Description	Where Used	Part Number
Corrosion Guard	Outside of engine	92-802878-55
Light gray primer		92-802878-52
Marine Cloud White paint (CMD part number: 4918660)		Obtain locally
Mercury Phantom Black	Shift plate and air filter housing	92-802878Q1

9. Your Cummins MerCruiser Diesel Authorized Repair Facility should now perform all checks, inspections, lubrications, and fluid changes outlined in **Maintenance Schedules**.

NOTICE

The universal joint bellows may develop a set when stored in a raised or up position, causing the bellows to fail when returned to service and allowing water to enter the boat. Store the sterndrive in the full down position.

10. **On Sterndrive models**, place the sterndrive in the full down (in) position.
11. Follow the battery manufacturer's instructions for storage and store the battery.

Extended Storage Instructions

1. Read all precautions and perform all procedures found in **Preparing Your Power Package for Seasonal or Extended Storage**.
2. Read all precautions and perform all procedures found in **Draining the Seawater System**.
3. Read all precautions and perform all procedures found in **Seasonal Storage Instructions**.

IMPORTANT: The seawater pump impeller material can be damaged by prolonged exposure to direct sunlight.

4. Refer to **Section 6A** and remove the seawater pump impeller. Store the impeller away from direct sunlight.
5. Place a caution tag at the instrument panel and in the engine compartment stating that the seawater pump is out and not to operate the engine. Also, warn an operator that the seacock must be opened or the water inlet hose reconnected prior to starting the engine.

Battery

Follow the battery manufacturer's instructions for storage.

Recommissioning

NOTE: Discharge of propylene glycol into the environment may be restricted by law. Contain and dispose of propylene glycol in accordance with federal, state, and local laws and guidelines.

1. On engines that were prepared for extended storage, reinstall the seawater pump impeller, if it was removed for storage. Refer to **Section 6A— Seawater Pump**.
2. On engines that were prepared for cold weather (freezing temperature), seasonal, or extended storage, see **Draining the Seawater System** and drain the propylene glycol into a suitable container. Dispose of the propylene glycol in accordance with federal, state, and local laws and guidelines.
3. Ensure that all cooling system hoses are in good condition, connected properly, and clamped tightly. Verify that all drain valves and drain plugs are installed and tight.
4. Inspect all drive belts.
5. Perform all lubrication and maintenance specified for completion according to **Annually** in **Maintenance Schedules**, except items that were performed at time of engine storage.
6. Fill the fuel tanks with fresh diesel fuel. Do not use old fuel. Check the general condition of the fuel lines and inspect the connections for leaks.
7. Replace the water-separating fuel filter or filters (some engines may have more than one).

⚠ CAUTION

Disconnecting or connecting the battery cables in the incorrect order can cause injury from electrical shock or can damage the electrical system. Always disconnect the negative (-) battery cable first and connect it last.

8. Install a fully charged battery. Clean the battery cable clamps and terminals. Reconnect the cables (see the CAUTION listed above). Secure each cable clamp when connecting. Coat terminals with a battery terminal anti-corrosion spray to help retard corrosion.
9. Perform all checks in the Starting Procedure column found in the **Operation Chart** found in the appropriate **Cummins MerCruiser Diesel Operation, Maintenance and Warranty Manual** provided with the product.

NOTICE

Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

10. Supply cooling water to the seawater inlet openings.
11. Start the engine and closely observe instrumentation. Ensure that all systems are functioning correctly.
12. Carefully inspect the engine for fuel, oil, fluid, water, and exhaust leaks.
13. Check the steering system, shift, and throttle control for proper operation.

Notes:

Important Information

Section 1C - Troubleshooting

Table of Contents

Troubleshooting Charts

Precautions For Troubleshooting

⚠ WARNING

Moving parts can cause serious injury or death. Wear eye protection and keep hands, hair, and clothing away from moving parts when performing tests or checking adjustments on an operating engine.

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

⚠ WARNING

Fuel is flammable and explosive. Ensure the key switch is off and the lanyard is positioned so that the engine cannot start. Do not smoke or allow sources of spark or open flame in the area while servicing. Keep the work area well ventilated and avoid prolonged exposure to vapors. Always check for leaks before attempting to start the engine and wipe up any spilled fuel immediately.

⚠ WARNING

Improper installation of brass fittings or plugs into the fuel pump or fuel filter base can crack the casting, causing a fuel leak and possible fire or explosion. Always install fittings and plugs correctly, and do not tighten with power tools.

⚠ WARNING

Fuel leakage is a fire or explosion hazard, which can cause serious injury or death. Periodically inspect all fuel system components for leaks, softening, hardening, swelling, or corrosion, particularly after storage. Any sign of leakage or deterioration requires replacement before further engine operation.

⚠ WARNING

Performing tests with the engine running may cause the propeller to rotate and result in serious injury or death. Use caution when performing a test that requires the engine running, and remove the propeller to avoid injury.

⚠ WARNING

Leaving the helm unattended while performing tests with the boat in the water may result in loss of boat control causing serious injury or death. Ensure someone is at the helm at all times, unless the boat is secured to a dock.

⚠ CAUTION

Failure to release pressure from the fuel system will result in fuel spraying out, which can cause a fire or explosion. Allow the engine to cool completely and release all fuel pressure before servicing any part of the fuel system. Always protect eyes and skin from pressurized fuel and vapors.

NOTICE

Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

NOTICE

Operating the engine out of the water at high speeds creates suction, which can collapse the water supply hose and overheat the engine. Do not operate the engine above 1400 RPM out of the water and without sufficient cooling water supply.

Poor Boat Performance, Poor Maneuverability, or Both

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to Section 5F—Troubleshooting the ECS System for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Symptom	Cause
Bow too low	Improper sterndrive trim angle
	Improper weight distribution
	Boat is underpowered
	Permanent or power hook in boat bottom
	False bottom full of water
	Improperly adjusted trim tabs (after planes)
Bow too high	Improper sterndrive trim angle
	Propeller pitch too great
	Dirty boat bottom (marine growth)
	Poor running engine
	Improper weight distribution
	Rocker in boat bottom
	False bottom full of water
	Improperly adjusted trim tabs (after planes)
Propeller ventilating	Sterndrive installed too high on transom
	Dirty or rough boat bottom
	Damaged propeller; pitch too small; diameter too small
	Keel located too close to propeller or too deep in the water
	Water pickup or accessories located too close to propeller
	Hook in boat bottom
	Propeller fouled by debris

Improper Full Throttle Engine RPM

RPM TOO HIGH

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5FTroubleshooting the ECS System** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Operation	Sterndrive trimmed up (out) too far
Propeller	Damaged
	Pitch too low
	Diameter too small
	Propeller hub slipping
Boat	Water pickup or accessories mounted too close to propeller (ventilation)
	Keel located too close to propeller and/or too deep in the water (ventilation)
	Sterndrive installed too high on transom
	Wrong gear ratio
Engine coupler	Slipping or damaged and must be replaced

RPM TOO LOW

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. See **Section 5F—Troubleshooting the ECS system** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Operation	Sterndrive trimmed down (in) too far
Propeller	Damaged
	Pitch too great
	Diameter too great
Boat	Dirty or damaged bottom
	Permanent or power hook in bottom
	False bottom full of water
	Drive installed too low
	Excessive boat load

Engine Cranks Over But Will Not Start or Starts Hard

ELECTRICAL

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5F—Troubleshooting the ECS System for engine control system** (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Battery, electrical connections, damaged wiring, Lanyard Stop Switch	Check all circuit breakers and fuses. Repair as needed.
Ignition switch	Refer to **Section 4D**.

FUEL SYSTEM

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. See section **5F—Troubleshooting the ECS system, for engine control system** (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Empty fuel tank	
Fuel shut off valve closed (if equipped)	
Low grade, stale fuel, or water in fuel	
Fuel waxing or frozen water separator (cold weather)	
Plugged fuel suction line or filter	
Air leaks, suction side fuel line or water separator	Sucks air into fuel system reducing fuel volume.
Plugged or pinched fuel line	
Fuel tank vent plugged	Engine will start initially. After a short time running, engine will stall and will not restart for a period of time. Can verify if it is a vent problem by running engine with filler cap loose. Filler cap will act as a vent.
Fuel pump actuator	Refer to **Section 5—Fuel System** section.
	Check lanyard stop switch operation.
High pressure fuel pump	Low pump pressure. Refer to **Section 5—Fuel System** in this manual for diagnosis.

MISCELLANEOUS

Cause	Special Information
Low grade or stale fuel.	
Water in fuel.	
Incorrect starting procedure.	Refer to the **Owners Manual**.
Internal mechanical damage (bent rods, etc.).	
Low compression.	Worn valves, rings, cylinder or head gasket.
Valve timing incorrect.	Timing gears improperly installed or cam slipped in drive gear.
Restricted or plugged exhaust.	

Engine Will Not Crank Over or Starter Inoperative

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5F—Troubleshooting the ECS System** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Remote control lever not in neutral position.	
Battery charge low, damaged wiring, loose electrical connections	
Circuit breaker tripped	
Defective (blown) fuse	
Defective ignition switch	
Defective starter solenoid	
Internal mechanical damage	Bent rods
Failed starter	Inspect starter and electrical connections for rust or corrosion.

Charging System Inoperative

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5F—Troubleshooting the ECS System for engine control system** (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Loose or broken serpentine belt	
Engine RPM too low on initial start	Rev engine to 1500 RPM.
Loose or corroded electrical connections	
Faulty battery gauge	Verify with multi-meter and replace if necessary.
Battery will not accept charge	Low electrolyte or failed battery
Faulty alternator or regulator	Replace alternator or regulator.
Refer to **Section 4BCharging System** for complete diagnostic procedures	

Noisy Alternator

Cause	Special Information
Loose mounting bolts	Tighten fasteners if undamaged. Refer to **Section 4B—Charging System**.
Serpentine belt	Replace belt if worn or frayed. If loose, inspect automatic tensioner.
Loose drive pulley	Tighten fastener if undamaged. Refer to **Section 4B—Charging System**.
Worn or dirty bearings	Replace alternator. Refer to **Section 4Charging System**.
Faulty diode trio or stator	Replace alternator. Refer to **Section 4B—Charging System**.
Faulty armature	Rubbing, broken wire or replace alternator. Refer to **Section 4B—Charging System**.

Engine Operates Poorly at Idle

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to Section 5F—Troubleshooting the ECS System, for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Clogged air cleaner	
Plugged fuel suction line or filter	
Air leaks: suction side fuel line, water separating fuel filter or loose intake manifold	
Water in fuel	
Low grade or stale fuel	
Fuel waxing or frozen water separating fuel filter (cold weather)	
Valve timing	Cam slipped in drive gear
Restricted or plugged exhaust	
Injectors not functioning properly	

Cause	Special Information
Low compression	Also check for defective (blown) head gasket
Water leaking into cylinders	Defective head gasket, exhaust manifold, cracked head or aftercooler
Loose or broken engine mounts	
Refer to **Section 5—Fuel System** for complete diagnostic procedures	

Engine Operates Poorly At High RPM

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to Section 5F—Troubleshooting the ECS System, for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Refer to **Section 5** for complete diagnostic procedures for the fuel injection system.	
See **Poor Boat Performance and Poor Maneuverability** troubleshooting in this section.	
Crankcase overfilled with oil	Check oil level with boat at rest in the water.
Plugged fuel tank vent	Loosen filler cap to act as a vent and operate engine to verify.
Low fuel supply	
Clogged fuel filter	Replace fuel filters.
Low grade of fuel or water in the fuel	Drain fuel tank, refill with proper fuel. Drain or replace fuel filters.
Obstructed or kinked fuel lines	
Injectors not functioning properly	Refer to **Section 5D—Fuel Injectors**.
Engine overheating	See **Engine Overheat** troubleshooting in this section.
Low compression	Worn valves, rings, cylinders, etc.
Restricted or plugged exhaust	Verify exhaust system is open and clear of debris.
Valve clearance or valve springs weak or broken	Adjust valve clearance or repair worn or damaged valve components.
Insufficient engine compartment ventilation	Increase engine compartment ventilation.
High pressure fuel pump	Worn or damaged fuel pump internal components. Repair or replace pump.
Turbocharger	Boost compensator hose broken or disconnected, intake or exhaust leaks, defective wastegate device, defective turbocharger.

Poor Fuel Economy

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to Section 5F—Troubleshooting the ECS System, for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Fuel leaks	
Operator habits	Prolonged idling; slow acceleration; failure to cut back on throttle once boat is on plane; boat overloaded; uneven weight distribution.
Engine laboring	Bent, damaged, or wrong propeller. Water test boat for proper operating RPM at WOT.
Clogged air cleaner	

Cause	Special Information
Engine compartment sealed too tight	Not enough air for engine to operate properly.
Boat bottom	Dirty (marine growth), hook, rocker.
Turbocharger malfunction	
Improper fuel	
Crankcase ventilation system not working	
Engine operating too hot or too cold	
Plugged or restricted exhaust	
Engine	Low compression.
Injectors not functioning properly	Refer to **Section 5D—Fuel Injectors**.

Engine Smoking

BLACK SMOKE

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5F—Troubleshooting the ECS System** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Overload	
Restricted air filter, intercooler, or both	
Excessive fuel delivery	Refer to **Section 5—Fuel System**.
Faulty injector, or injectors	Refer to **Section 5—Fuel System**.
Restricted or plugged exhaust	
Insufficient coolant temperature	Defective thermostat.
Excessive idle time (injector coking)	
Leaking head gaskets	
Worn piston rings	
Insufficient engine compartment ventilation	Increase combustion air supply to engine.
Low boost pressure	Check turbocharger and related parts.

BLUE SMOKE

Cause	Special Information
Worn piston rings	Check compression.
Sticking piston rings	Check compression.
Crankcase overfilled—incorrect dipstick reading	
Leaking head gaskets	
Turbocharger	High oil consumption caused by worn seals. Refer to **section 7C—Turbocharger**.

WHITE SMOKE

Cause	Special Information
Faulty injector or injectors	Refer to **Section 5—Fuel System**.
Low compression	
Plugged fuel suction line or filter	

Cause	Special Information
Air leaks: suction side fuel line or water separating fuel filter	
Questionable fuel quality	
Leaking head gaskets	
Engine overheating	Internal engine damage

Exhaust Gas Temperature

HIGH

Cause	Special Information
Excessive load	
Faulty wastegate	Refer to **Section 7C—Turbocharger**.
Faulty Injectors	Refer to **Section 5—Fuel System**.

LOW

Cause	Special Information
Excessive idling time or light loads	

Turbocharger

Cause	Special Information
Smoke from exhaust	Not enough air getting to engine air intake
	Clogged air filter
	Boost pressure too low
	See **Engine Smoking—Black, Blue, or White** of this section.
Loss of power due to turbocharger	Not enough air getting to engine air intake
	Clogged air cleaner
	Boost pressure too low
	Poor lubrication of turbocharger
	Defective wastegate valve. Excessive oil residue buildup in compressor turbine housing
	Rubbing of compressor or turbine impellers against housing
	Air leaking from high-pressure side of turbocharger
Unusual noises and vibrations at turbocharger	Poor lubrication of turbocharger
	Rubbing of compressor or turbine impellers against housing
	Air leaking from high-pressure side of turbocharger
Rubbing of compressor or turbine impellers against housing	Poor lubrication of turbocharger
	Low oil pressure at turbocharger
	Defective bearings in turbocharger
Oil leakage from compressor side	Clogged air cleaner
	Boost pressure too low

Engine Noise

⚠ WARNING

Moving parts can cause serious injury or death. Wear eye protection and keep hands, hair, and clothing away from moving parts when performing tests or checking adjustments on an operating engine.

No definite rule or test will positively determine the source of engine noise; therefore, use the following information only as a general guide to engine noise diagnosis.

1. Use a diagnostic strobe light to determine if noise is timed with engine speed or one-half engine speed. Noises timed with engine speed are related to crankshaft, rods, pistons, piston pins, and flywheel. Noises timed to one-half engine speed are valve train related.
2. The use of a stethoscope can aid in locating a noise source; however, because noise will travel to other metal parts not involved in the problem, caution must be exercised.
3. Try to isolate the noise to location in engine working from front to back or top to bottom. This can help determine which components are at fault.
4. Sometimes noises can be caused by moving parts coming in contact with other components. Examples are: flywheel or coupler, external exhaust flappers rattling against exhaust pipe, crankshaft striking (pan, pan baffle, or dipstick tube), rocker arm striking valve cover, and loose flywheel cover. In many cases if this is found to be the problem, a complete engine teardown is not necessary.
5. When noise is isolated to a certain area and component, removal and inspection will be required. Refer to proper sections of service manual for the required information for service.
6. If noise cannot be isolated in either the engine or drive unit, remove the drive from boat. Run a water supply directly to the engine and run the engine without the drive to determine if noise persists.

VALVE COVER AREA NOISE

Location	Possible Cause
Valve cover area, timed to one-half engine speed, noise could be confined to one cylinder or may be found in any multitude of cylinders	Rocker arm striking valve cover
	Defective hydraulic valve lifter
	Worn rocker arm
	Bent push rod
	Worn camshaft
	Sticking valve

CYLINDER AREA NOISE

Location	Possible Causes
Cylinder area, may be confined to one cylinder or found in more than one cylinder, timed to engine speed	Sticking valve
	Carbon build-up
	Connecting rod installed wrong
	Bent connecting rod
	Piston
	Piston rings
	Piston pin
	Cylinder worn
Engine knocking	Faulty injector (white smoke)
	Worn delivery valve
	Defective hydraulic valve lifter
	Tight piston pin

CAMSHAFT AREA NOISE

Location	Possible Causes
Camshaft area, front of engine, timed to engine speed	Camshaft timing gear
	Injection pump
	Fuel pump
	Valve lifter (camshaft wear)
	Cam bearings
Camshaft area, center of engine, timed to engine speed	Fuel pump
	Valve lifter (camshaft wear)
	Cam bearings
Camshaft area, rear of engine, timed to engine speed	Valve lifter (camshaft wear)
	Cam bearings
Camshaft area, throughout engine, timed to engine speed	Loss of oil pressure
	Valve lifter (camshaft wear)
	Cam bearings

CRANKSHAFT AREA NOISE

Location	Possible Causes
Crankshaft area, front of engine, timed to engine speed	Crankshaft timing gear
	Oil Pump
	Rod bearing
	Main bearing
Crankshaft area, center of engine, timed to engine speed	Crankshaft striking pan or pan baffle speed
	Rod bearing
	Main bearing

Location	Possible Causes
Crankshaft area, rear of engine, timed to engine speed	Loose flywheel cover
	Loose coupler or drive plate
	Loose flywheel
	Rod bearing
	Main bearing
Crankshaft area, throughout engine, timed to engine speed	Loss of oil pressure
	Rod bearings
	Main bearings

MISCELLANEOUS NOISE

Location	Possible Causes
Squeaks, squeals, hissing, or whistle	Leaking exhaust (manifold or pipes)
	Leaking air intake system
	Leaking head gasket
	Loose or leaking cylinder heads
	Dry or tight bearing in an accessory
	Drive belt slipping
	Defective turbocharger
	Parts rubbing together

Oil Pressure

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to Section 5F—Troubleshooting the ECS System, for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Item	Special Information
Incorrect engine installation angle	Verify correct engine installation angle. Incorrect engine installation angle can cause damaging oil pressure fluctuations.
Measuring oil pressure	Use a good automotive oil pressure test gauge rather than the oil pressure gauge in the boat.
Check engine oil level with boat at rest in the water	Oil level should be between the minimum and maximum marks
Oil level in crankcase above maximum mark	May cause loss of engine RPM, oil pressure gauge fluctuation, drop in oil pressure, and hydraulic valve lifter noise at high RPM
Oil level in crankcase below minimum mark	Low oil pressure, oil pressure gauge fluctuation; internal engine noise and/or damage
Change in oil pressure	This may be a normal condition. Oil pressure may read high in the cooler times of the day, and when engine is not up to operating temperature. As the air temperature warms up and engine is running at normal opening temperature, it is normal for oil pressure to drop.

Item	Special Information
Low engine oil pressure at idle	With modern engines and engine oils, low oil pressure readings at idle do not necessarily mean there is a problem. If valve lifters are not noisy at idle, there is a sufficient volume of oil to lubricate all internal moving parts properly. The reason for the drop in oil pressure is that engine heat causes an expansion of the internal tolerances in the engine and, also, the oil will thin out somewhat from heat.
Low engine oil pressure at idle after running at a high RPM	See *Change in oil pressure* and *Low engine oil pressure at idle* preceding.
Boats with dual engines	It is not uncommon to see different oil pressure readings between the two engines, as long as both engines fall within specifications. Differences in oil pressure can be attributed to differences in engine tolerances, gauges, wiring, senders, etc.
Boats with dual stations	

LOW OIL PRESSURE

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to Section 5F—Troubleshooting the ECS System for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Incorrect engine installation angle	Verify correct engine installation angle. Incorrect engine installation angle can cause damaging oil pressure fluctuations.
Low oil level in crankcase.	Test gauge.
Defective oil pressure gauge and/or sender.	Verify with an automotive test gauge.
Thin or diluted oil	Oil broken down; contains water or fuel; wrong viscosity; engine running too hot or too cold; excessive idling in cold water (condensation).
Faulty oil pressure relief or bypass valve.	
Valve stuck open.	Replace or repair.
Oil pump.	Relief valve stuck open; pickup tube restricted; worn parts in oil pump; air leak on suction side of oil pump or pickup oil tube.
Oil leak can be internal or external.	Oil passage plugs leaking, cracked or porous cylinder block.
Excessive bearing clearance.	Cam bearings, main bearings, rod bearings.

HIGH OIL PRESSURE

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to Section 5F—Troubleshooting the ECS System for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Incorrect engine installation angle	Verify correct engine installation angle. Incorrect engine installation angle can cause damaging oil pressure fluctuations.
Oil too thick	Wrong viscosity, oil full of sludge or tar
Defective oil pressure gauge and/or sender	
Clogged or restricted oil passage	

Cause	Special Information
Oil pump relief valve stuck closed	

IMPORTANT: Oil pressure slightly higher than normal does not always indicate a problem. Oil viscosity and weather conditions can cause high oil pressure.

Excessive Oil Consumption

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5F—Troubleshooting the ECS System** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

Cause	Special Information
Incorrect engine installation angle	Verify correct engine installation angle. Incorrect engine installation angle can cause damaging oil pressure fluctuations.
Oil leaks	Clean bilge, run engine with clean white paper on bilge floor, locate the oil leak, or leaks.
Oil too thin	Oil diluted or wrong viscosity
Oil level too high	
Drain holes in cylinder head plugged	Oil will flood valve guides
Defective valve stem seals (if equipped)	
Worn valve stems or valve guides	
Defective oil cooler (if equipped)	Crack in cooler tubes
Defective piston rings	Glazed, scuffed, worn, stuck, improperly installed; ring grooves worn; improper break-in; wrong end gap
Defective cylinders	Out of round, scored, tapered, glazed; excessive piston to cylinder clearance; cracked piston
Defective turbocharger	Oil leaking into intake or exhaust

Water or Coolant in the Engine

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5F—Troubleshooting the ECS System** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

IMPORTANT: To begin diagnosis, identify the primary area of contaminating water (or coolant) accumulation.

IMPORTANT: For proper diagnosis, determine if the contaminating fluid is seawater or coolant. Test moderate sized samples of contaminating water for coolant with a propylene glycol tester. Small samples may require the use of an electronic, refractive tester.

Four common areas of water (or coolant) contamination are: on top of the pistons, in the crankcase oil, in the air intake system, and in the exhaust system.

Remove all water (or coolant) from the engine after identifying the nature of the contamination.

1. Remove all glow plug port plugs and injectors.
2. Disconnect the fuel pump actuator electrical connector at the back of the high pressure injection pump.
3. Crank the engine to expel contaminating water (or coolant) from the cylinders.
4. Connect the fuel pump actuator electrical connector at the back of the high pressure injection pump.
5. Change the engine oil and oil filter.

NOTICE

Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

Start the engine and attempt to duplicate the contamination condition. If the problem can be duplicated, it is most likely a mechanical problem rather than the result of operator error or water ingestion. Rust and scaling in the intake or exhaust system is generally a sign of water ingestion contamination.

WATER OR COOLANT IN THE ENGINE OIL

Cause	Special Information
Water in boat bilge	Boat has been submerged or bilge water was high enough to run in through dipstick tube
Water seeping past piston rings or valves	Refer to **Section 7B - Elbows, Risers, Intake and Exhaust Manifold** of this manual.
Intake manifold leaking near a water passage	
Cracked or porous casting	Check cylinder head, cylinder block, and intake manifold
Oil cooler leaking	Inspect the oil cooler for cracks or damage
Engine running cold	Defective thermostat, missing thermostat; pro-longed idling in cold water

WATER OR COOLANT ON TOP OF THE PISTONS

Cause	Special Information
Rain water running onto air cleaner	Hatch cover
Backwash through the exhaust system	
Improper engine or exhaust hose installation	Refer to **Exhaust Specifications**in the appropriate installation manual.
Cracked exhaust manifold	
Improper manifold to elbow gasket installation	
Loose cylinder head bolts	
Blown cylinder head gasket	Check for warped cylinder head or cylinder block
Cracked or leaking aftercooler	Defective O-rings or tubes
Porous or cracked casting	Check cylinder heads, valve bridges, cylinder block, and intake manifold

Engine Overheat—Cooling System

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. Refer to **Section 5F—Troubleshooting the ECS System** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

IMPORTANT: Verify that the engine is overheating to quickly eliminate a faulty temperature gauge or sender.

Cause	Special Information
Seacock (seawater shut off valve) partially or fully closed (if equipped)	

Cause	Special Information
Low coolant level	If persistent, find and repair the source of any closed cooling system leaks.
Antifreeze incorrect type or not mixed properly	Use low silicate type with special additives.
Loose or broken drive belt	
Clogged or improperly installed sea strainer	
Loose hose connections between seawater pickup and seawater pump inlet	Pump will suck air; pump may fail to prime or will force air bubbles into cooling system.
Seawater inlet hose kinked or collapsed	Inlet hose must be wire reinforced to prevent collapsing, and positioned to prevent kinks or restrictions.
Seawater pickup clogged	
Obstruction on boat bottom causing water turbulence	Obstruction will be in front of seawater pickup, causing air bubbles to be forced into cooling system.
Defective thermostat	
Exhaust elbow water outlet holes plugged	
Insufficient seawater pump operation	Worn pump impeller
Obstruction in cooling system such as casting flash, sand, rust, salt, etc.	Refer to the **Water Flow Diagram** in **Section 6—Cooling System** for engine type being serviced.
Engine water circulating pump defective	
Heat exchanger core or tubes plugged	

Engine Overheat—Mechanical

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process. refer to **Section 5F—Troubleshooting the ECS System** for engine control system (ECS) and SmartCraft diagnostic trouble codes (DTC).

IMPORTANT: Verify that the engine is overheating to quickly eliminate a faulty temperature gauge or sender.

Cause	Special Information
Engine RPM below specifications at wide open throttle (engine laboring)	Damaged or wrong propeller, growth on boat bottom, false bottom full of water.
Seawater pump impeller worn or slipping	Inspect the seawater pump impeller, refer to **Section 6 - Cooling System**.
Exhaust restriction	
Valve timing off	Jumped timing chain, or gears improperly installed.
Insufficient lubrication to moving parts of engine	Defective oil pump, plugged oil passage, low oil level.
Defective wastegate on turbocharger	Wastegate stuck closed causing excessive boost pressure.

Power Steering—Poor, Erratic, or No Assist

Cause	Special Information
Drive belt	Worn, broken, or out of adjustment.
Low fluid level	
Air in system	Air leak in lines, pump, or air from installation. Refer to **Section 9—Power-assisted Steering System** for bleeding procedure.

Cause	Special Information
Leaking hoses	Refer to **Section 9—Power-assisted Steering System** for bleeding procedure.
Steering cables and/or steering helm	Cable or helm partially frozen from corrosion or rus, cable over-lubricated, improper cable installation.
Binding in sterndrive	Refer to the appropriate **Mercury MerCruiser Sterndrive Service Manual**.
Restriction in hydraulic hos	Causes a loss of pressure.
Control valve not positioned properly, not balanced properly, or the mounting nut is loose	
Mounting bracket adjusting screw loose or mounting tube is loose	
Faulty pump	Flow control valve may be sticking.
Worn piston ring or scored housing bore in cylinder	Causes loss of pressure
Leaking valve body or loose fitting spool	

Power Steering—Noisy Pump

Cause	Special Information
Drive belt	Check belt tension.
Low fluid level	
Air in fluid	Air leak in lines, pump, or air from installation.
Faulty pump	Use stethoscope to listen for noise in pump.
Restricted fluid passages	Kinks or debris in hoses or debris in passages.
Stop nut adjusted improperly	Refer to the appropriate **Mercury MerCruiser Sterndrive Service Manual**.
Incorrect or substandard steering cables installed that do not meet ABYC standards	Refer to the appropriate **Mercury MerCruiser Sterndrive Service Manual**.

Power Steering—Fluid Leaks

Cause	Special Information
Loose hose connections	Refer to **Section 9A** for bleeding instructions.
Damaged hose	
Oil leaking from top of pump	System overfilled, fluid contains water, fluid contains air.
Cylinder piston rod seal	
Faulty seals in valve	
Faulty seals in O-rings in pump	
Cracked or porous metal parts	

Seawater Pump—Insufficient Water Flow

Cause	Special Information
Drive belt	Loose, worn, or broken
Seawater shut off valve partially or fully closed	
Clogged or improperly installed sea strainer	

Cause	Special Information
Loose hose connections between seawater pickup and seawater pump inlet	Pump will draw in air, pump may fail to prime or will force air bubbles into cooling system.
Seawater inlet hose kinked or plugged	
Seawater pickup plugged	
Obstruction on boat bottom causing water turbulence	Obstruction will be in front of seawater pickup, causing air bubbles to be forced into cooling system.
Faulty seawater pump	Inspect the seawater pump impeller, see **Section 6—Cooling System**.

ZF Marine Hydraulic Transmission

Problem	Possible Cause	Remedy
Transmission gears cannot be shifted	Shifting lever loose	Tighten clamping screw on shifting lever.
	Remote control does not permit lever travel required for testing	Lift remote control off. If gears can be shifted by hand, correct remote control.
	Remote control faulty	Repair remote control.
	No shifting pressure available	See **No shifting pressure**.
Gears are shifted sluggishly	Lever travel of remote control is too short; lever shift just short of minimum traveling distance	Lift remote control off, if gears can be shifted by hand, correct remote control.
Clutch is slipping; propeller speed too low as compared to engine speed	Incorrect fluid used	Drain and refill with correct fluid, flush transmission while engine runs in neutral position, drain fluid, refill transmission.
	Fluid contains water	
	Shifting pressure too low	
	Wear on clutch discs	Disassemble transmission and (or;) replace clutch discs.
	Piston rings in clutch are damaged	Disassemble transmission and (or;) replace clutch.
Transmission is blocked	Medium piston ring in input shaft in control block is faulty	Remove control block, replace piston ring, replace control block if worn.
Output shaft turns in neutral position	Rotary slide valve in control block is worn	Replace control block.
	Faulty needle bearing on input shaft	Disassemble transmission and input shaft, then (or;) replace bearing.
	Dished discs due to over-heating of slipping clutch	
Shifting pressure too low	Fluid filter dirty	Replace fluid filter.
	Transmission fluid level is too low	Fill with fluid; check the transmission, fluid cooler, and fluid hoses for leaks. See *Fluid leakage at input shaft*, *Fluid leakage at output shaft*, *Fluid leakage at venting filter*, *Fluid leakage at joints or screw connections*.
	Fluid pump is worn out	Replace control block together with fluid pump.
	Piston rings in input shaft in control block are faulty	Remove control block and replace piston rings. Also replace control block.
	Piston rings in clutch are faulty.	Disassemble transmission and (or;) replace clutch.

Problem	Possible Cause	Remedy
No shifting pressure	Direction of engine rotation does not agree with arrow on transmission	Replace with LH rotation engine.
	No fluid in transmission	Refill with fluid.
	Fluid filter is dirty	Replace fluid filter.
	Transmission fluid level is too low	Fill with fluid; check the transmission, fluid cooler, and fluid hoses for leaks. See *Fluid leakage at input shaft*, *Fluid leakage at output shaft*, *Fluid leakage at venting filter*, *Fluid leakage at joints or screw connections*.
	Fluid pump is worn out	Replace control block together with fluid pump.
	Fitting key in input shaft for fluid pump drive is broken	Remove control block. Replace fitting key and any other faulty parts.
	Shifting pressure relief valve spring is broken	Replace control block.
Excessive fluid temperature	Excessive fluid in transmission	Remove excessive fluid with commercial fluid pump.
	Fluid cooler is dirty on water side	Remove coolant lines and clean fluid cooler on water side.
	Worn fluid pump in control block	Replace control block and fluid pump.
	Faulty piston rings in input shaft in control block	Remove control block, replace piston rings in input shaft. Check control block and replace if damaged from faulty piston rings.
	Clutch is slipping	See *Clutch is slipping; propeller speed too low as compared to engine speed*.
	Clutch does not open completely due to worn clutch discs	Dismount transmission and (or;) replace inner disc all faulty parts.
	Clutch does not open completely due to broken clutch cup springs	Disassemble transmission and (or;) replace inner disc support and/or clutch.
	Low water flow from seawater pump	Repair or replace seawater pump.
Water in fluid or fluid looks milky	Fluid cooler faulty	Repair leakage at cooler or replace cooler and replace cooler.
	High water level in engine compartment, water entering at output shaft seal	Remedy cause for water level in engine compartment and (or;) change transmission fluid.
Fluid leakage at input shaft	Breather clogged by paint or dirt	Remove dirt or paint from breather.
	Shaft seal faulty	Disassemble transmission and (or;) replace seal. If seal location on input shaft is worn repair surface.
Fluid leakage at output shaft	Breather clogged by paint or dirt	Remove dirt or paint from breather.
	Shaft seal faulty	Disassemble transmission and (or;) replace seal. If seal location on input shaft is worn repair surface.
Fluid leakage at venting filter	Excessive fluid in transmissio	Pump out excessive fluid with commercial hand pump.
Fluid leakage at joints or screw connections	Bolts are not tight	Tighten bolts to specified torque.
	Seals on bolts have been reused several times	Replace seals. Tighten bolts to specified torque.

Problem	Possible Cause	Remedy
Fluid leakage at filter cap or breather	Filter cap not flush or tight	Reinstall filter cap flush with housing and tighten.
	Filter cap O-ring damaged	Replace O-ring.
	Fluid level too high	Correct fluid level.
Transmission noise changes, becomes louder	Fluid level too low so that pump sucks in air	Top off fluid to fill mark.
	Damage starting on flexible coupling due to wear or fatigue, possible due to misalignment between engine and transmission	Replace flexible coupling. Check alignment between engine and transmission.
	Beginning damage of bearings in transmission; torsional vibrations, running without fluid, overload, wrong alignment of transmission, excessive engine output	Disassemble transmission or replace bearings concerned and other faulty parts.
	Beginning damage of gearings; torsional vibrations, running without, fluid, overload	Disassemble transmission and (or;) remove faulty parts.
	Fluid baffle on transmission has come loose	Disassemble transmission and (or;) attach baffle plate.
	Fluid suction pipe in transmission has come loose	Disassemble transmission and (or;) fix fluid suction pipe.
Chattering transmission noise mainly at low speed	The engine or propeller generate torsional vibrations, which produce a chattering noise in the transmission.	Mount a flexible coupling with another stiffness factor between engine and transmission; a coupling with a higher stiffness factor might be sufficient.
	Misaligned cardan shafts on input or output shafts	Mount and align cardan shaft strictly according to instructions issued by cardan shaft manufacturer.

Removal And Installation

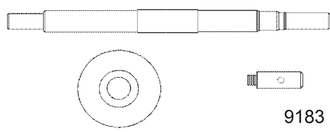
Section 2A - Sterndrive Models

Table of Contents

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Engine mounting hardware threads and nuts	92-34227 1
25	Liquid Neoprene	Exposed terminals and connections	92- 25711 3
80	SAE Engine Oil 30W	Shift cable pivot points	Obtain Locally
91	Engine Coupler Spline Grease	Coupler splines	92-802869A1

Special Tools

Alignment Tool Assembly	91-805475A 1
 9183	Aligns the engine and the sterndrive during installation.

Engine Removal

⚠ WARNING

Fuel vapors trapped in the engine compartment may be an irritant, cause difficulty breathing, or may ignite resulting in a fire or explosion. Always ventilate the engine compartment before servicing the power package.

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

1. Disconnect the battery cables from the battery.

IMPORTANT: The sterndrive must be removed before removal of the engine. Refer to the appropriate Mercury MerCruiser sterndrive service manual if additional service is required for the sterndrive or transom.

2. Remove the sterndrive.
3. Disconnect the battery cables from the engine.
4. Lift and detach the engine cover from the engine cover mounts.
5. Disconnect the engine to VIP harness from the engine wiring harness connectors.
6. Close the fuel shut-off valve, if equipped.
7. Disconnect and plug the fuel lines to prevent fuel from leaking into the bilge.
8. Disconnect the throttle cable and retain the fasteners.
9. Disconnect the shift cables from the shift plate and retain the fasteners.
10. Disconnect the power-assisted steering hydraulic hose fittings from the steering control valve and connect the hoses together to prevent leaking.
11. Remove the gear lube monitor and hose and place out of the way.

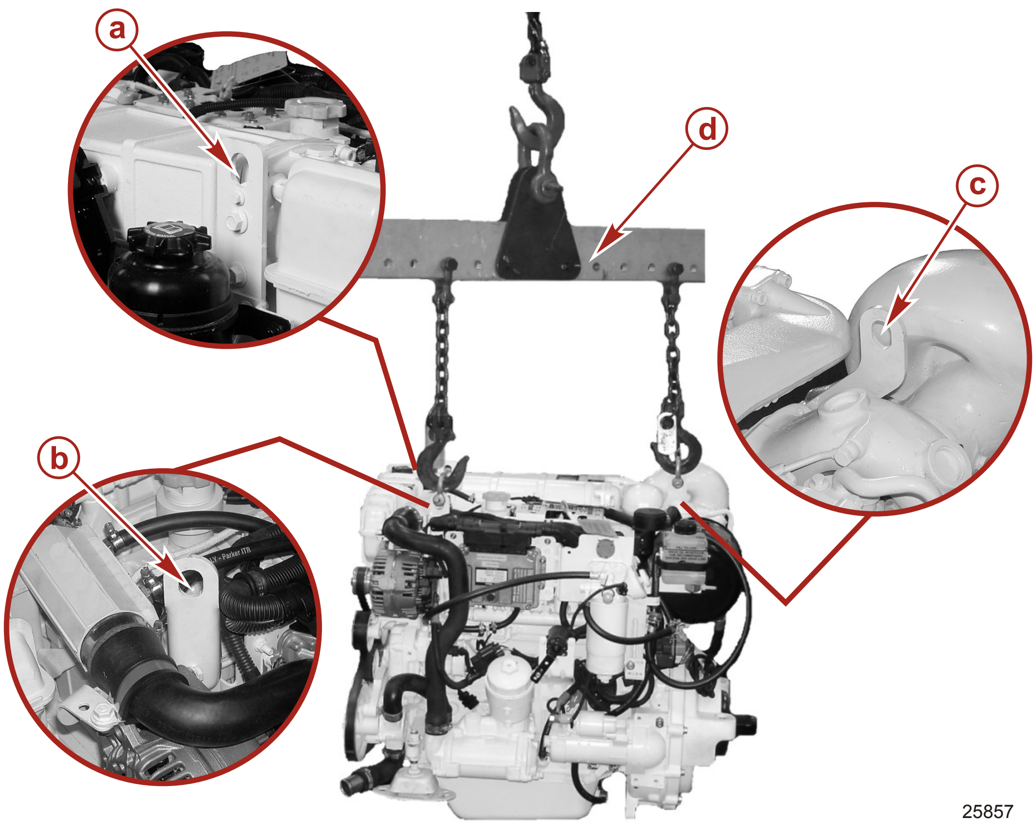
NOTE: After wires are disconnected, loosen them from any clamps or cable ties retaining them to the engine or hoses.

12. Disconnect the wires from the MerCathode controller assembly and disconnect the MerCathode quick connect fitting, if equipped.
13. **If the boat is to remain in the water**, close the seacock (if equipped) or disconnect and plug the seawater inlet hose.
14. Disconnect the seawater inlet hose.
15. Disconnect the exhaust system hoses.
16. Disconnect any grounding wires and accessories that are connected to the engine.

⚠ WARNING
Failure of the lifting eyes will cause the engine to fall suddenly from the hoist, resulting in serious injury, death, or property damage. Keep the engine level while it is hoisted. Do not tilt the engine more than 12° in any direction during installation.

⚠ CAUTION
Improper lifting during removal or installation of the engine can cause injury or damage to engine components. Use a hoist, lifting arm, or other approved lifting device. Do not allow the lifting device to hook or compress any engine components.

17. Support the engine with a sling and lifting arm through the lifting eyes on the engine.



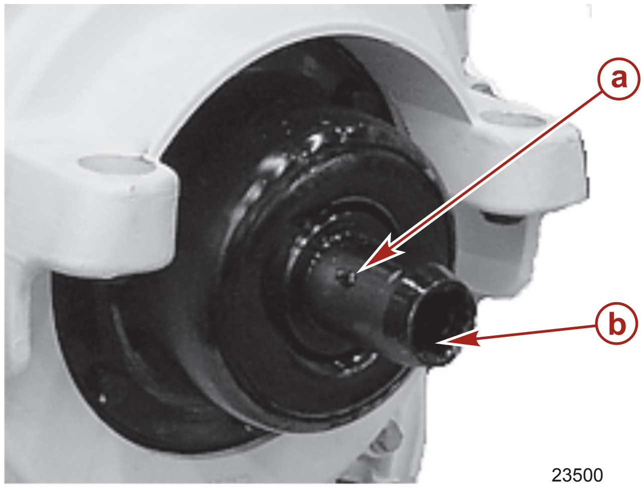
Typical

- **a -** Front starboard side engine lifting eye (back side of engine)
- **b -** Front port side engine lifting eye
- **c -** Rear engine lifting eye
- **d -** Sling and lifting arm

18. Remove the front and rear engine mounting bolts and retain the fasteners.
19. Using an overhead hoist, carefully remove the engine. Do not damage the power-assisted steering control valve.

Engine Installation

1. Ensure that the front mount adjusting nuts are positioned midway on the studs so that adequate up and down adjustment exists for engine alignment.
2. Lubricate the coupler splines.



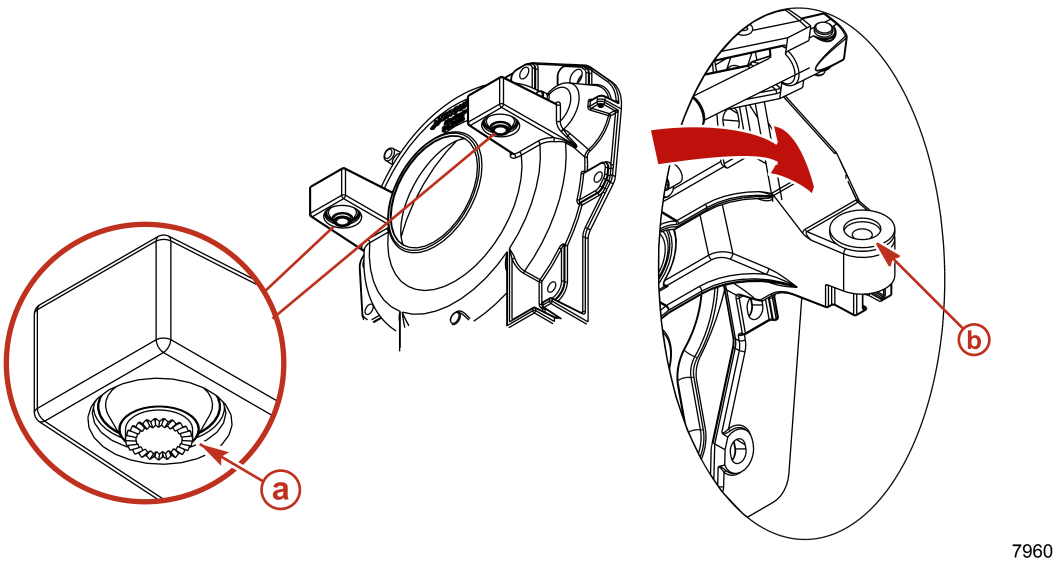
a - Grease fitting **b -** Coupler splines

Tube Ref No.	Description	Where Used	Part No.
91	Engine Coupler Spline Grease	Coupler splines	92-802869A1

NOTICE

Mismatched flywheel housing mounts and inner transom plate mounting hardware will result in improper engine alignment and possible engine damage. Ensure that the flywheel housing mounts and the inner transom plate mounting hardware, port and starboard, are the correct parts and match before installing the engine.

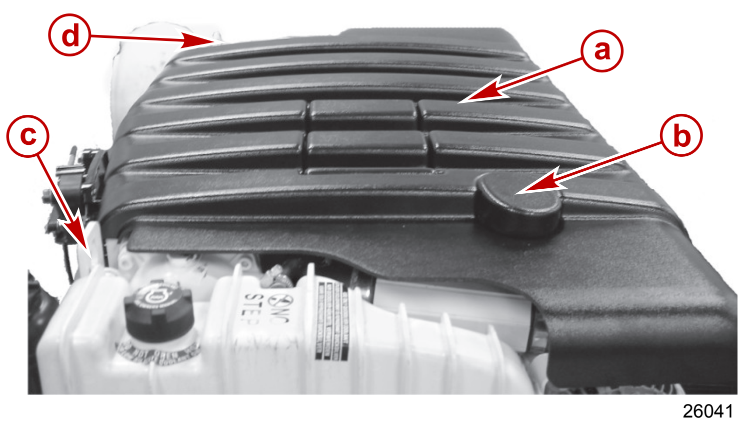
3. Position the rear engine mount attaching hardware on the inner transom plate mounts as shown.



Starboard side shown, port side similar

a - New design mount—knurled surface
b - Fiber washer

4. Remove the front port lifting eye access cover in the engine cover or remove the entire engine cover to gain access to the lifting eyes.



a - Engine cover
b - Front port side lifting eye access cover
c - Front starboard side lifting eye
d - Rear lifting eye

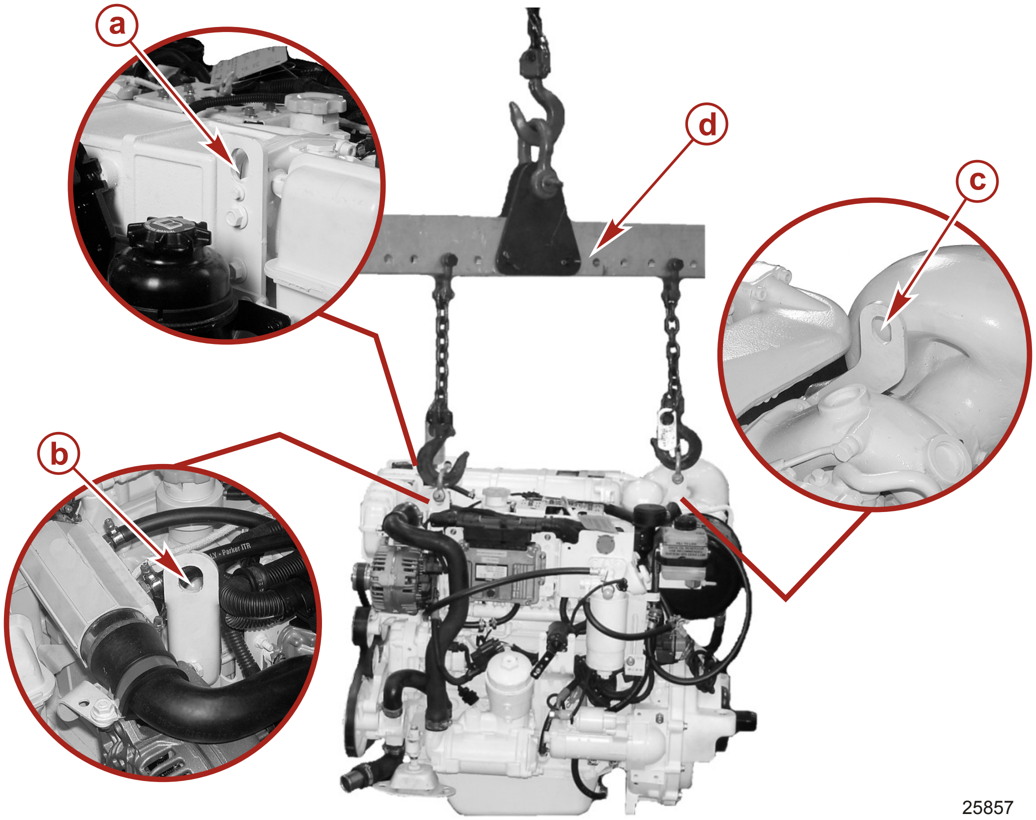
⚠ CAUTION
Improper lifting during removal or installation of the engine can cause injury or damage to engine components. Use a hoist, lifting arm, or other approved lifting device. Do not allow the lifting device to hook or compress any engine components.

5. Attach a suitable sling and lifting arm to the engine lifting eyes and adjust so that engine is level when suspended.

⚠ WARNING

Failure of the lifting eyes will cause the engine to fall suddenly from the hoist, resulting in serious injury, death, or property damage. Keep the engine level while it is hoisted. Do not tilt the engine more than 12° in any direction during installation.

6. Lift the engine into position in the boat using an overhead hoist.



Typical

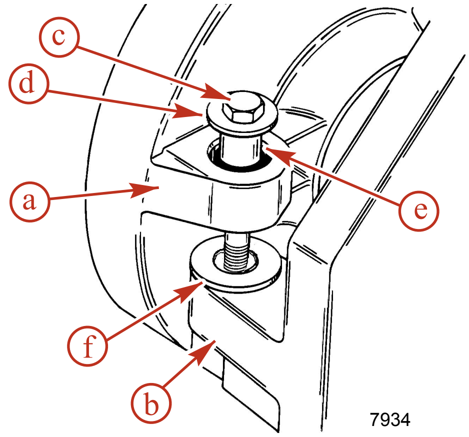
- **a -** Front starboard side engine lifting eye (back side of engine)
- **b -** Front port side engine lifting eye
- **c -** Rear engine lifting eye
- **d -** Suitable sling and lifting arm

IMPORTANT: When lowering engine into position do not set the engine on the shift cable.

7. Ensure that the fiber washers and locknuts are on the inner transom plate mounts.
8. Align the rear engine mounts with the inner transom plate mounts, then set the engine onto the inner transom plate mounts. Simultaneously align the exhaust elbow with the exhaust tube. Do not relieve the tension on the hoist.

IMPORTANT: Install the engine mounting hardware in the sequence shown.

9. Install and torque both rear engine mounting bolts with the hardware as shown.



Typical model

a - Rear engine mount
b - Inner transom plate mount
c - Bolt
d - Washer
e - Spacer
f - Fiber washer

Description	Nm	lb. in.	lb. ft.
Rear engine mounting bolts	51		38

10. Adjust the front engine mounts until they rest on the boat stringers.
11. Set the engine on the boat stringers.
12. Relieve the tension on the hoist.
13. Disconnect the sling from the engine lifting eyes.

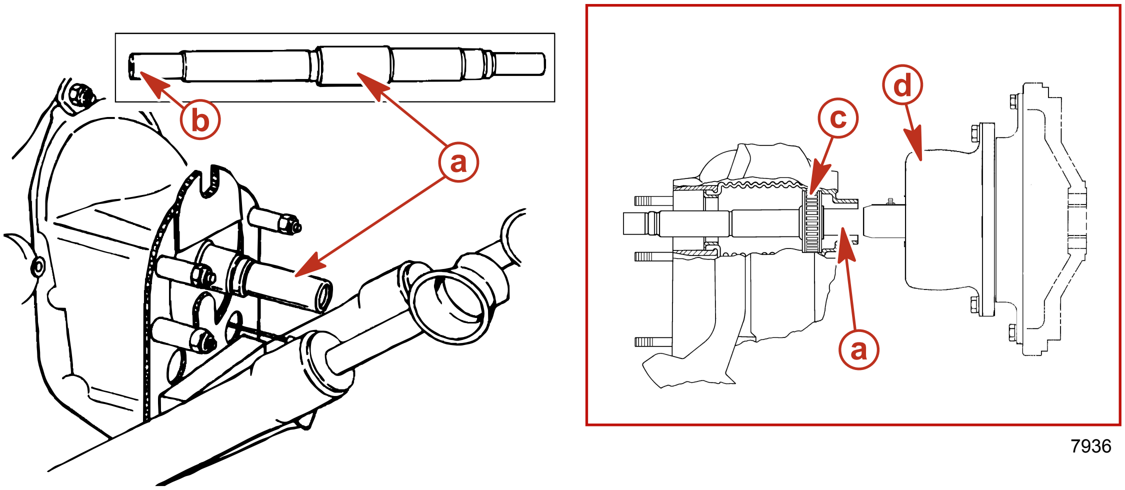
Alignment

NOTICE

Improper use of the alignment tool may result in personal injury or damage to the gimbal bearing or engine coupler. Do not operate the engine with the alignment tool installed. Do not attempt to force the alignment tool, raise or lower the engine with the tool inserted in the gimbal bearing or engine coupler, or raise the engine mount bracket above the top of the engine mount stud.

IMPORTANT: Alignment tools from other manufacturers may cause improper alignment and damage to the gimbal bearing or engine coupler. Use only the Quicksilver Alignment Tool.

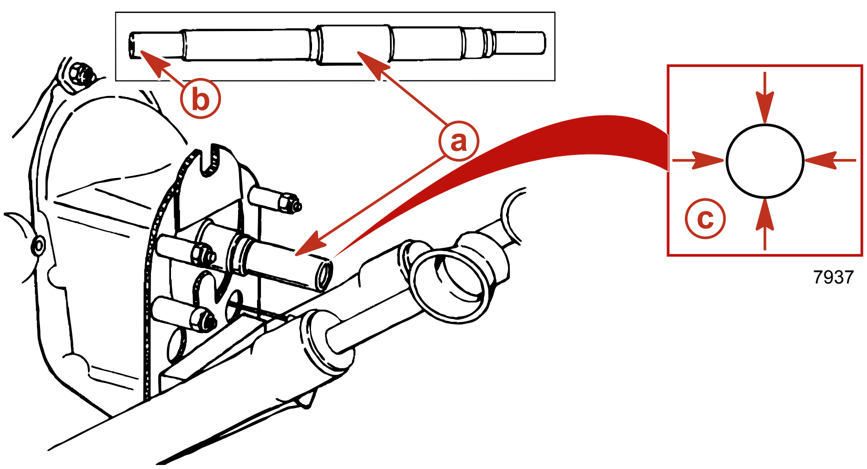
1. Attempt to insert the solid end of the alignment tool through the gimbal bearing and into the engine coupler splines.



7936

a - Alignment tool
b - End of alignment tool to insert through the gimbal housing assembly
c - Gimbal bearing
d - Engine coupler

2. If necessary, firmly strike the sides of the alignment tool with a synthane hammer at 90° increments to help align the gimbal bearing to the coupler.



7937

a - Alignment tool
b - Inserted through the gimbal housing assembly
c - 90° increments

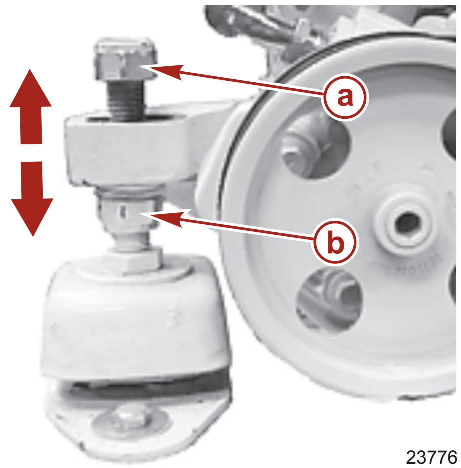
Alignment Tool Assembly	91-805475A 1

3. Attempt to insert the solid end of the alignment tool through the gimbal bearing and into the engine coupler splines.

4. If the alignment tool does not fit, remove it and carefully and adjust the engine mounts.

IMPORTANT: Turn both front engine mount adjustment nuts an equal amount in the direction required to align the engine.

a. **To adjust the engine up or down**, loosen the locknuts on both front mounts. Turn the adjusting nuts as necessary. Tighten the locknuts.



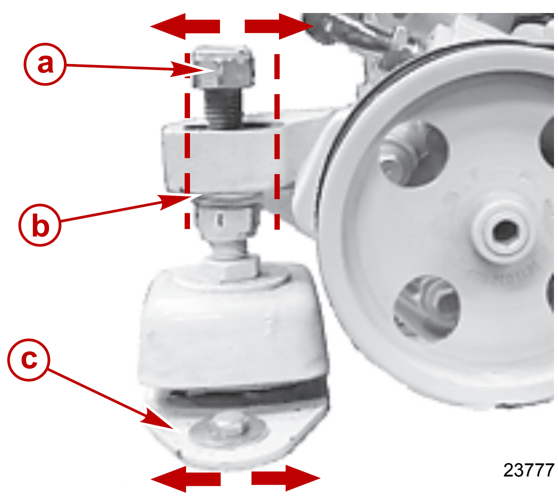
Typical front mount

a - Locknut

b - Adjusting nut

b. **To move the engine left or right**, loosen the locknuts on both front mounts. Move the engine as necessary in the slotted mount holes.

NOTE: The slots on the engine mount pads provide a small amount of left or right adjustment.



Typical front mount

a - Locknut

b - Slotted mount hole

c - Engine mount pad

5. Attempt to insert the solid end of the alignment tool through the gimbal bearing and into the engine coupler splines.
6. Repeat the necessary steps until the alignment tool installs easily **(slides freely with two fingers)** all the way into and out of the engine coupler splines. Do not check by turning the alignment tool.

7. Fasten the front mount assemblies to the boat stringers using appropriate hardware (lag bolts or thru-bolts and so on).
8. Tighten both front mount locking (jam) nuts.

Description	Nm	lb. in.	lb. ft.
Front mount locking (jam) nuts	80	–	59

9. Recheck alignment with the alignment tool. The tool must enter the coupler splines freely. If not, remove the alignment tool and readjust the front mounts.
10. Remove the alignment tool.
11. If operating in a saltwater environment, apply sealant to the threads and nuts of the engine mounting hardware to help protect against corrosion. This allows for easier loosening in the case of readjustment.

Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Engine mounting hardware threads and nuts	92-34227 1

12. Remove the sling from the front lifting eyes.

Exhaust System Connections

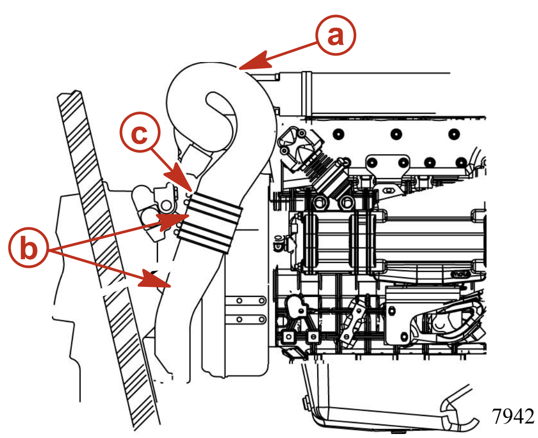
NOTICE

Hot spots in exhaust hoses can damage hoses and cause leaks. Ensure that discharge water from the exhaust elbow flows without restriction through all hoses and fittings.

IMPORTANT: Exhaust bellows, hoses, and tubes must be secured at each connection with at least two hose clamps.

All exhaust connections, including those at the exhaust elbow, should be secured with two hose clamps. ABYC standards also specify the use of stainless steel clamps with a minimum 13 mm (1/2 in.) band width. Do not use spring tension clamps.

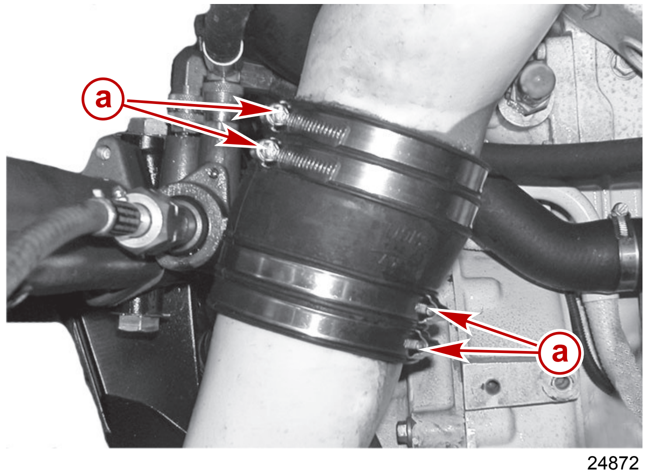
1. Connect the exhaust hoses and tubes so that they do not restrict the flow of discharge water from the exhaust elbow.
2. Install at least two hose clamps on each exhaust hose and tube connection.



Typical

a - Exhaust riser
b - Exhaust tubes
c - Hose clamps

3. Torque the exhaust system hose clamps.



a - Exhaust system hose clamps (4)

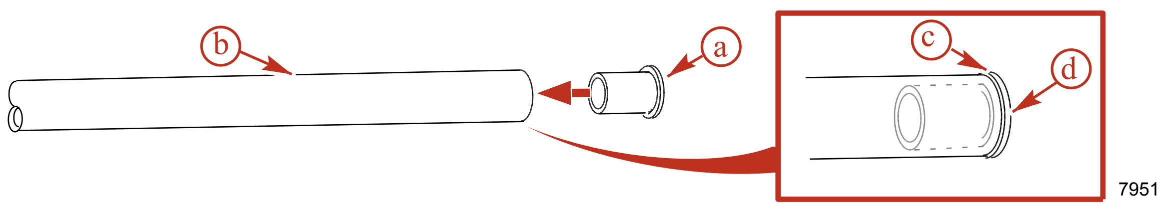
Description	Nm	lb. in.	lb. ft.
Exhaust system hose clamps	3.4–6.8	30–60	

Fluid Connections

Seawater Hoses

IMPORTANT: Seawater hoses must be wire-reinforced to avoid collapsing when suction is created by the seawater pump impeller.

1. Ensure that the hose reducer is installed in the end of the seawater inlet hose that will connect to the sterndrive seawater inlet fitting. The hose reducer flange must touch the end of the hose to be properly installed.

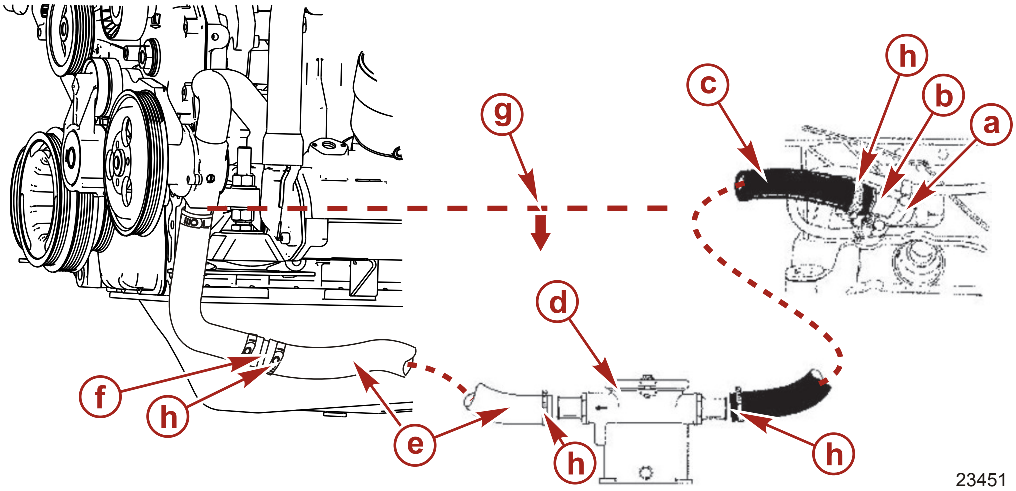


a - Hose reducer
b - Seawater inlet hose
c - Hose reducer flange
d - End of hose

IMPORTANT: Make gradual bends in the seawater hoses to avoid kinks. Hoses must not come in to contact with steering system components, the engine coupler, or the drive shaft.

2. Install the seawater hose from the seawater pickup fitting to the seawater pump inlet hose connector or the seawater strainer inlet (if equipped).
3. If equipped with a seawater strainer, install the seawater hose from the seawater strainer outlet to the seawater pump inlet hose connector.

4. Tighten the seawater hose clamps securely.



Seawater hose standard connections

a - Standard seawater inlet fitting, optional seacock hose connection not shown
b - Hose reducer
c - Seawater hose to seawater strainer
d - Optional quicksilver seawater strainer
e - Seawater hose to seawater pump
f - Seawater pump hose connector
g - Below seawater pump level
h - Hose clamp

Power-Assisted Steering Hoses

HOSES WITH QUICK-CONNECT FITTINGS

⚠ WARNING

Stress on hose fittings or kinks in the hoses can damage hydraulic steering components, leading to serious injury or death due to loss of boat control. Extreme heat can lower the hoses' burst pressure or melt the hose. Route hydraulic hoses to avoid kinks, heat sources, or stress on the hose fittings.

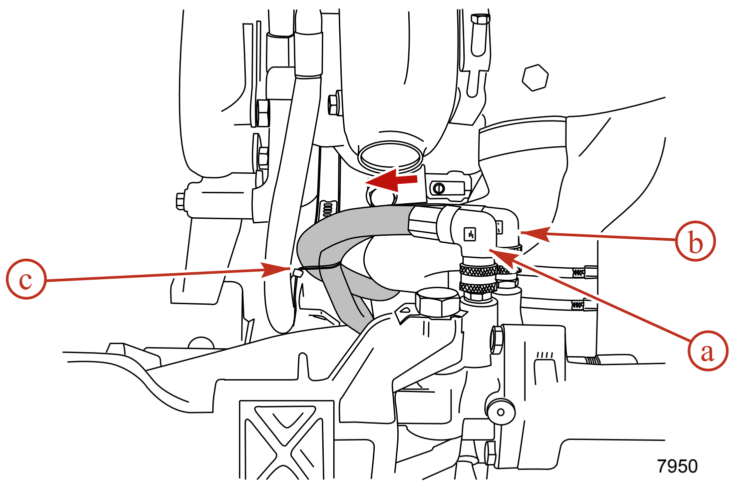
1. Route the power steering hydraulic hoses to avoid extreme heat, stress on hose fittings, and hose kinks.

IMPORTANT: Make hydraulic connections as quickly as possible to prevent fluid leaks.

2. Disconnect the hydraulic lines quick-connect fittings from each other.

a - Hydraulic lines quick-connect fittings

3. Connect the power-assisted steering hoses to the control valve. Ensure that the quick-connect fittings snap into place.



a - Rear fitting (pressure hose)
b - Front fitting (return hose)
c - cable tie

IMPORTANT: Hydraulic hoses must not come in contact with steering system components, engine coupler, U-joint shaft or drive shaft.

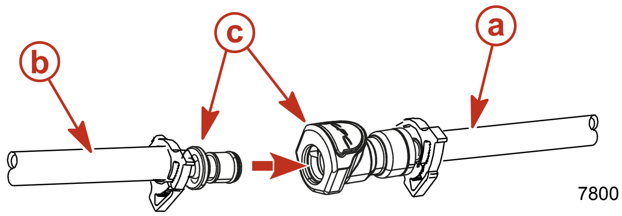
4. Secure the hydraulic hoses to avoid contact with hot or moving components.

Gear Lube Monitor

IMPORTANT: Route hoses to determine the minimum length of hose needed and trim off the excess to avoid low spots in the system. Avoid kinks and route in a straight path to avoid low spots (traps) in the system.

1. Locate the quick-connect fitting of the white gear lube monitor at the rear of the engine.
2. Ensure that the gear lube monitor hose is mounted in the J-clip on the transom plate.

3. Fasten the quick-connect fitting between the gimbal housing hose assembly and the gear lube monitor hose assembly.



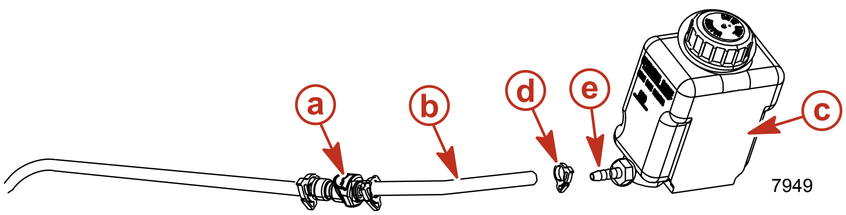
a - Gear lube monitor hose assembly from transom

b - Gear lube monitor hose assembly from gear lube monitor

c - Quick-connect fitting

IMPORTANT: Avoid using excessive hose when routing to the gear lube monitor. The hose should be routed directly to the oil reservoir in as straight a line as possible to avoid low spots (traps) in the system.

4. Route the gear lube monitor hose, or hose assemblies, if equipped, with quick-connect fittings, to the gear lube monitor.
5. If necessary, cut the gear lube monitor hose to the correct length at the gear lube monitor.
6. Connect and securely clamp the gear lube monitor hose to the gear lube monitor fitting.



Typical

a - Quick-connect, if equipped

b - Gear lube monitor hose

c - Gear lube monitor

d - Clamp

e - Fitting

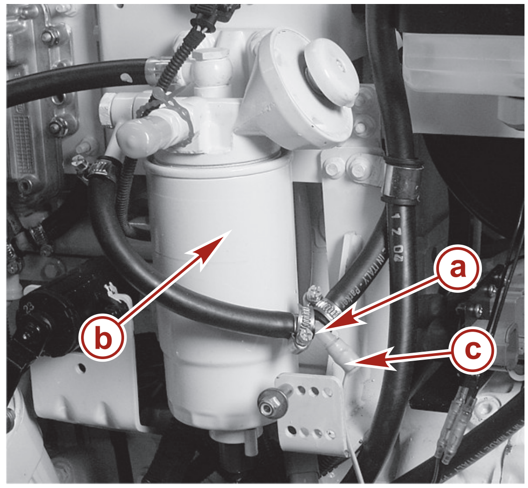
IMPORTANT: The gear lube monitor hose must not come in contact with the steering system components, engine coupler, or drive shaft.

7. Secure the gear lube monitor hose with cable ties.

Fuel Lines

1. Remove the protective cap or plug.
2. Connect a flexible fuel hose to the fuel inlet fitting.

3. Secure with hose clamps.



2.8 shown, 4.2 similar

a - Fuel inlet fitting
b - Water-separating fuel filter
c - Protective cap

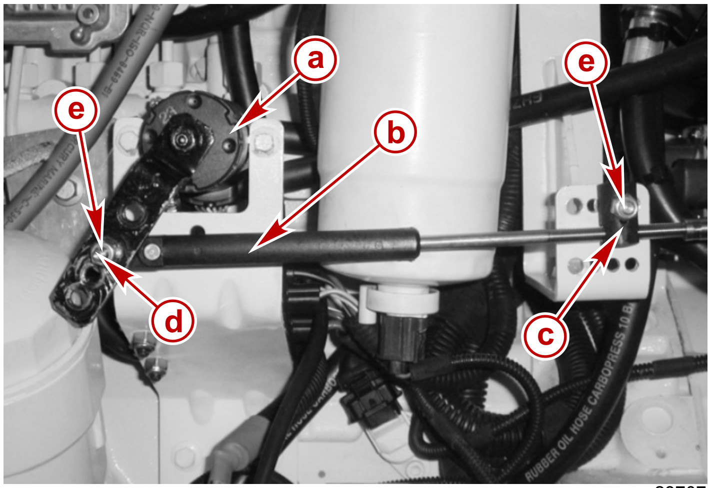
Throttle and Shift Cable Installation and Adjustment

Throttle Cable Installation and Adjustment

IMPORTANT: When installing throttle cables, route the cables to avoid sharp bends and to avoid contact with moving parts. Do not fasten any items to the throttle cables.

1. Install the end guide of the throttle cable anchor stud in the third hole from the end of the throttle position sensor (TPS) lever.
2. Place the remote throttle lever in the neutral and idle position.
3. Install the cable end guide on the throttle lever. Hand tighten the locknut only.

4. Install the throttle cable barrel anchor stud in the third hole from the left on the top row of the anchor bracket. Hand tighten the locknut only.



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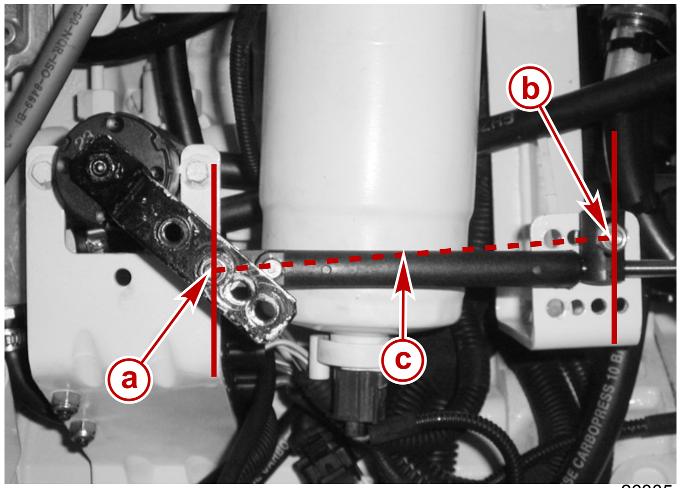
a - Throttle position sensor (TPS)
b - Throttle cable end guide
c - Flat washer and locknut
d - Cable barrel
e - Anchor stud

IMPORTANT: The engine will reach 100% WOT before the TPS reaches the mechanical stop. Adjust the throttle cable so that the throttle position sensor does not contact the mechanical stop at 100% WOT. Contact between the TPS at WOT and the mechanical stop could result in premature TPS failure.

5. **If using the CDS tool to adjust the throttle cable**:
   a. Move the throttle lever forward until the CDS tool reads 100% WOT.
   b. Adjust the throttle cable end guide and barrel anchor stud so that the throttle position lever can move past 100% WOT but will not contact the TPS mechanical stop.

6. **If the CDS tool is unavailable, then adjust the throttle cable as follows**:
   a. Move the throttle lever forward to the WOT location.
   b. Measure the distance between the anchor stud on the throttle lever and the and the center of the anchor stud on the cable barrel as shown. The distance between them at WOT is 140 mm (5 ½ in.).



26385

a - Cable end guide anchor stud
b - Throttle cable barrel location on anchor bracket
c - 140 mm (5 ½ in.)

   c. Adjust the throttle cable end guide and barrel anchor stud to the dimensions specified and ensure that the throttle position lever is not contacting the TPS WOT mechanical stop. The engine will reach 100% WOT before the TPS reaches the mechanical stop.
7. Tighten the locknuts until they contact the washers, then loosen 1/2 turn.
8. Place the remote control lever in the neutral and idle position. Adjust the throttle cable barrel if the throttle position sensor did not return to the idle position.
9. Place the remote control lever fully in the forward WOT position.
10. Operate the remote control and check that the throttle position sensor lever reaches wide-open or 100% throttle position.

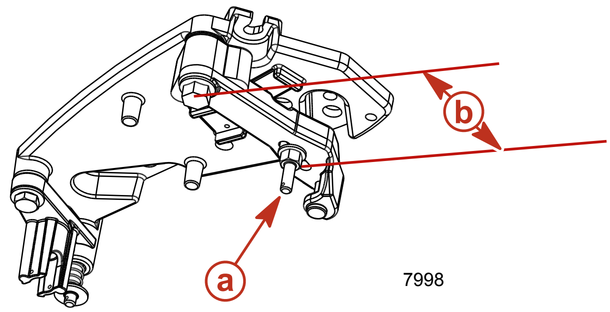
Shift Cable Installation and Adjustment

NOTE: The Shift Cable Adjustment Tool (91-12427) allows the shift cables to be installed and adjusted with or without the sterndrive attached.

1. Install the shift cable onto the remote control. Refer to the appropriate remote control instructions.

IMPORTANT: Do not overtighten the stud. Overtightening the stud can cause shift lever damage.

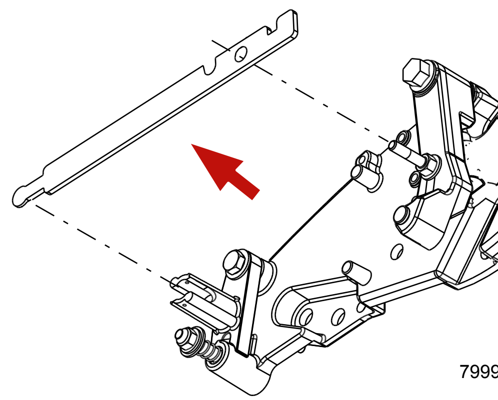
2. Loosen the stud and move it to the dimension shown. Retighten the stud.



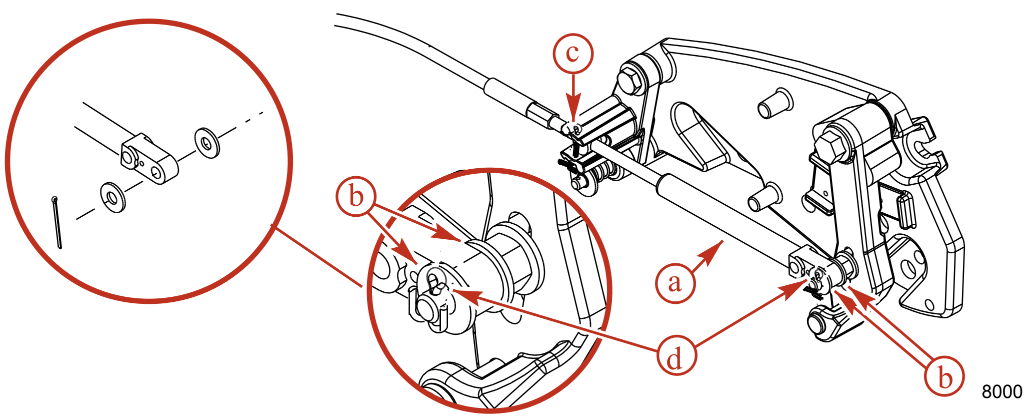
a - Stud

b - 76 mm (3 in.)—distance from the center of pivot bolt to the center of the stud

3. Remove the adjustment tool.



4. Install the sterndrive shift cable.
5. Insert the cotter pins from the top. Spread the ends of the cotter pins fully.



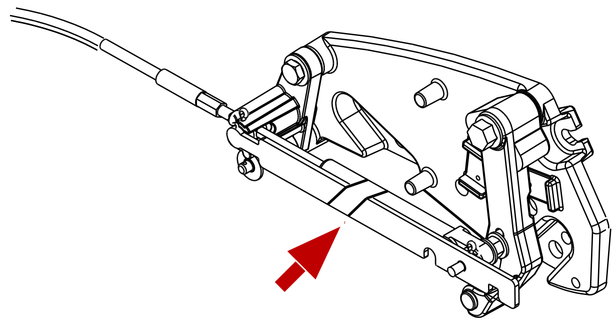
a - Sterndrive shift cable

b - Washers (2)

c - Long cotter pin

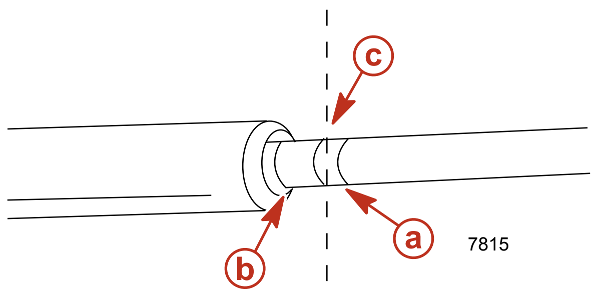
d - Short cotter pin

6. Place the adjustment tool over the sterndrive shift cable as shown. Hold the tool in place using a piece of tape over the barrel retainer.



8001

7. Locate the center of the remote control and control cable play (backlash).
   a. Shift the remote control to neutral.
   b. Push in on the control cable end with enough pressure to remove play and mark position "a" on the tube.
   c. Pull out on the control cable end with enough pressure to remove play and mark "b" on the tube.
   d. Measure the difference between marks "a" and "b" and mark position "c" half-way between marks "a" and "b."



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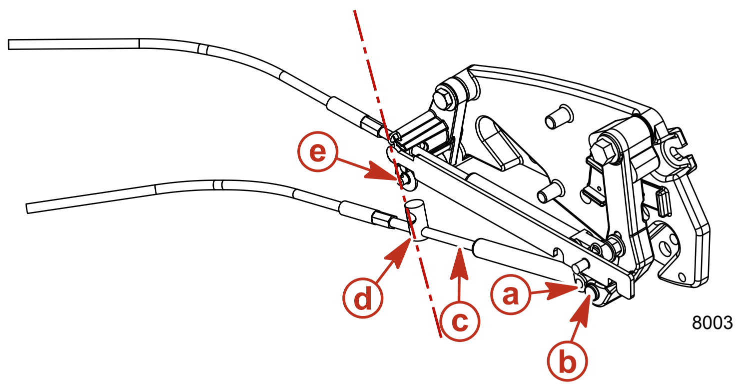
IMPORTANT: Be sure to keep center mark "c" aligned with the edge of the control cable end guide when making the following adjustment.

8. Adjust the control cable as follows:
    a. Temporarily install the control cable end guide into the shift lever, and insert the clevis pin.
    b. Adjust the control cable barrel so that the hole in the barrel aligns with the vertical centerline of the stud. Ensure that the backlash center mark "c" is aligned with edge of the control cable end guide.

⚠ CAUTION

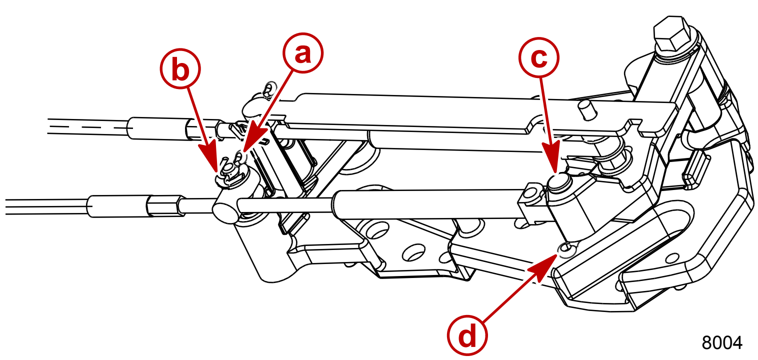
Do not attempt to install or remove control cable barrel from stud without first removing end guide anchor pin from shift lever and removing cable. Attempting to bend control cable to install or remove barrel will place undue stress on cable end guide and shift lever and damage to both could occur.

    c. Remove the control cable end guide from the shift lever by removing the clevis pin.



a - Control cable end guide
b - Clevis pin
c - Backlash center
d - Control cable barrel
e - Stud

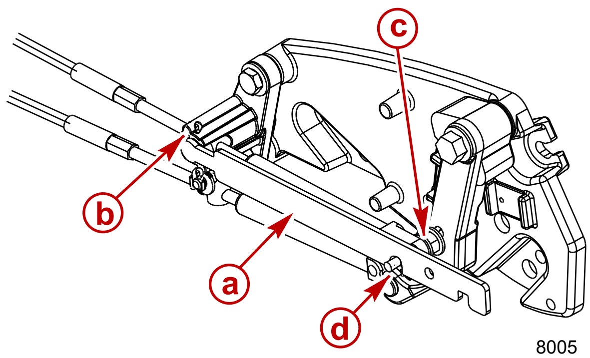
9. Install the control cable.
10. Install the washer and cotter pin to secure the barrel. Spread the ends of the cotter pin fully.
11. Install the clevis pin.
12. Install the cotter pin into the clevis pin. Spread the ends of the cotter pin fully.



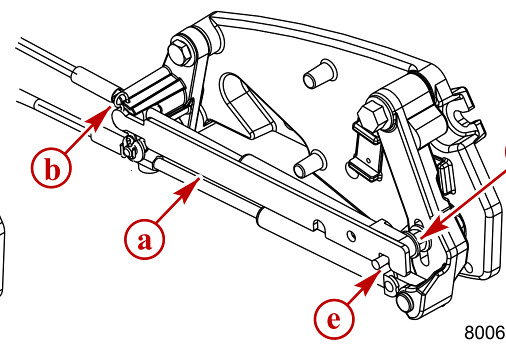
a - Cotter pin
b - Washers (both sides of barrel)
c - Clevis pin
d - Cotter pin (partially shown)

13. Remove the adjustment tool.

14. Shift the remote control lever into the full forward position. Place the end of the adjustment tool in the barrel retainer.
    a. **RH Rotation Bravo One, Two, and Three Model**: The rear slot in the tool should fit over the shift lever stud.
    b. **LH Rotation Bravo One and Two**: The forward slot in the tool should fit over the shift lever stud.
15. If the slot does not fit over the stud, loosen the shift lever stud and slide the stud up or down until the slot in the tool fits over the stud. When adjustment is correct, retighten the stud.



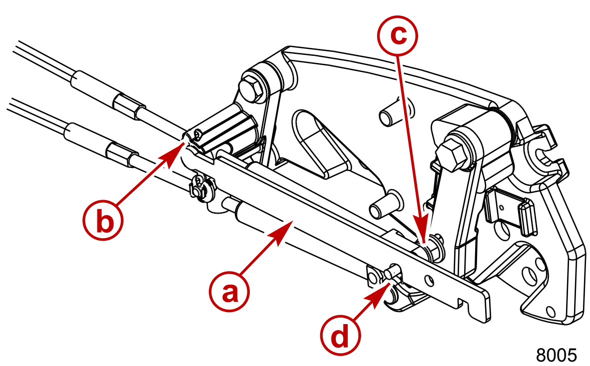
RH Rotation—Bravo One, Two, Three



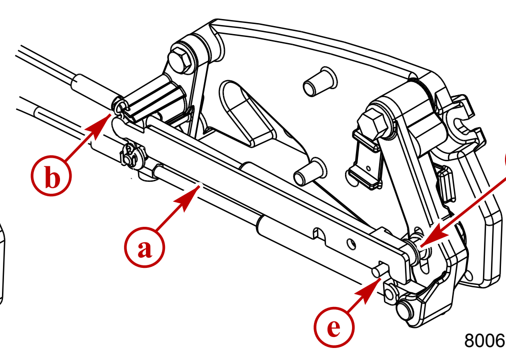
LH Rotation—Bravo One and Two

- **a -** Adjustment tool
- **b -** Barrel retainer cotter pin
- **c -** Shift lever stud
- **d -** Shift lever adjustment tool, rear slot
- **e -** Shift lever adjustment tool, forward slot

16. Remove the adjustment tool.
17. Shift the remote control into reverse and repeat the adjustment process.
    a. **LH Rotation Bravo One and Two**: The rear slot in the tool should fit over the shift lever stud.
    b. **RH Rotation Bravo One, Two, and Three Model**: The forward slot in the tool should fit over the shift lever stud.
18. If the slot does not fit over the stud, loosen the shift lever stud and slide the stud up or down until the slot in the tool fits over the stud. When the adjustment is correct, retighten the stud.



LH Rotation—Bravo One and Two



RH Rotation—Bravo One, Two, Three

- **a -** Adjustment tool
- **b -** Barrel retainer cotter pin
- **c -** Shift lever stud
- **d -** Shift lever adjustment tool, rear slot
- **e -** Shift lever adjustment tool, forward slot

19. Remove the adjustment tool.

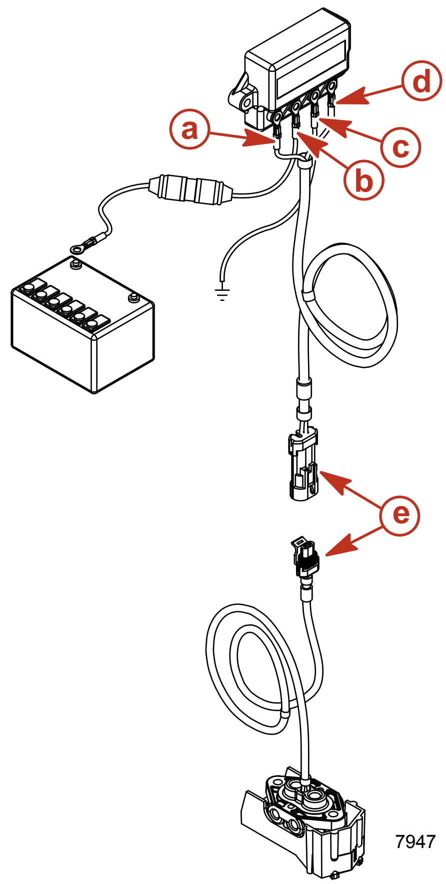
20. Ensure that all cotter pins are secure and that the cotter pins are spread to 180°.
21. Lubricate the shift cable pivot points.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Shift cable pivot points	Obtain Locally

Electrical Connections

Quick-Connect MerCathode System Connection

1. Connect the wires to the MerCathode controller assembly if they are not already connected. Connect the male and female quick-connect terminals.



a - Orange lead—from anode on transom assembly (through the quick-connect fitting)
b - Red/purple wire—to positive (+) battery terminal
c - Black wire—from engine harness, if equipped, or to negative (–) battery terminal
d - Brown wire—from electrode on transom assembly (through the quick-connect fitting)
e - Male and female quick-connect terminals

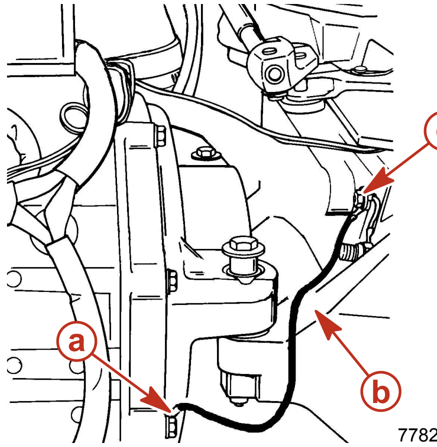
2. Apply a thin coat of sealant to all wire connections.

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Exposed terminals and connections	92- 25711 3

Continuity Circuit

1. Connect the continuity circuit wire from the transom assembly to the engine. Tighten the inner transom plate screw securely.

IMPORTANT: Do not attach any accessory ground (–) wires at the inner transom plate grounding screw.



Typical

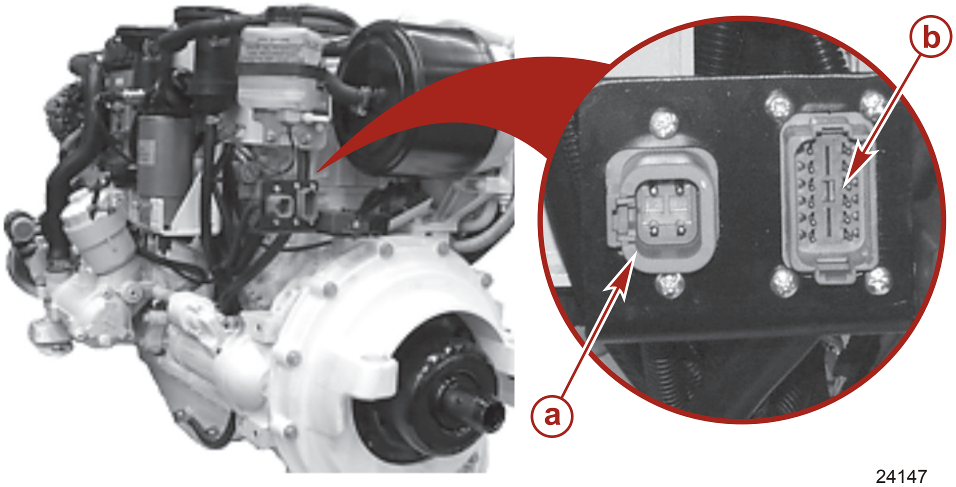
- **a -** Flywheel housing screw
- **b -** Continuity circuit wire
- **c -** Inner transom plate grounding screw

Engine to VIP Harness

1. Route the harness so that it meets the following conditions:
   - The harness does not come into contact with any moving parts.
   - The harness does not come into contact with surfaces or components radiating excessive heat.
   - The harness does not rub or get pinched.
   - The harness and harness connections have minimum exposure to moisture.
   - The harness is mounted in the most direct route possible to minimize voltage drop due to wire resistance.
   - The harness is fastened to the boat at least every 460 mm (18 in.) using appropriate fasteners.

***NOTE:** Follow all ABYC guidelines that govern the installation of signal and DC power wiring in marine vessels.*

2. Connect both the engine to VIP harness and the engine power harness to their respective connectors on the back of the engine. (see diagram).



a - Power connector
b - Engine to VIP harness connector

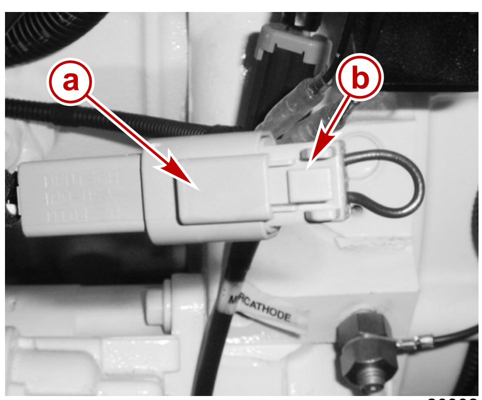
3. Ensure that the harness connectors are securely connected.

Neutral Safety Switch Connection

The neutral safety switch connection prevents the engine from starting while the remote control is in either the forward or reverse gear.

⚠ WARNING
Improperly installing the remote control can result in serious injury or death. Always remove the jumper plug from the neutral safety connection on the engine and install it correctly to the remote control.

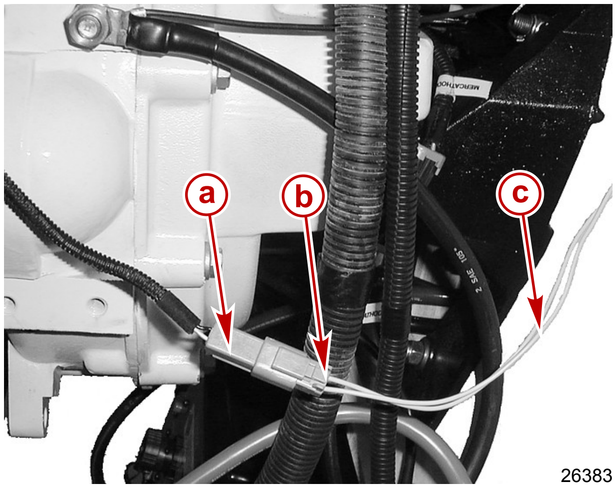
1. Disconnect the jumper plug from the neutral safety switch connector located on the engine.



a - Neutral safety switch connector
b - Jumper plug

2. Install a proper connector to the neutral switch wires leading to the remote control.

3. Connect the neutral switch wires from the remote control to the neutral safety switch connector on the engine.



a - Neutral safety switch connector
b - Proper connector for wires from the remote control
c - Neutral switch wires leading to the remote control

Battery Cable Connection

IMPORTANT: The sterndrive must be installed before connecting the battery. Refer to the appropriate Mercury MerCruiser sterndrive installation manual.

IMPORTANT: Engine electrical system is negative (–) ground.

1. Ensure that the power trim pump, the MerCathode controller, and the accessory wiring (if equipped) are properly connected to the battery terminals.
2. Connect the battery cables to the battery by first connecting the positive (+) battery cable (usually red) to the positive (+) battery terminal. Tighten the clamp securely.
3. Connect the negative (–) battery cable (usually black) to the negative (–) battery terminal. Tighten the clamp securely.
4. Ensure that all of the battery terminal connections are tight. Spray the terminals with a battery connection sealant to help retard corrosion.
5. Apply sealant to the exposed terminals and electrical connections.

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Exposed terminals and connections	92- 25711 3

Sterndrive Installation

Install and adjust the sterndrive. Refer to the appropriate **Mercury MerCruiser Sterndrive Service Manual**.

Notes:

Removal And Installation

Section 2B - Inboard Models

Table of Contents

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Engine mounting hardware threads and nuts	92-34227 1
25	Liquid Neoprene	Exposed terminals and connections	92- 25711 3

Engine Removal

⚠ WARNING

Fuel vapors trapped in the engine compartment may be an irritant, cause difficulty breathing, or may ignite resulting in a fire or explosion. Always ventilate the engine compartment before servicing the power package.

⚠ WARNING

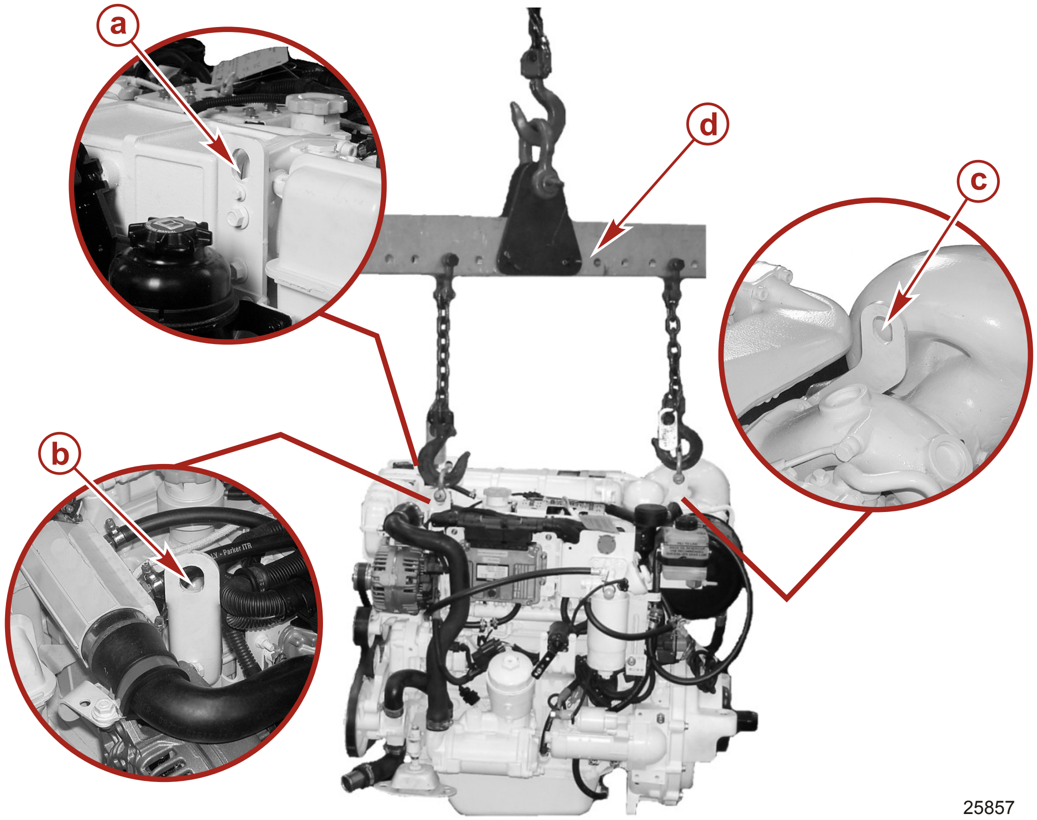
Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

1. Disconnect the negative (–) battery cable (usually black) from the negative (–) battery terminal.
2. Disconnect the positive (+) battery cable (usually red) from the positive (+) battery terminal.
3. Lift and detach the engine cover from the engine cover mounts.
4. Disconnect the engine to VIP harness from the engine wiring harness connectors.
5. Close the fuel shut-off valve, if equipped.
6. Disconnect and plug the fuel lines to prevent fuel from leaking into the bilge.
7. Disconnect the throttle cable and retain the fasteners.
8. Disconnect the shift cable from the transmission and retain the fasteners.
9. **If the boat is to remain in the water**, close the seacock, if equipped, or disconnect and plug the seawater inlet hose.
10. Disconnect the seawater inlet hose.
11. Disconnect the exhaust system hoses if the boat is to remain in the water. Plug the hoses and position them appropriately to prevent seawater from entering the boat.
12. Disconnect any grounding wires and accessories that are connected to the engine.
13. Disconnect the propeller shaft coupler from the transmission output flange. On models with V-drive transmissions, remove the propeller shaft coupler.

⚠ CAUTION

Improper lifting during removal or installation of the engine can cause injury or damage to engine components. Use a hoist, lifting arm, or other approved lifting device. Do not allow the lifting device to hook or compress any engine components.

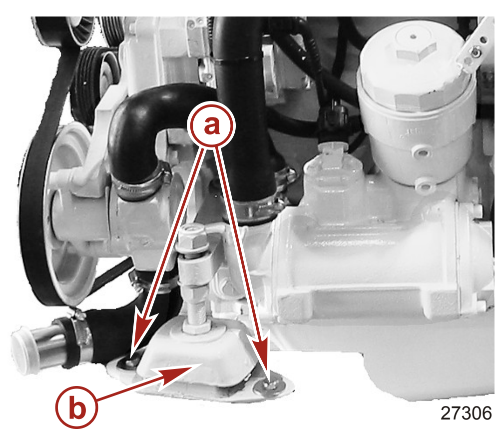
14. Support the engine with a sling and lifting arm through the lifting eyes on the engine.



Typical

a - Front starboard side engine lifting eye (back side of engine)
b - Front port side engine lifting eye
c - Rear engine lifting eye
d - Sling and lifting arm

15. Remove and retain the bolts and hardware that fasten the front and rear engine mounts to the engine bed.



Front mount shown. Rear mount bolts and hardware are similar.

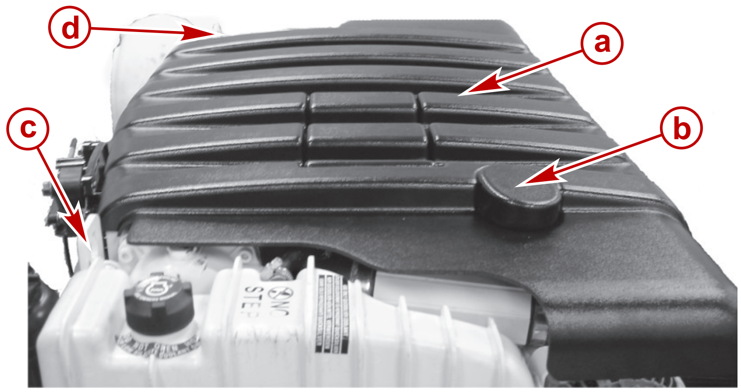
a - Bolts and hardware
b - Front mount

16. Using an overhead hoist, carefully remove the engine and transmission.

17. For transmission removal and installation procedures refer to the appropriate marine transmission manufacturer's service manual.

Engine Installation

1. Remove the front port lifting eye access cover in the engine cover or remove the entire engine cover to gain access to the lifting eyes.



26041

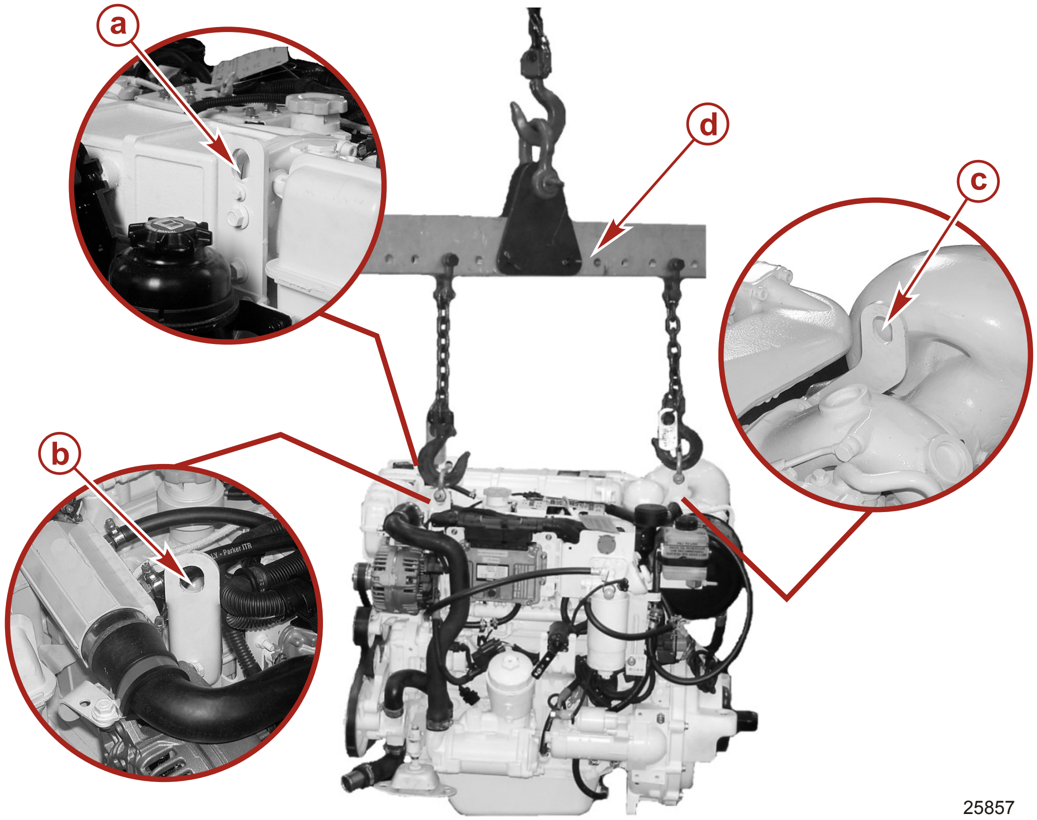
a - Engine cover
b - Front port side lifting eye access cover
c - Front starboard side lifting eye
d - Rear lifting eye

⚠ CAUTION
Improper lifting during removal or installation of the engine can cause injury or damage to engine components. Use a hoist, lifting arm, or other approved lifting device. Do not allow the lifting device to hook or compress any engine components.

2. Attach a suitable sling and lifting arm to the engine lifting eyes and adjust so that engine is level when suspended.

⚠ WARNING
Failure of the lifting eyes will cause the engine to fall suddenly from the hoist, resulting in serious injury, death, or property damage. Keep the engine level while it is hoisted. Do not tilt the engine more than 12° in any direction during installation.

3. Lift the engine into position in the boat using an overhead hoist.



Typical

a - Front starboard engine lifting eye
b - Front port engine lifting eye
c - Rear engine lifting eye
d - Suitable sling and lifting arm

IMPORTANT: When lowering engine into position do not set the engine on the shift cable.

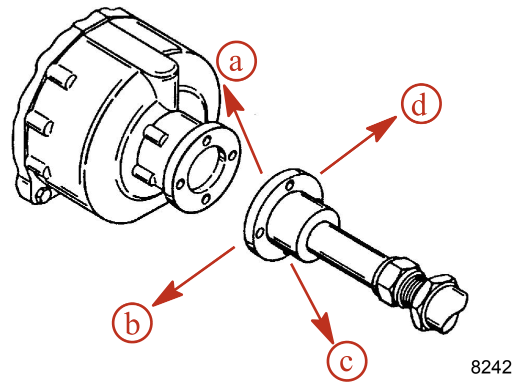
4. Ensure that the mating faces on the transmission output flange and propeller shaft coupler are clean and flat.

Centering the Propeller Shaft in the Shaft Log

Use the following method to center the propeller shaft in the shaft log.

1. Push down and then lift the shaft as far as it will move, then place the shaft in the middle of the movement.

2. Move the shaft to port then to starboard as far as the shaft will move. Then place the shaft in the middle of the movement.



Typical down-angle (V-drive similar)

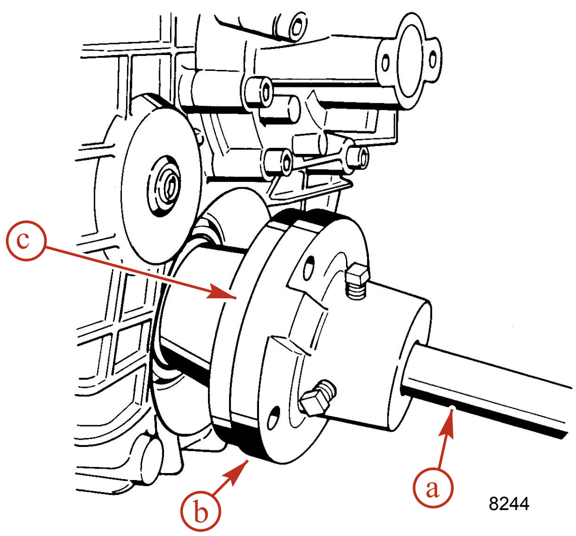
a - Up
b - Down
c - Port
d - Starboard

3. With the shaft in the center of the shaft log as determined by the preceeding steps, align the engine to the shaft. See **Aligning the Engine to the Propeller Shaft**.

Aligning the Engine to the Propeller Shaft

MODELS WITH ZF MARINE 8° DOWN-ANGLE TRANSMISSION OR TECHNODRIVE 485-A TRANSMISSION

1. Position the engine on the engine bed with the transmission output flange and the propeller shaft coupler visibly aligned so that no gap is visible between the coupling faces when butted together.



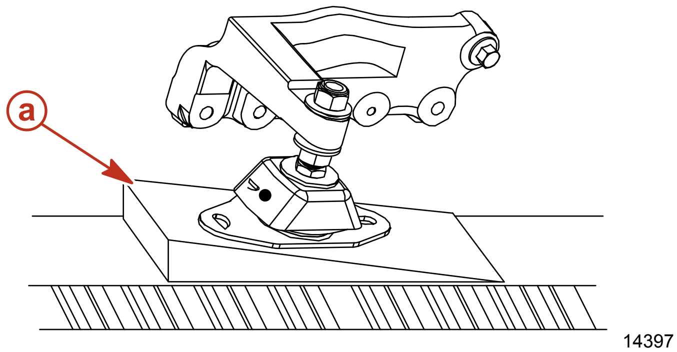
Typical

a - Propeller shaft
b - Propeller shaft coupler
c - Transmission output flange

2. If necessary, adjust the engine bed height to obtain the proper alignment. Do not use mount adjustments to adjust the engine position at this time.

IMPORTANT: The engine mounts must be installed parallel to the engine centerline to maintain uniform mount compression.

3. If necessary, insert wedges under the engine mounts on the engine bed or boat stringers to keep the engine mounts parallel to the engine centerline.



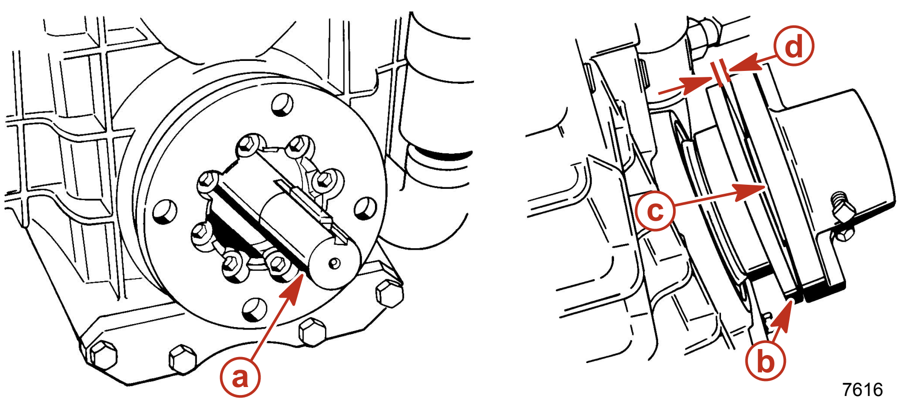
a - Typical wedge

IMPORTANT: Position the engine bed so that the engine has a minimum of 6 mm (1/4 in.) up and down adjustment still exists on all four mounts. This play is necessary to allow for final alignment.

4. Position all four mounts properly, and then fasten the mounts to the engine bed with 10 mm (3/8 in.) diameter lag bolts or thru-bolts with flat washers. Tighten the bolts securely.
5. Disconnect the overhead hoist and remove the lifting arm and the sling.

MODELS WITH ZF MARINE V-DRIVE TRANSMISSION

1. Position the engine on the engine bed so that the propeller shaft protrudes through the transmission and output flange. The shaft should protrude far enough for the propeller shaft coupler to be installed.
2. Install the propeller shaft coupler and position the engine so that no gap can be seen between the coupling faces when butted together.



ZF Marine 63IV

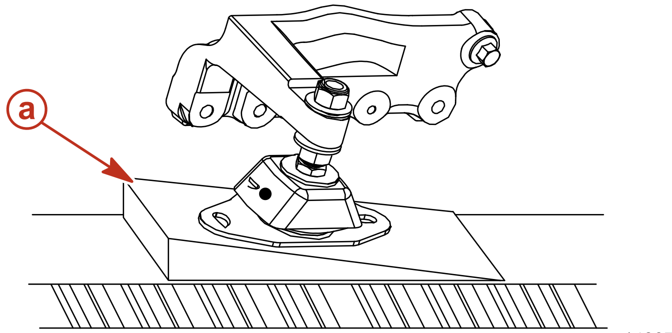
a - Propeller shaft	**c -** Transmission output flange
b - Propeller shaft coupler	**d -** No visible gap

IMPORTANT: The engine bed must position the engine so that a minimum of 6 mm (1/4 in.) up and down adjustment still exists on all four mounts. This play is necessary to allow for final alignment.

3. If necessary, adjust the engine bed height to obtain the proper alignment. Do not use mount adjustments to adjust the engine position at this time.

4. If necessary, insert wedges under the engine mounts on the engine bed or boat stringers to keep the engine mounts parallel to the engine centerline.

IMPORTANT: Install the engine mounts parallel to the engine centerline to maintain uniform mount compression.



a - Typical wedge

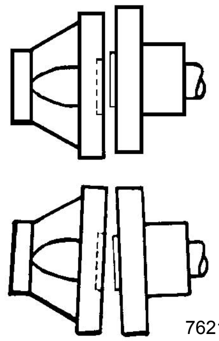
5. Position all four mounts properly, and then fasten the mounts to the engine bed with 10 mm (3/8 in.) diameter lag bolts or thru-bolts with flat washers. Tighten the bolts securely.
6. Disconnect the overhead hoist and remove the lifting arm and sling.

Final Engine Alignment

IMPORTANT: Check the engine alignment with the boat in the water, fuel tanks filled, and with a normal load on board.

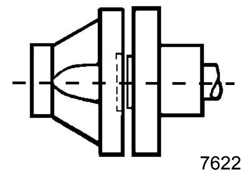
Align the engine so that the transmission and propeller shaft coupling centerlines are aligned and coupling faces are parallel within 0.07 mm (0.003 in.). This requirement applies to installations with solid couplings as well as flexible couplings.

1. Check that the coupling centerlines align by butting the propeller shaft coupler against the transmission output flange. The shoulder on the face of the propeller shaft coupler should engage the recess on the transmission output flange face with no resistance.



7621

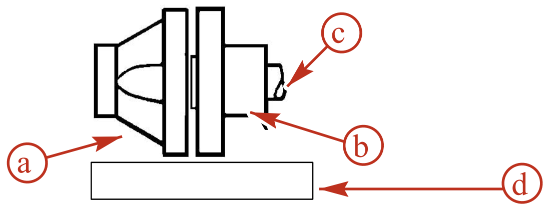
Incorrect



7622

Correct

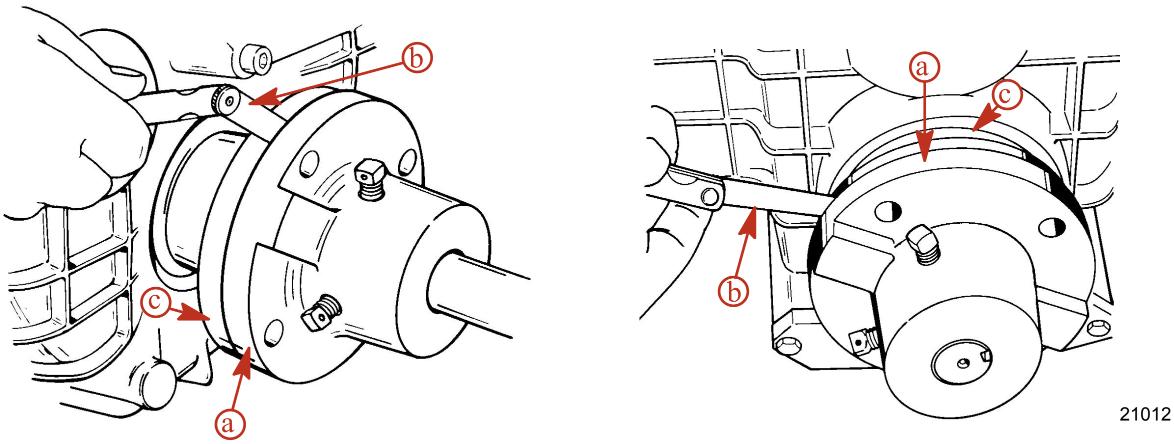
NOTE: Some propeller shaft couplers may not have a shoulder on the mating face. On these installations, use a straight edge to check centerline alignment.



7623

a - Transmission output flange
b - Propeller shaft coupler
c - Straight edge
d - Propeller shaft

2. Check for angular misalignment by holding the coupling faces tightly together and checking that the gap between mating faces is no greater than specified. Check the gap at 90° intervals.



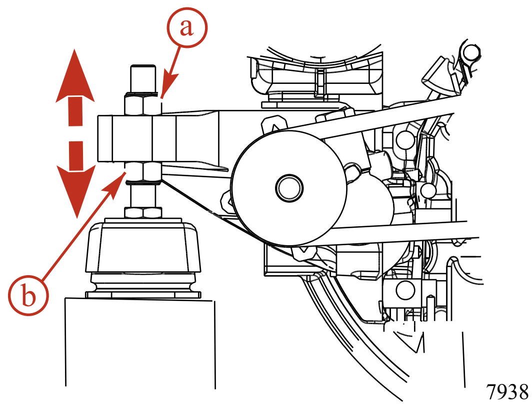
Down-angle transmission | V-drive transmission

a - Propeller shaft coupler
b - Feeler gauge
c - Transmission output flange

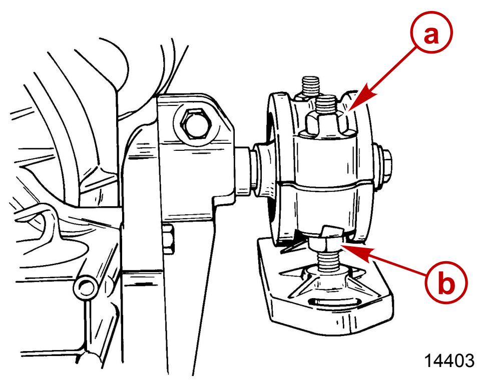
Coupling	
Angular misalignment	0.07 mm (0.003 in.) maximum

3. If the coupling centerlines do not align or the coupling faces are out alignment more than specified, adjust the engine mounts. Check for the specified gap with a feeler gauge at 90° intervals.
   a. **To adjust the engine up or down**, loosen the locking (jam) nuts on the mounts requiring adjustment. Turn the adjusting nuts as necessary.

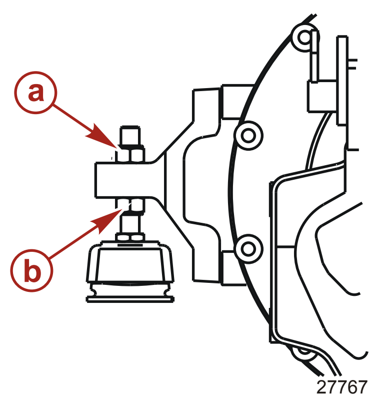
IMPORTANT: Both front mount or rear mount adjusting nuts must be turned equally to keep the engine level from side to side.



Typical front mount



ZF V-drive transmission trunnion mount

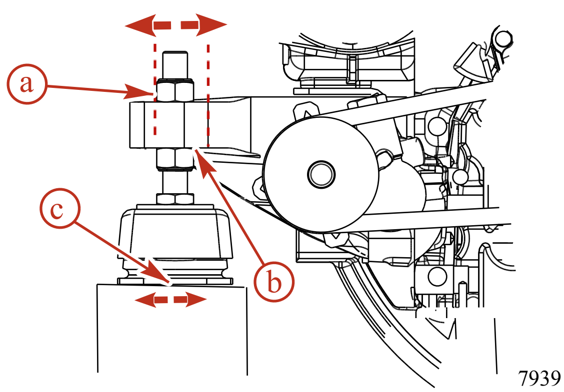


Technodrive and ZF 8° down-angle transmission rear mount

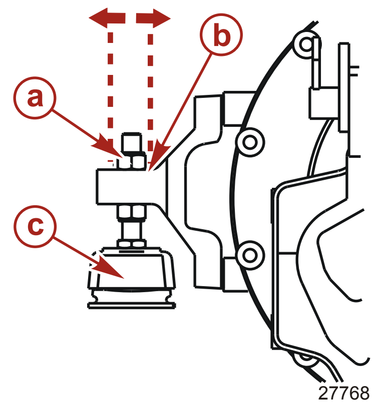
a - Locknut | **b -** Adjusting nut

   b. **To move engine to the left or right**, loosen the locknuts on the front mounts and Technodrive or ZF 8° down-angle transmission rear mounts and move the engine as necessary in the mount bracket slotted holes. On the ZF V-drive transmission trunnion mounts, loosen the trunnion clamp bolt on the mount brackets and move the engine as necessary.

***NOTE:** You can obtain a small amount of adjustment with the slot on the front end of some mount brackets.*



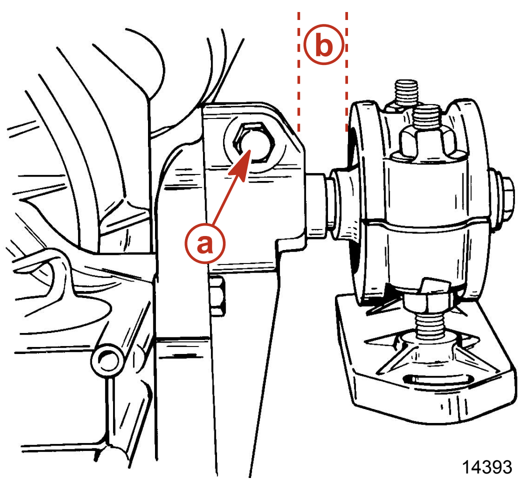
Typical front mount



Technodrive and ZF 8° down-angle transmission rear mount

a - Locknut
b - Slotted hole in mount bracket
c - Mount pad

IMPORTANT: The large diameter of the mount trunnion must not extend over 19 mm (3/4 in.) from mount brackets on any of the mounts.



ZF V-drive transmission trunnion mount

a - Trunnion clamp bolt
b - Mount trunnion maximum extension

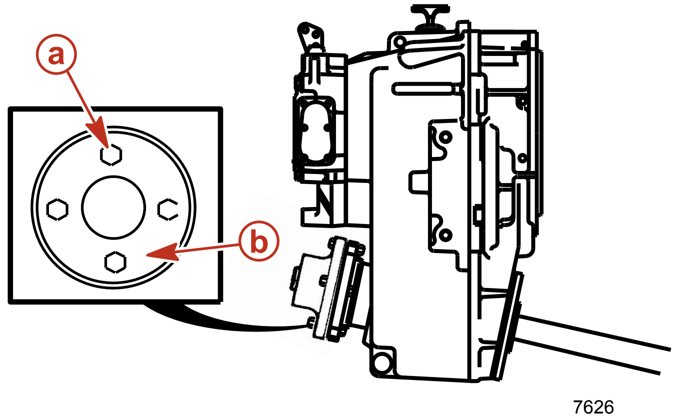
4. After the engine has been properly aligned, secure the engine mounts to the engine bed or boat stringer using the appropriate hardware and lag bolts or thru-bolts.
5. Torque the trunnion clamp bolts on the mount brackets.

Description	Nm	lb. in.	lb. ft.
Trunnion clamp bolt	68		50

6. Tighten the engine mount locknuts on all mounts.

Description	Nm	lb. in.	lb. ft.
Engine mount locknut	80		59

7. Secure the coupling together with bolts, lockwashers, and nuts. Torque the bolts.



V-drive transmission, 8° down-angle transmission similar

a - Bolt
b - Coupling

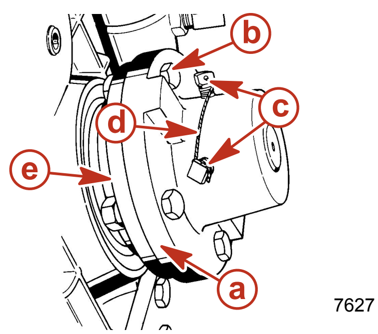
Description	Nm	lb. in.	lb. ft.
Coupling bolt and nut	68		50

a. If the propeller shaft coupler has set screws, remove the set screws and mark dimple locations using a transfer punch.

b. To drill dimples, remove the propeller shaft coupler and drill shallow dimples at locations marked with the transfer punch.

c. Reinstall the propeller shaft coupler and torque the coupling bolts.

d. Install the set screws and tighten securely. Connect the safety wire between the set screws.



V-drive transmission, down-angle transmission similar

a - Propeller shaft coupler
b - Bolt
c - Set screw
d - Safety wire
e - Transmission output flange

Description	Nm	lb. in.	lb. ft.
Coupling bolt and nut	68		50

8. If operating in a saltwater environment, apply sealant to the threads and nuts of the engine mounting hardware to help protect against corrosion and to permit easier adjustment in the future.

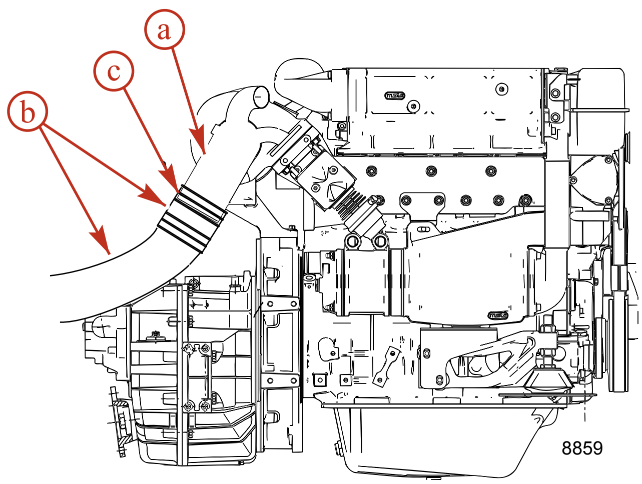
Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Engine mounting hardware threads and nuts	92-34227 1

Exhaust System Connections

> ***NOTICE***
>
> **Hot spots in exhaust hoses can damage hoses and cause leaks. Ensure that discharge water from the exhaust elbow flows without restriction through all hoses and fittings.**

IMPORTANT: Exhaust bellows, hoses, or tubes must be secured at each connection with at least two hose clamps.

1. Connect the exhaust hoses and tubes so that they do not restrict the flow of discharge water from the exhaust elbow.
2. Install at least two hose clamps on each exhaust hose and tube connection.
3. Tighten the exhaust system hose clamps securely.



Typical

a - Exhaust elbow
b - Exhaust tube or hose
c - Hose clamps

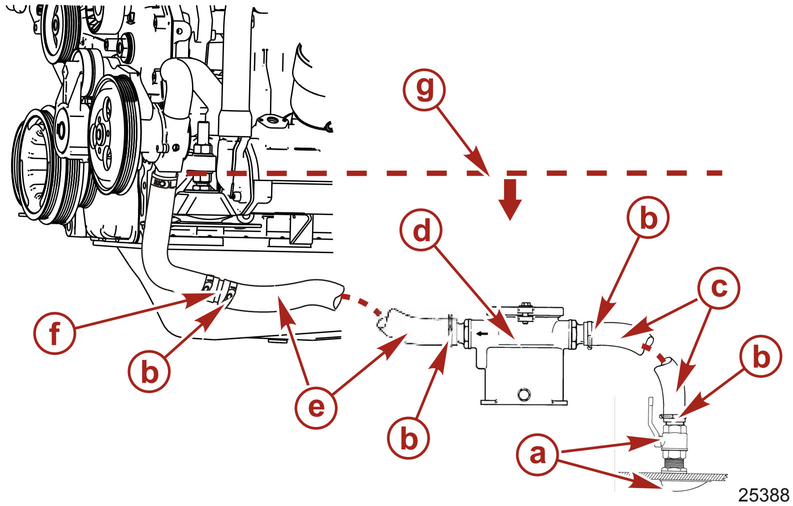
Fluid Connections

Seawater Hoses

IMPORTANT: The seawater hose used must be wire-reinforced to avoid collapsing the hose when suction is created by seawater pump impeller.

1. Connect the seawater hose from the seacock to the seawater strainer.
2. Connect the seawater hose from the seawater strainer to the seawater pump hose connector.

3. Tighten the hose clamps securely.



2.8 shown, 4.2 similar

- **a -** Quicksilver seawater pickup and seacock
- **b -** Hose clamp
- **c -** Seawater hose to seawater strainer
- **d -** Quicksilver seawater strainer
- **e -** Seawater hose to engine
- **f -** Seawater pump hose connector
- **g -** Below seawater pump level

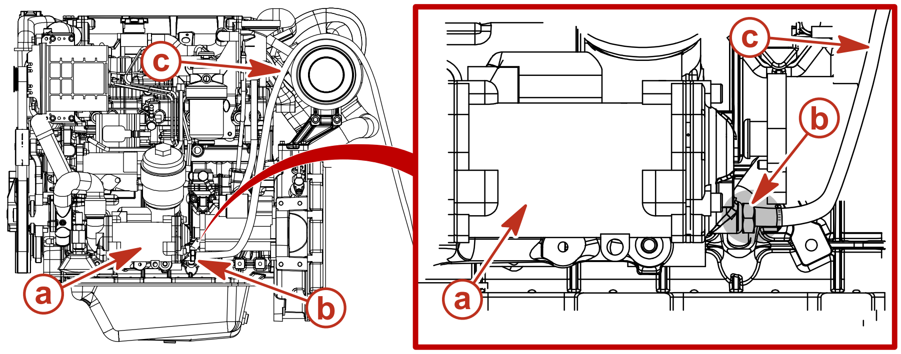
Propeller Shaft Log Seal (Stuffing Box) Connections, If Equipped

NOTICE
Incorrectly installing the water supply hose to the shaft log seal can cause increased exhaust system corrosion or submersion or freeze damage due to siphoning. Position and securely fasten the water supply hose with a portion of the hose above the engine exhaust elbows.

1. Connect the propeller shaft log seal (stuffing box) cooling hose to the barb fitting on the end cover of the engine oil cooler.

NOTICE
Incorrectly installing the water supply hose to the shaft log seal can cause increased exhaust system corrosion or submersion or freeze damage due to siphoning. Position and securely fasten the water supply hose with a portion of the hose above the engine exhaust elbows.

2. Route the propeller shaft log seal hose so that a portion of the hose extends above the top of the engine exhaust elbow. This should prevent a siphoning action when the engine is not operating.



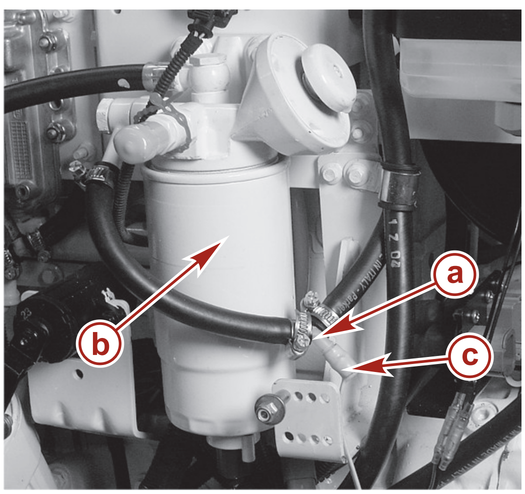
Propeller shaft log seal connection

a - Engine oil cooler
b - Barb fitting
c - Propeller shaft log seal hose

3. Securely fasten the propeller shaft log seal hose using tie straps to keep it properly positioned.

Fuel Lines

1. Remove the protective cap or plug.
2. Connect a flexible fuel hose to the fuel inlet fitting.
3. Secure with hose clamps.



2.8 shown, 4.2 similar

a - Fuel inlet fitting
b - Water-separating fuel filter
c - Protective cap

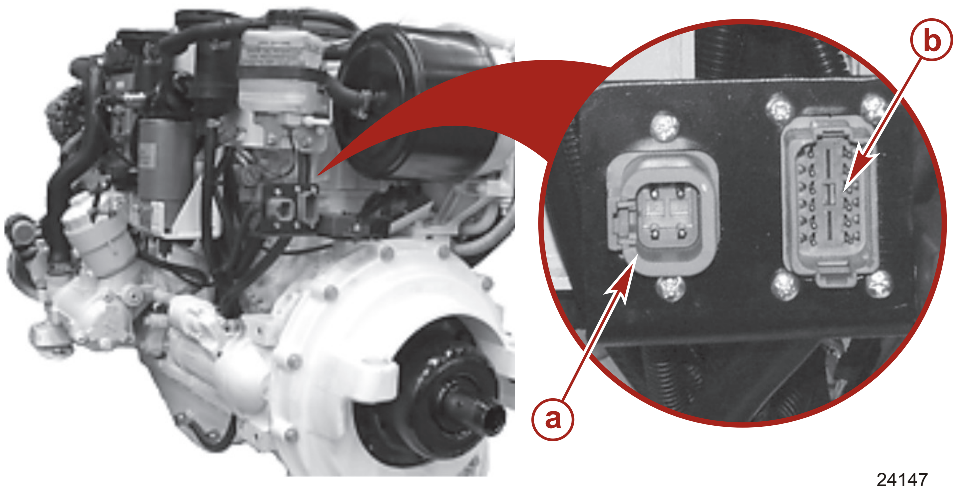
Electrical Connections

Engine to VIP Harness

1. Route the harness so that it meets the following conditions:
   - The harness does not come into contact with any moving parts.
   - The harness does not come into contact with surfaces or components radiating excessive heat.
   - The harness does not rub or get pinched.
   - The harness and harness connections have minimum exposure to moisture.
   - The harness is mounted in the most direct route possible to minimize voltage drop due to wire resistance.
   - The harness is fastened to the boat at least every 460 mm (18 in.) using appropriate fasteners.

NOTE: *Follow all ABYC guidelines that govern the installation of signal and DC power wiring in marine vessels.*

2. Connect both the engine to VIP harness and the engine power harness to their respective connectors on the back of the engine. (see diagram).



24147

a - Power connector   **b -** Engine to VIP harness connector

3. Ensure that the harness connectors are securely connected.

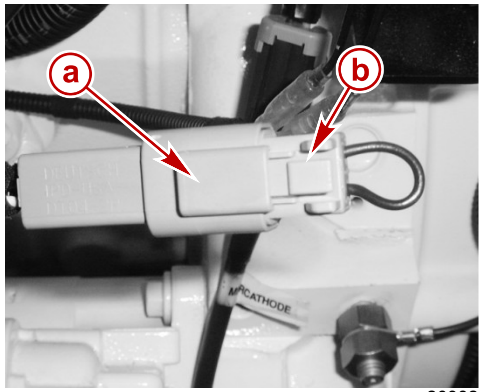
Neutral Safety Switch Connection

The neutral safety switch connection prevents the engine from starting while the remote control is in either the forward or reverse gear.

⚠ WARNING

Improperly installing the remote control can result in serious injury or death. Always remove the jumper plug from the neutral safety connection on the engine and install it correctly to the remote control.

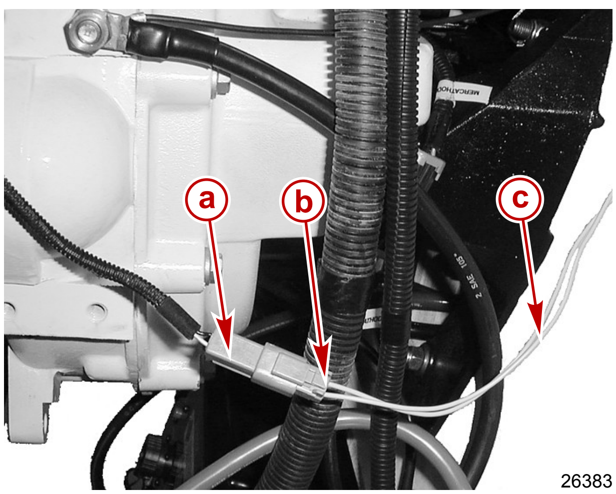
1. Disconnect the jumper plug from the neutral safety switch connector located on the engine.



26382

a - Neutral safety switch connector
b - Jumper plug

2. Install a proper connector to the neutral switch wires leading to the remote control.
3. Connect the neutral switch wires from the remote control to the neutral safety switch connector on the engine.



a - Neutral safety switch connector
b - Proper connector for wires from the remote control
c - Neutral switch wires leading to the remote control

Battery Cable Connection

IMPORTANT: Engine electrical system is negative (–) ground.

1. Ensure that the accessory wiring (if equipped) is properly connected to the battery terminals.
2. Connect the battery cables to the battery by first connecting the positive (+) battery cable (usually red) to the positive (+) battery terminal. Tighten the clamp securely.

3. Connect the negative (–) battery cable (usually black) to the negative (–) battery terminal. Tighten the clamp securely.
4. Ensure that all of the battery terminal connections are tight. Spray the terminals with a battery connection sealant to help retard corrosion.
5. Apply sealant to the exposed terminals and electrical connections.

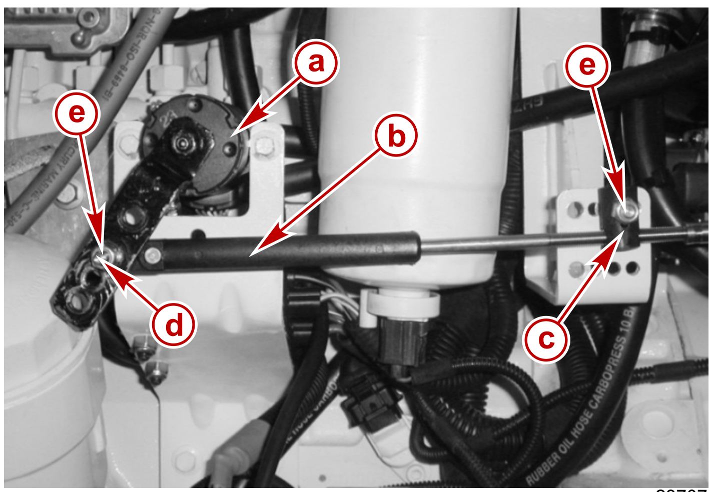
Tube Ref No.	Description	Where Used	Part No.
	Liquid Neoprene	Exposed terminals and connections	92- 25711 3

Throttle and Shift Cable Installation and Adjustment

Throttle Cable Installation and Adjustment

IMPORTANT: When installing throttle cables, route the cables to avoid sharp bends and to avoid contact with moving parts. Do not fasten any items to the throttle cables.

1. Install the end guide of the throttle cable anchor stud in the third hole from the end of the throttle position sensor (TPS) lever.
2. Place the remote throttle lever in the neutral and idle position.
3. Install the cable end guide on the throttle lever. Hand tighten the locknut only.
4. Install the throttle cable barrel anchor stud in the third hole from the left on the top row of the anchor bracket. Hand tighten the locknut only.



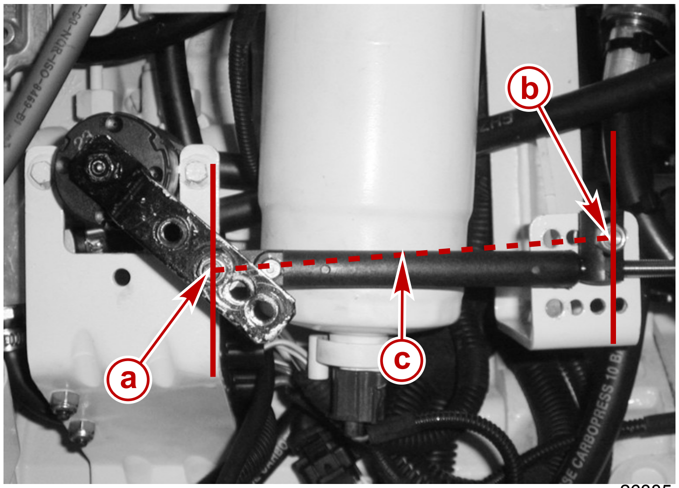
23707

a - Throttle position sensor (TPS)
b - Throttle cable end guide
c - Flat washer and locknut
d - Cable barrel
e - Anchor stud

IMPORTANT: The engine will reach 100% WOT before the TPS reaches the mechanical stop. Adjust the throttle cable so that the throttle position sensor does not contact the mechanical stop at 100% WOT. Contact between the TPS at WOT and the mechanical stop could result in premature TPS failure.

5. **If using the CDS tool to adjust the throttle cable**:
   a. Move the throttle lever forward until the CDS tool reads 100% WOT.
   b. Adjust the throttle cable end guide and barrel anchor stud so that the throttle position lever can move past 100% WOT but will not contact the TPS mechanical stop.

6. **If the CDS tool is unavailable, then adjust the throttle cable as follows**:
   a. Move the throttle lever forward to the WOT location.
   b. Measure the distance between the anchor stud on the throttle lever and the and the center of the anchor stud on the cable barrel as shown. The distance between them at WOT is 140 mm (5 ½ in.).



26385

a - Cable end guide anchor stud
b - Throttle cable barrel location on anchor bracket
c - 140 mm (5 ½ in.)

   c. Adjust the throttle cable end guide and barrel anchor stud to the dimensions specified and ensure that the throttle position lever is not contacting the TPS WOT mechanical stop. The engine will reach 100% WOT before the TPS reaches the mechanical stop.
7. Tighten the locknuts until they contact the washers, then loosen 1/2 turn.
8. Place the remote control lever in the neutral and idle position. Adjust the throttle cable barrel if the throttle position sensor did not return to the idle position.
9. Place the remote control lever fully in the forward WOT position.
10. Operate the remote control and check that the throttle position sensor lever reaches wide-open or 100% throttle position.

Shift Cable Installation and Adjustment

See Section 8A.

Engine Mechanical

Section 3A - QSD 2.8 and 4.2 Diesel Engines

Table of Contents

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A

Engine Specifications

Camshaft

Camshaft		
Lobe lift	Exhaust	7.303 mm (0.288 in.)
	Intake	6.850 mm (0.250 in.)
Journal diameter	Front	53.495–53.510 mm (2.1061–2.1066 in.)
	Center	53.450–53.470 mm (2.1043–2.1051 in.)
	Rear	53.480–53.500 mm (2.1055–2.1062 in.)
Bearing clearances	Front	0.080–0.125 mm (0.003-0.005 in.)
	Center	0.080–0.150 mm (0.003–0.006 in.)
	Rear	0.050–0.120 mm (0.002–0.005)
Camshaft thrust plate thickness		3.95–4.05 mm (0.155–0.159 in.)

Cylinder Head

Cylinder Head	
Height	89.50–90.50 mm (3.523–3.563 in.)
Cylinder head end spacer height	89.920–90.000 mm (3.540–3.543 in.)

Cylinder Liner Diameter

Cylinder Liner Diameter	
Standard	94.015–93.995 (3.7013–3.7005 in.)
Maximum out of round	0.10 mm (0.0039 in.)

Cylinder Liner Protrusion

Cylinder Liner Protrusion		
Liner recess below cylinder block (without shim)	**Shim to be used (thickness)**	**Liner protrusion above cylinder block (with shim)**
0.10–0.13 mm (0.0039 – 0.0051 in.)	0.15 mm (0.0059 in.)	0–0.05 mm (0–0.0020 in.)
0.13–0.16 mm (0.0051–0.0063 in.)	0.17 mm (0.0067 in.)	
0.16–0.19 mm (0.0063–0.0075 in.)	0.20 mm (0.0078 in.)	
0.19–0.22 mm (0.0075–0.0087 in.)	0.23 mm (0.0091 in.)	
0.22–0.25 mm (0.0087–0.0098 in.)	0.25 mm (0.0098 in.)	

Connecting Rod

Connecting Rod		
Connecting rod bearing inside diameter		53.955–53.940 mm (2.1242–2.1236 in.)
Connecting rod bearing clearance		0.022–0.076 mm (0.0008–0.0029 in.)
Allowable wear or taper	Service limit	0.01 mm (0.0004 in.)
Piston pin and bearing journal axis deviation from parallel (measured at 100 mm 3.937 in.distance)		0.15 mm (0.006 in.)

Connecting Rod		
Weight (connecting rods are color coded by weight range)	green	978-992.9 g (2.156-2.189 lb)
	blue	992.9-1007.9 g (2.189-2.222 lb)
	white	1007.9-1022.9 g (2.222-2.255 lb)
	yellow	1022.9-1038 g (2.255-2.289 lb)

Connecting Rod Bushing

Connecting Rod Bushing		
Connecting rod bushing inner diameter		32.005–32.035 mm (1.260–1.261 in.)
Piston pin outer diameter		31.990–31.996 (1.259–1.260)
Clearance	Minimum	0.009–0.045 mm (0.0004–0.0018 in.)
	Service limit	0.060 mm (0.0023 in.)

Crankshaft

Crankshaft		
Main journal outside diameter	Front	62.985–63.005 mm (2.4797–2.4805 in.)
	Center	63.005–63.020 mm (2.4805–2.4810 in.)
	Rear	79.985–80.000 mm (3.1490–3.1496 in.)
Main journal wear	Service limit	0.1 mm (0.0039 in.)
Main bearing inside diameter	Front	63.013–63.053 mm (2.4808–2.4824 in.)
	Center	63.005–63.020 (2.4805–2.4811 in.)
	Rear	80.045–80.070 mm (3.1514–3.1524 in.)
Main bearing clearance	Front	0.008–0.068 mm (0.0003–0.0027 in.)
	Center	0.030–0.088 mm (0.0011–0.0034 in.)
	Rear	0.045–.085 mm (0.0018–0.0033 in.)
Connecting rod journal outside diameter		53.940–53.955 mm (2.1236–2.1242 in.)
Maximum connecting rod journal wear		0.25 mm (0.010 in.)
Crankshaft end play (axial clearance)		0.080–0.280 mm (0.0031–0.0110 in.)
Thrust washers	Standard	2.310–2.360 mm (0.0909–0.0929 in.)
	First oversized	2.410–2.460 mm (0.0949–0.0969 in.)
	Second oversized	2.510–2.560 mm (0.0988–0.1008 in.)

Flywheel

Flywheel	
Ring gear teeth	119

Head Gasket

IMPORTANT: Replacement head gaskets should be the same thickness as those removed unless otherwise specified.

Head Gasket		Gasket Thickness	Identification Notches
Piston protrusion above cylinder block	0.60–0.72 mm (0.024–0.028 in.)	1.42 mm (0.056 in.)	none
	0.73–0.82 mm (0.028–0.032 in.)	1.52 mm (0.060 in.)	two
	0.83–0.95 mm (0.031–0.037 in.)	1.62 mm (0.064 in.)	one

Oil Pump

Oil Pump	
Impeller height	32.487–32.500 mm 1.2790–1.2795 in.
Clearance between rotors	0.070–0.200 mm (0.0028–0.0079 in.)
Clearance between outer rotor and housing	0.105–0.160 mm (0.004–0.006 in.)
Clearance between pump support and gear (axial)	0.15–0.25 mm (0.0059–0.0098 in.)
Inner diameter of rotor housing	58.105–58.130 mm (2.2875–2.2885 in.)
Rotor and gear coupling rolling torque resistance	88 Nm 65 lb. ft.

Oil Thermostat

Oil Thermostat		
Oil thermostat	Minimum opening	7.8 mm (0.3071 in.)
	Begins to open	80°–84° C (177–183.2 °F)
	Fully open	94.5° C (202.1° F)

Piston

Piston		
Outer diameter (measure 12.5 mm (0.49 in.) from the bottom of the piston skirt)		93.898–93.912 mm (3.6967–3.6973 in.)
Groove width	First compression (tapered)	3.0 mm 0.1181 in.
	Second compression	2.06–2.08 mm (0.0811–0.0818 in.)
	Oil control	3.03–3.05 mm (0.1192–0.1201 in.)

Piston Rings

Piston Rings		
Ring to groove clearance	First compression (tapered)	not measured - taper
	Second compression	0.10 mm (0.0039 in.) maximum
	Oil control	0.08 mm (0.0031 in.) maximum
End gap	First compression	0.50 mm (0.0196 in.)
	Second compression	0.50 mm (0.0196 in.)
	Oil control	0.60 mm (0.0236 in.)

Rocker Arm

Rocker Arm	
Rocker arm support journal diameter	24.97–25.00 mm (0.983–0.984 in.)
Bushing inside diameter	25.020–25.041 mm (0.9850–0.9842 in.)

Rocker Arm		
Clearance	Minimum	0.020 mm (0.0007 in.)
	Maximum	0.062 mm (0.0024 in.)

Valve

Valve			
Head diameter		Exhaust	37.900–38.100 mm (1.492–1.500 in.)
		Intake	40.800–41.000 mm (1.606–1.614 in.)
Face width		Exhaust	2.815 mm (0.146 in.)
		Intake	3.710 mm (0.111 in.)
Margin	Production	Exhaust	1.73 mm (0.068 in.)
		Intake	1.82 mm (0.071 in.)
	Service limit (after surfacing)	Exhaust	1.30 mm (0.051 in.)
		Intake	
Seat angle	Production	Exhaust	45° 30’
		Intake	60° 30’
Stem diameter		Intake	7.940–7.960 mm (0.312–0.313 in.)
		Exhaust	7.921–7.939 mm (0.312–0.313 in.)

Valve Clearance

Valve Clearance		
Clearance	Exhaust	Hydraulically controlled
	Intake	

Valve Guide

Valve Guide			
Clearance	Service limit	Exhaust	0.093 mm (0.0036 in.)
		Intake	0.073 mm (0.0028 in.)
Valve guide inner diameter		Exhaust	8.000–8.015 mm (0.315–0.316 in.)
		Intake	
Height above spring seat counterbore		Exhaust	1.50–2.00 mm (0.0590–0.0787 in.)
		Intake	

Valve Lifter

Valve Lifter	
Lifter outer diameter	22.195–22.212 mm (0.8738–0.8745 in.)

Valve Seat

Valve Seat			
Valve recession	Service limit	Exhaust	0.3 mm (0.011 in.)
		Intake	
Head surface to seat		Exhaust	2.05–2.25 mm (0.080–0.088 in.)
		Intake	2.17–2.37 mm (0.085–0.093 in.)

Valve Seat		
Counter-bore inner diameter	Exhaust	38.964–38.988 (1.5340–1.5349 in.)
	Intake	41.962–41.985 mm (1.6520–1.6529 in.)
Seat outer diameter	Exhaust	39.050–39.066 mm (1.5375–1.5380 in.)
	Intake	42.070–42.086 mm (1.6562–1.6569 in.)
Seat height	Exhaust	7.85–7.95 mm (0.309–0.313 in.)
	Intake	7.730–7.830 mm (0.304–0.308 in.)
Seat width	Exhaust	1.6–1.8 mm (0.062–0.070 in.)
	Intake	
Seat angle	Exhaust	45°
	Intake	30°

Valve Spring

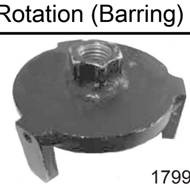
Valve Spring		
Free standing height		44.65 mm (1.757 in.)
Valve closed	At 32–36 kg (71–79 lb.) pressure	38.60 mm (1.520 in.)
Valve open	At 88.8 kg–96.2 kg (197–212 lb.) pressure	28.20 mm (1.110 in.)
Spring inclination	Service limit	2 mm (0.079 in.)

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
	Johnson EP Lube	Outer surfaces and ends of the valve pushrods	Obtain Locally
		Rocker arm and rocker arm contact surfaces	
		Threads of the rocker arm support studs	
		Oil pan gasket joints	
		Valve lifters and camshaft lobes - new parts	
		Main bearing bores	
		Cylinder liner surfaces	
4	Needle Bearing Assembly Lubricant	Valve stem locks	92-802868A1
		Camshaft lobes (in a specified mixture)	
		Connecting rod bearings and crankshaft journal	
		Connecting rod screw threads and the underside of the screw head	
		Rear bearing carrier thrust washer	
		Lower centering collars in cylinder block	
7	Loctite 271 Threadlocker	Sterndrive coupler or inboard drive plate bolt	92-809819
9	Loctite 567 PST Pipe Sealant	Oil thermostat threads	92-809822
		Oil cooler seawater drain plug	
12	Loctite Master Gasket Kit	Valve cover gasket	92-12564 2
		Coolant manifold gasket to cylinder head	
		Coolant temperature adaptor (if equipped) and sensor threads	
		Timing gear cover gasket	
		Cylinder liner surfaces	
51	Loctite 222 Threadlocker	Rear mount bracket screws	92-809818
66	Loctite 242 Threadlocker	Oil pressure relief valve assembly threads	92-809821
67	Loctite 290	Outer diameter of expansion plugs	Obtain Locally

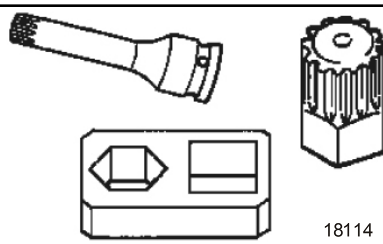
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Cylinder bores	Obtain Locally
		Bolt threads and underside of bolt heads of all 12M cylinder head bolts	
		Rocker arm bushing and rocker arm support journal	
		Valve lifter contact surfaces	
		Oil pump housing and the inner and outer oil pump rotor surfaces	
		Idler gear assembly with bearing and idler gear bushing	
		Oil pickup tube O-ring	
		Inside of oil pressure relief valve seat and body bore and components	
		Camshaft lobes (in a specified mixture)	
		Camshaft bearings	
		Outer surface of new camshaft bearings	
		Valve lifters	
		Outer surfaces and ends of valve push rods	
		Crankshaft journal and connecting rod bearing surfaces	
		Crankshaft journal and bearing surface	
		Connecting rod bushing, piston pin bore, and piston pin	
		Cylinder bore and piston rings	
		Connecting rod bearings and crankshaft journal	
		Connecting rod crankshaft journal and rod bearing surfaces	
		Flywheel retaining bolts	
		Bearing carrier bolts and washers	
		Bearing bore and bearing outer surface	
		Bearing inner surface	
		Crankshaft journal main bearing surfaces	
		Main bearing carrier screw	
		Rear bearing carrier O-ring	
		Rear crankshaft journal and rear bearing	
		Piston cooling jet O-ring	
		Balance shaft assembly	
		Lower centering collars in cylinder block	
		Flywheel bolt threads	
91	Engine Coupler Spline Grease	Flywheel O-ring	92-802869A1
113	Loctite Moly Paste (Molybdenum Disulfide Grease)	Threads and underside of bolt heads on all 14M cylinder head bolts	Obtain Locally
		Threads on the left-hand thread crankshaft pulley nut and on the crankshaft pulley contact side	
116	RTV 587 Ultra Blue Silicone Sealer	Oil pan flange	92-809825
		Lower end of the dipstick tube	

Special Tools

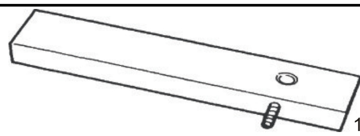
Crankshaft Rotation (Barring) Tool	91-898154
 17990	Used to rotate the crankshaft on assembled engines.

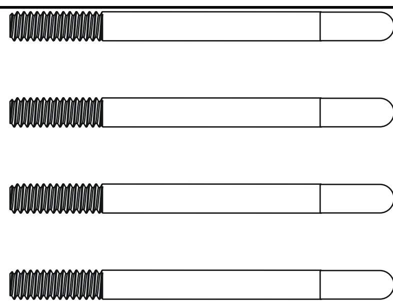
Cylinder TDC Tool	91-898127
 18063	Gauges TDC from the injector seat with the injector removed.

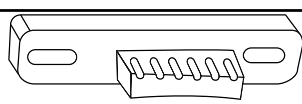
Flywheel TDC Pin Tool	91-889331001
 18062	Screws into the flywheel housing to locate and set engine cylinder number 1 at TDC.

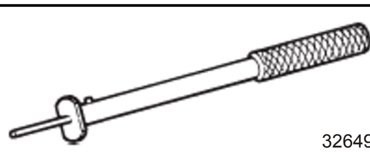
Cylinder Head Service Tool Kit	91-806563A 1
 18114	Aids in the removal and installation of special triple square cylinder head bolts.

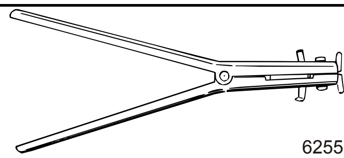
Dial Indicator	91-58222A1
 9479	Measures gear backlash and pinion gear location.

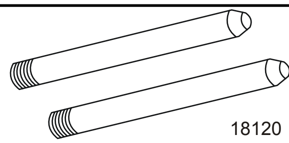
Support Block	91-814812A 1
 18117	Holds and supports a dial indicator for various measurements; also used as a base for the dial indicator.

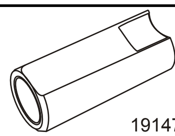
Cylinder Head Guide Pins	91-801333501
 32650	Aids in cylinder head alignment and installation.

Flywheel Holder Tool	91-895472
 18042	Prevents crankshaft rotation during certain service procedures; used only with the starter removed.

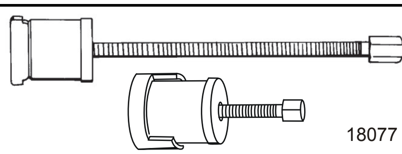
Valve Lifter Tool	91-898282
 32649	Aids in the removal, installation, and alignment of the valve lifters.

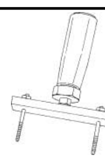
Piston Ring Expander	91-24697
 6255	Expands piston rings for removal and installation.

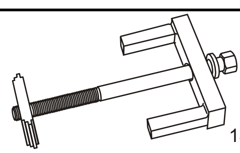
Flywheel Assembly Guide Pins	91-898282001
 18120	Aids in the removal and installation of the flywheel.

Crankshaft Gear Cover Assembly Tool	91-801333504
 19147	Protects the crankshaft gear and bearings during crankshaft removal and installation.

Crankshaft Gear Puller	91-898210
 18071	Aids in the removal of the crankshaft gear.

Bearing Removal And Installation Tool	91-801333508
 18077	Removes and installs crankshaft bearings and camshaft bearings

Balance Shaft Installation Tool	91-898155
 17980	Aligns the counterweights on the balance shaft assembly prior to installation.

Cylinder Liner Puller	91-801333502
 18080	Removes the cylinder liners.

General Information

Repair Procedure Information

Some of the repairs in this section must be completed with the engine removed from the boat. Engine removal depends upon the type of repair and boat design. Place the engine on a repair stand for major repairs.

This section primarily covers servicing the cylinder heads and engine block. Some external components that are not mentioned in the procedural steps must be removed. Refer to appropriate sections of this manual for complete service information concerning any component that hinders service or repairs to the cylinder heads and engine block.

When engine removal is not required, ensure that the battery cables are disconnected at the battery before performing any onboard repair procedures.

Lubricate all moving parts during reassembly with clean engine oil or as specified. Apply appropriate lubricant, sealant, or adhesive to all fasteners as specified.

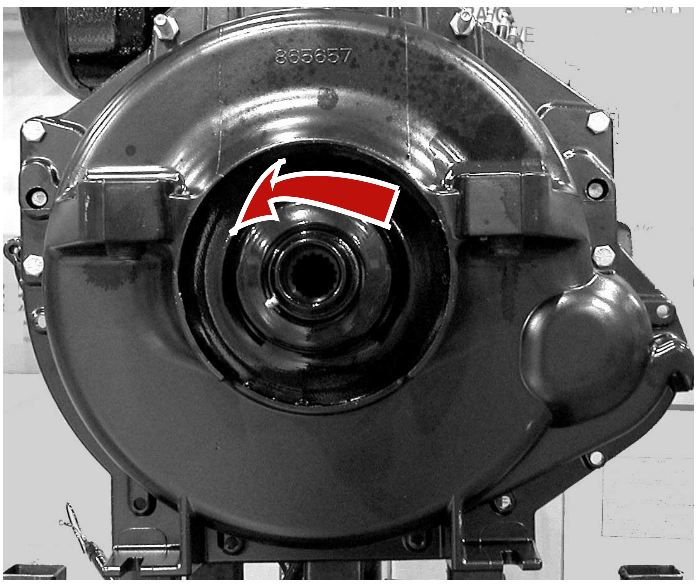
⚠ CAUTION
Using compressed air can cause serious injury. Always wear eye protection when working with compressed air to prevent injury from ruptured hoses or flying debris.

Engine Rotation

Engine rotation is described as observed from the rear of the engine (flywheel end) looking forward (water pump end).

Propeller rotation direction is not necessarily the same as engine rotation.

IMPORTANT: All engines covered by this service manual are left-hand (LH) rotation.



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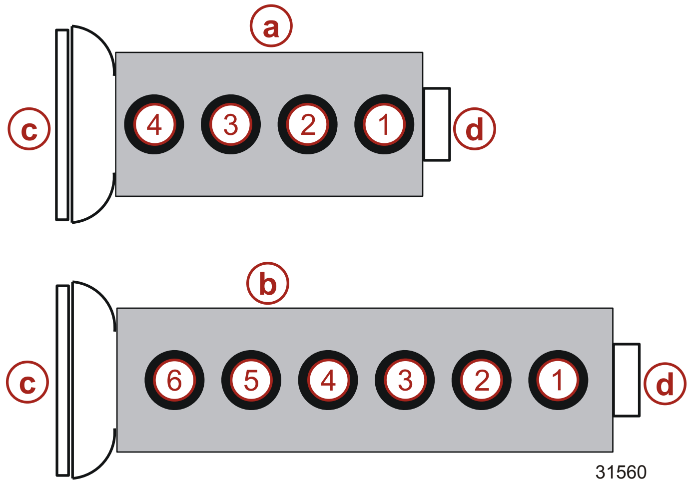
Left hand rotation (counter clockwise)

Engine Firing Order



Engine cylinder numbering

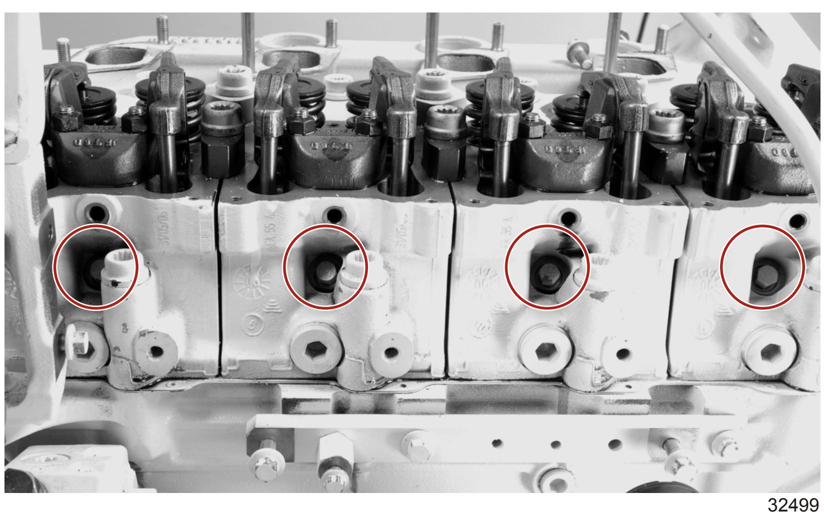
a - 2.8 liter
b - 4.2 liter
c - Flywheel housing
d - Crankshaft pulley

Engine Firing Order	
2.8	1-3-4-2
4.2	1-5-3-6-2-4

Manual Engine Rotation—2.8

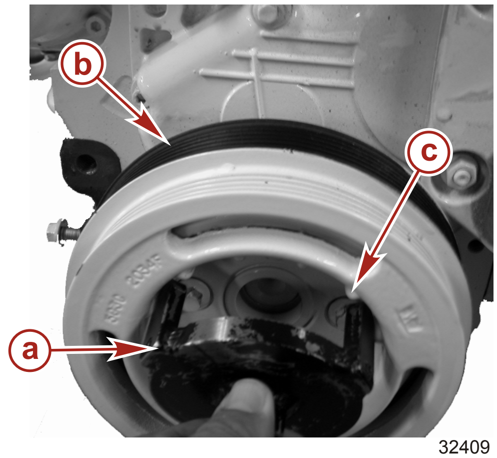
NOTE: Remove the screw plugs from the glow plug holes to release compression when turning the crankshaft. Due to their advanced computer managed fuel system, QSD model engines do not use glow plugs.

1. Remove the screw plugs in the glow plug holes to release compression when turning the crankshaft.



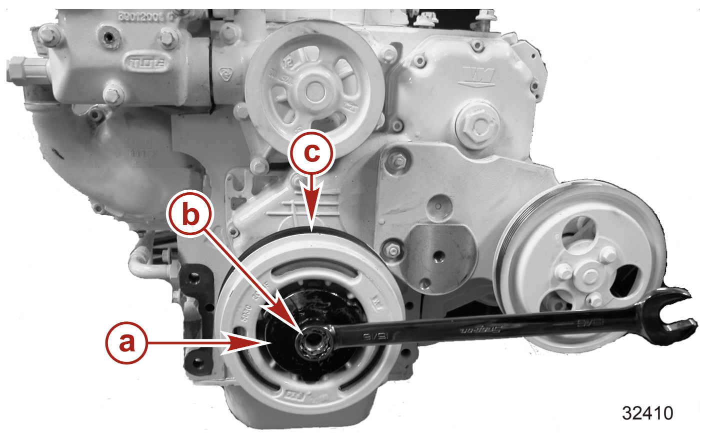
Glow plug hole engine block screw plugs

2. Insert the tabs of the Crankshaft Rotation (Barring) Tool into the slots in the front of the crankshaft pulley.



2.8 engine

a - Barring tool
b - Crankshaft pulley
c - Slot



a - Barring tool
b - Wrench
c - Crankshaft Pulley

Crankshaft Rotation (Barring) Tool	91-898154

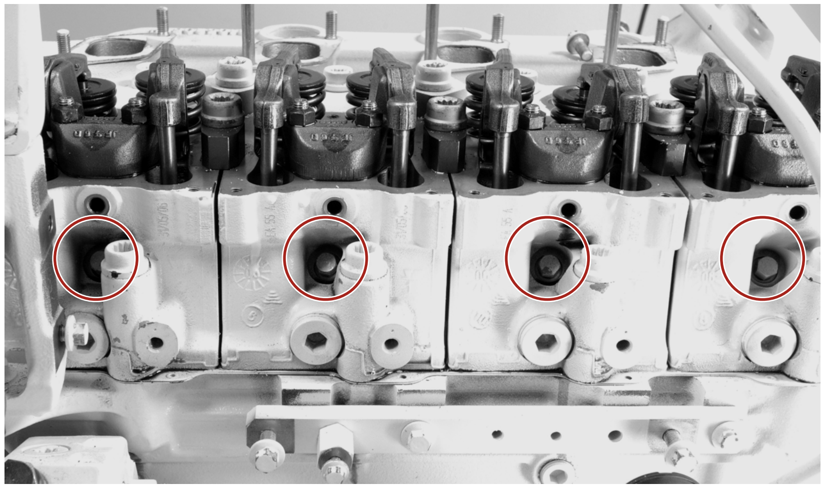
3. Attach an appropriately sized socket to the Crankshaft Rotation (Barring) Tool. Turn the engine with a large socket drive or break-over bar.

Manual Engine Rotation—4.2

The crankshaft balancer of the QSD 4.2L engine is not equipped the slots for the barring tool. Rotate the QSD 4.2L engine by placing the appropriately sized socket on the crankshaft balancer nut and turn the engine over with a socket drive or break-over bar.

NOTE: *Remove the screw plugs from the glow plug holes to release compression when turning the crankshaft. Due to their advanced computer managed fuel system, QSD model engines do not use glow plugs.*

1. Remove the glow plug hole screw plugs.



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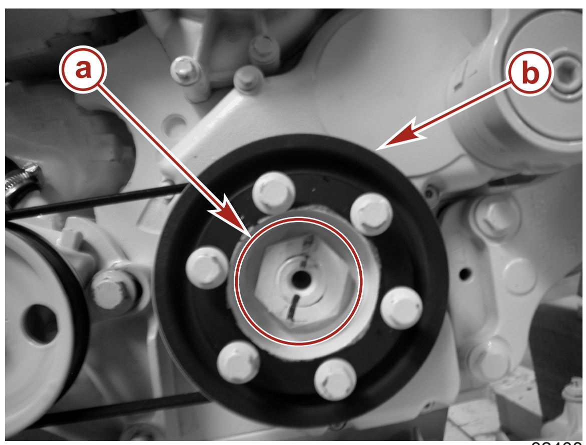
Glow plug hole engine block screw plugs 2.8 shown, 4.2 similar

2. Place a 46 mm socket on the crankshaft balancer nut.



32408

a - Crankshaft pulley nut **b -** Crankshaft pully

3. Rotate the engine with a large socket drive or break-over bar.

Establishing TDC (Top Dead Center)

To avoid component damage, some procedures require the engine to be set at cylinder number 1 Top Dead Center (TDC). Other procedures require individual cylinders to be set at TDC, such as during installation of the rocker arm assembly.

The Cylinder TDC Tool temporarily replaces the fuel injector in the selected cylinder and uses an attached dial gauge to verify actual piston position..

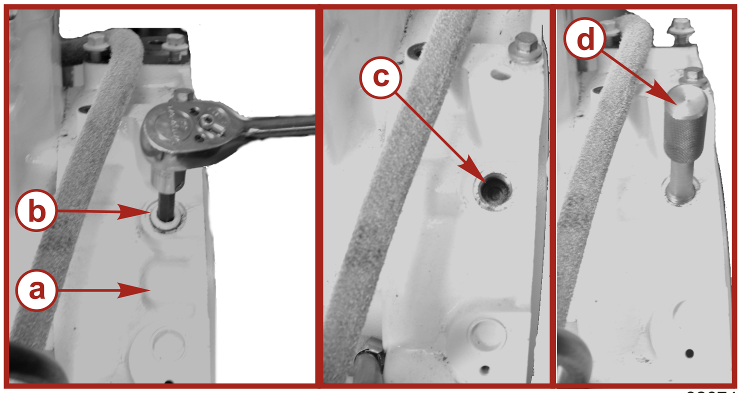
Cylinder TDC Tool	91-898127

The Flywheel TDC Pin Tool engages a two-step drilling in the flywheel when cylinder number 1 is at TDC. This tool threads into the engine block and is used during some assembly procedures.

Flywheel TDC Pin Tool	91-889331001

Use the Flywheel TDC Pin Tool and the following procedure to establish cylinder number 1 TDC.

1. Remove the access plug from the upper port side of the flywheel housing.



32674

a - Flywheel housing
b - Access plug
c - Access hole
d - Flywheel TDC Pin installed

2. **On partially assembled engines:**
   a. Temporarily insert a push rod into both cylinder number 1 lifters.
   b. Slowly rotate the crankshaft **clockwise** (as viewed from the water pump end looking toward the flywheel) while watching the front-most valve push rod for cylinder number 1 intake valve.
   c. Continue to rotate the engine until after the intake valve push rod has moved up (rocker arm went down—intake valve opened) and then the valve push rod moved down (rocker arm came up—intake valve closed).
   d. Temporarily stop rotating the crankshaft and proceed as instructed in step 4.
3. **On assembled engines:**
   a. Remove the cylinder number 1 glow plug or the screw plug, as equipped.
   b. With a finger on the glow plug hole, slowly rotate the crankshaft **clockwise** until compression is felt in cylinder number 1.
   c. Temporarily stop rotating the crankshaft and proceed as instructed in step 4.
4. While looking through the access hole, slowly rotate the engine **clockwise** until the Flywheel TDC Pin Tool can be inserted into the guide hole machined into the flywheel.
5. Thread the Flywheel TDC Pin Tool into the access hole until the tool's tip engages the guide hole in the flywheel. Cylinder number 1 piston is now set at compression stroke TDC.

Flywheel TDC Pin Tool	91-889331001

6. Make a reference mark on the crankshaft pulley and timing cover to identify the cylinder number 1 TDC position.

IMPORTANT: Remove the Flywheel TDC Pin Tool from the flywheel and housing when the procedure is completed.

7. Remove the Flywheel TDC Pin Tool.
8. If appropriate, turn the crankshaft clockwise 180° to bring the next cylinder in the firing order to TDC.

Firing Order	
2.8	1-3-4-2

Firing Order	
4.2	1-5-3-6-2-4

9. Repeat step 8 if TDC needs to be established for additional cylinders.

Engine Compression Testing

A loss of engine compression causes loss of power, increased fuel consumption, rough idle, hard starts, exhaust smoke, and engine overheating.

1. Start the engine and allow it to reach normal operating temperature.
2. Stop the engine and shut off the fuel supply.
3. Ensure that the battery is fully charged.

IMPORTANT: To achieve the cranking RPMs needed (300 RPM minimum) for a proper compression test, it will be necessary to remove all the injectors before testing.

4. See **Section 5C—Fuel Injectors**. While observing the precautions listed, remove all the fuel injectors.
5. Clean the injector bore and install the Compression Tester Adapter Tool.

Compression Tester Adapter Tool	91-881737

6. Install and torque the injector clamp.

Description	Nm	lb. in.	lb. ft.
Injector clamp	24	–	18

7. Connect the compression gauge to the Compression Tester Adapter Tool and set the gauge to zero "0" reading.
8. Operate the starter. The engine should be cranking at approximately 300 RPM minimum.
9. Check the compression gauge reading and compare to the following specifications.

Engine compression—2.8 and 4.2	
Compression at approximately 300 RPM minimum	30–32 bar (435–464 psi)
Pressure difference between cylinders	500 kPa (72 PSI) maximum

10. Remove the compression gauge and the Compression Tester Adapter Tool.
11. Readings lower than specified or pressure differences between cylinders greater than specified indicate engine problems exist (such as faulty rings, valves, cylinders, and pistons). See the appropriate sections. Repair as needed.
12. If readings are within specifications, install the injectors in the cylinder heads from which they were removed previously. See **Section 5C—Fuel Injectors**.
13. Purge the air from the injectors. See **Section 5C—Fuel Injectors**.

Engine Break-In

20-HOUR BREAK-IN PERIOD

IMPORTANT: The first 20 hours of operation are a break-in period for the engine. Correct break-in is essential to obtain minimum oil consumption and maximum engine performance. During this break-in period, observe the following rules:

- Do not operate below 1500 RPM for extended periods of time during the first 10 hours. Advance the throttle above 1500 RPM as soon as conditions permit safe operation.
- Do not consistently operate at one speed for extended periods.
- Do not exceed 3/4 throttle during the first 10 hours, during the next 10 hours do not operate at full throttle for more than five minutes at a time.

- Do not accelerate at full-throttle from idle speed.
- Do not operate at full throttle until the engine reaches normal operating temperature.
- High oil consumption is normal during the break-in period. Frequently check the engine oil level.

AFTER THE 20-HOUR BREAK-IN PERIOD

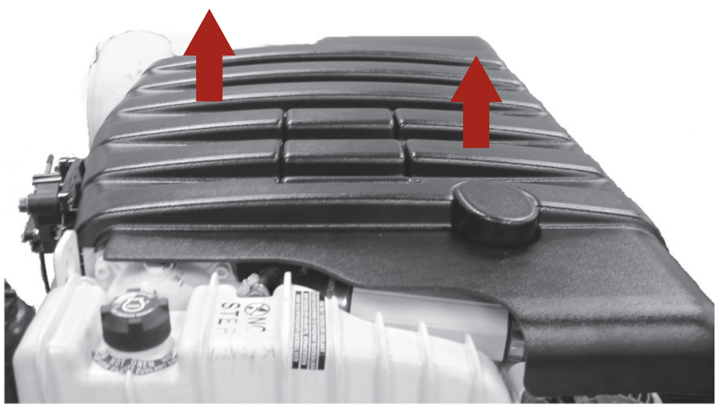
To help extend the life of your power package, Cummins MerCruiser Diesel recommends:

- Changing the engine oil and filter, and the transmission fluid on inboard models, at the interval indicated in the **Maintenance Schedule**.
- Using a propeller that allows the engine to operate at the rated engine RPM when at full throttle with a maximum boat load.
- Operating at 3/4 throttle or lower. See the duty cycle information listed in **Section 1A: Operation—Duty Cycle**.

Engine Cover

Removal

1. Lift and detach the engine cover from the mounts.


27326

Engine cover

Cleaning

1. Clean the cover with warm soapy water.
2. Air dry the cover.

Inspection

1. Inspect the engine cover for cracks or deterioration.
2. Inspect the rubber grommets for deterioration.
3. Inspect the hardware used with each grommet.
4. Replace damaged parts.

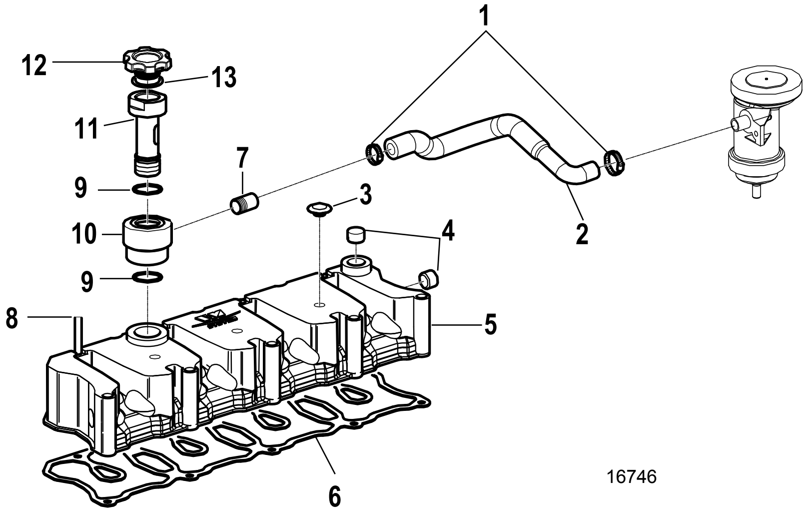
Installation

1. Set the engine cover over the mounts.
2. Press the engine cover down above each mount to reattach the engine cover.

Notes:

Valve Cover

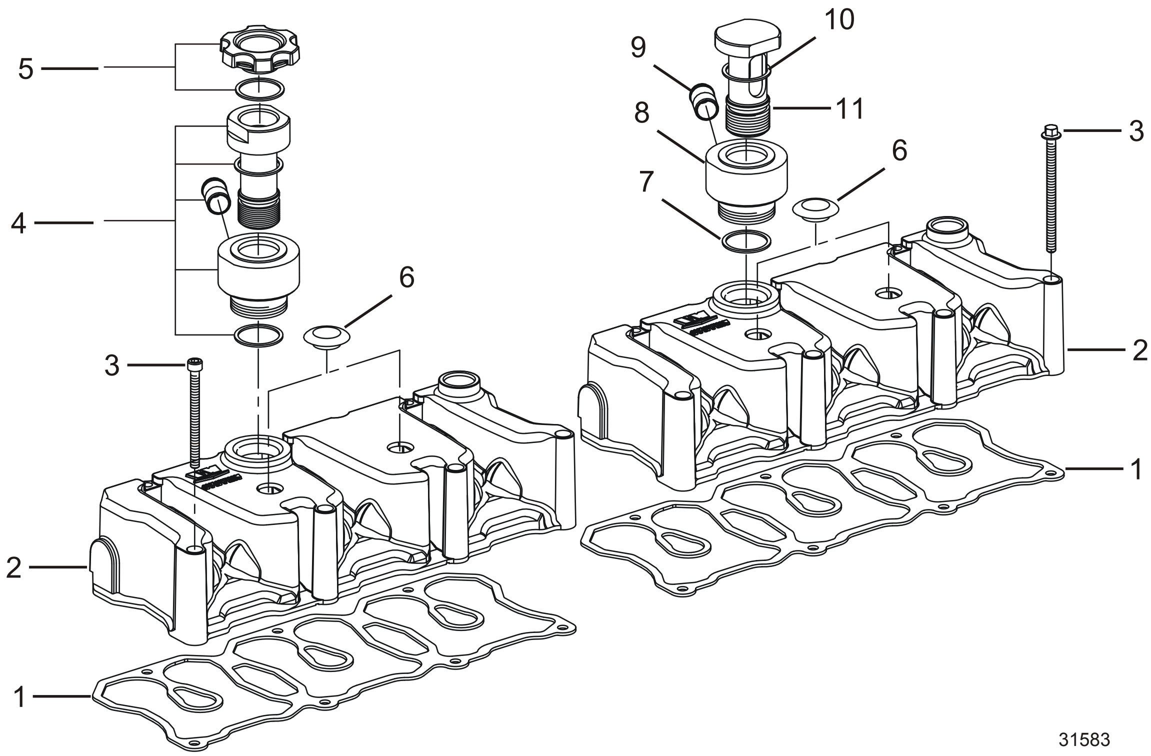
Exploded View—2.8L Valve Cover



Exploded View—2.8L Valve Cover

Ref. No.	Qty.	Description	Torque		
			Nm	lb. In.	lb. ft.
1	2	Hose clamps			
2	1	Oil separator vent hose			
3	3	Plastic plug			
4	2	Valve cover plug			
5	1	Valve cover			
6	1	Valve cover gasket			
7	1	Vent hose adapter			
8	8	Valve cover screw	11.8	104	–
9	2	Sealing washer			
10	1	Oil fill tube adapter			
11	1	Oil fill tube extension	19.6	173	–
12	1	Oil fill cap			
13	1	Oil fill cap gasket			

Exploded View—4.2L Valve Cover

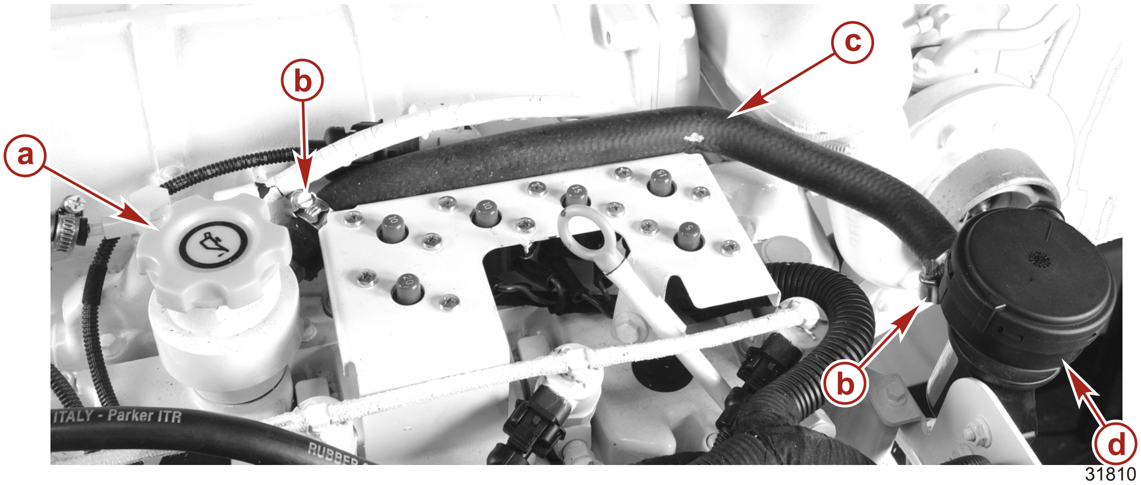


Exploded View—4.2L Valve Cover

Ref. No.	Qty.	Description	Torque		
			Nm	lb. In.	lb. ft.
1	2	Valve cover gasket			
2	2	Valve cover			
3	8	Valve cover screw	11.8	104	–
4	1	Oil fill tube and vent assembly	19.6	173	–
5	1	Oil fill cap			
6	4	Plastic valve cover plug			
7	2	O-ring			
8	2	Oil vent			
9	2	Oil vent hose fitting			
10	2	Sealing washer			
11	1	Oil vent tube extension			

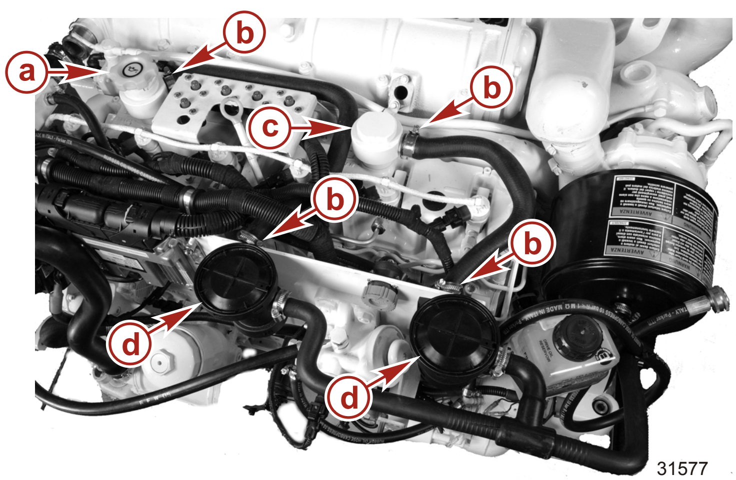
Removal

1. Remove the engine cover.
2. Remove the oil separator vent hoses.



2.8L

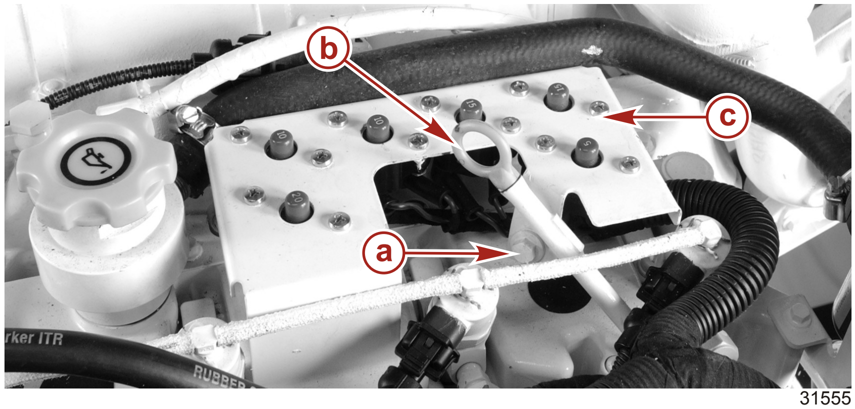
a - Engine oil vent and fill cap
b - Oil separator vent hose clamp
c - Oil vent hose
d - Oil separator



4.2L

a - Engine oil vent and fill cap
b - Oil separator vent hose clamp
c - Oil vent hose
d - Oil separator

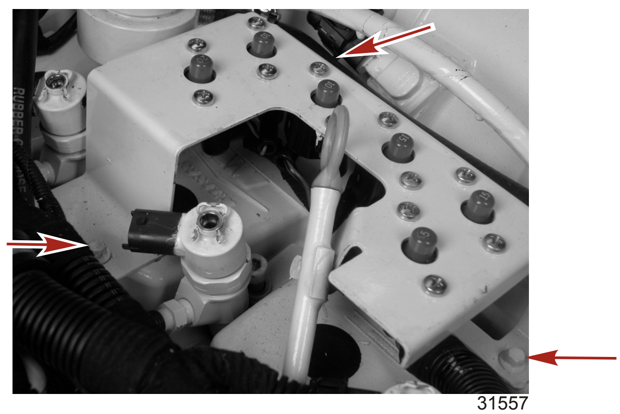
3. Remove the bolt retaining the oil dipstick tube to circuit breaker panel.



2.8L shown, 4.2L similar

a - Retaining bolt
b - Dipstick and tube
c - Circuit breaker panel

4. Remove the three screws retaining the circuit breaker panel to the valve cover.

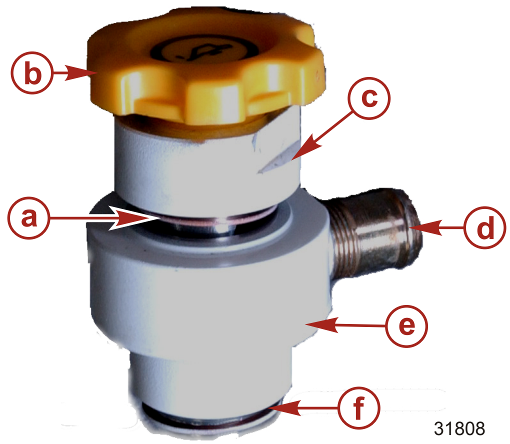


Circuit breaker panel screws

NOTE: *Leave the circuit breaker panel attached to the engine wiring harness and move aside.*

5. Remove the fuel injectors. See **Section 5C – Fuel Injectors**.

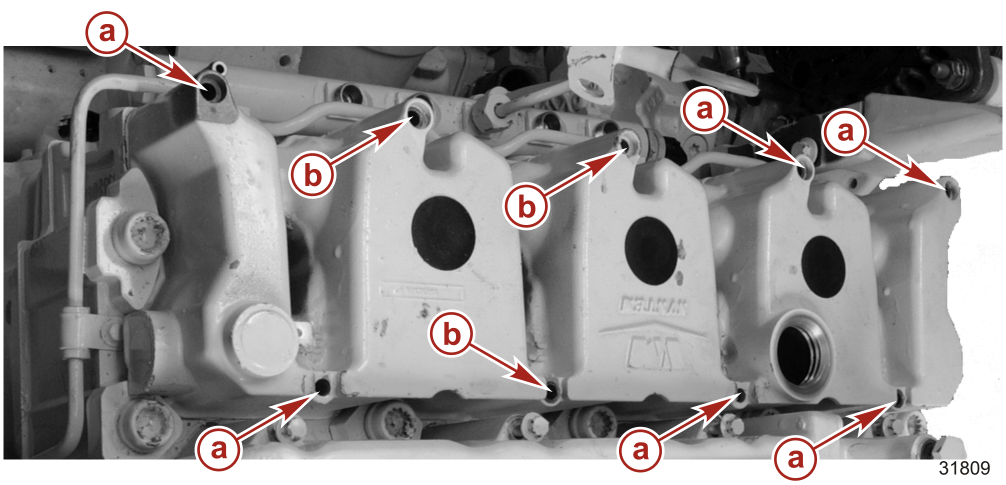
6. Remove the oil fill extension tube, the oil separator and vent hose adapter, and the sealing washers.



Oil fill extension

a - Seal
b - Oil fill cap
c - Threaded body
d - Vent tube connector
e - Adaptor
f - Seal

7. Remove the remaining screws retaining the valve cover to the cylinder head.



2.8 valve cover, 4.2 similar

a - Valve cover screw holes
b - Valve cover and circuit breaker panel screw holes

8. Using a rubber mallet, tap against the side of the valve cover to loosen.
9. Lift the valve cover from the heads.

Cleaning

IMPORTANT: Do not drop anything into the cylinder head openings.

1. Clean the gasket material from all sealing surfaces.
2. Clean the valve cover.
3. Clean the sealing surfaces on the cylinder head and valve cover with cleaning solvent.
4. Remove the copper sealing washer from the injectors or injector seats. See **Section 5C**.

Inspection

1. Inspect the sealing surfaces for deep nicks and scratches.
2. Inspect the valve cover and vent hose connectors for damage.
3. Inspect the plastic plugs for cylinder head screw hole covers.
4. Replace or repair parts as needed.

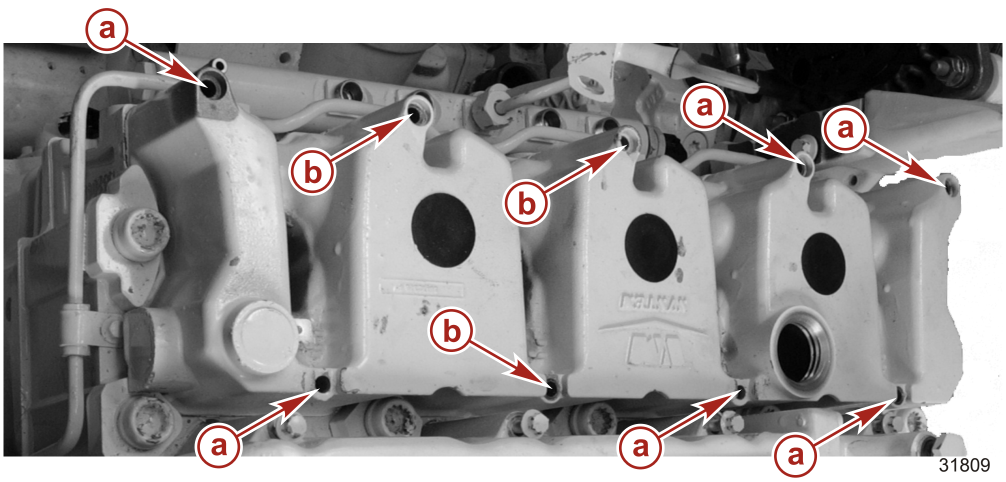
Installation

1. Install a new valve cover gasket to the valve cover.

NOTE: A small amount of sealant can be used to hold a gasket in place during installation.

Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Valve cover gasket	92-12564 2

2. Install the valve cover on the cylinder heads.
3. Install and finger tighten the Allen head valve cover screws.

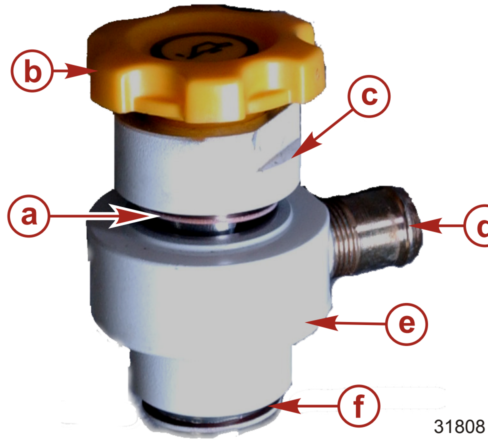


2.8 valve cover, 4.2 similar

a - Valve cover screw holes

b - Valve cover and circuit breaker panel screw holes

4. Install and hand tighten the oil fill cap extension tube, with the oil separator and vent hose adapter. Use new sealing washers.



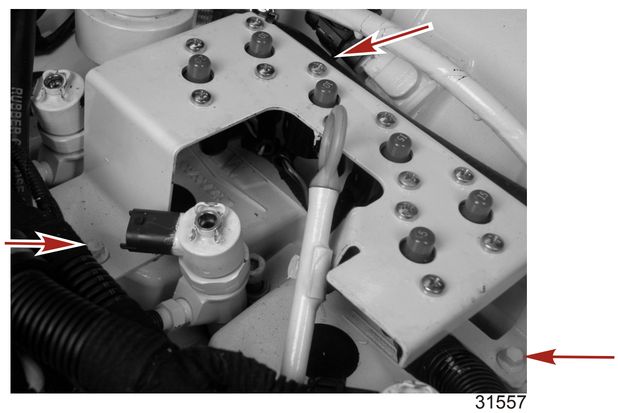
Oil fill extension

- **a -** Seal
- **b -** Oil fill cap
- **c -** Threaded body
- **d -** Vent tube connector
- **e -** Adaptor
- **f -** Seal

5. Torque the oil fill extension tube and oil separator.

Description	Nm	lb. in.	lb. ft.
Oil fill extension tube	19.6	173	–
Oil Separator	19.6	173	–

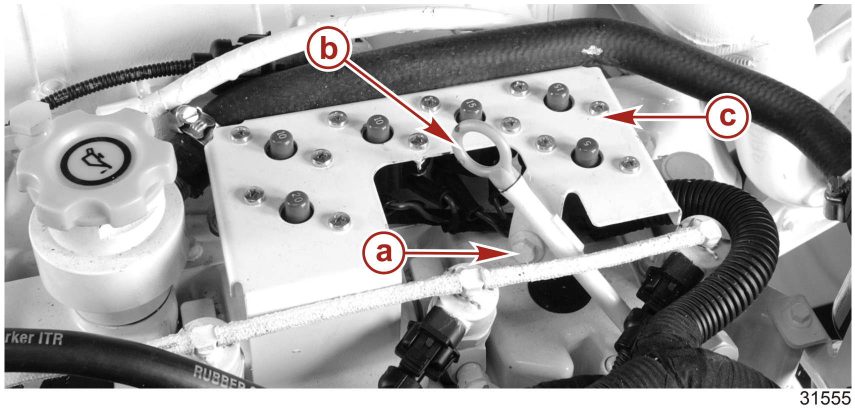
6. Install the fuel injectors. See **Section 5C – Fuel Injectors**.
7. Install the circuit breaker panel.



Circuit breaker panel screws

8. Install the circuit breaker panel to valve cover screws.

9. Install the bolt retaining the oil dipstick tube to circuit breaker panel.



2.8L shown, 4.2L similar

a - Retaining bolt
b - Dipstick and tube
c - Circuit breaker panel

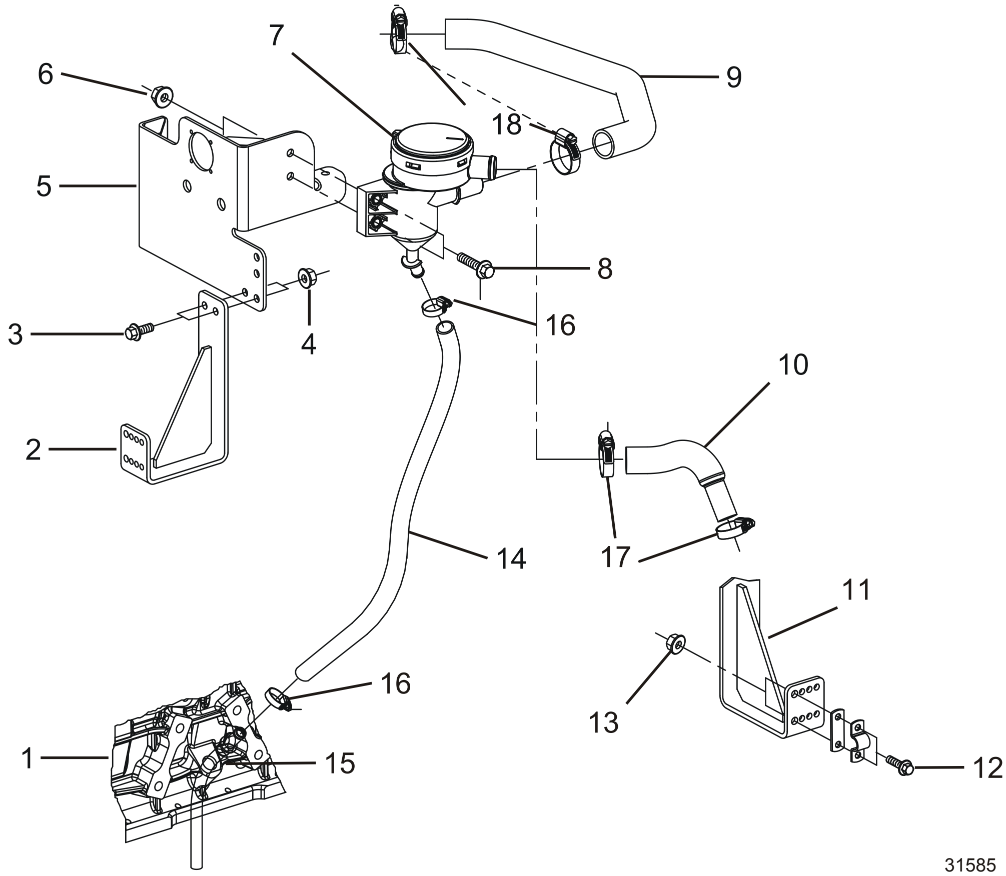
10. Install the oil separator vent hose on the connectors. Tighten the clamps.
11. Torque the valve cover screws, including the three bolts that also attach the circuit breaker panel, starting from the middle of the valve cover, working out toward each end of the valve cover in a diagonal pattern.

Description	Nm	lb. in.	lb. ft.
Valve cover screws	11.8	104	–

12. Install the engine cover.

Oil Separator and Vent System

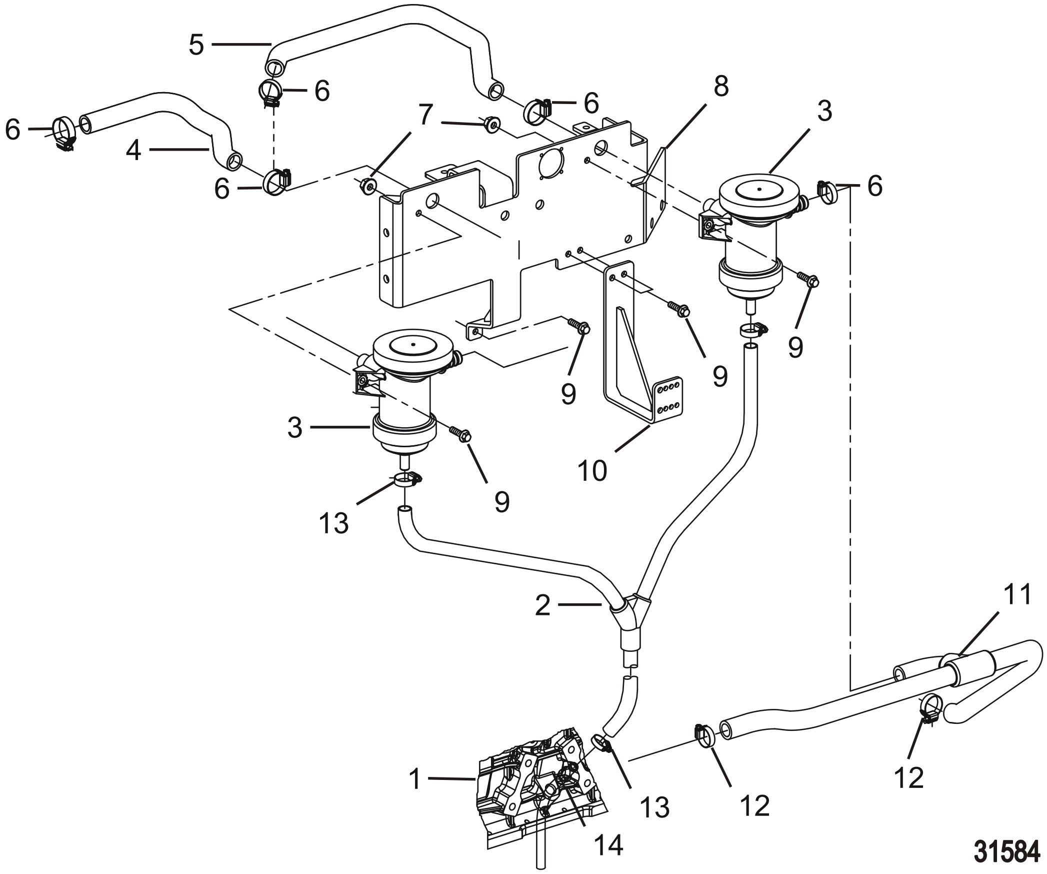
Exploded View—2.8L Oil Separator and Vent System



Exploded View—2.8L Oil Separator and Vent System

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Engine block			
2	1	Bracket			
3	2	Bolt			
4	2	Nut	24.5	–	18
5	1	Bracket			
6	2	Nut	11.8	104	–
7	1	Oil Separator			
8	2	Bolt	10.8	95	–
9	1	Hose, oil separator to valve cover vent			
10	1	Hose, oil separator to air filter housing			
11	1	Bracket			
12	2	Bolt			
13	2	Nut	24.5	–	18
14	1	Hose, oil separator to engine oil pan vent fitting			
15	1	Engine oil pan vent fitting			
16	2	Hose clamp			
17	2	Hose clamp			
18	2	Hose clamp			

Exploded View—4.2L Oil Separator and Vent System

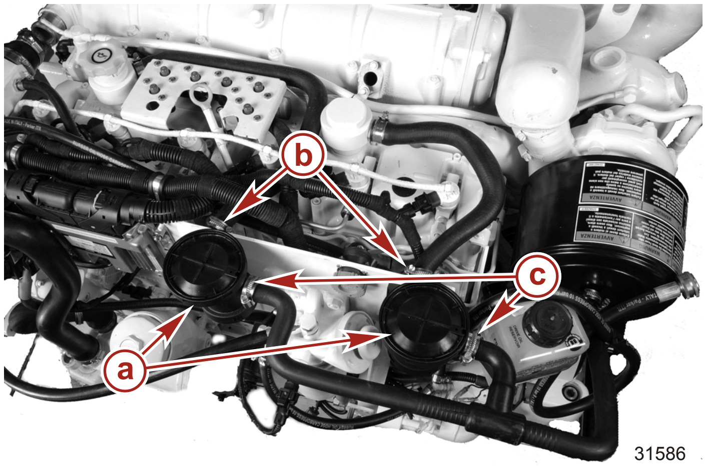


Exploded View—4.2L Oil Separator and Vent System

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Engine block			
2	1	Hose, oil separator to engine oil pan vent fitting			
3	2	Oil Separator			
4	1	Hose, oil separator to valve cover vent			
5	1	Hose, oil separator to valve cover vent			
6	4	Hose clamp			
7	2	Nut	10.8	95	–
8	1	Bracket			
9	5	Bolt	11.8	104	–
10	1	Bracket			
11	1	Hose, oil separators to air filter housing			
12	2	Hose clamp			
13	3	Hose clamp			
14	1	Engine oil pan vent fitting			

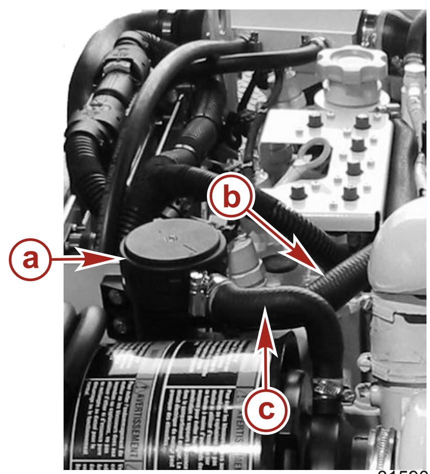
Removal

1. Disconnect the air cleaner vent and valve cover vent hoses from the oil separator.



4.2L

a - Oil separator
b - Valve cover vent hose
c - Air cleaner vent hose

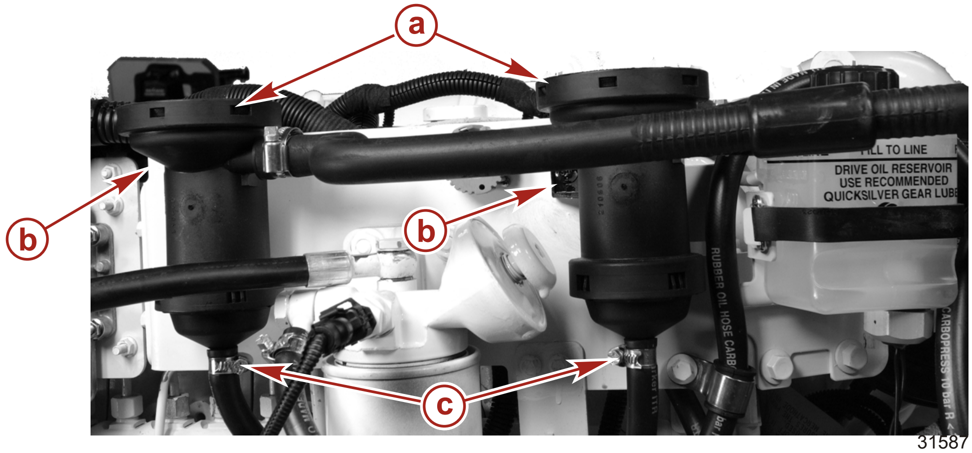


2.8L

a - Oil separator
b - Valve cover vent hose
c - Air cleaner vent hose

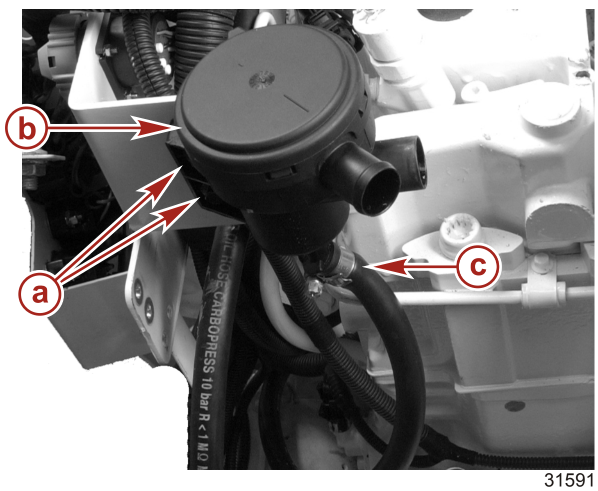
2. **For the 2.8L engine only**, remove the air cleaner assembly

3. Disconnect the oil drain hose from the oil separator.



4.2L

a - Oil separator
b - Retaining screws, oil separator
c - Oil drain hose



2.8L

a - Oil separator
b - Retaining screws, oil separator
c - Oil drain hose

4. Remove the flange nut and the bolts retaining the oil separator to the engine bracket.
5. Remove the oil separator.

Cleaning

1. Put on safety glasses.
2. Wash the oil separator in cleaning solvent.
3. Dry the components with compressed air.
4. Wipe the hoses and fittings with a clean shop cloth.

Inspection

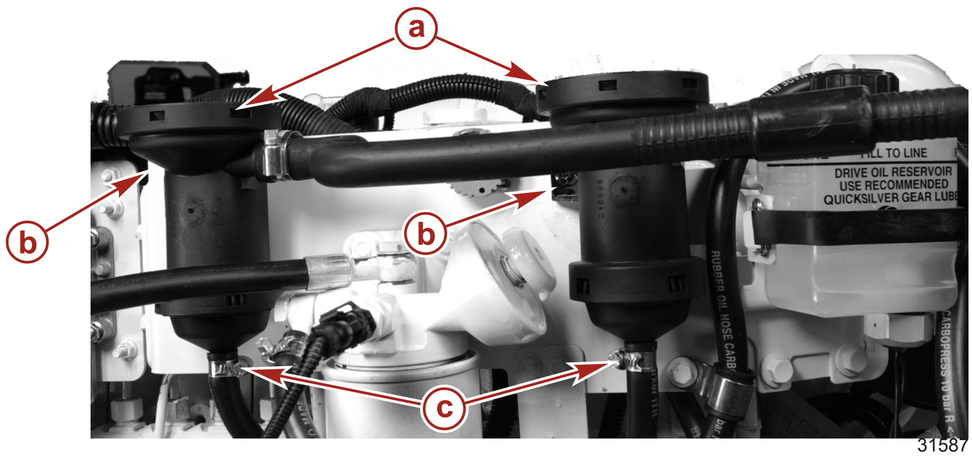
1. Inspect the hoses and the hose fittings for cracks or deterioration.
2. Inspect the oil separator for cracks or signs of leaking.
3. Replace or repair damaged parts.

Installation

1. Attach the oil separator to the bracket.
2. Torque the retaining nuts and bolts.

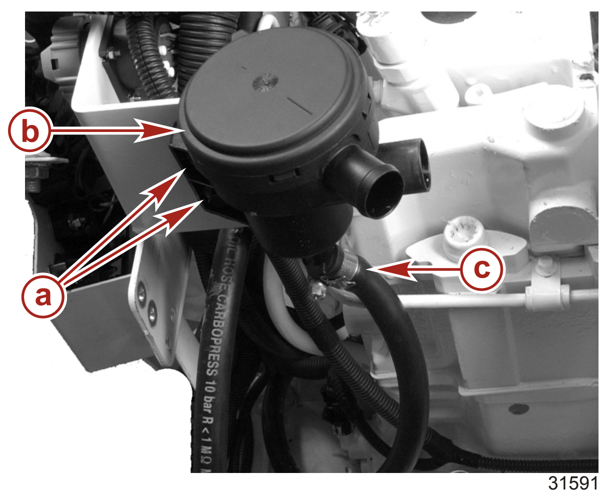
Description	Nm	lb. in.	lb. ft.
Oil separator flange nut	10.8	95	–

3. Install the oil drain hose to the oil separator.



4.2L

a - Oil separator
b - Retaining screws, oil separator
c - Oil drain hose

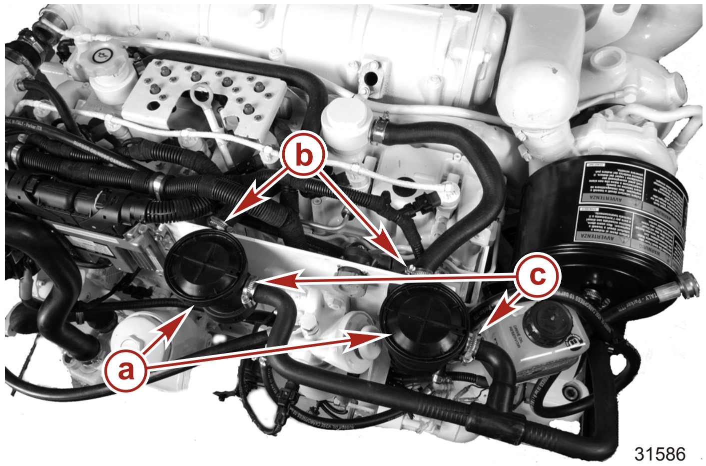


2.8L

a - Oil separator
b - Retaining screws, oil separator
c - Oil drain hose

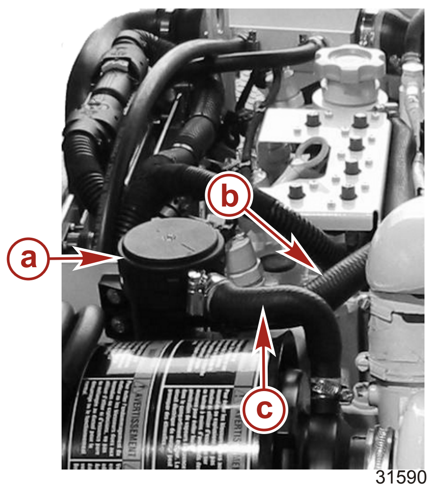
4. **For the 2.8L engine only**, install the air cleaner assembly.

5. Connect the air cleaner vent and valve cover vent hoses to the oil separator.



4.2L

a - Oil separator
b - Valve cover vent hose
c - Air cleaner vent hose



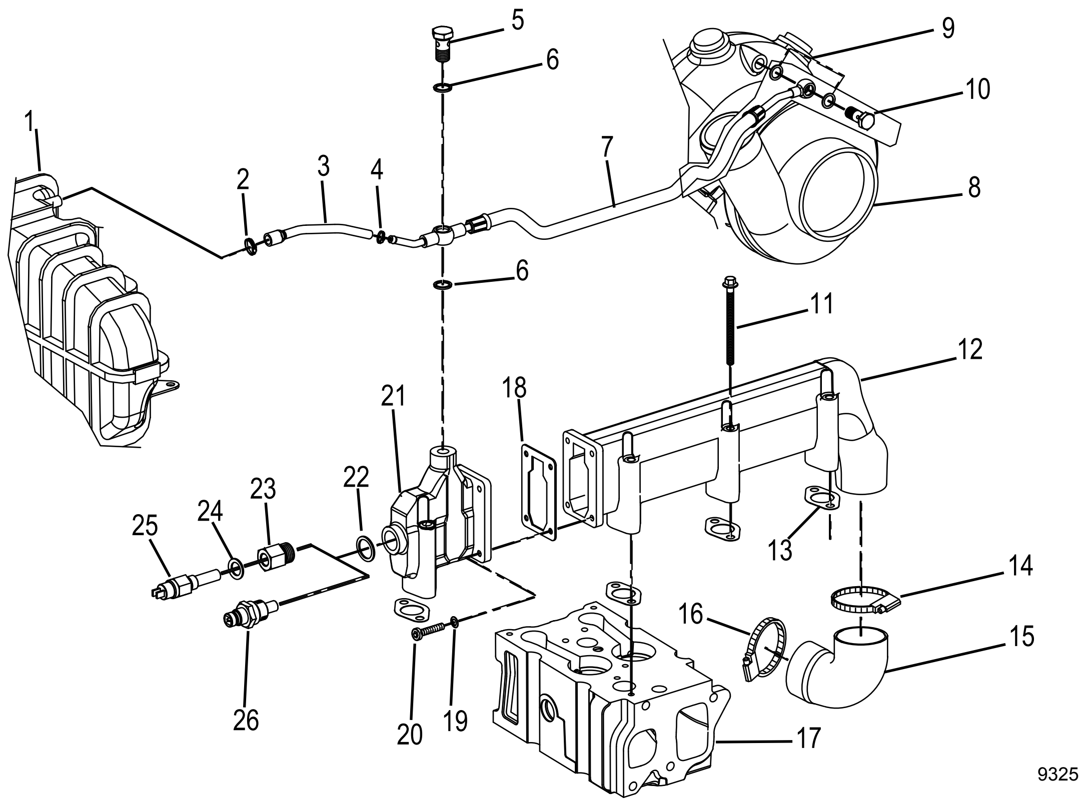
2.8L

a - Oil separator
b - Valve cover vent hose
c - Air cleaner vent hose

6. Tighten all hose clamps securely.

Coolant Manifold Assembly

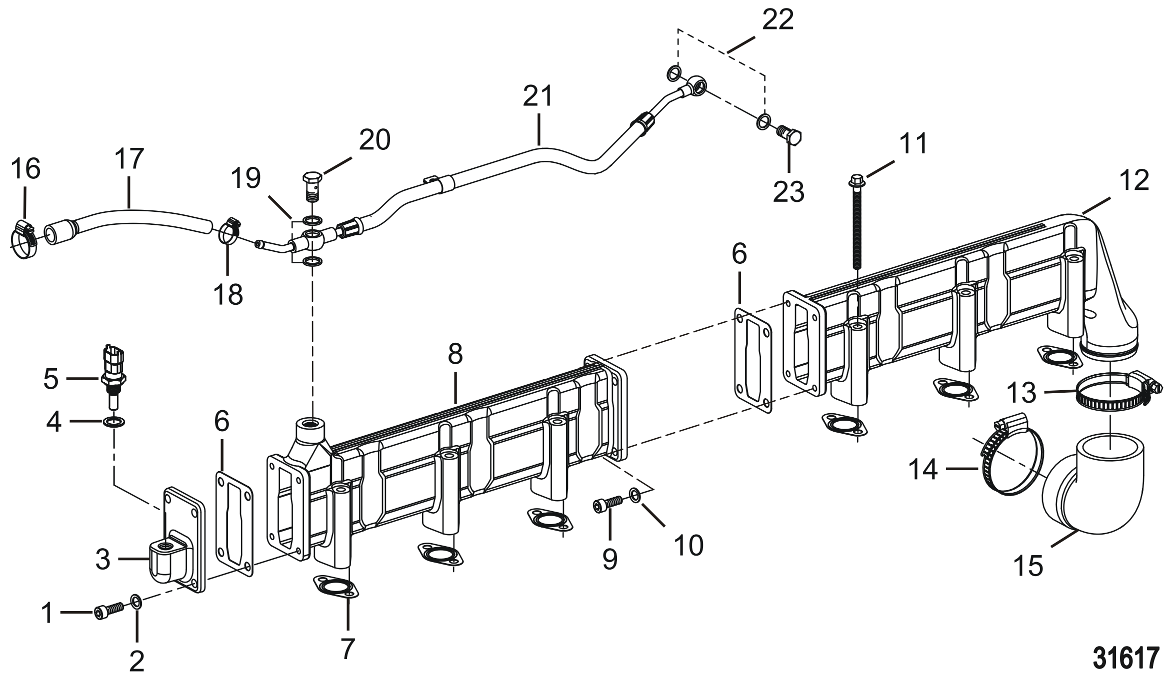
Exploded View—2.8 Coolant Manifold Assembly



Exploded View—2.8 Coolant Manifold Assembly

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Coolant reservoir			
2	1	Hose clamp			
3	1	Vent hose to coolant reservoir			
4	1	Hose clamp			
5	1	Coolant manifold vent pipe hollow bolt	27	–	20
6	2	Sealing washer			
7	1	Turbocharger vent pipe			
8	1	Turbocharger			
9	2	Sealing washer			
10	1	Turbocharger vent pipe hollow bolt	14.7	130	–
11	8	Flange screw	11.8	104	–
12	1	Coolant manifold			
13	4	Gasket			
14	1	Hose clamp			
15	1	Hose			
16	1	Hose clamp			
17	4	Cylinder head			
18	1	End cover gasket			
19	4	Washer			
20	4	Coolant manifold end cover screw	10.8	95	–
21	1	End cover			
22	1	Sealing washer			
23	1	Adapter (if equipped)	39.2	–	29
24	1	Sealing washer (if equipped)			
25	1	Primary station temperature sender	19.6	173	–
26	1	Dual station temperature sender (if equipped)	19.6	173	–

Exploded View—4.2 Coolant Manifold Assembly



Exploded View—4.2 Coolant Manifold Assembly

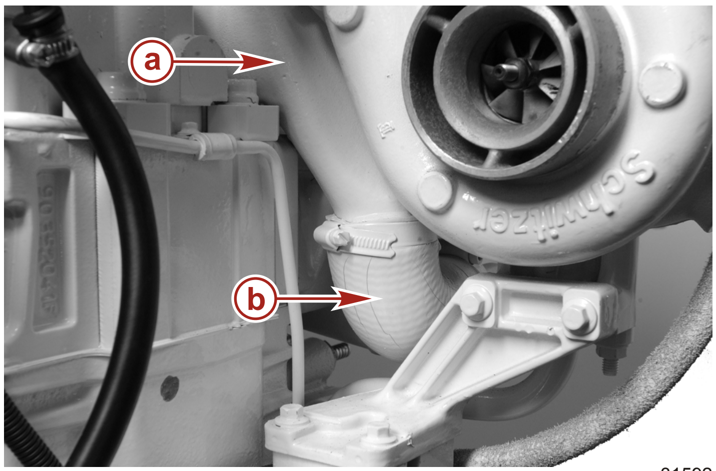
Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	4	Coolant manifold end cover screw	10.8	95	–
2	4	Washer			
3	1	End cover			
4	1	Sealing Washer			
5	1	Primary station temperature sender	39.2	–	28
6	2	End cover gasket			
7	6	Gasket			
8	1	Coolant manifold			
9	4	Screw	10.8	95	–
10	4	Washer			
11	12	Flange screw	11.8	104	–
12	1	Coolant manifold			
13	1	Hose clamp	5.7	–	50
14	1	Hose clamp	5.7	–	50
15	1	Hose			
16	1	Hose clamp	5.7	–	50
17	1	Vent hose to coolant reservoir			
18	1	Hose clamp	5.7	–	50
19	2	Sealing washer			
20	1	Coolant manifold vent pipe hollow bolt	27.5	–	20
21	1	Turbocharger vent pipe			
22	2	Sealing washer			
23	1	Turbocharger vent pipe hollow bolt	14.7	130	–

Removal

NOTICE

Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

1. Drain the engine coolant. Refer to **Section 6A: Draining the closed cooling system**.
2. Loosen the hose clamp on the water hose at the rear of the coolant manifold where it connects to the rear cover of the intake and exhaust manifold.

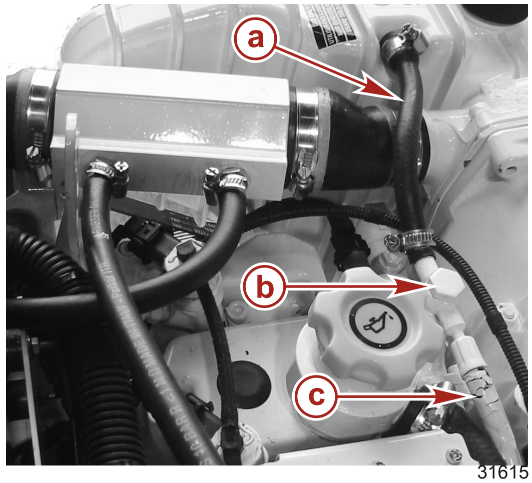


2.8L shown, 4.2L similar

a - Coolant manifold
b - Coolant hose

3. Loosen the hose clamp and disconnect the vent hose to the coolant reservoir.

4. Remove the hollow bolt and sealing washers used to retain the vent pipe on the coolant manifold end cover.

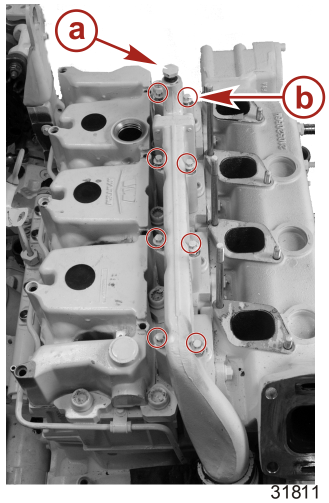


a - Coolant vent hose
b - Hollow bolt fitting
c - Coolant vent pipe

NOTE: *The vent pipe can remain attached to the turbocharger if it does not require replacement.*

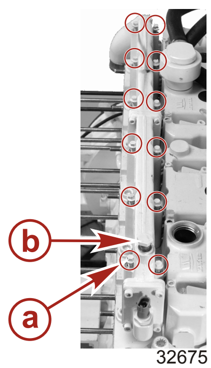
5. Disconnect the wire terminal from the coolant temperature sender.

6. Remove the screws retaining the coolant manifold assembly to the cylinder heads.



2.8 coolant manifold

a - Coolant vent fitting
b - Screws (8)



4.2 coolant manifold

a - Screws (12)
b - Coolant vent fitting

7. Using a rubber mallet, tap against the side of the coolant manifold assembly to loosen from the cylinder heads.
8. Remove the coolant manifold assembly.
9. Remove the four screws and washers and separate the end cover from the coolant manifold.

Cleaning

IMPORTANT: Do not drop anything into the cylinder head openings.

1. Discard the existing hollow bolt sealing washers.
2. Clean the gasket material from cylinder heads, coolant manifold flanges and end cover.
3. Clean the coolant manifold assembly components with cleaning solvent.
4. Put on safety glasses and dry the components with compressed air.
5. Remove all traces of oil and debris from the threaded mounting holes in the cylinder heads for the coolant manifold assembly.

Inspection

1. Inspect the sealing surfaces for deep nicks and scratches.

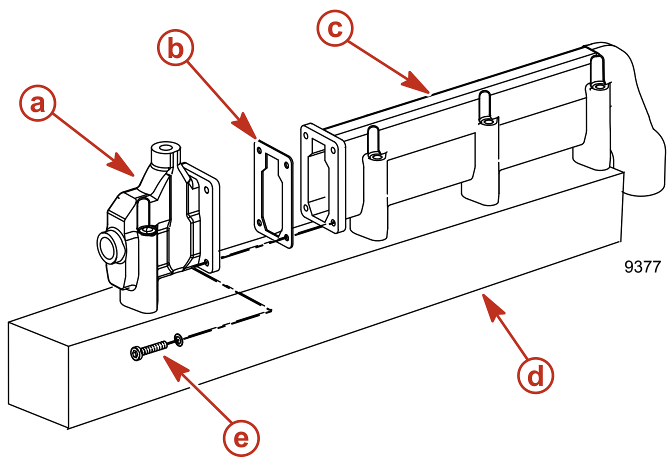
2. Inspect the castings for cracks or corrosion that might prevent a proper seal.
3. Inspect the vent pipe, vent hose, and water hose for signs of damage.
4. Replace or repair components as needed.

Installation

1. Use a new gasket and install the end cover on the coolant manifold using the four screws and washers. Finger-tighten the screws.

IMPORTANT: The end cover and the coolant manifold gasket flanges must align for proper sealing on the cylinder heads. Align the flanges using a machinist straight edge as shown.

2. If removed, align the coolant manifold end cover and the coolant manifold using a machinist straightedge and torque the coolant manifold end cover screws evenly in a diagonal pattern.



a - Coolant manifold end cover
b - Gasket
c - Coolant manifold
d - Straightedge device
e - Coolant manifold end cover screw and washer (4)

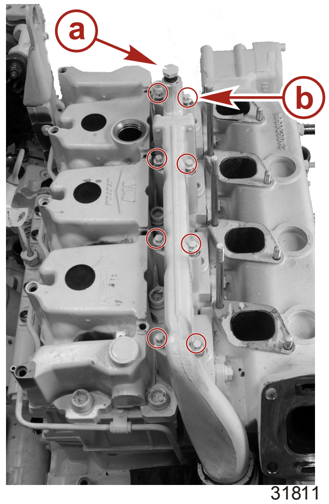
Description	Nm	lb. in.	lb. ft.
Coolant manifold end cover screw	10.8	95	–

3. Place new gaskets in position on the cylinder heads.

NOTE: A small amount of sealant can be used to hold a gasket in place during installation.

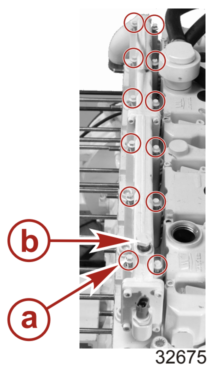
Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Coolant manifold gasket to cylinder head	92-12564 2

4. Install the coolant manifold assembly while simultaneously positioning the water hose onto the rear of the manifold. Finger-tighten the eight coolant manifold screws.



2.8 coolant manifold

a - Coolant vent fitting
b - Screws (8)



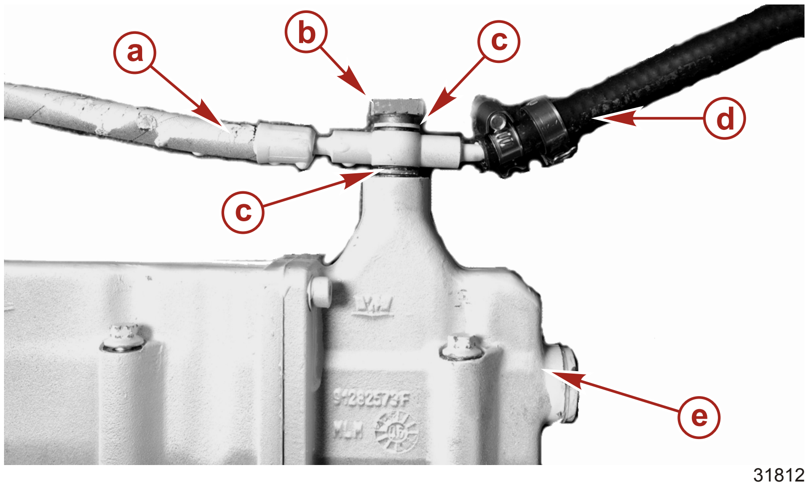
4.2 coolant manifold

a - Screws (12)
b - Coolant vent fitting

5. Torque the coolant manifold screws in a diagonal pattern from the center to the outer ends.

Description	Nm	lb. in.	lb. ft.
Coolant manifold screw	11.8	104	–

6. Install the turbocharger vent pipe onto the coolant manifold using the hollow bolt and new sealing washers. Torque the coolant manifold vent pipe hollow bolt while simultaneously positioning the vent pipe.



Coolant vent hose hollow bolt fitting

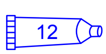
- **a -** Coolant vent hose from turbocharger
- **b -** Hollow bolt fitting
- **c -** Sealing washer
- **d -** Coolant vent hose from coolant reservoir
- **e -** Coolant manifold

Description	Nm	lb. in.	lb. ft.
Coolant manifold vent pipe hollow bolt	27.5	–	20

7. Connect the vent hose to the coolant reservoir. Tighten the hose clamps.

NOTE: Dual helm applications may have an adaptor and dual station coolant temperature sensor installed.

8. Install the coolant temperature sender adaptor (if equipped). Install the coolant temperature sensor. Apply sealant to all threads.

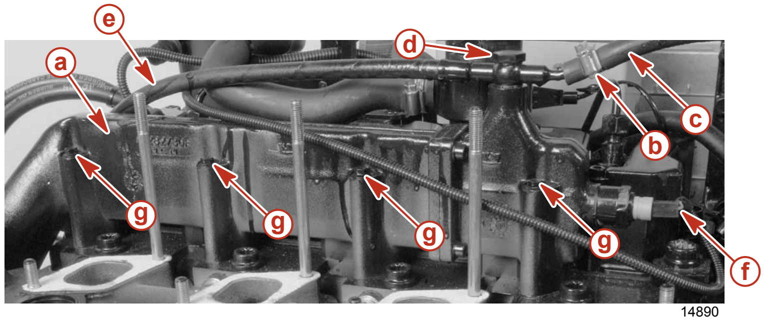
Tube Ref No.	Description	Where Used	Part No.
 12	Loctite Master Gasket Kit	Coolant temperature adaptor (if equipped) and sensor threads	92-12564 2

9. Torque the coolant temperature sensor adaptor (if equipped) and the coolant temperature sensor.

Description	Nm	lb. in.	lb. ft.
Coolant temperature sensor adaptor (if equipped)	39.2	–	29
Coolant temperature sensor	19.6	173	–

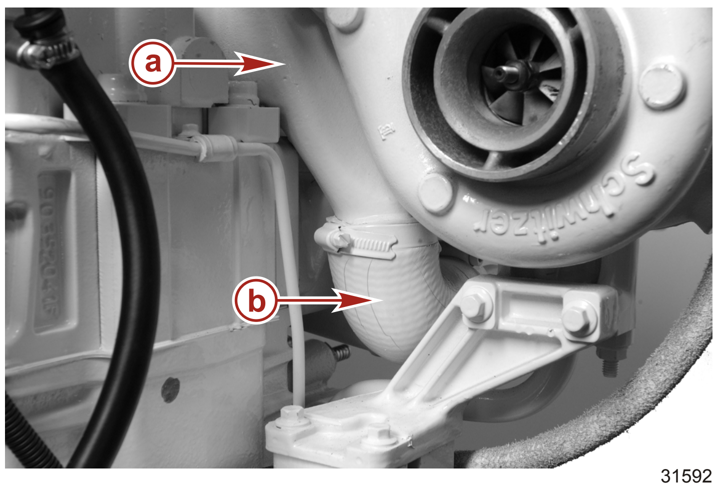
10. Connect the wire terminal to the coolant temperature sender.

NOTE: Coolant manifold assembly shown with aftercooler removed for visual clarity only.



a - Coolant manifold assembly
b - Hose clamp
c - Vent hose to coolant reservoir
d - Hollow bolt and sealing washers
e - Vent pipe to turbocharger
f - Wire terminal
g - Coolant manifold screw (starboard 4 shown, port 4 not visible)

11. Tighten the hose clamp on the coolant hose at the rear of the coolant manifold.



2.8L shown, 4.2L similar

a - Coolant manifold
b - Coolant hose

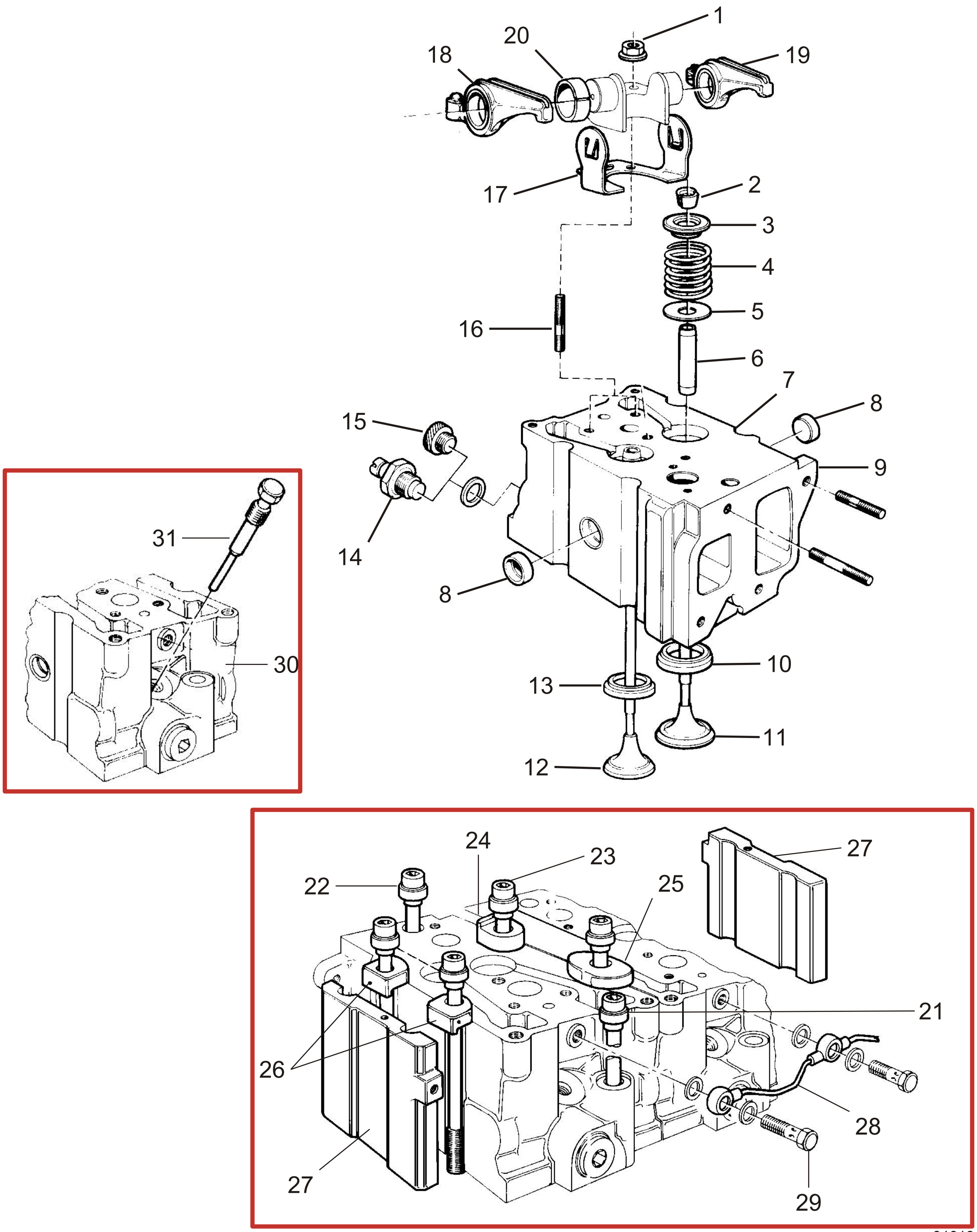
12. See **Section 6** for appropriate procedures on filling the closed cooling system and test the engine operation.
13. Check for leaks upon first starting the engine.

Cylinder Heads

Exploded View—Cylinder Head

The QSD 2.8 and 4.2 engines each utilize one cylinder head per cylinder.

Notes: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Exploded View—Cylinder Head

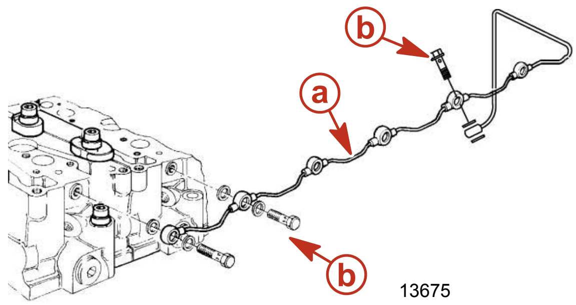
Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	8	Rocker pedestal nut	29	–	21
2	8	Valve cone (valve keeper)			
3	8	Valve spring retainer			
4	8	Valve spring			
5	8	Plate washer			
6	8	Valve Guide (four intake, four exhaust in standard or 0.10 mm oversize)			
7	4	Cylinder head			
8	8	Expansion plugs (two per cylinder head)			
9	–	Cylinder head identification code stamping location			
10	4	Intake valve seat			
11	4	Intake valve			
12	4	Exhaust valve			
13	4	Exhaust valve seat			
14	1	Engine coolant temperature (ECT), depending on cylinder head location			
15	1	Plug (depending on cylinder head location)			
16	8	Rocker arm support stud			
17	4	Strap			
18	4	Rocker arm			
19	8	Rocker arm			
20	16	Rocker arm bushing			
21	4	12M cylinder head bolt, injector side	Refer to Cylinder Head - Installation procedure.		
22	4	12M cylinder head bolt, manifold side			
23	10	14M cylinder head center bolt			
24	5	Formed spacer washer (manifold side clamp)			
25	3	Formed spacer washer (intermediate clamp)			
26	4	Formed spacer washer (front and rear, end spacer)			
27	2	End spacer			
28	1	Oil pipe			
29	4	Hollow bolt and sealing washers	10.8	95	–
30	–	Injector side of cylinder head			
31	4	Plug, glow plug hole	11.8	104	–

Removal

1. Drain the engine coolant. See **Section 6A: Draining the Closed Cooling System**.
2. Remove the oil separator and vent system. See **Section 3A: Oil Separator and Vent System**.
3. Remove the valve cover. See **Section 3A: Valve Cover**.
4. Remove the coolant manifold. See **Section 3A: Coolant Manifold**.
5. Remove the turbocharger. See **Section 7C: Turbocharger**.
6. Remove the intake and exhaust manifold. See **Section 7B: Elbows, Risers and Intake and Exhaust Manifold**.

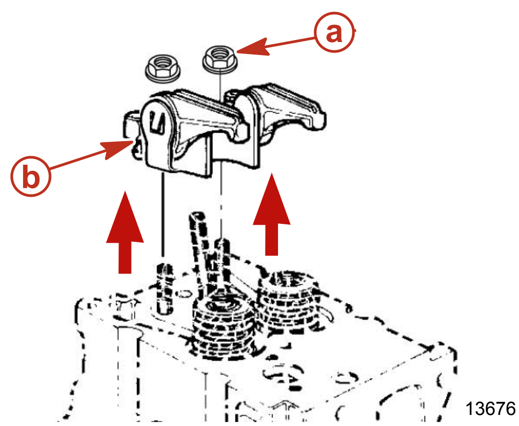
IMPORTANT: Mark or store the components to aid diagnosis and for reassembly in their original location.

7. Mark the location of the rocker arm assemblies and cylinder heads for reassembly.
8. Remove the rocker arm oil feed pipe hollow bolts with sealing washers.
9. Remove the oil feed pipe from the cylinder heads and from the rear (starboard) of cylinder block.



a - Oil feed pipe
b - Hollow bolts with sealing washers

10. Unscrew the rocker arm support flanged nuts.
11. Remove the rocker arm assembly.

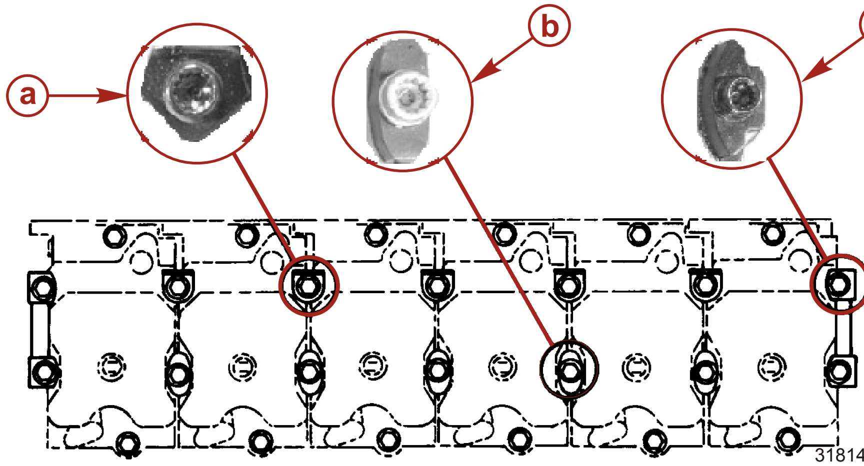


a - Flanged nuts
b - Rocker arm assembly

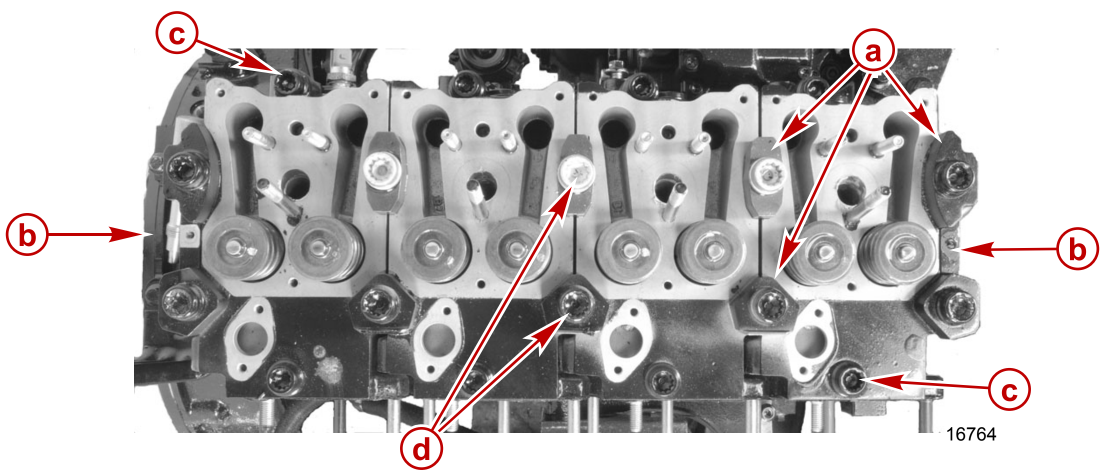
12. Remove the valve push rods. Mark or store the components for reassembly in their original location.

IMPORTANT: To avoid distorting the cylinder heads, remove the cylinder heads only when the engine is cold.

13. Note the shape and location of the formed spacer washers and the first and last cylinder head end spacers (plates).



14. Starting at one end of the engine and using the appropriate XZN wrench from the cylinder head service tool kit:
    a. Remove the 12M cylinder head side bolts.
    b. Remove all the 14M cylinder head center bolts and formed spacer washers except for the two outer center bolts and formed spacer washers holding the two end spacers (plates) in place.
    c. Remove the two outer, center bolts and end spacers (plates).



2.8 shown, 4.2 similar

a - Formed spacer washer	**c -** 12M cylinder head side bolt
b - End spacer (plate)	**d -** 14M cylinder head center bolt

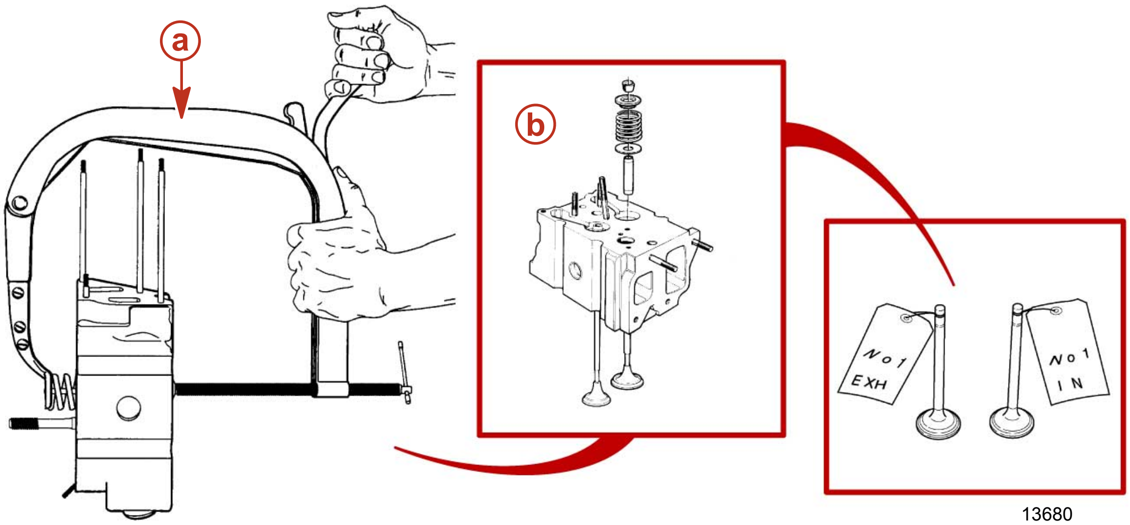
Cylinder Head Service Tool Kit	91-806563A 1

15. Tap on the side of the cylinder heads with a rubber mallet to loosen.
16. Remove the cylinder heads.
17. Place the cylinder heads on wooden blocks to prevent damage to the gasket surfaces.

Disassembly

1. Using a valve spring compressor, remove the valve locks, retainers, springs, and spring plates.

2. Remove the valves from the cylinder head and place in a rack or label the parts in order for later reassembly in their original locations.



a - Typical valve spring compressor
b - Valve spring and related components

Cleaning

1. Clean the gasket material and the sealer from the engine block and cylinder head sealing surfaces.
2. Clean all the carbon from the combustion chambers and valve ports using a carbon remover brush.
3. Clean the carbon from valves using a wire wheel.
4. Wash the cylinder head and components in a cleaning solvent.
5. Clean the cylinder head bolt threads and engine block bolt hole threads to ensure that no dirt, old oil, or coolant remain.
6. Put on safety glasses and dry the components with compressed air, including cylinder head bolt threads and engine block bolt hole threads.

Inspection

GENERAL

NOTE: The QSD 2.8 and 4.2 engines do not use glow plugs. Threaded plugs or inoperative glow plugs are used to seal the glow plug holes.

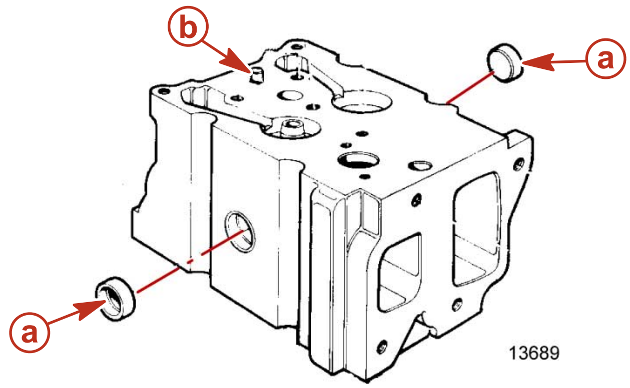
IMPORTANT: Do not remove the glow plug sealing plugs unless necessary for the service being performed.

1. Inspect the glow plug holes and seats for damage.
2. Inspect the injector seats for damage.
3. Inspect all gasket surfaces for grooves or pitting.
4. Inspect for combustion chamber damage, such as melted aluminum caused by faulty fuel injectors.
5. Inspect the rocker arm support journals for scoring.
6. Inspect the rocker arm bushings for excessive wear.
7. Ensure that the rocker pedestal guide pin is present.
8. Replace or repair damaged parts.

EXPANSION PLUGS

1. Remove and replace all expansion plugs if any are leaking or damaged.

NOTE: *These plugs may be removed with a sharp punch or drilled and pried out.*



a - Expansion plugs
b - Rocker pedestal pin

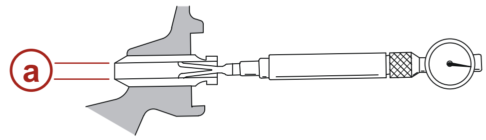
VALVE GUIDES

1. Inspect the valve guides for cracks or chips.
2. Inspect the valve guide bores for seizure marks, carbon deposits or scoring.
3. Inspect the valve guide installed height.

Valve guide installed height (Measured from the top of the guide to the bottom of the valve spring seat)	
Exhaust	7.92 - 7.94 mm (0.311 - 0.312 in.)
Intake	7.94 - 7.96 mm (0.312 - 0.313 in.)

4. Remove the valve stem seals.
5. Insert a new valve into the valve guide.

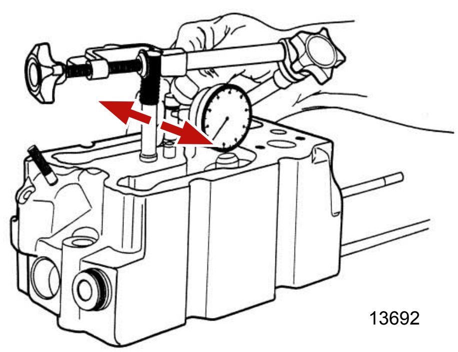
6. Measure valve stem clearance:
   a. Measure the valve guide inner diameter with a valve guide bore gauge. Replace the valve guide if diameter exceeds specification. .



Typical

Valve guide inner diameter	
Exhaust	7.99 - 8.00 mm (0.3145 - 0.3149 in.)
Intake	

   b. Attach a dial indicator to cylinder head. Position it against the valve stem close to the valve guide.
   c. Hold the valve head off of the seat by about 2 mm (1/16 in.). Rock the valve stem back and forth in the directions shown. Valve stem clearance is one half the valve stem's total range of motion. Replace the valve if clearance exceeds specification.

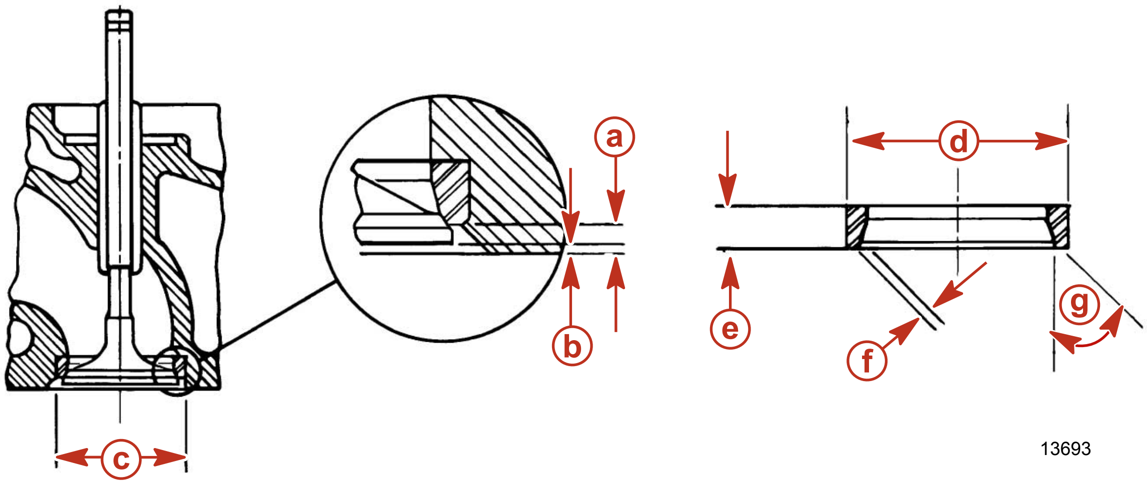


Valve guide maximum clearance	
Exhaust	0.093 mm (0.0036 in.)
Intake	0.073 mm (0.0028 in.)

VALVE SEATS

1. Inspect the valve seats for cracks, excessive wear, and looseness in cylinder head.
2. Measure exhaust and intake valve seats. Refer to valve seat specifications.

3. If the measured values are not as specified, recondition the valve seat. If the valve seats cannot be repaired, it will be necessary to replace the cylinder head. Refer to **Repair—Valve Seat Reconditioning**.



Measurements

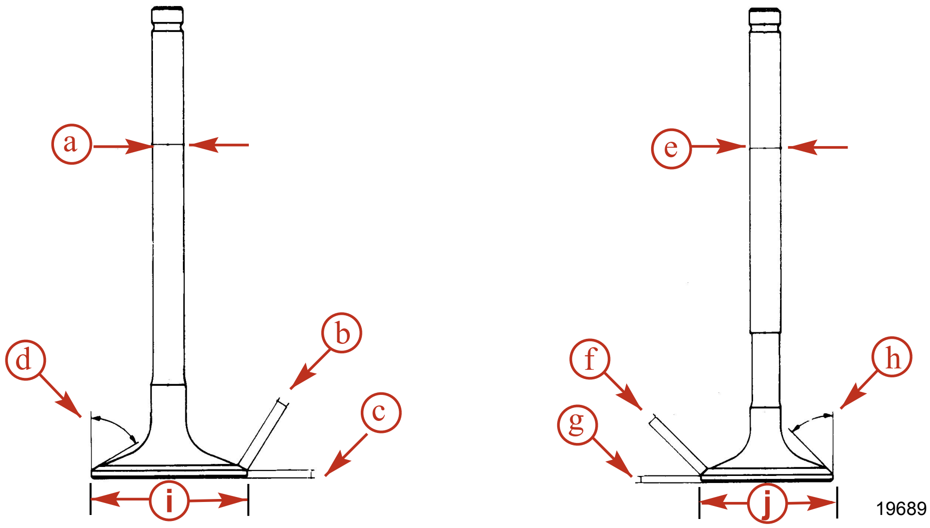
a - Valve recession
b - Head surface to seat
c - Valve seat bore inner diameter
d - Seat outer diameter
e - Seat height
f - Seat width
g - Seat angle

Valve Seats		
Valve recession (service limit)	Exhaust	0.3 mm (0.01 in.)
	Intake	
Head surface to seat	Exhaust	2.05 - 2.25 mm (0.080 - 0.088 in.)
	Intake	2.17 - 2.37 mm (0.085 - 0.093 in.)
Seat height	Exhaust	7.73 - 7.83 mm (0.304 - 0.308 in.)
	Intake	
Seat width	Exhaust	1.6 - 1.8 mm (0.062 - 0.070 in.)
	Intake	
Seat angle	Exhaust	45°
	Intake	30°

VALVES

1. Inspect valves for damage and warping. Replace if necessary.

2. Measure the valve and compare to specifications. Recondition any valves that fail to meet any of the specifications. Refer to **Valve Reconditioning**. Replace valves that can not be reconditioned.



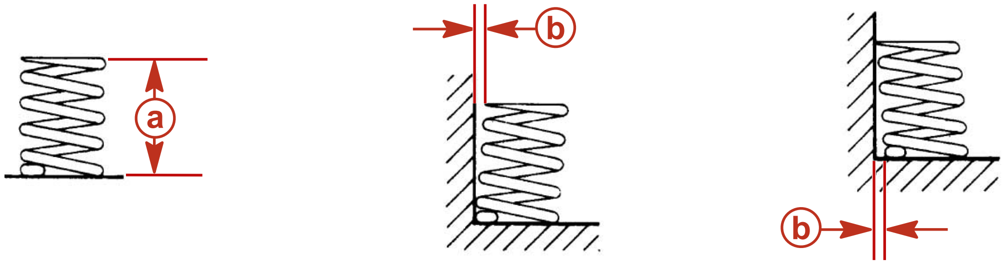
a - Stem diameter, intake valve
b - Face width, intake valve
c - Margin thickness, intake valve
d - Face angle, intake valve
e - Stem diameter, intake valve
f - Face width, exhaust valve
g - Margin thickness, exhaust valve
h - Face angle, exhaust valve
i - Head diameter, intake valve
j - Head diameter, exhaust valve

Valves		
Stem diameter	Exhaust	7.93 mm (0.3122 in.)
	Intake	7.95 mm (0.3129 in.)
Face width	Exhaust	2.640 - 2.992 mm (0.1039 - 0.1177 in.)
	Intake	3.57 - 3.85 mm (0.1405 - 0.1515 in.)
Margin thickness—Production (new)	Exhaust	1.73 mm (0.068 in.)
	Intake	1.82 mm (0.071 in.)
Margin thickness—Service limit	Exhaust	1.30 mm (0.051 in.)
	Intake	
Face angle (production)	Exhaust	44° 30’
	Intake	29° 30’
Head diameter	Exhaust	38 mm (1.49 in.)
	Intake	41 mm (1.61 in.)

VALVE SPRINGS

1. Inspect the valve springs for discoloration due to excessive heat.
2. Inspect the valve spring valve locks, the retainers, and the washer for wear, distortion, or cracks.
3. Measure the free standing height of each spring. Replace the spring if measured value is other than specified.

4. Measure the spring inclination (distortion). If the measured value exceeds the specified limit, the valve spring must be replaced.

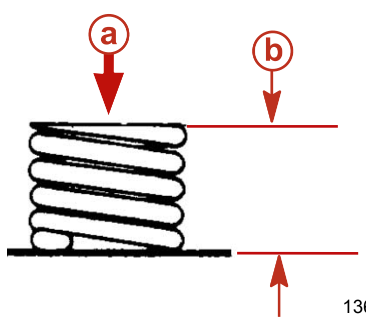


13694

a - Free standing height
b - Spring inclination

Valve Springs		
Free standing height	Exhaust	44.65 mm (1.757 in.)
	Intake	
Spring Inclination—Service limit	Exhaust	2.0 mm (0.079 in. or 5/64 in.)
	Intake	

5. Use a spring tester to measure the spring tension when the valve is open. Replace the spring if the measured value is less than specified at the height shown.



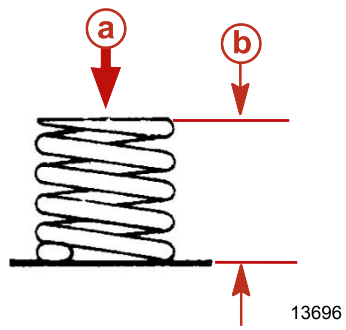
13695

Valve open

a - Applied pressure
b - Height

Valve Open	
Applied pressure	88.8 - 96.2 kg (196 - 212 lb.)
Height	28.20 mm (1.110 in.)

6. Use a spring tester to measure the spring tension when the valve is closed. Replace the spring if measured value is less than specified at the height shown.



Valve closed

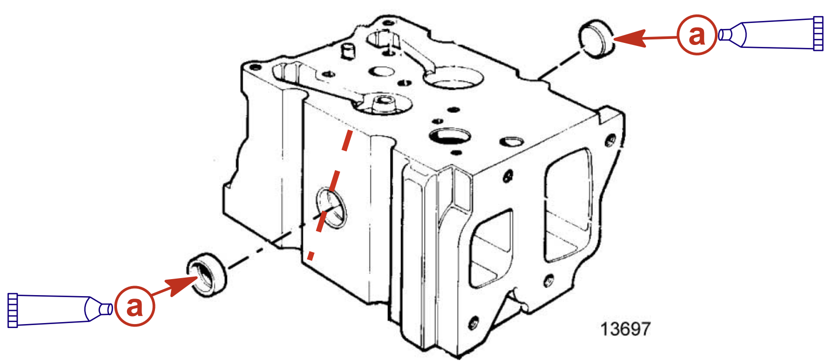
a - Applied pressure
b - Height

Valve Closed	
Applied pressure	32 - 36 kg (71 - 79 lb.)
Height	38.60 mm (1.520 in.)

Repair

EXPANSION PLUGS

1. Apply sealant to the outer diameter of the expansion plugs.
2. Install the plugs flush to the outer surface of the cylinder head.



a - Expansion plug

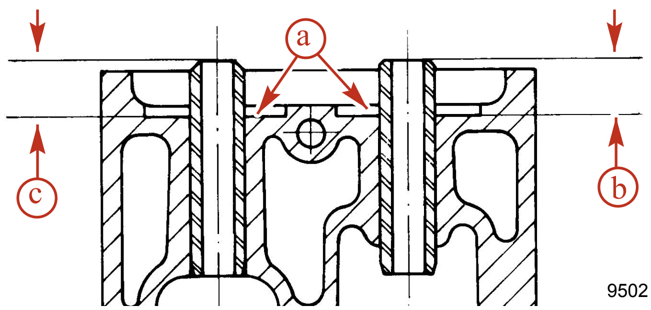
Tube Ref No.	Description	Where Used	Part No.
67	Loctite 290	Outer diameter of expansion plugs	Obtain Locally

VALVE GUIDE REPLACEMENT

NOTICE

Heating aluminum cylinder heads without a controlled, even heat source can result in distorted heads, damaging the engine. If replacing valve seats or guides, heat cylinder heads to specific temperatures at even intervals using equipment designed specifically for that purpose.

1. Remove the valve stem seals.
2. Heat the cylinder head in an oven to 85° C (185° F).
3. Using a suitable drift, drive out the old guide from the underside of the cylinder head.
4. With the cylinder head temperature at 85° C (185° F), press the new guide in to obtain measurement as shown.



a - Valve spring seat
b - Intake guide height measurement
c - Exhaust guide height measurement

Valve guide installed height measurement (above valve spring seat)	
Exhaust	7.92 - 7.94 mm (0.311 - 0.312 in.)
Intake	7.94 - 7.96 mm (0.312 - 0.313 in.)

IMPORTANT: If the valve guide is removed replace both the valve and valve guide as a set.

VALVE SEAT RECONDITIONING

NOTE: Several different types of equipment are available for reconditioning valve seats. Follow the equipment manufacturer's recommendations to attain proper results.

IMPORTANT: The valve guide bores must be free of all contaminants to ensure proper pilot centering and accurate machine work.

Recondition pitted or worn valve seats to the following specified angles.

Valve seat angle	
Exhaust	45°
Intake	30°

VALVE RECONDITIONING

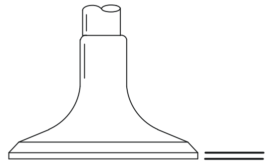
NOTE: Various equipment is available to recondition valves. Follow the manufacturer's recommendations to attain proper results.

Pitted valves can be refaced to a proper angle on a valve grinder, thus ensuring the correct relation between the cylinder head seat and the valve mating surface.

Replace valves with excessively worn or warped valve stems. Warped valve stems will result in ineffective valve reconditioning.

Confirm that all reconditioned valves meet specifications. Replace valves that do not meet specifications.

1. Recondition the valve face to the proper angle.
2. After reconditioning, measure the valve margin. Replace valves exceeding specification.



20972

Valve margin (thickness after reconditioning)		
Exhaust	Service limit	1.30 mm (0.051 in.)
Intake		

CYLINDER HEAD RESURFACING

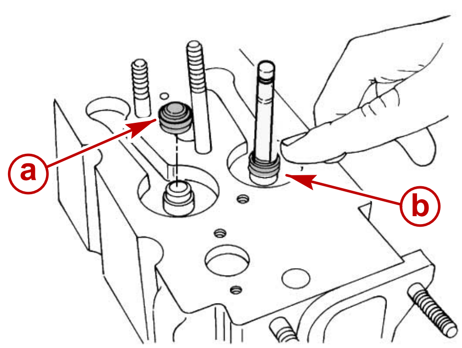
IMPORTANT: Do not resurface the cylinder heads. The cylinder heads on these marine diesel engines are treated with a protective nickel coating to resist corrosion. Resurfacing will remove the nickel coating allowing unacceptable corrosion.

Assembly

VALVES

NOTE: Valve stem seals are used on intake and exhaust valves.

1. Lubricate valve guides and valve stems with engine oil.
2. Install each valve in the port from which it was removed or for which it has been fitted.
3. Install the valve guide seal onto the valve stem and push down until seated against the guide.



13698

a - Valve stem seal
b - Seal installed on guide

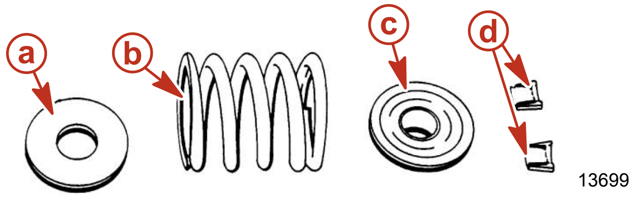
4. Install the plate washer, valve spring, and the retainer on the valve stem.
5. Compress the valve spring using valve spring compressor.

NOTE: Lubricant may be used to hold valve locks in place while releasing the compressor tool.

6. Coat the valve stem locks with lubricant to hold in place.

Tube Ref No.	Description	Where Used	Part No.
4	Needle Bearing Assembly Lubricant	Valve stem locks	92-802868A1

7. Install the valve stem locks.



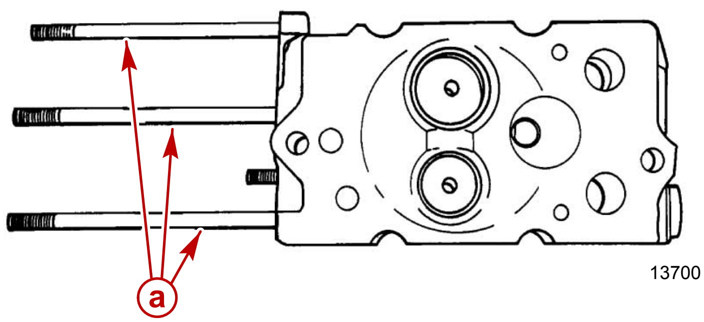
a - Plate washer
b - Valve spring
c - Retainer
d - Valve locks

8. Slowly release the valve spring compressor, ensuring that the valve locks seat properly in the valve stem groove.

CYLINDER HEAD STUDS

IMPORTANT: Some long cylinder head studs are longer than others and are used for attaching accessories. These studs must be in the correct location before the exhaust manifold is installed.

1. Remove the cylinder head studs when replacing the cylinder head. Note the length and location of the studs.
2. Install the studs in the same location on the new cylinder head.



a - Long cylinder head studs (lengths vary)

DETERMINING HEAD GASKET THICKNESS

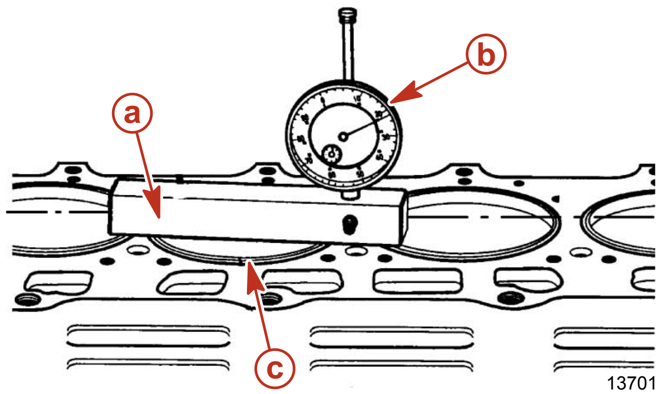
NOTICE
The thickness of the head gasket installed on these engines is critical. Severe engine damage may result if the head gaskets installed are too thin or too thick. Precisely measure the appropriate engine components to select a cylinder head gasket of the required thickness.

IMPORTANT: When cylinder heads are removed for service but pistons and cylinder liners are not disturbed, use the same thickness gaskets that were removed. See Head Gasket Identification.

Refer to the following procedures during a complete engine rebuild or when pistons and liners are being replaced.

1. Use the dial indicator and Support Block tool (liner gauge bar) to measure piston height above the cylinder block with the piston at Top Dead Center (TDC).

2. Place the Support Block tool parallel to the cylinder center line and across the liner with a dial indicator attached, as shown.

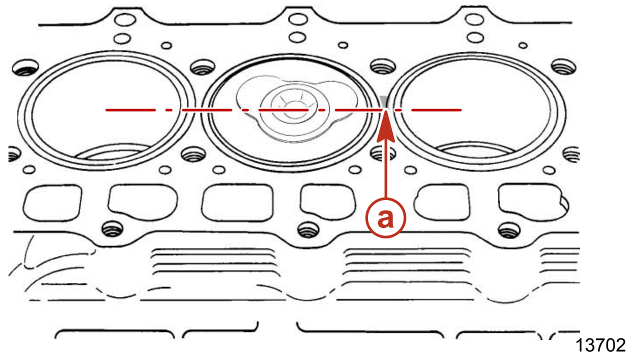


a - Support Block tool
b - Dial indicator
c - Liner

Dial Indicator	91-58222A1

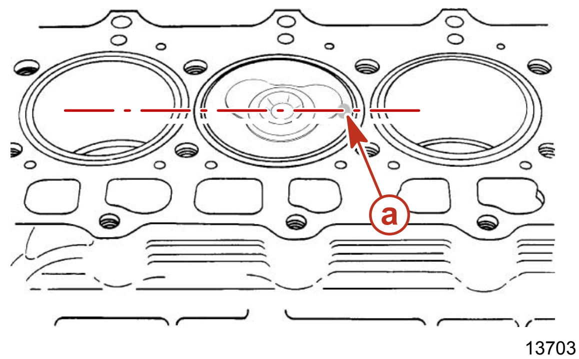
Support Block	91-814812A 1

3. Set the dial indicator to zero degrees (0°) at the point shown on the cylinder block.



a - Dial indicator 0° point

4. Move the dial indicator to the point shown on the piston. Record the measurement.

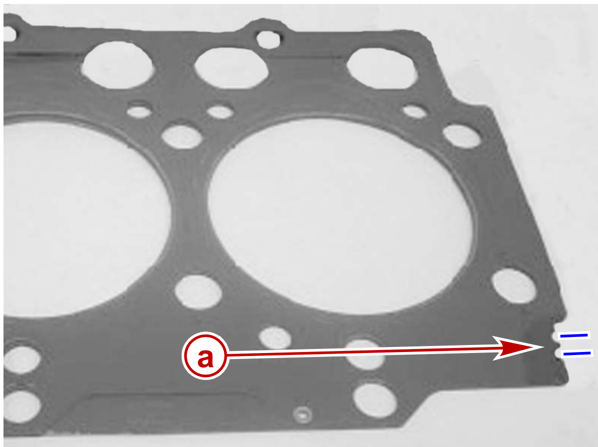


a - Measurement point

5. Measure the piston protrusion (height) of all pistons. Use the largest measurement to determine the gasket thickness required for all cylinders.

Cylinder head gasket required		
Piston protrusion (height) above cylinder block	0.60 - 0.72 mm 0.0236 - 0.0283 in.)	1.42 mm (0.056 in.)
	0.73 - 0.82 mm (0.0287 - 0.0322 in.)	1.52 mm (0.060 in.)
	0.83 - 0.95 mm (0.0326 - 0.0374 in.)	1.62 mm (0.064 in.)

6. After determining the head gasket thickness required, identify and select the proper the cylinder head gasket by holding the gasket with the pushrod holes up. Note the identification marks in the lower right corner.
   a. No notches indicates a thickness of 1.42 mm (0.056 in.).
   b. Two notches indicates a thickness of 1.52 mm (0.060 in.).
   c. One notch indicates a thickness of 1.62 mm (0.064 in.).



14501

Two notch gasket shown

a - Notches

Installation

IMPORTANT: The engine block and cylinder heads must be free of all contaminants (dirt, old oil, gasket material, or coolant).

1. Clean the gasket surfaces on the block and heads.

IMPORTANT: To attain proper torque values the cylinder head bolt holes must be clean.

2. Clean out all bolt holes, water passages and oil passages.
3. Lubricate the cylinder bores.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Cylinder bores	Obtain Locally

IMPORTANT: Cylinder head bolts may be installed as many as three times, and then must be replaced with new bolts. Replace the cylinder head bolts if there is any uncertainty about the number of times they have be used.

NOTE: New cylinder head bolts should already be lubricated with an anti-seizing lubricant from the manufacturer and do not require additional lubrication.

4. Clean all existing cylinder head bolts and washers, including all formed spacer-washers (terminal bridges, three types) and cylinder head spacers (for ends of the first and last cylinder heads).

5. Lubricate the bolt threads and the underside of the bolt heads of all 12M (12 mm) cylinder head bolts.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Bolt threads and underside of bolt heads of all 12M cylinder head bolts	Obtain Locally

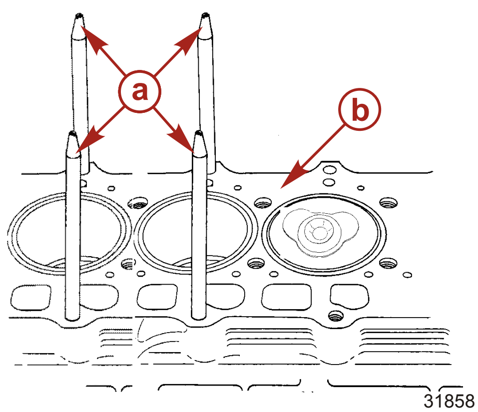
6. Lubricate the threads and underside of bolt heads on all 14M (14 mm) cylinder head bolts.

Tube Ref No.	Description	Where Used	Part No.
113	Loctite Moly Paste (Molybdenum Disulfide Grease)	Threads and underside of bolt heads on all 14M cylinder head bolts	Obtain Locally

7. Place all the parts on a clean surface or lint-free shop cloth.

IMPORTANT: Cylinder head gasket must be installed dry. Do not use any sealant or adhesive on the gasket.

8. Position the cylinder head gasket on the cylinder block.
9. Using a screwdriver, install two Cylinder Head Guide Pins into the 12 mm bolt holes in the gasket and cylinder block at each cylinder head location. These pins will align the gasket and cylinder heads.

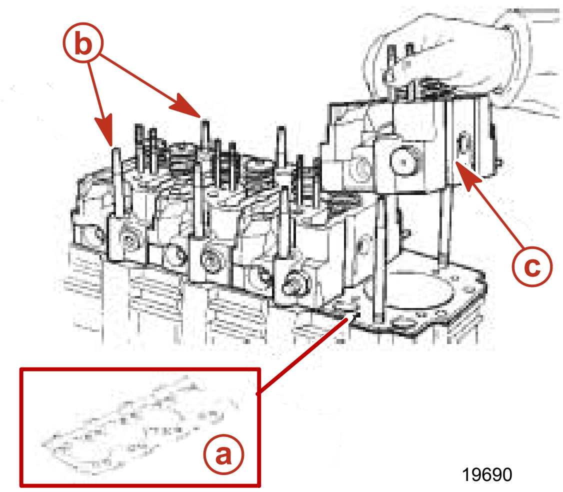


a - Guide pins
b - Cylinder head

Cylinder Head Guide Pins	91-801333501

10. Beginning with cylinder number 1, install the cylinder heads over the guide pins.

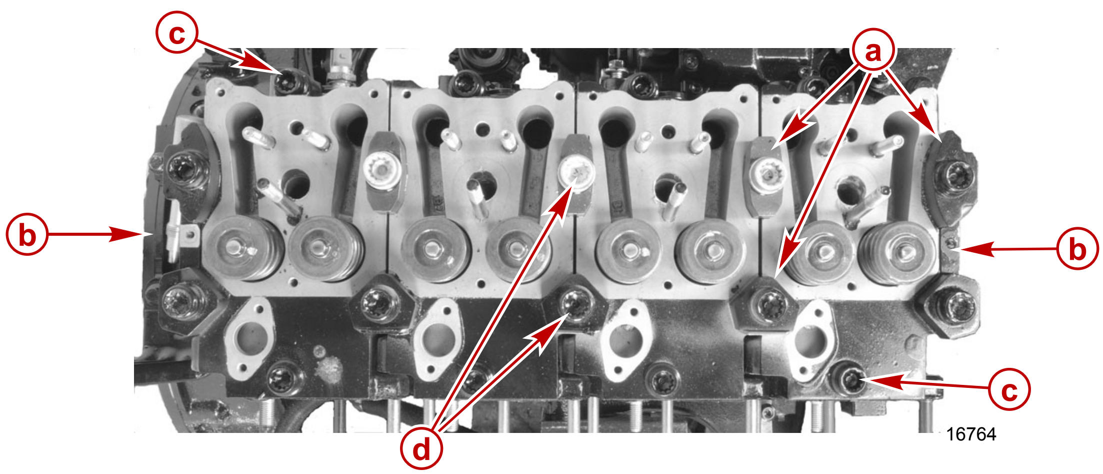
11. Repeat for each cylinder head and corresponding cylinder.



2.8 shown, 4.2 similar

a - Cylinder head gasket
b - Guide pin locations (two at each cylinder)
c - Cylinder head

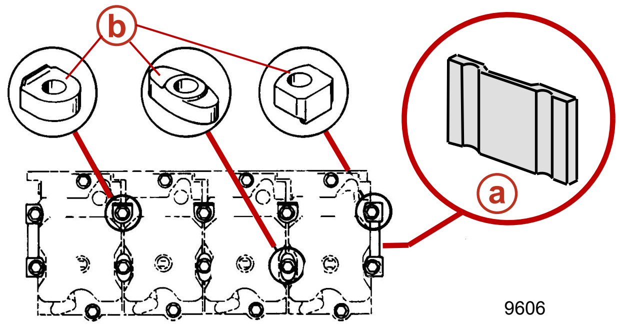
12. One at a time, remove the Cylinder Head Guide Pins and install the oiled 12M cylinder head bolts, with washers, finger-tight. Do not disturb the cylinder head.



2.8 shown, 4.2 similar

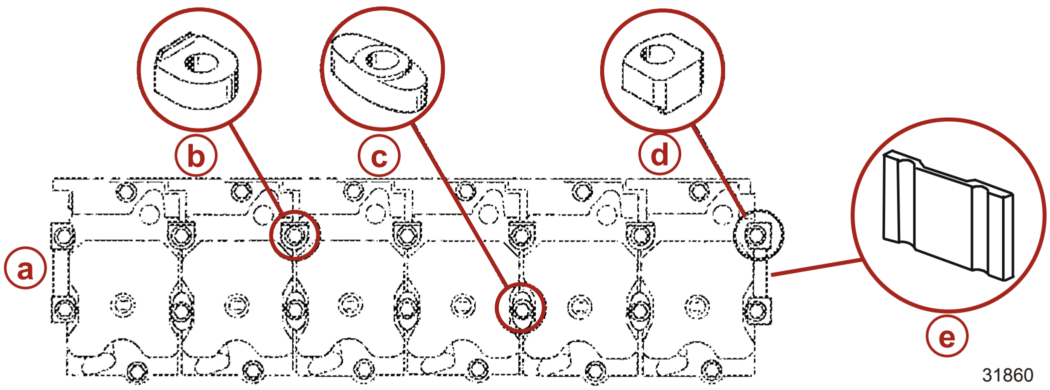
a - Formed spacer washer
b - End spacer (plate)
c - 12M cylinder head side bolt
d - 14M cylinder head center bolt

13. Install and finger-tighten all lubricated 14M cylinder head bolts with the correct machined clamping washers (three types) and cylinder head spacers for the ends of the first and last cylinder heads, as shown in the following.



2.8

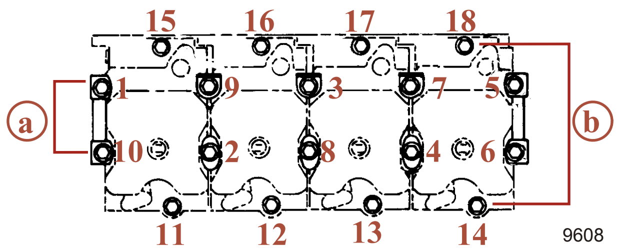
a - Spacer, first and last cylinder head ends
b - Machined clamping washers



4.2

a - Cylinder head spacer, installed
b - Machined clamping washers, head edge
c - Machined clamping washers, head bridge
d - Machined clamping washers, head ends
e - Cylinder head spacer

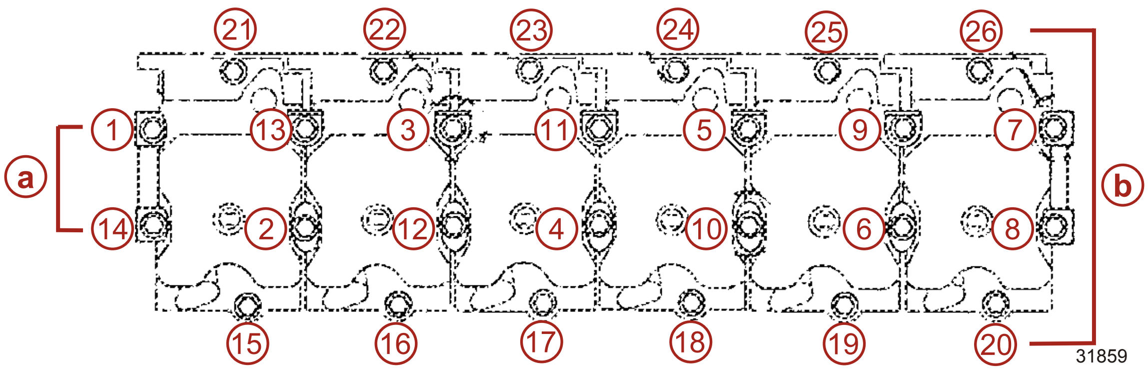
14. Using the appropriate wrench from the cylinder head service kit, **lightly** hand-tighten the bolts in the numbered torque sequence shown.



2.8 torque sequence bolt numbering

a - Center (14M) bolt set

b - Side (12M) bolt set



4.2 torque sequence bolt numbering

a - Center (14M) bolt set

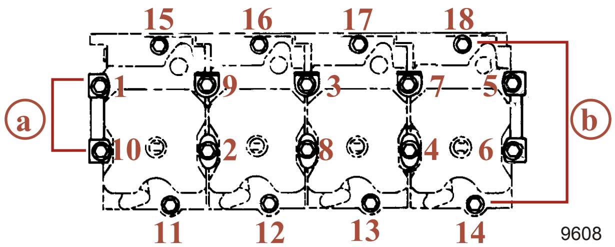
b - Side (12M) bolt set

Cylinder Head Service Tool Kit	91-806563A 1

15. Correctly align the cylinder heads by temporarily installing the exhaust manifold with gaskets and finger-tighten each flange nut.
16. Slightly loosen the 12M and 14M bolts as needed to allow the cylinder heads to align.
17. Hand tighten the exhaust manifold nuts sufficiently to align the cylinder heads to the exhaust manifold.
18. Hand tighten all 14M and 12M cylinder head bolts in the numbered torque sequence given in step 14.

19. **2.8 Engine**: Torque the 14M center bolt set as specified and in the sequence shown.

NOTE: Do not torque the 12M side bolts at this time.



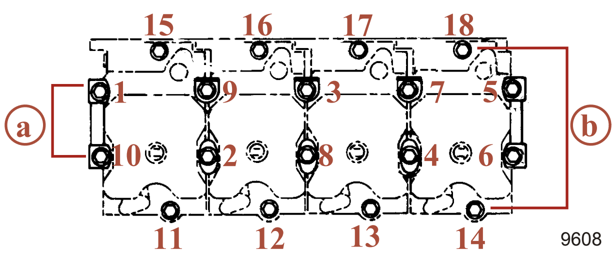
2.8 torque sequence bolt numbering

a - Center (14M) bolt set

b - Side (12M) bolt set

Description	Sequence		Nm	lb. in.	lb. ft.
2.8 center (14M) cylinder head bolts	3-2-1-4-5-8-9-10-7-6	**First**	30	–	22
	1-2-3-4-5-6-7-8-9-10	**Second**	+ 65° Torque Angle		
	1-2-3-4-5-6-7-8-9-10	**Final**	+ 65° Torque Angle		

20. **2.8 Engine**: Torque the 12M side bolt numbered sets as specified and in the sequence shown.



Torque sequence diagram

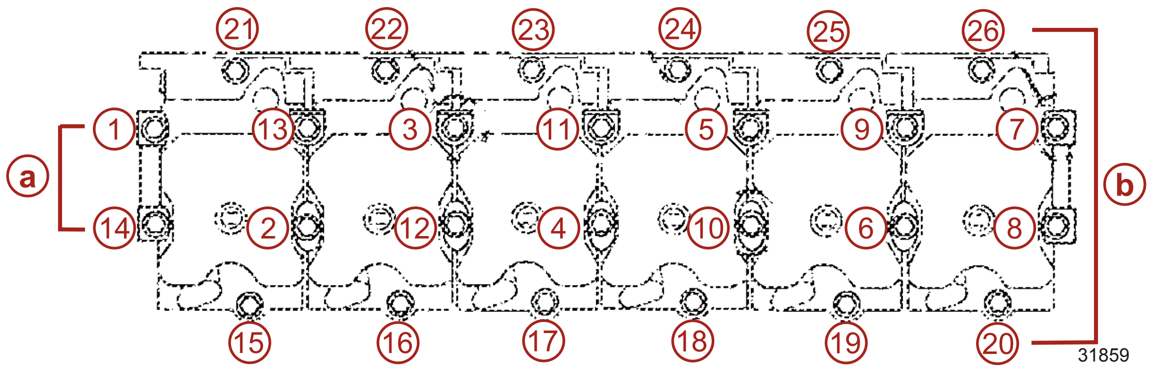
a - Center (14M) bolt set

b - Side (12M) bolt set

Description	Sequence	Pass	Nm	lb. in.	lb. ft.
2.8 side (12M) cylinder head bolts	11-12-13-14	**First**	30	–	22
	11-12-13-14	**Second**	+ 85° Torque Angle		
	15-16-17-18	**Third**	30	–	22
	15-16-17-18	**Final**	+ 85° Torque Angle		

21. **4.2 Engine**: Torque the 14M center bolt set as specified and in the sequence shown.

NOTE: Do not torque the 12M side bolts at this time.



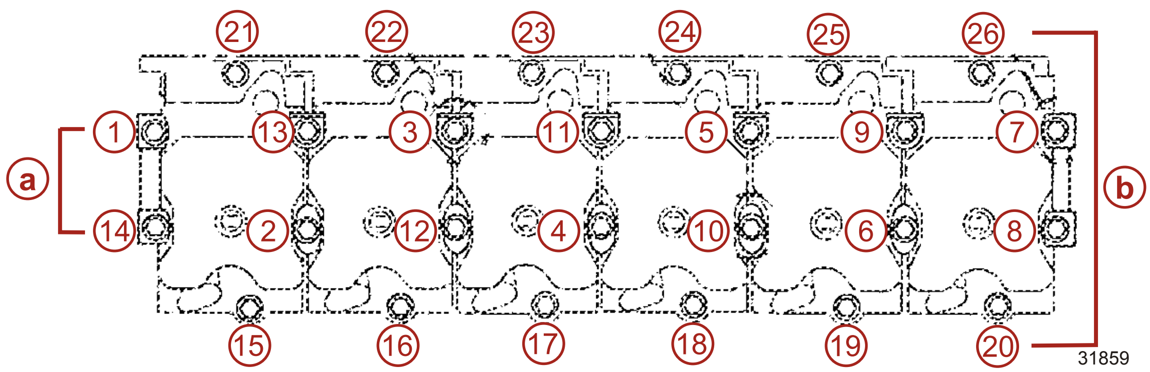
4.2 torque sequence bolt numbering

a - Center (14M) bolt set

b - Side (12M) bolt set

Description	Sequence		Nm	lb. in.	lb. ft.
4.2 center (14M) cylinder head bolts	11-12-13-14-10-9-8-4-3-2-1-5-6-7	**First**	30	–	22
	11-12-13-14-10-9-8-4-3-2-1-5-6-7	**Second**	+ 65° Torque Angle		
	11-12-13-14-10-9-8-4-3-2-1-5-6-7	**Final**	+ 65° Torque Angle		

22. **4.2 Engine**: Torque the 12M side bolt numbered sets as specified and in the sequence shown.



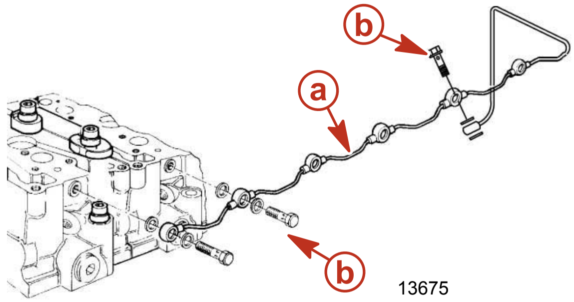
4.2 torque sequence

a - Center (14M) bolt set

b - Side (12M) bolt set

Description	Sequence	Pass	Nm	lb. in.	lb. ft.
4.2 side (12M) cylinder head bolts	15-16-17-18-19-20-21-22-23-24-25-26	**First**	30	–	22
	15-16-17-18-19-20-21-22-23-24-25-26	**Final**	+ 85° Torque Angle		

23. Using the hollow bolts and new sealing washers, install the rocker arm oil feed pipe onto the cylinder heads and the rear (starboard side) of the cylinder block.



a - Oil feed pipe
b - Hollow bolts with sealing washers

24. Complete the engine assembly.
25. Perform engine run-in procedure.

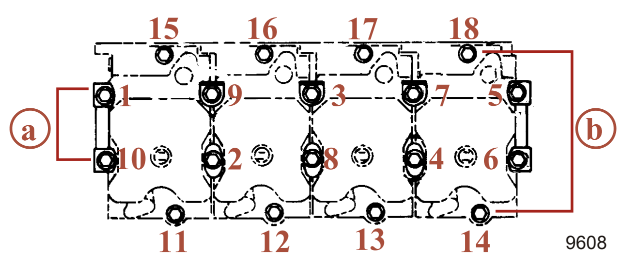
Torque Procedure After the First 20–30 Minutes of Operation

NOTICE

The cylinder head mounting may loosen after the first operation. To avoid component or engine failure caused by loose cylinder head mounting, apply additional angular and conventional torque after the first operation. Tighten the cylinder head mounting bolts as specified after the first 20-30 minutes of operation.

IMPORTANT: Observe the engine for water or coolant leaks during warm-up.

1. Operate the engine at a fast idle until the coolant temperature reaches 70° C (158° F.). Then operate the engine at 2000 RPM for approximately 20–30 minutes at normal operating temperature.
2. Let the engine cool down completely, overnight if possible, or until the engine coolant temperature is less than 40° C (104° F).
3. **2.8 Engine**: Individually loosen and torque each of the M14 center cylinder head bolts in the following the sequence.



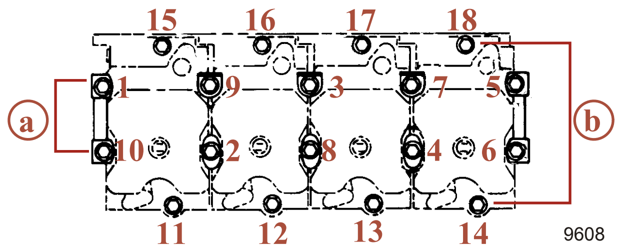
2.8 torque sequence diagram

a - Center (14M) bolts
b - Side (12M) bolts

Description	Sequence		Nm	lb. in.	lb. ft.
2.8 center (14M) cylinder head bolts	1-2-3-4-5-6-7-8-9-10	**First**	30	–	22
	1-2-3-4-5-6-7-8-9-10	**Final**	+ 120° Torque Angle		

***NOTE:** The 12M side bolts do not require tightening again. If necessary, check the 12M side bolts with a conventional torque wrench.*

4. **2.8 Engine**: If necessary, check the torque of each 12M side bolt as indicated. **Do not loosen**.

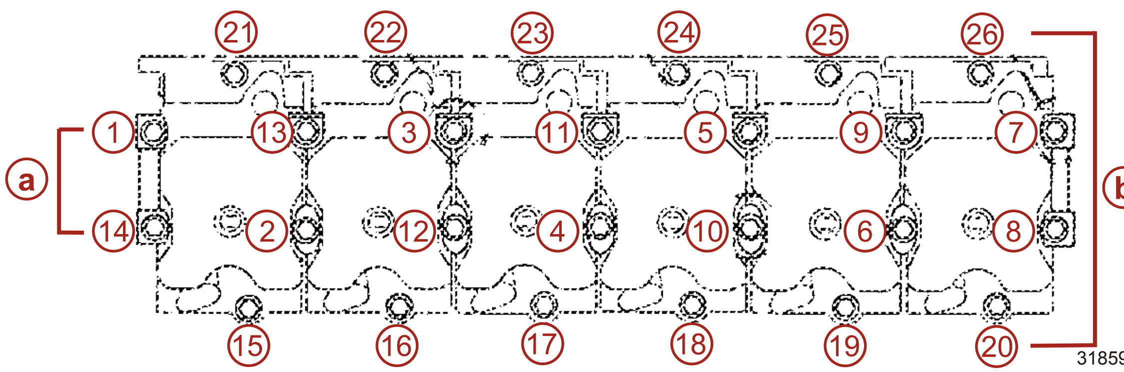


2.8 torque sequence diagram

a - Center (14M) bolt set
b - Side (12M) bolt set

Description	Sequence	Nm	lb. in.	lb. ft.
2.8 side (12M) cylinder head bolts	11-12-13-14-15-16-17-18	90	–	66

5. **4.2 Engine**: Individually loosen and torque each of the M14 center cylinder head bolts in the following the sequence.



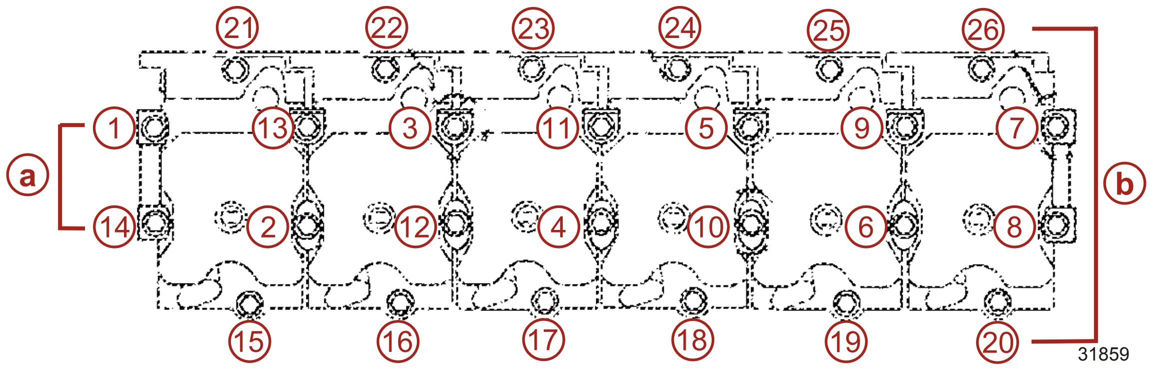
4.2 torque sequence diagram

a - Center (14M) bolt set
b - Side (12M) bolt set

Description	Sequence		Nm	lb. in.	lb. ft.
4.2 center (14M) cylinder head bolts	11-12-13-14-10-9-8-4-3-2-1-5-6-7	**First**	30	–	22
	11-12-13-14-10-9-8-4-3-2-1-5-6-7	**Final**	+ 120° Torque Angle		

NOTE: *The 12M side bolts do not require tightening again. If necessary, check the 12M side bolts with a conventional torque wrench.*

6. **4.2 Engine**: If necessary, check the torque of each 12M side bolt as indicated. **Do not loosen**.



4.2 torque sequence diagram

a - Center (14M) bolt set

b - Side (12M) bolt set

Description	Sequence	Nm	lb. in.	lb. ft.
4.2 side (12M) cylinder head bolts	15-16-17-18-19-20-21-22-23-24-25-26	90	–	66

Rocker Arm

Removal

NOTE: *When servicing the rocker arms of only one cylinder, bring that cylinder to approximately 90° before TDC before removing the rocker arms. When servicing all rocker arms, turn the crankshaft until cylinder number 1 piston is approximately 40°-45°, before TDC.*

1. Remove the valve covers.

IMPORTANT: Mark or store the components during removal for reassembly in their original location.

2. Remove the rocker arm assemblies and valve push rods. Place the components in a numbered rack according to their position in the engine or mark the parts in order for reassembly to the original location.

Cleaning

1. Wash the components in cleaning solvent.
2. Put on safety glasses and dry the components with compressed air.

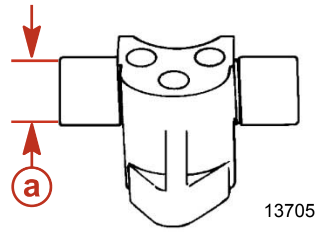
Inspection

1. Inspect components for excessive wear, cracks or damage.

NOTE: *The push rods are hollow and serve as oil galleries to lubricate each individual rocker arm assembly.*

2. Visually inspect each pushrod for wear and deposits. Ensure that the valve pushrod oil passage is not restricted.
3. Roll each valve pushrod on a flat surface and inspect the shaft for bends.
4. Replace all damaged parts.

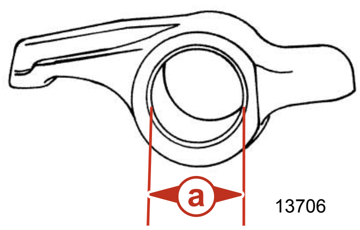
5. Using a micrometer, measure the outside diameter of the rocker arm support journals. Replace the rocker arm support if the journal outside diameter is less than specified.



a - Rocker arm support journal outside diameter

Rocker arm support journal	
Outside diameter	24.97-25.00 mm (0.9830 - 0.9842 in.)

6. Using an inside micrometer, measure inside diameter of the rocker arm bushing.



a - Rocker arm bushing inside diameter

Rocker arm bushing		
Inside diameter	Production	25.020 - 25.021 mm (00.9850 - 0.9851 in.)

7. Replace the rocker arm bushing if the difference between the bushing inside diameter and journal outside diameter is less than or greater than specified.

Rocker arm bushing and journal clearance	
Minimum	0.020 mm (0.0007 in.)
Maximum	0.062 mm (0.0024 in.)

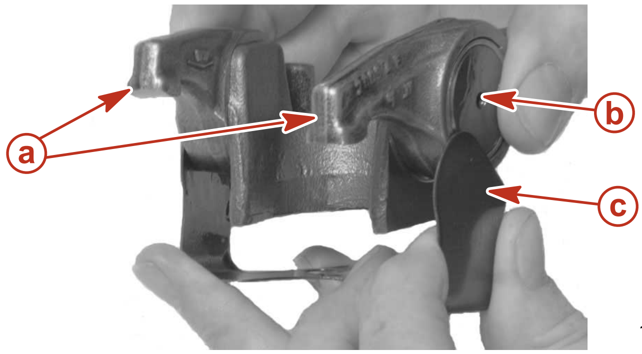
Assembly

1. Lubricate the rocker arm bushings and rocker arm support journals.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Rocker arm bushing and rocker arm support journal	Obtain Locally

2. Install the rocker arms on the rocker arm support journals. Position as shown.

3. Install the strap around the rocker arm assembly. Ensure that the strap is not spread open. Otherwise the valve cover will not fit.



19712

a - Rocker arm
b - Rocker arm support
c - Strap

Installation

NOTE: *When servicing or installing the rocker arms of only one cylinder, bring that cylinder to approximately 90° before TDC. When servicing or installing all rocker arms, turn the crankshaft in the direction of rotation until cylinder number 1 piston is approximately 40°–45°, before TDC.*

1. Turn the crankshaft in the direction of rotation until cylinder number 1 piston is approximately 40°–45°, before TDC.
2. Lubricate the outer surfaces and ends of the valve pushrods.

Tube Ref No.	Description	Where Used	Part No.
	Johnson EP Lube	Outer surfaces and ends of the valve pushrods	Obtain Locally

3. Lubricate the valve lifter contact surfaces.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Valve lifter contact surfaces	Obtain Locally

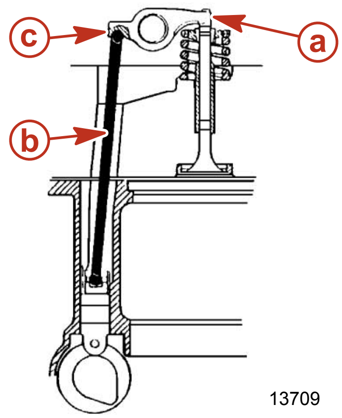
4. Install the valve pushrods in their original locations. Ensure that the valve pushrods seat in the lifter sockets.
5. Lubricate the rocker arm and rocker arm contact surfaces.

Tube Ref No.	Description	Where Used	Part No.
	Johnson EP Lube	Rocker arm and rocker arm contact surfaces	Obtain Locally

6. Lubricate the threads of the rocker arm support studs.

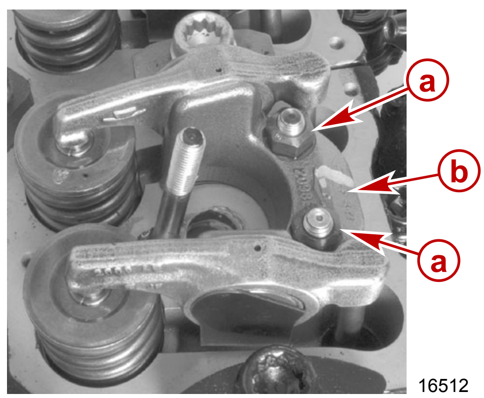
Tube Ref No.	Description	Where Used	Part No.
	80W Gear Lube	Threads of the rocker arm support studs	Obtain Locally

7. Install the rocker arm assembly onto the rocker arm support studs. Simultaneously align the valve pushrods with the rocker arm sockets.



a - Rocker arm assembly
b - Pushrod
c - Rocker arm socket

8. Install both rocker arm support nuts on the rocker arm support. Torque the rocker arm support nuts evenly.



a - Rocker arm support nut
b - Rocker arm support

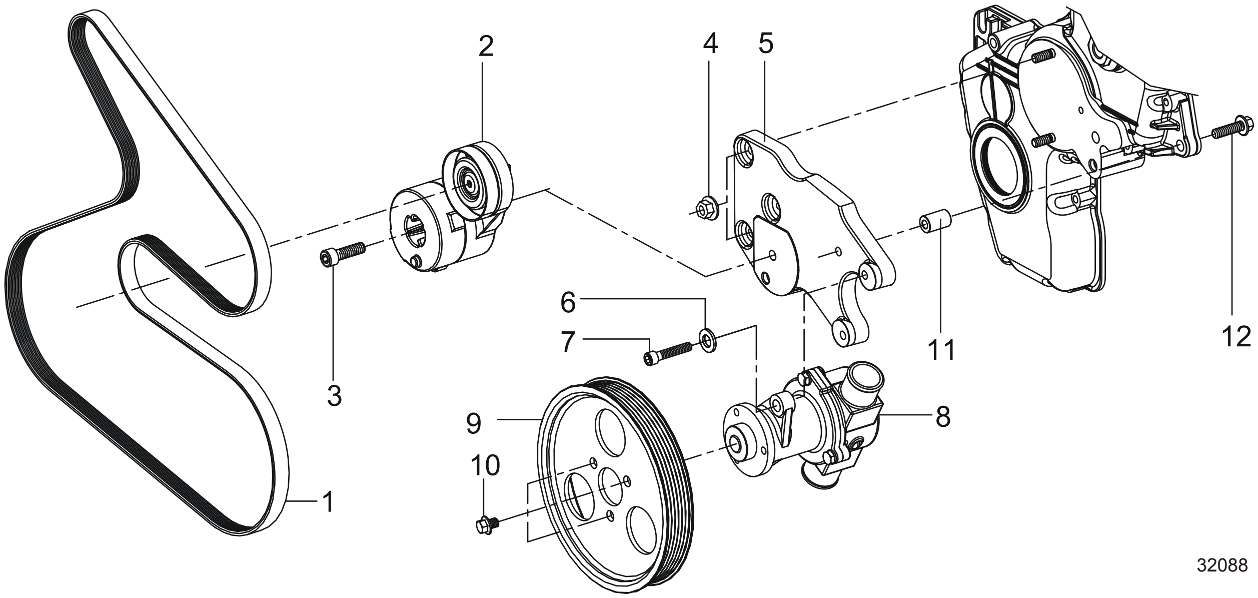
Description	Nm	lb. in.	lb. ft.
Rocker arm support nut	29		21

IMPORTANT: Valve lash adjustment, or valve clearance, is hydraulically controlled and automatically set when the rocker arm support flanged nuts are properly torqued.

9. Repeat the steps for the rocker arm assembly on each cylinder. No valve lash adjustment is required.
10. Install the valve cover and related components.
11. Check for leaks upon first operating the engine.

2.8 Engine Front Bracket and Timing Gear Cover

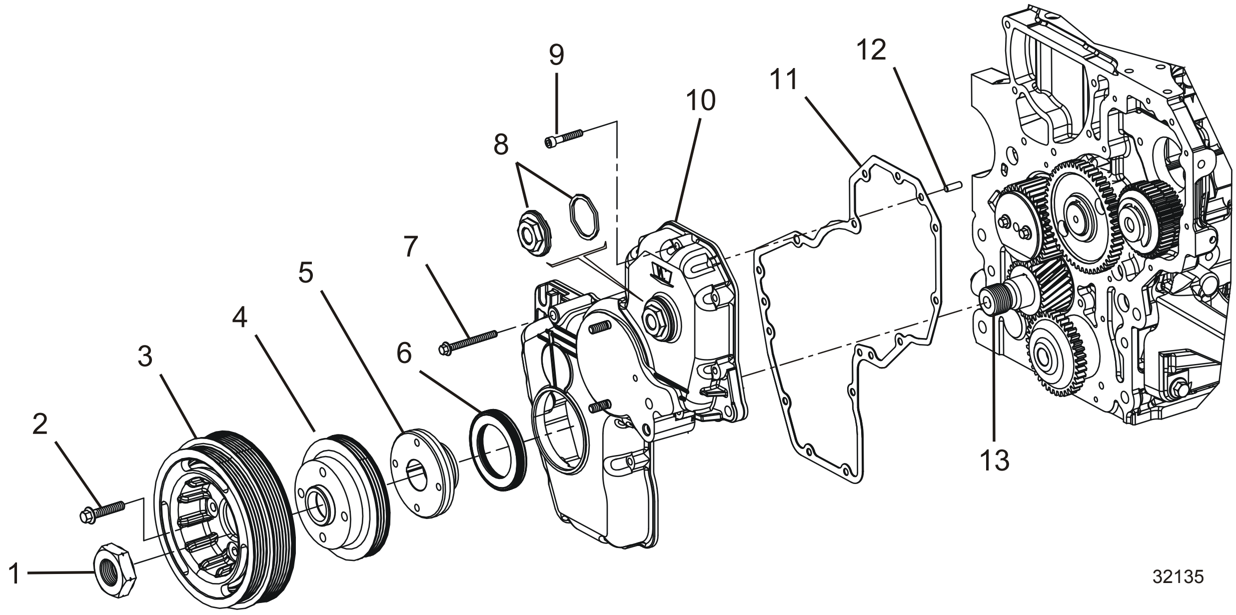
Exploded View—2.8 Front Bracket Components



Exploded View—2.8 Front Bracket Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Serpentine belt			
2	1	Automatic tensioner assembly			
3	1	Automatic tensioner assembly mounting screw	78.5	–	57
4	2	Engine front bracket flange nut	24.5	–	18
5	1	Engine front bracket			
6	2	Washer			
7	2	Seawater pump mounting screw	47.1	–	34
8	1	Seawater pump			
9	1	Seawater pump pulley			
10	3	Seawater pump pulley screw	24.5	–	18
11	1	Spacer			
12	1	Engine front bracket aft flange screw	47.1	–	34

Exploded View—2.8 Timing Gear Cover Components

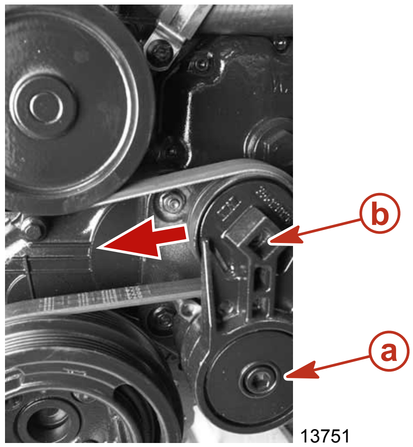


Exploded View—2.8 Timing Gear Cover Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Crankshaft nut (left-hand thread)	400	–	295
2	4	Crankshaft damper Allen-head screw	32.4	–	24
3	1	Crankshaft damper			
4	1	Crankshaft pulley			
5	1	Spacer, if equipped			
6	1	Timing cover seal			
7	1	Flange screw	27.5	–	20
8	1	Injection pump gear cover and seal			
9	13	Timing gear cover Allen-head screw	12.7	112	–
10	1	Timing gear cover assembly			
11	1	Gasket			
12	1	Alignment pin			
13	1	Crankshaft			

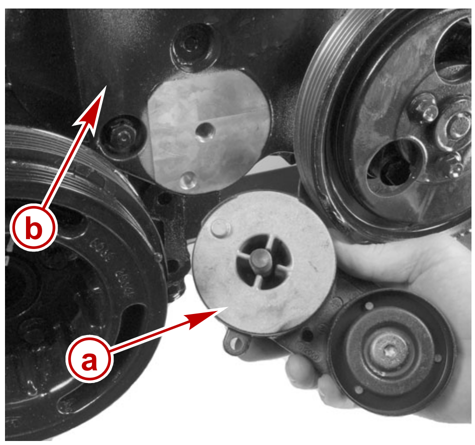
2.8 Removal

1. **On sterndrive models**: remove the power steering pump belt. Refer to **Section 9A: Power-assisted Steering System**.
2. Position a suitable tool in the automatic tensioner release slot. Move (rotate) the tensioner pulley and remove the serpentine belt.
3. Release the automatic tensioner slowly.



a - Automatic tensioner **b -** Release slot

4. Remove the automatic tensioner assembly from the engine front bracket.



a - Automatic tensioner assembly **b -** Engine front bracket

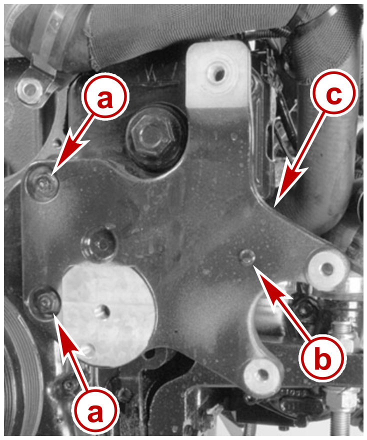
5. Close the seacock, if equipped. If the boat is not equipped with a seacock, remove and plug the seawater inlet hose.
6. Remove the seawater pump. Refer to **Section 6: Cooling System**.

*NOTE: The idler pulley mounting screw has a **left-hand thread**. Do not damage the threads in the engine front bracket when removing or installing the idler pulley mounting screw.*

7. Remove the <u>left-hand thread</u> idler pulley screw.

NOTE: A spacer is mounted between the engine front bracket and the timing gear cover on the aft flange screw. Note the spacer and aft flange screw positions.

8. Remove the two engine front bracket flange nuts and the aft flange screw with spacer.



14524

a - Engine front bracket flange nut

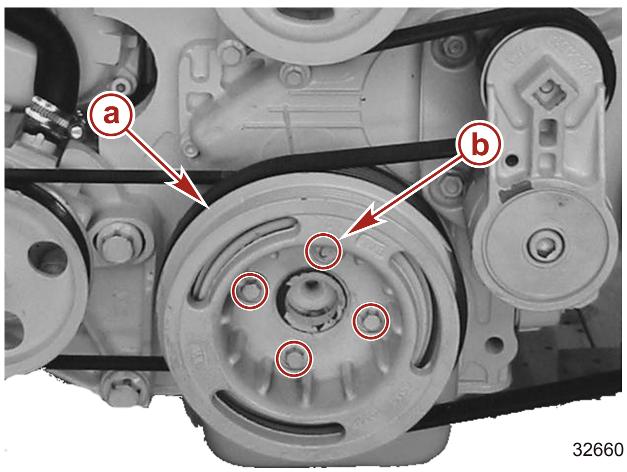
b - End of engine front bracket aft flange screw

c - Engine front bracket aft flange screw with spacer (not visible in this view)

9. Remove the engine front bracket.
10. Block the rotation of the crankshaft by installing the Flywheel Holder Tool in place of the starter motor. Refer to **Section 4A: Starting System** for starter removal and installation procedures.

Flywheel Holder Tool	91-895472

11. Remove the four screws attaching the drive belt crankshaft pulley.



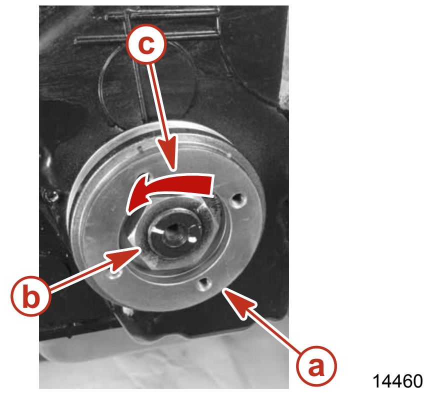
32660

a - Drive belt crankshaft pulley

b - Drive belt crankshaft pulley screws

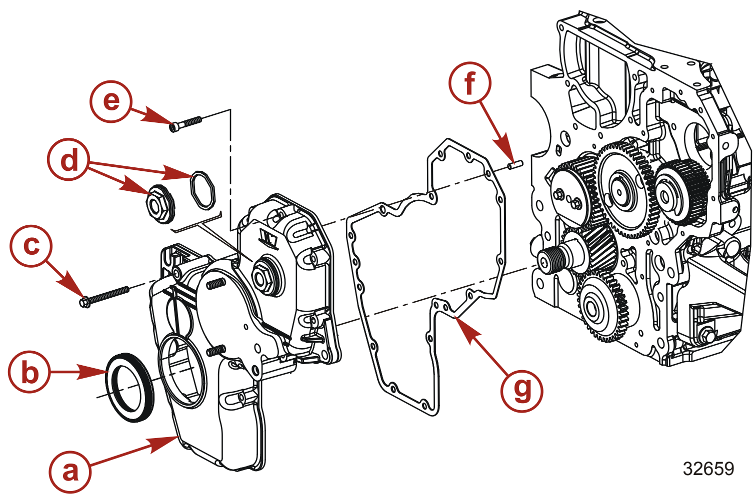
12. Remove the drive belt crankshaft pulley.

13. Remove the **left-hand thread** crankshaft pulley nut with a 41 mm socket.



a - Crankshaft pulley
b - Crankshaft pulley nut
c - Left-hand thread

14. Remove the timing gear cover screws. Note size and position of fasteners for reassembly.



a - Timing gear cover
b - Seal
c - Screw (1)
d - Plug and seal
e - Screw (13)
f - Pin
g - Gasket

15. Remove the timing gear cover assembly.

Cleaning

1. Remove the old gasket material from the cylinder block and timing gear cover. Be careful not to gouge or nick the sealing surfaces.
2. Put on safety glasses.
3. Clean the crankshaft pulley contact surfaces and crankshaft nut with cleaning solvent and dry with compressed air.
4. Clean the crankshaft threads.
5. Clean the crankshaft gear surfaces in contact with the crankshaft pulley.
6. If the timing gear cover oil seal is removed for replacement, clean the seating surface in the cover.

Inspection

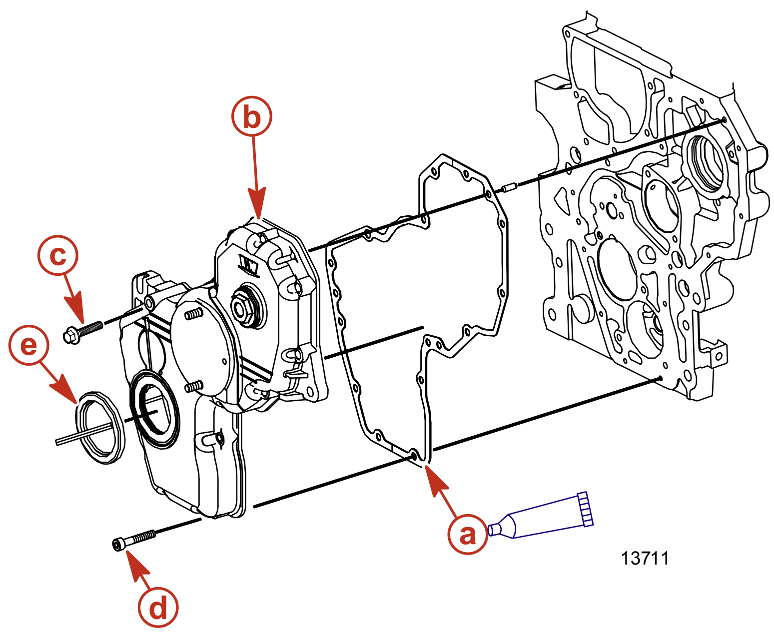
1. Inspect the parts for cracks or damage.
2. Check the oil seal for wear or damage. Replace the oil seal if needed.

NOTE: The bore in the timing cover for the oil seal must not be worn. The oil seal must fit securely in the cover.

Installation

IMPORTANT: Dirty oil seals can cause leaks. When fitting or replacing an oil seal, do not touch the inside the oil seal or the oil seal lip with your bare hands or dirty gloves.

1. Using a suitable tool, replace the timing gear cover oil seal, if needed. Do not touch inside the oil seal or touch the oil seal lip with your bare hands or with dirty gloves.
2. Apply sealant to the new timing gear cover gasket.
3. Install the timing gear cover gasket on the engine.
4. Install the timing gear cover.
5. Torque the timing gear cover flange screws evenly, in a cross pattern.



a - Timing gear cover gasket
b - Timing gear cover
c - Timing gear cover flange screw
d - Allen head screw
e - Oil seal

Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Timing gear cover gasket	92-12564 2

Description	Nm	lb. in.	lb. ft.
Timing gear cover flange screw	12.7	112	–

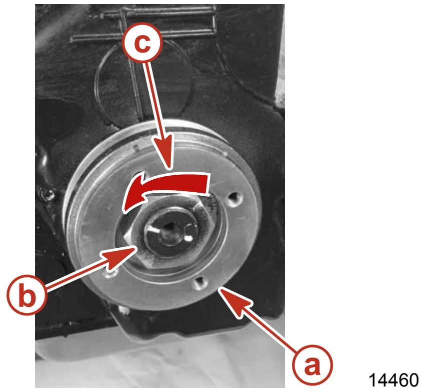
6. Install the crankshaft pulley.
7. Install the Flywheel Holder Tool in place of the starter motor.

Flywheel Holder Tool	91-895472

8. Apply lubricant to the threads of the left-hand thread crankshaft pulley nut and on the surface of the pulley nut that contacts the crankshaft pulley.

Tube Ref No.	Description	Where Used	Part No.
113	Loctite Moly Paste (molybdenum disulfide grease)	Threads on the left-hand thread crankshaft pulley nut and on the crankshaft pulley contact side	Obtain Locally

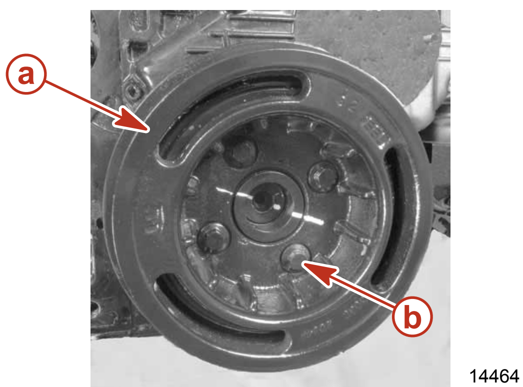
9. Install and torque the left-hand thread crankshaft pulley nut.



a - Crankshaft pulley
b - Left-hand thread crankshaft pulley nut
c - Direction of torque

Description	Nm	lb. in.	lb. ft.
Crankshaft pulley nut,**left-hand thread**	400	–	295

10. Install the crankshaft damper. Torque the four Allen-head crankshaft damper screws.

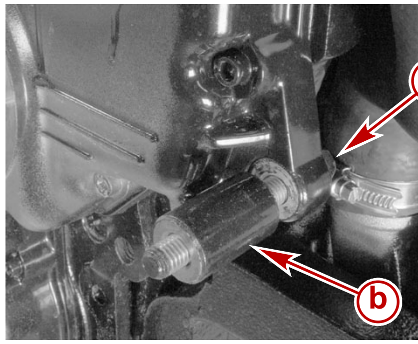


a - Crankshaft damper
b - Crankshaft damper screws

Description	Nm	lb. in.	lb. ft.
Crankshaft damper screw	32.4	–	24

11. Remove the Flywheel Holder Tool.

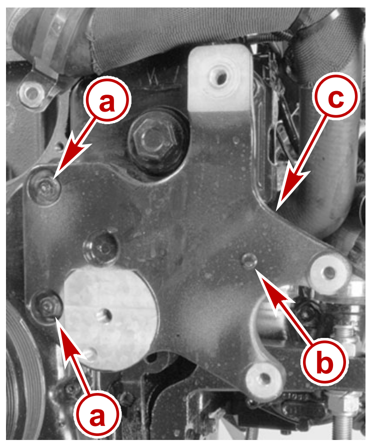
12. Install the front bracket aft flange screw with spacer onto the timing gear cover.



16518

a - Aft flange screw
b - Spacer

13. Ensure the engine front bracket aligns with the dowel pin on the timing gear cover and install the front bracket.
14. Install the two engine front bracket flange nuts and thread the aft flange screw into the engine front bracket.
15. Torque the flange nuts and aft flange screw.



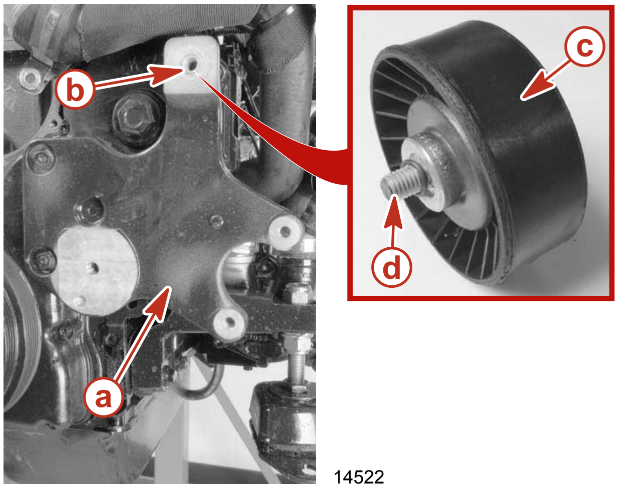
14524

a - Engine front bracket flange nut
b - Aft flange screw threaded into engine front bracket
c - Engine front bracket aft flange screw with spacer (not visible in this view)

Description	Nm	lb. in.	lb. ft.
Engine front bracket flange nut	24.5	–	18
Engine front bracket aft flange screw	47.1	–	34

IMPORTANT: The idler pulley mounting screw has a left-hand thread. Do not damage the threads in the engine front bracket.

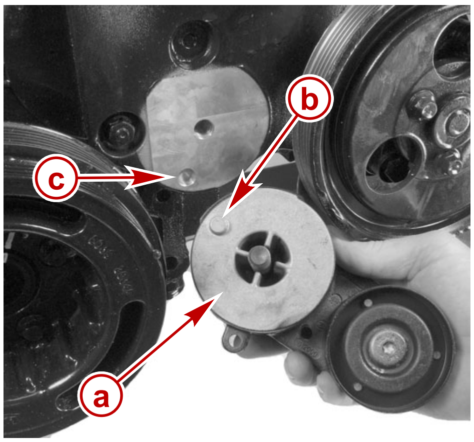
16. Install the idler pulley. Torque the left-hand thread mounting screw for the idler pulley.



a - Engine front bracket
b - Idler pulley left-hand thread mounting hole
c - Idler pulley
d - Idler pulley mounting screw

Description	Nm	lb. in.	lb. ft.
Idler pulley mounting screw, **left-hand thread**	47.1	–	34

17. Align the pin with the drilling in the engine front bracket and install the automatic tensioner assembly. Torque the automatic tensioner mounting screw.

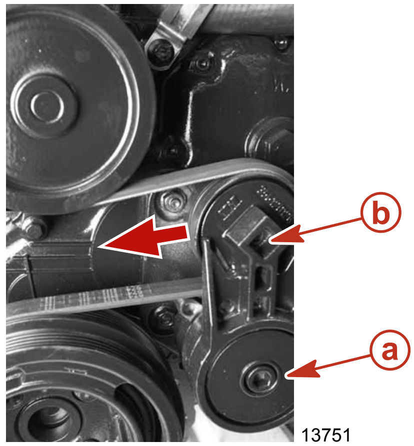


a - Automatic tensioner assembly
b - Pin
c - Drilling

Description	Nm	lb. in.	lb. ft.
Automatic tensioner assembly mounting screw	78.5	–	57

18. Install the seawater pump. Refer to **Section 6: Cooling System**.
19. Position a suitable tool in the automatic tensioner release slot and move (rotate) the tensioner pulley. Install the serpentine belt.

20. Release the automatic tensioner slowly.

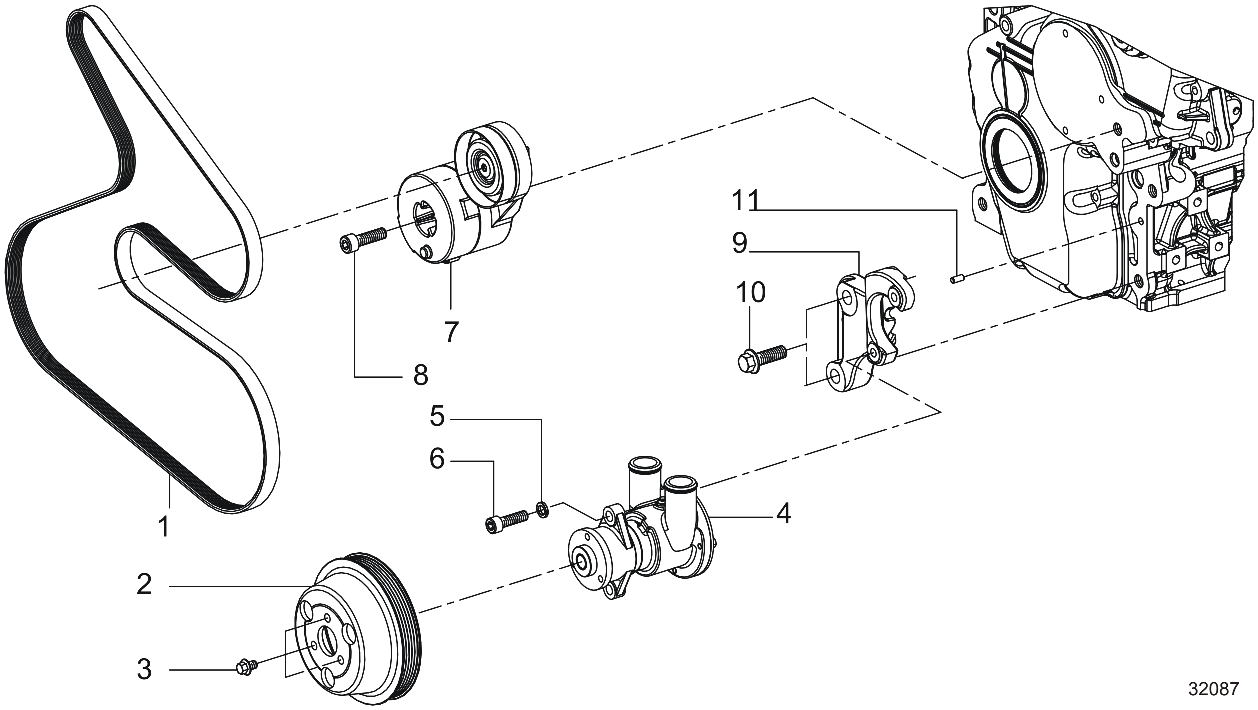


a - Automatic tensioner
b - Release slot

21. **On sterndrive models**: install the power steering pump belt and apply the specified tension. Refer to **Section 9A: Power-assisted Steering System**.
22. Before starting the engine, open the seacock, if equipped, or remove the plug and connect the seawater inlet hose.
23. Check for leaks when you start the engine.

4.2 Engine Front Bracket and Timing Gear Cover

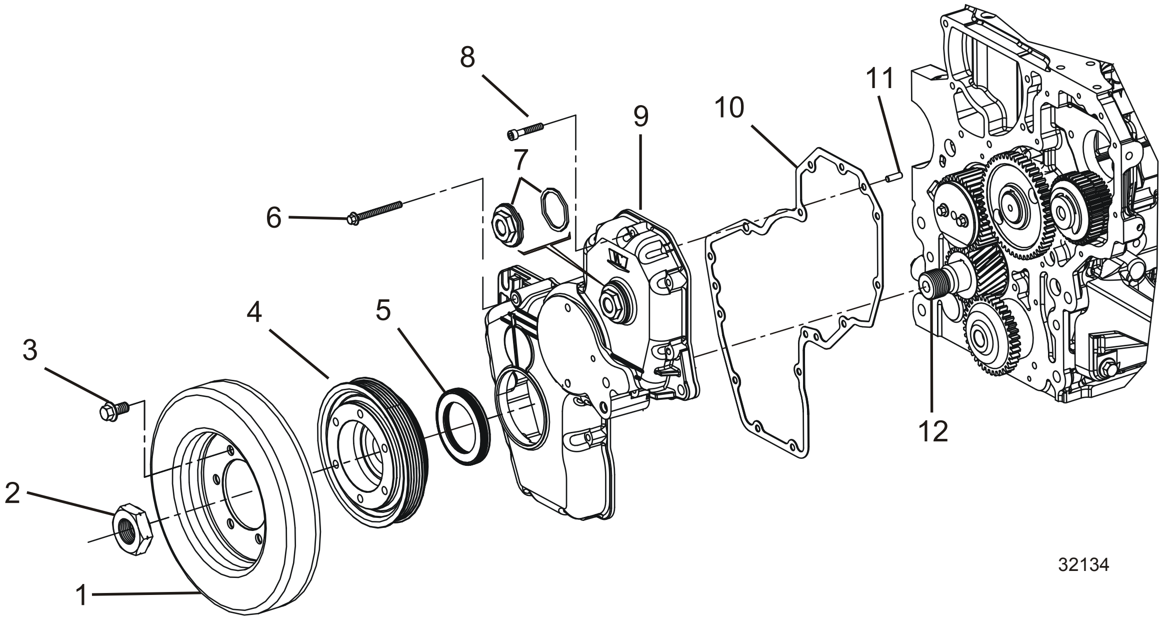
Exploded View—4.2 Front Bracket Components



Exploded View—4.2 Front Bracket Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Serpentine belt			
2	1	Seawater pump pulley			
3	3	Seawater pump pulley screw	24.5	–	18
4	1	Seawater pump			
5	2	Washer			
6	2	Seawater pump mounting screw	47.1	–	34
7	1	Automatic tensioner assembly			
8	1	Automatic tensioner assembly mounting screw	78.5	–	57
9	1	Engine front bracket			
10	2	Engine front bracket aft flange screw	47.1	–	34
11	1	Alignment pin			

Exploded View—4.2 Timing Gear Cover Components

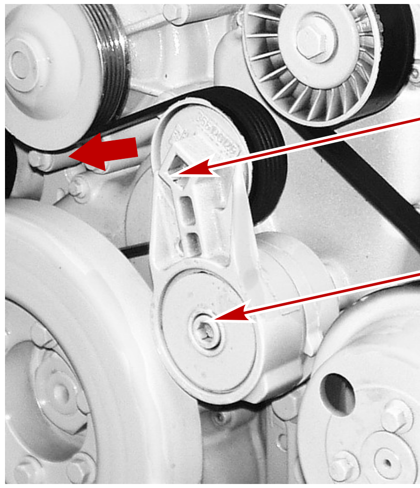


Exploded View—4.2 Timing Gear Cover Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Crankshaft damper			
2	1	Crankshaft nut (left-hand thread)	400	–	295
3	6	Crankshaft damper Allen-head screw	32.4	–	24
4	1	Crankshaft pulley			
5	1	Timing cover seal			
6	1	Flange screw	27.5	–	20
7	1	Injection pump gear cover and seal			
8	13	Timing gear cover Allen-head screw	12.7	112	–
9	1	Timing gear cover assembly			
10	1	Gasket			
11	1	Alignment pin			
12	1	Crankshaft			

Removal

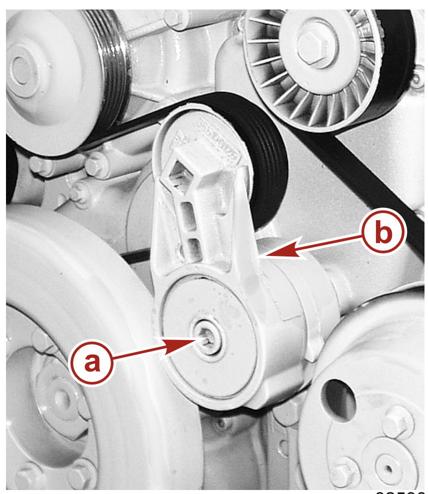
1. **On sterndrive models**: remove the power steering pump belt. Refer to **Section 9A: Power-assisted Steering System**.
2. Position a suitable tool in the automatic tensioner release slot. Move (rotate) the tensioner pulley and remove the serpentine belt.



23256

a - Automatic tensioner
b - Release slot

3. Release the automatic tensioner slowly.
4. Remove the automatic tensioner assembly from the engine front bracket.



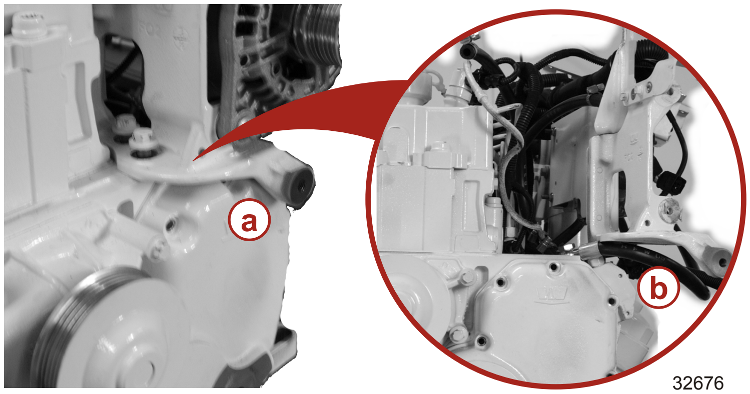
32590

a - Automatic tensioner bolt
b - Tensioner and front bracket

5. Remove the alternator. Refer to **Section 4B: Charging System**.
6. Remove the 3 screws attaching the alternator bracket to the engine.

NOTE: *It is not necessary to completely remove the alternator bracket by detaching it from the ECM bracket. The alternator bracket only needs to be loose enough to provide clearance to remove the timing cover.*

7. Position the alternator bracket to provide clearance to remove the timing cover.

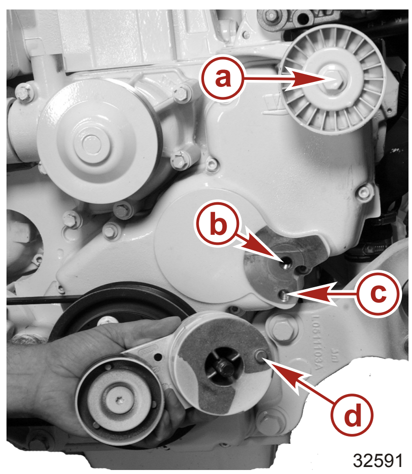


a - Alternator bracket interference
b - Alternator bracket moved for clearance

8. Close the seacock, if equipped. If the boat is not equipped with a seacock, remove and plug the seawater inlet hose.
9. Remove the seawater pump. Refer to **Section 6: Cooling System**.

IMPORTANT: The idler pulley mounting screw has a left-hand thread. Do not damage the threads in the engine front bracket when removing or installing the idler pulley mounting screw.

10. Remove the **left-hand thread** idler pulley screw.

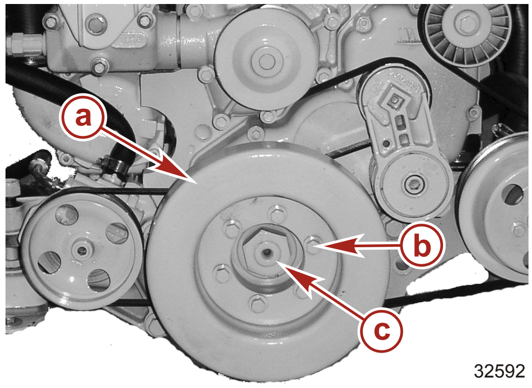


a - Idler pulley screw
b - Tensioner screw hole
c - Tensioner pin hole
d - Tensioner pin

11. Block the rotation of the crankshaft by installing the Flywheel Holder Tool in place of the starter motor. Refer to **Section 4A: Starting System** for starter removal and installation procedures.

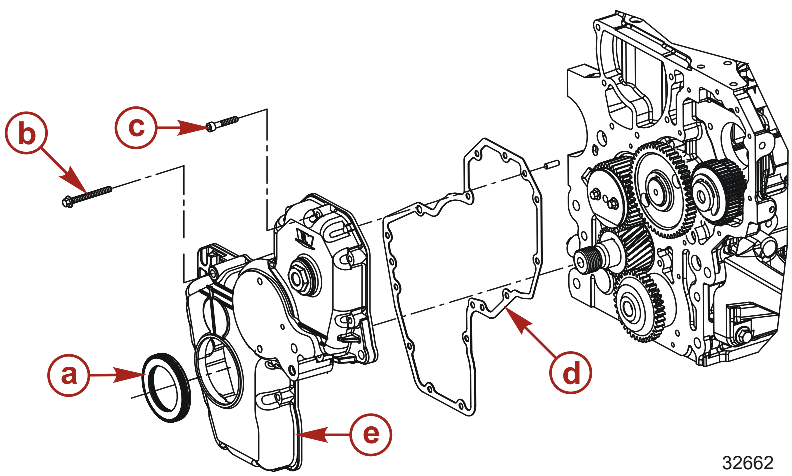
Flywheel Holder Tool	91-895472

12. Remove the crankshaft damper.



a - Crankshaft damper
b - Bolt
c - Crankshaft pulley nut

13. Using a suitable 46 mm socket, remove the large, **left-hand thread** crankshaft pulley nut.
14. Remove the crankshaft pulley.
15. Remove the timing gear cover screws. Note size and position of fasteners for reassembly.



a - Oil seal
b - Timing gear cover flange screw (1)
c - Allen head screw (13)
d - Timing gear cover gasket
e - Timing gear cover

16. Remove the timing gear cover assembly.

Cleaning

1. Remove the old gasket material from the cylinder block and timing gear cover. Be careful not to gouge or nick the sealing surfaces.
2. Put on safety glasses.
3. Clean the crankshaft pulley contact surfaces and crankshaft nut with cleaning solvent and dry with compressed air.
4. Clean the crankshaft threads.
5. Clean the crankshaft gear surfaces in contact with the crankshaft pulley.

6. If the timing gear cover oil seal is removed for replacement, clean the seating surface in the cover.

Inspection

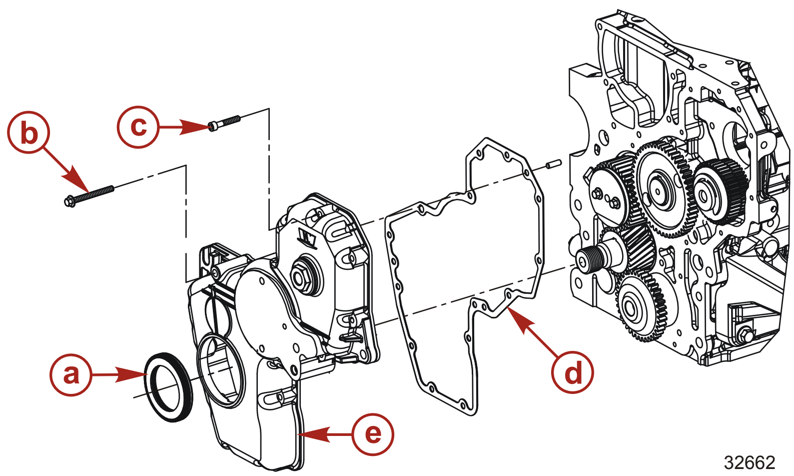
1. Inspect the parts for cracks or damage.
2. Check the oil seal for wear or damage. Replace the oil seal if needed.

NOTE: The bore in the timing cover for the oil seal must not be worn. The oil seal must fit securely in the cover.

Installation

IMPORTANT: Dirty oil seals can cause leaks. When fitting or replacing an oil seal, do not touch the inside the oil seal or the oil seal lip with your bare hands or dirty gloves.

1. Using a suitable tool, replace the timing gear cover oil seal, if needed. Do not touch inside the oil seal or touch the oil seal lip with your bare hands or with dirty gloves.
2. Apply sealant to the new timing gear cover gasket.
3. Install the timing gear cover gasket on the engine.
4. Install the timing gear cover.
5. Torque the timing gear cover flange screws evenly, in a cross pattern.



a - Oil seal
b - Timing gear cover flange screw (1)
c - Allen head screw (13)
d - Timing gear cover gasket
e - Timing gear cover

Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Timing gear cover gasket	92-12564 2

Description	Nm	lb. in.	lb. ft.
Timing gear cover flange screw, short	12.7	112	–
Timing gear cover flange screw, long	27.5	–	20

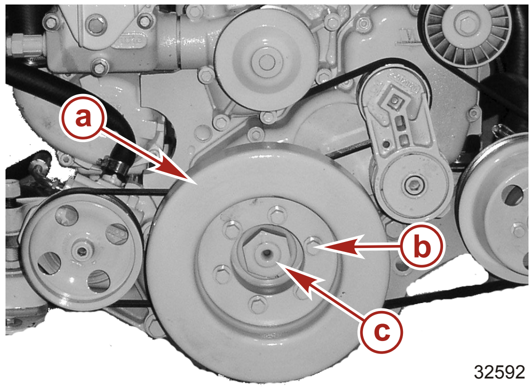
6. Install the crankshaft pulley.
7. Install the Flywheel Holder Tool in place of the starter motor.

Flywheel Holder Tool	91-895472

8. Apply lubricant to the threads of the left-hand thread crankshaft pulley nut and on the surface of the pulley nut that contacts the crankshaft pulley.

Tube Ref No.	Description	Where Used	Part No.
	Loctite Moly Paste (molybdenum disulfide grease)	Threads on the left-hand thread crankshaft pulley nut and on the crankshaft pulley contact side	Obtain Locally

9. Install and torque the **left-hand thread** crankshaft pulley nut.



a - Crankshaft damper
b - Bolt
c - Crankshaft pulley nut

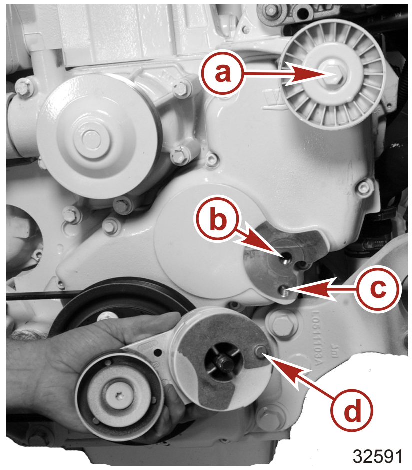
Description	Nm	lb. in.	lb. ft.
Crankshaft pulley nut, **left-hand thread**	400	–	295

10. Install the crankshaft damper.
11. Torque the crankshaft damper screws.

Description	Nm	lb. in.	lb. ft.
Crankshaft damper screw	32.4	–	24

12. Remove the Flywheel Holder Tool.

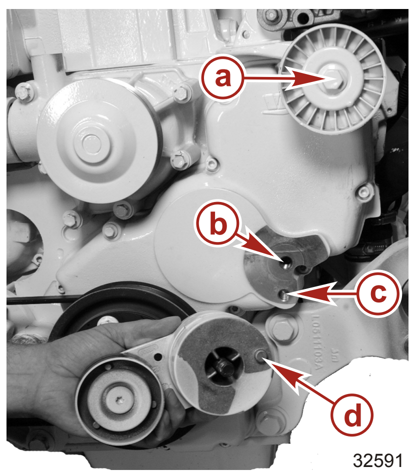
13. Install the idler pulley. Torque the **left-hand thread** mounting screw for the idler pulley.



a - Idler pulley screw
b - Tensioner screw hole
c - Tensioner pin hole
d - Tensioner pin

Description	Nm	lb. in.	lb. ft.
Idler pulley mounting screw, **left-hand thread**	32.4	–	24

14. Align the pin with the drilling in the engine front bracket and install the automatic tensioner assembly. Torque the automatic tensioner mounting screw.



a - Idler pulley screw
b - Tensioner screw hole
c - Tensioner pin drilling
d - Tensioner pin

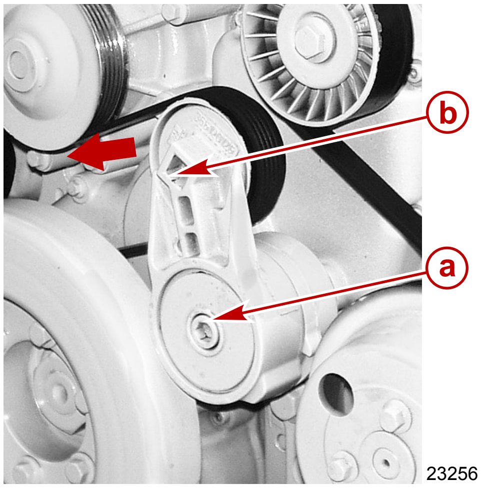
Description	Nm	lb. in.	lb. ft.
Automatic tensioner assembly mounting screw	78.5	–	57

15. Install the alternator bracket. Torque screws to specification.

Description	Nm	lb. in.	lb. ft.
Automatic tensioner assembly mounting screw	47.1	–	35

16. Install the alternator. Refer to **Section 4B: Charging System**.

17. Install the seawater pump. Refer to **Section 6: Cooling System**.
18. Position a suitable tool in the automatic tensioner release slot and move (rotate) the tensioner pulley.

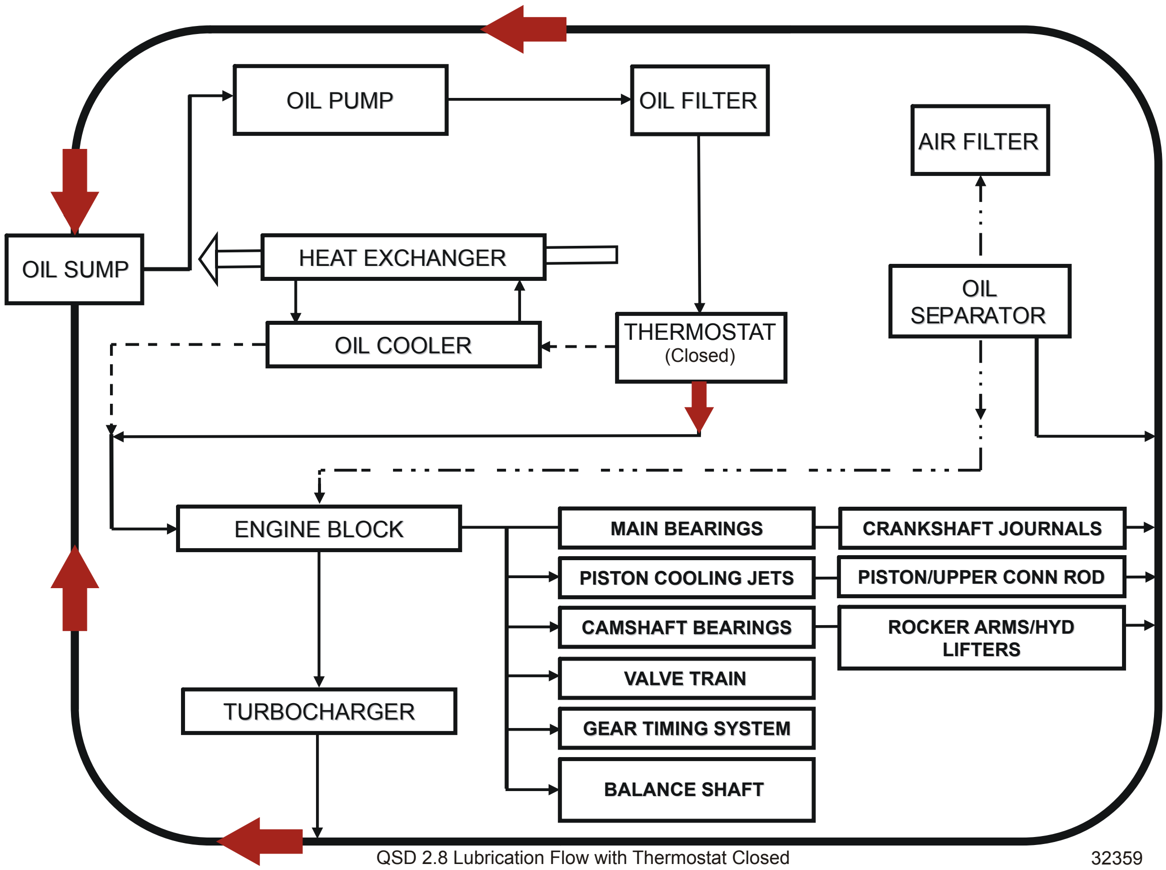


a - Automatic tensioner
b - Release slot

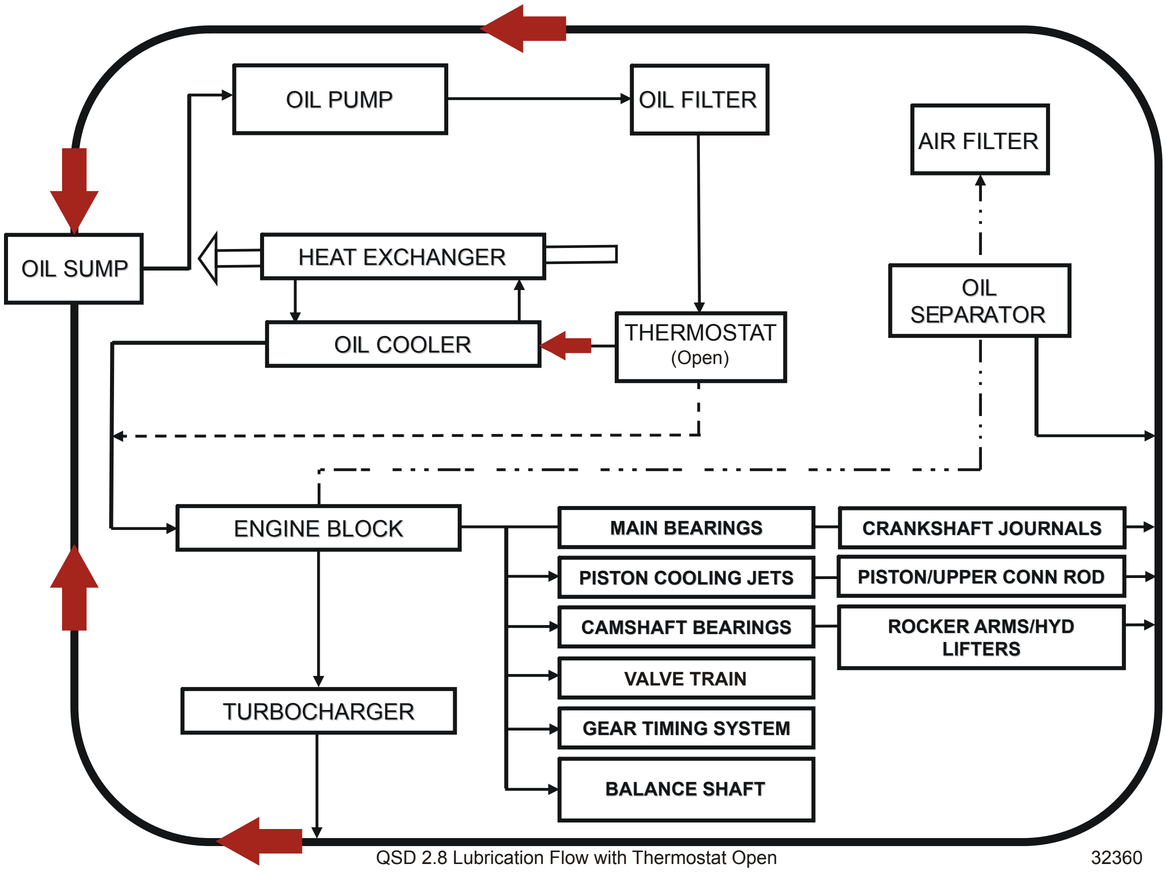
19. Install the serpentine belt.
20. Release the automatic tensioner slowly.
21. **On sterndrive models**: install the power steering pump belt and apply the specified tension. Refer to **Section 9A: Power-assisted Steering System**.
22. Before starting the engine, open the seacock, if equipped, or remove the plug and connect the seawater inlet hose.
23. Check for leaks when you start the engine.

Oil Pump

2.8 Oil Flow Diagrams



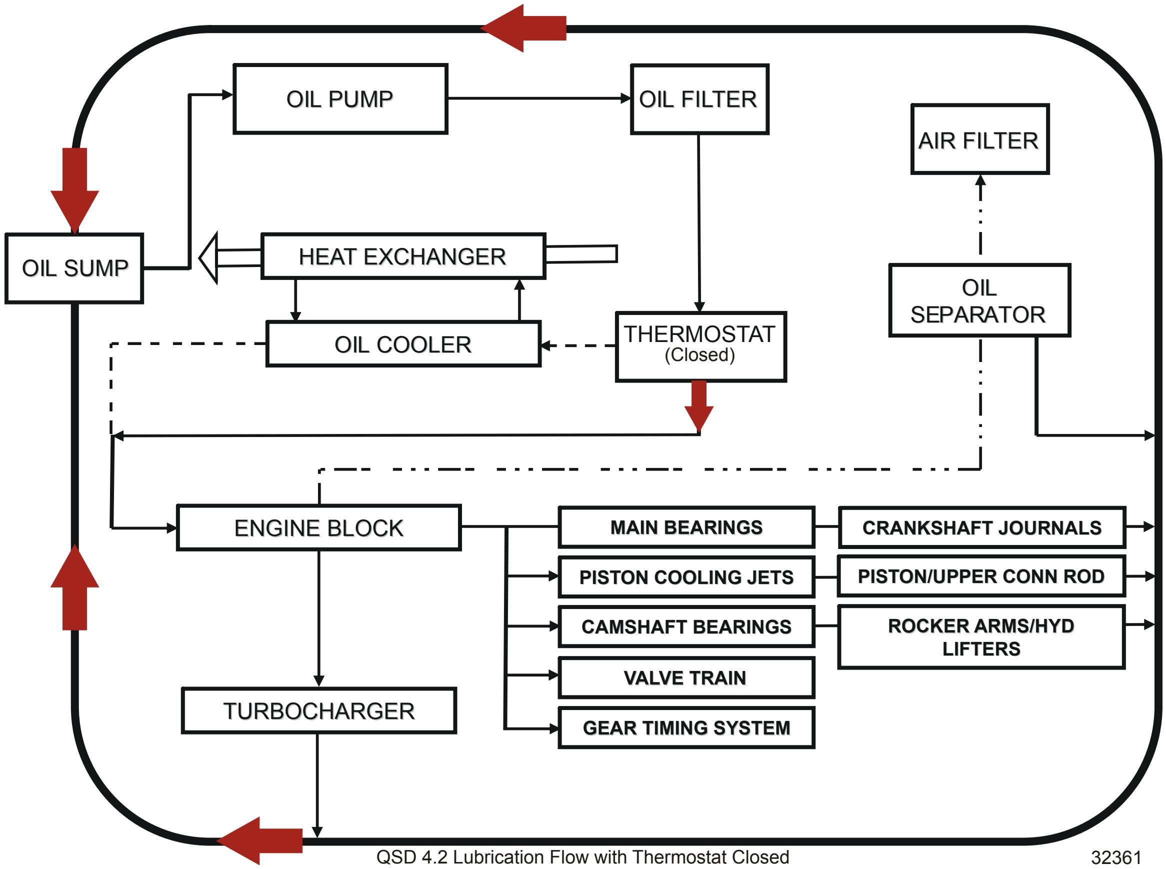
2.8 Oil thermostat closed



QSD 2.8 Lubrication Flow with Thermostat Open 32360

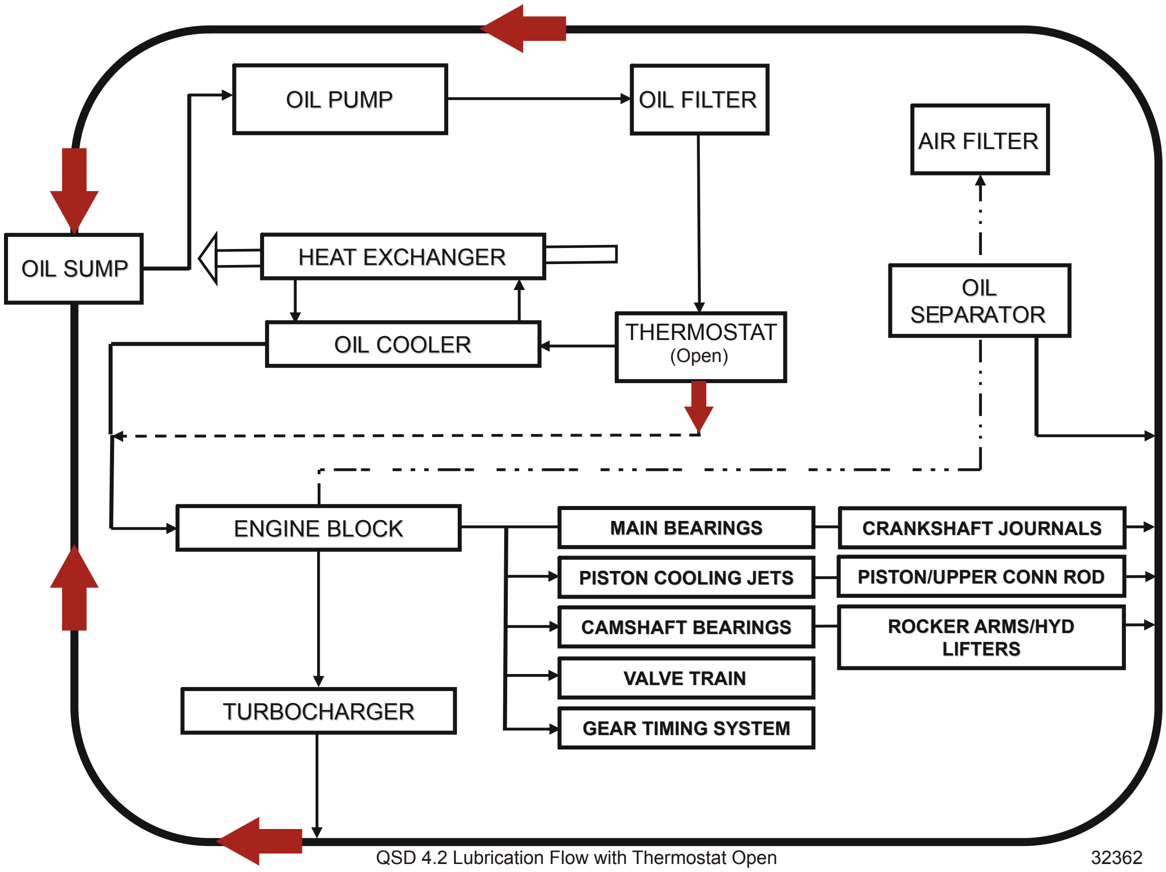
2.8 Oil thermostat open

4.2 Oil Flow Diagrams



QSD 4.2 Lubrication Flow with Thermostat Closed 32361

4.2 Oil thermostat closed



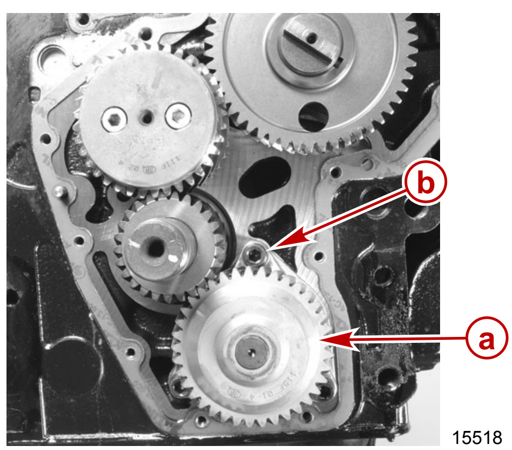
4.2 Oil thermostat open

Removal

1. Remove the timing gear cover.

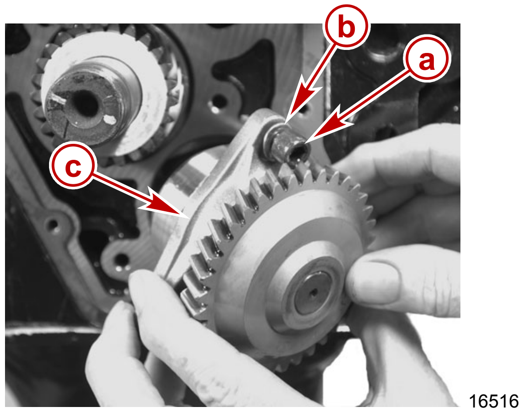
NOTE: The oil pump screws may not clear the oil pump gear during removal and should be removed with the oil pump. After the oil pump is removed, the screws can be removed from the oil pump.

2. Loosen the three oil pump screws.



a - Oil pump
b - Screw and lockwasher

3. Remove the oil pump with screws and spring washers from the cylinder block.



a - Screw
b - Spring washer
c - Oil pump

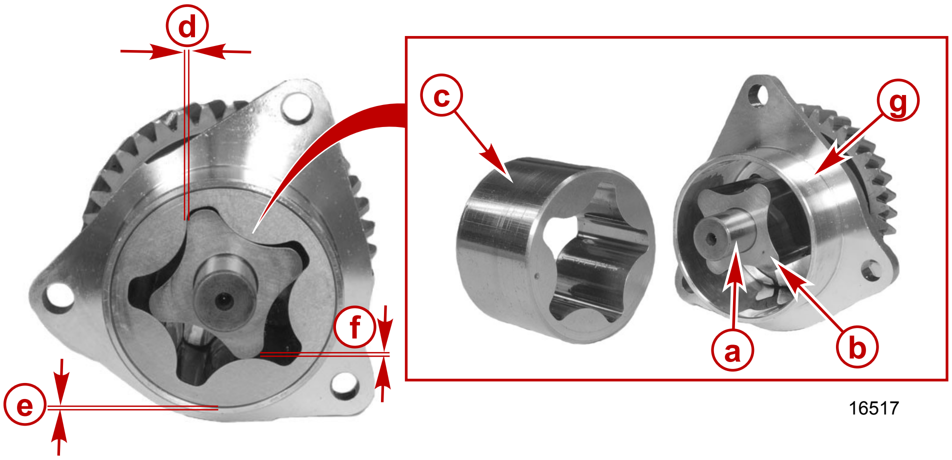
Cleaning

1. Disassemble and wash all parts in cleaning solvent.
2. Put on safety glasses and dry parts with compressed air.

Inspection

1. Inspect the oil pump shaft, rotors, and housing for excessive wear or damage. Replace the oil pump assembly if excessive wear or damage is found.
2. Check clearance between the inner and outer oil pump rotors.
3. Check clearance between the outer rotor and housing.
4. Check the outer and inner rotor end float.
5. If the measured values are greater than specified, the pump is faulty and must be replaced as a complete unit.

6. Check the rotor and gear coupling rolling torque.



a - Shaft
b - Inner rotor
c - Outer rotor
d - Clearance between rotors
e - Clearance between housing and outer rotor
f - Difference between height of inner rotor and outer rotor seat
g - Rotor housing

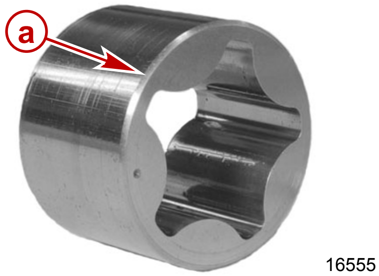
Oil Pump	
Clearance between rotors	0.070–0.200 mm (0.0028–0.0079 in.)
Clearance between housing and outer rotor	0.105–0.160 mm, limit 0.500 mm (0.0041–0.0063 in., limit 0.0197 in.)
Axial clearance between gear and pump body	0.150–0.250 mm (0.0059–0.0098 in.)
Rotor height	32.487–32.500 (1.2790–1.2795 in.)
Rotor seat depth in the housing	32.403–32.406 mm (1.2757–1.2758 in.)
Difference between height of inner rotor and outer rotor seat	0.081–0.097 (0.0032–0.0035 in.)
Inside diameter of rotor housing	58.105–58.130 mm (2.287–2.288 in.)
Rotor and gear coupling rolling torque resistance	9 kgm (32.4 oz.)

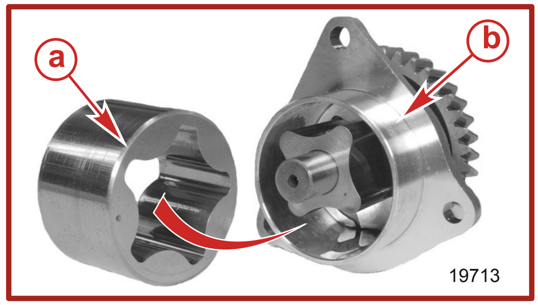
Reassembly

1. Lubricate the oil pump rotor housing and the inner and outer rotor surfaces.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Oil pump housing and the inner and outer oil pump rotor surfaces	Obtain Locally

2. Install the beveled (chamfered) end of the outer rotor towards the seat (the inside) of the rotor housing.

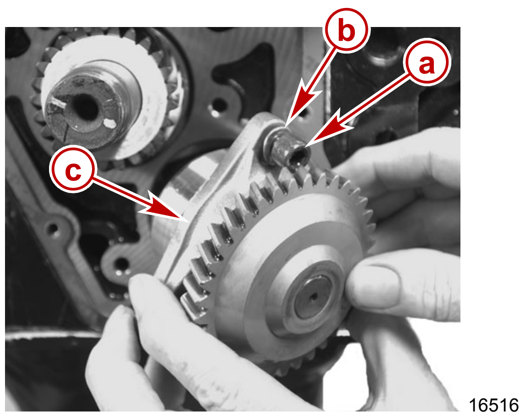




a - Beveled (chamfered) end
b - Rotor housing

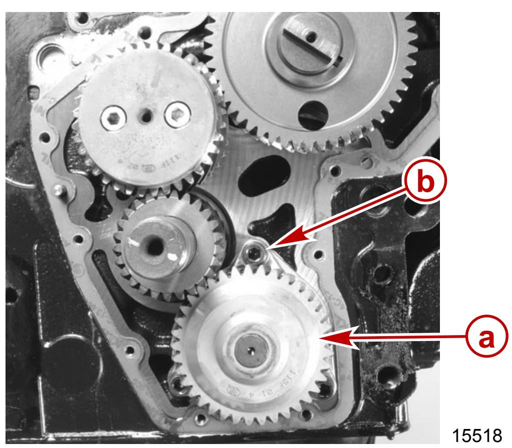
Installation

1. Install the three screws and spring washers into the mounting holes on the oil pump.
2. Install the oil pump in the cylinder block.



a - Screw
b - Spring washer
c - Oil pump

3. Torque the three oil pump screws evenly in a diagonal pattern.



a - Oil pump
b - Screw

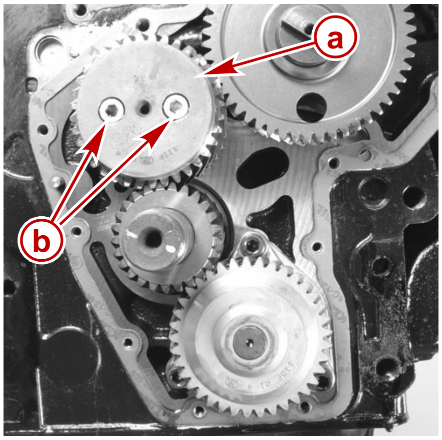
Description		Nm	lb. in.	lb. ft.
Oil pump screw		27.5		20

4. Check that the oil pump gear is not in a bind by ensuring that there is some clearance (backlash) between the crankshaft gear and oil pump gear. Check the installation if no backlash is detected between the gears.
5. Install the timing gear cover.
6. Complete the engine assembly.
7. Verify oil pressure and check for leaks when you start the engine.

Idler Gear

Removal

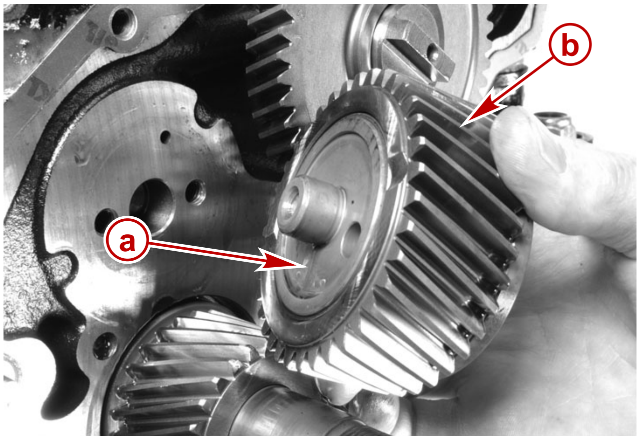
1. Position the engine at cylinder number 1 TDC and lock or pin the flywheel. See **Establishing TDC (Top Dead Center)**.
2. Remove the timing gear cover.
3. Remove the two idler gear bushing screws.



16262

a - Idler gear bushing
b - Idler gear bushing screw

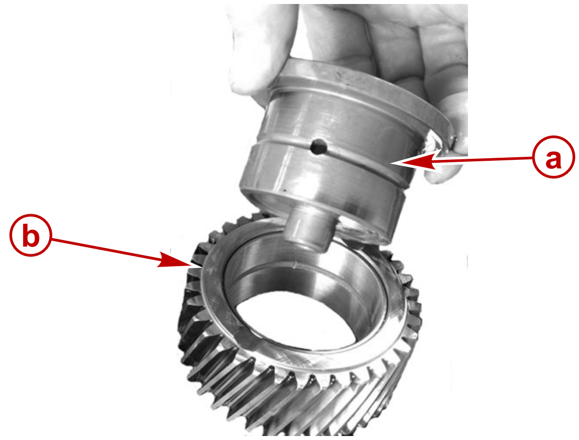
4. Remove the idler gear bushing and idler gear assembly.



16263

a - Idler gear bushing
b - Idler gear assembly

5. Separate the idler gear bushing from the idler gear assembly.



a - Idler gear bushing **b -** Idler gear assembly

Cleaning

1. Wash the idler gear bushing and idler gear assembly in cleaning solvent.
2. Put on safety glasses and dry the components with compressed air.

Inspection

1. Inspect the idler gear assembly and the idler gear bushing. Replace both components if worn or damaged.

NOTE: *As an alternative to the following method of calculating clearance, use a feeler gauge to measure the clearance between the assembled idler gear components.*

2. Measure the inner diameter of the idler gear assembly and the outer diameter of the idler gear bushing. Replace the idler gear components if the difference between the measurements does not meet specifications.

Idler Gear		
Inner diameter of idler gear assembly		53.450–53.465 mm (2.1043–2.1049 in.)
Outer diameter of Idler gear bushing		53.500–53.519 mm (2.1063–2.1070 in.)
Clearance	Minimum	0.035 mm (0.0014 in.)
	Maximum	0.089 mm (0.0035 in.)

NOTE: *Perform the following procedure before removing the idler gear, or after installation, with the adjacent crankshaft and camshaft gears in position.*

3. With the idler gear installed, measure the gear backlash (clearance) between the teeth of the idler gear and crankshaft gear using a dial indicator (appropriately mounted on the engine block) or a feeler gauge. Turn the crankshaft at 90° intervals and measure the gear backlash. Repeat this procedure for the idler gear and camshaft gear. Replace the idler gear assembly if the gear backlash is more than specified at any interval.

Idler gear	
Gear backlash	0.10–0.20 mm (0.0039–0.0078 in.)

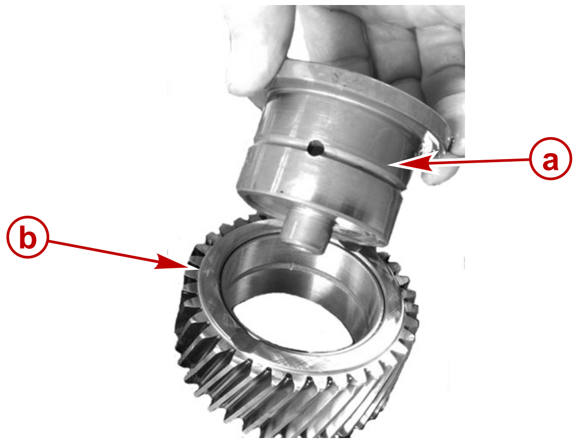
4. If the idler gear assembly has been replaced during assembly and gear backlash is not within specification, refer to the appropriate procedure or section for inspecting the crankshaft gear and camshaft gear for wear or damage.

Installation

1. Lubricate the idler gear assembly with bearing and idler gear bushing.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Idler gear assembly with bearing and idler gear bushing	Obtain Locally

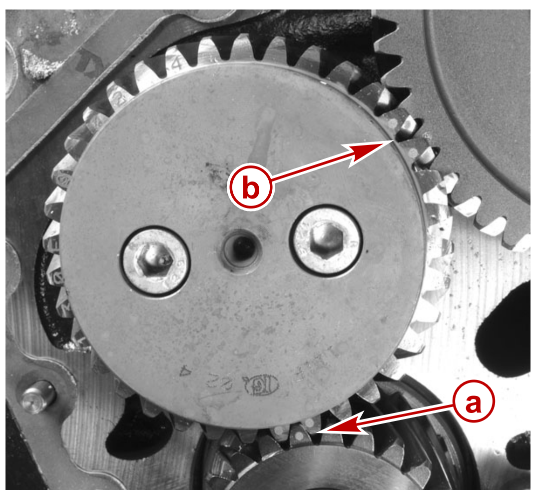
2. Install the idler gear bushing into the idler gear assembly.



16276

a - Idler gear bushing
b - Idler gear assembly

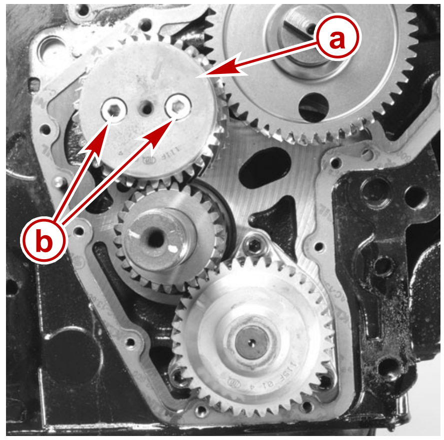
3. Install the idler gear bushing and idler gear assembly. Ensure the timing marks on the adjacent gears are properly aligned.



16289

a - Crankshaft and idler gear assembly timing marks aligned
b - Idler gear assembly and camshaft gear timing marks aligned

4. Torque the 2 idler gear bushing screws.



16262

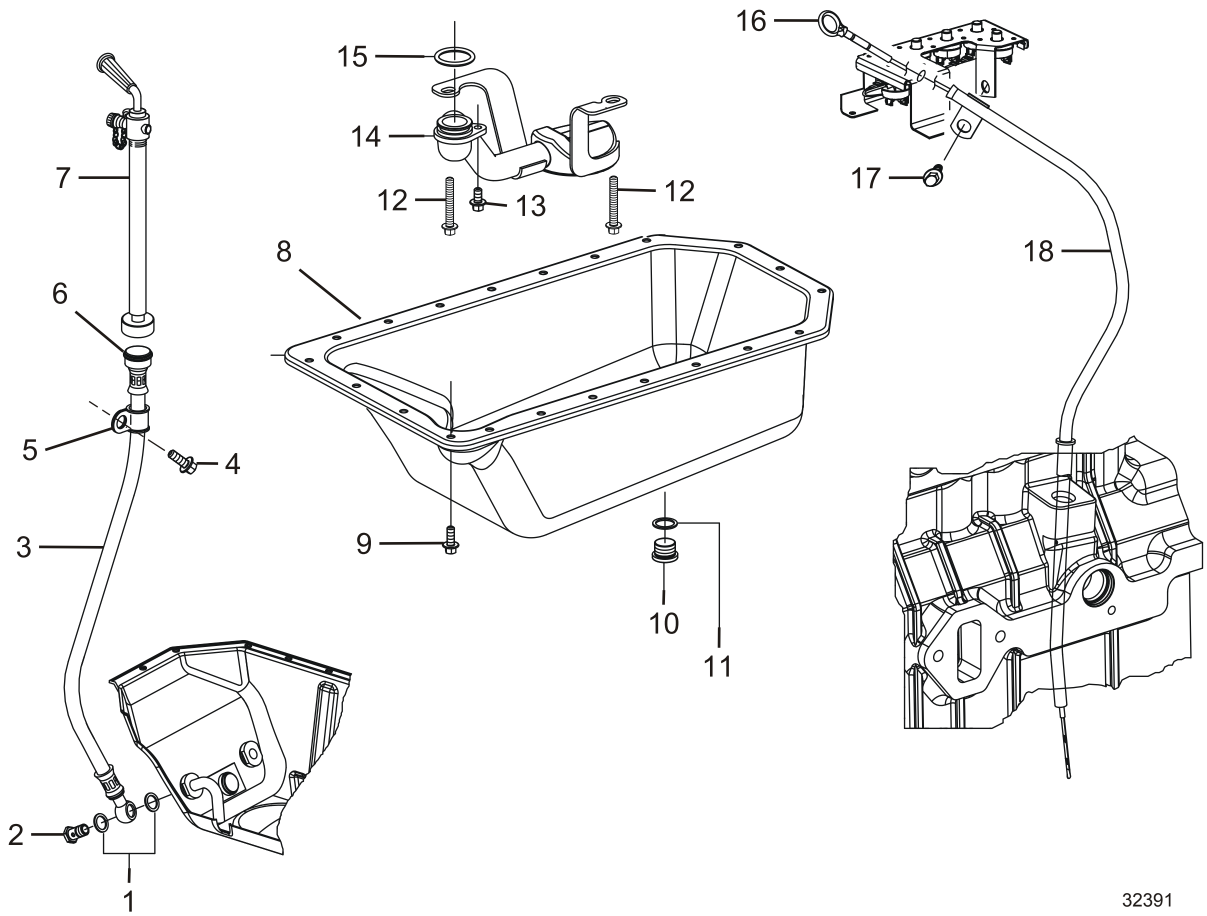
a - Idler gear bushing
b - Idler gear bushing screw

Description	Nm	lb. in.	lb. ft.
Idler gear bushing screw	32.4		23

5. Remove the flywheel lock or pin tool.
6. Install the timing gear cover and related components.
7. Check for leaks when you start the engine.

2.8 Oil Pan, Oil Pickup, and Related Components

Exploded View— 2.8 Oil Pan and Related Components



Exploded View— 2.8 Oil Pan and Related Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	2	Sealing washer			
2	1	Hollow bolt	16.7	147	–
3	1	Oil drain hose			
4	1	Screw	24.5	–	18
5	1	J-clip			
6	1	Cap			
7	1	Oil extraction pump (optional accessory)			
8	1	Oil Pan			
9	21	Oil pan screw	12.7	112	–
10	1	Drain plug	37.3	–	28
11	1	Sealing washer			
12	2	Screw, M8 x 50 mm	32.4	–	23
13	1	Screw	12.7	112	–
14	1	Oil pickup assembly			
15	1	O-Ring			
16	1	Dipstick			
17	1	Bolt	12.7	112	–
18	1	Dipstick tube			

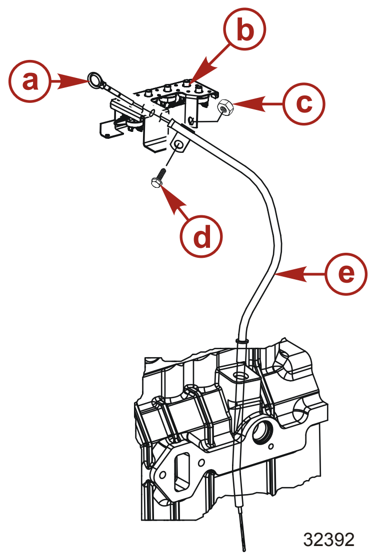
Removal

OIL DIPSTICK AND TUBE

1. Remove the oil dipstick.
2. Remove the dipstick tube nut and bolt from the circuit breaker panel.

NOTE: The engine oil dipstick tube interference fits into the engine block and is held in place by sealant. Moderate twisting of the oil dipstick tube will break sealant adhesion and ease removal.

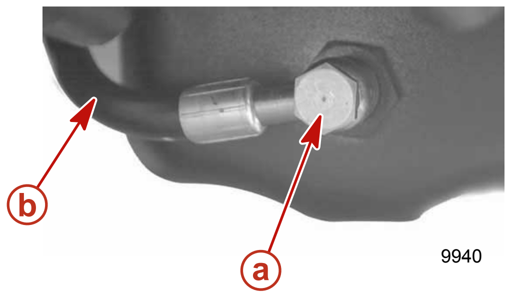
3. Remove the dipstick tube.



a - Oil dipstick
b - Circuit breaker panel
c - Nut
d - Bolt
e - Dipstick tube

OIL DRAIN HOSE

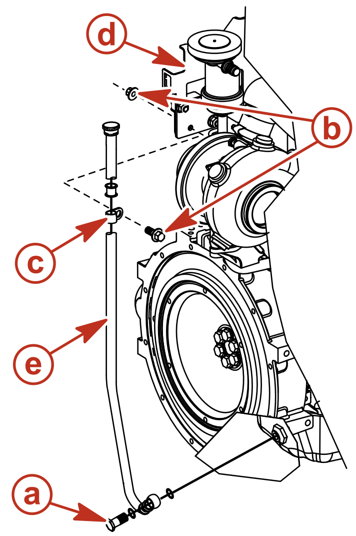
1. Drain or pump the oil out of the engine. See the **Maintenance** section.
2. Remove the hollow bolt with sealing washers and disconnect the oil drain hose from the oil pan.



a - Hollow bolt with sealing washers
b - Oil drain hose

3. Remove the J-clip flange nut and bolt from the gear lube monitor bracket.

4. Remove the oil drain hose.

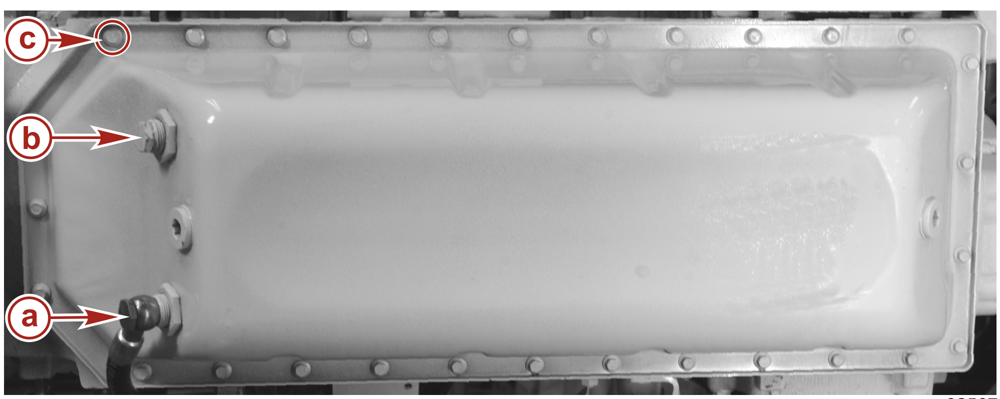


16217

a - Hollow bolt with sealing washers
b - Flange nut and bolt
c - J-clip
d - Gear lube monitor bracket
e - Oil drain hose

OIL PAN

1. Drain or pump the oil out of the engine. Refer to the **Maintenance** section.
2. Remove the oil drain hose from the oil pan



32567

a - Oil drain hose fitting
b - Oil drain plug
c - Oil pan screw

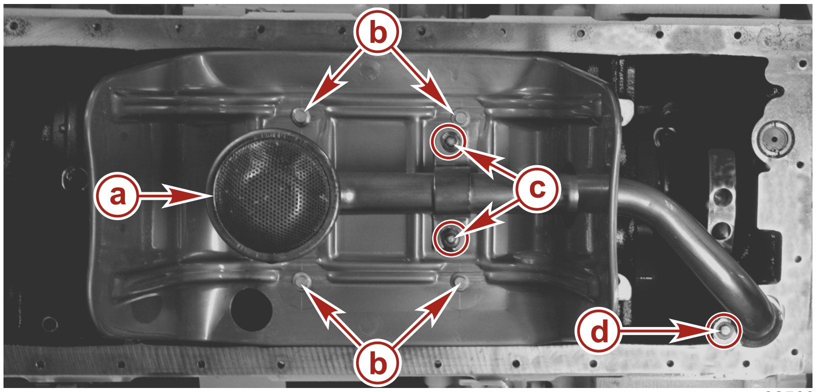
.

3. Remove the oil pan screws.
4. Remove the oil pan.

OIL PICKUP

NOTE: The Oil pickup tube and strainer is attached to the oil splash shield with 2 nuts and bolts. To simplify installation, remove the oil pickup and splash shield as an assembly unless component replacement is necessary.

1. Remove the oil pickup tube to block mounting screw.

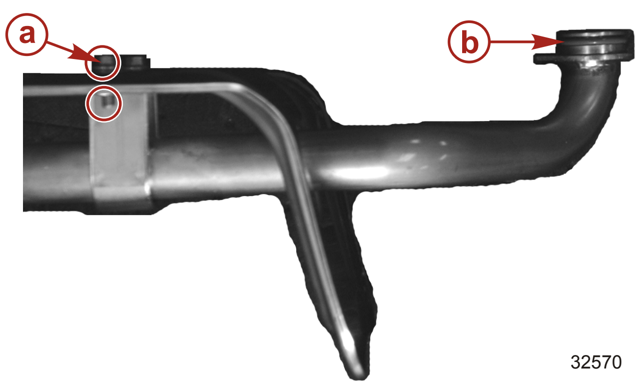


32568

a - Oil pickup strainer
b - Oil splash shield mounting screws
c - Oil strainer mounting screws
d - Oil pickup tube to block screw

NOTE: The oil pickup tube is fitted into the block with an O-ring seal. Pull the oil pickup tube straight out from the block when removing.

2. Remove the oil splash shield mounting screws.
3. Remove the oil pickup tube and strainer, and oil splash shield assembly.
4. Remove the old oil pickup tube O-ring.



a - Nut and bolt
b - O-ring

5. If component replacement is necessary, remove the nuts and bolts attaching the oil pickup to the splash shield.

Cleaning

1. Clean the cylinder block bolt holes to ensure that no dirt or oil remain.
2. Clean the sealer from cylinder block and oil pan flange sealing surfaces.
3. Wash the non-rubber parts in cleaning solvent (rubber parts can be damaged by cleaning solvents).

4. Put on safety glasses and dry the parts with compressed air, including the cylinder block bolt holes.
5. Clean the pick up tube seat in the cylinder block.
6. Clean the dipstick tube seat in the cylinder block.

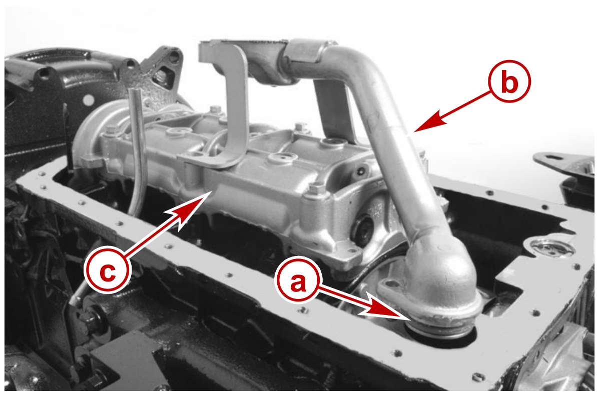
Inspection

1. Inspect the components for fatigue cracks or damage.
2. Check all welds for leaks.
3. Replace parts if necessary.

Installation

OIL PICKUP

1. Replace the oil pickup tube O-ring.
2. Lubricate the oil pickup tube O-ring.
3. Install the oil pickup tube and strainer on the engine block and balance shaft assembly.

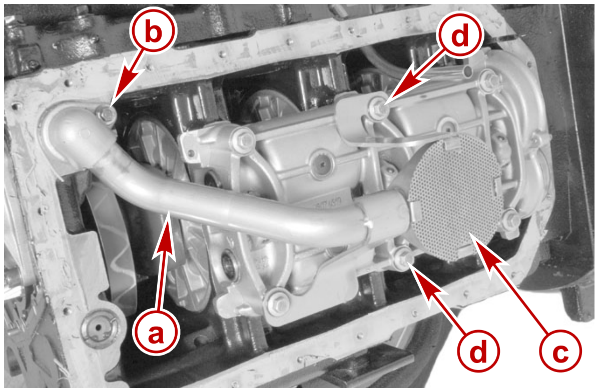


16561

a - Oil pickup tube O-ring
b - Oil pickup tube and strainer
c - Balance shaft assembly

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Oil pickup tube O-ring	Obtain Locally

4. Install the oil pickup tube and strainer screws. Torque the screws.



16538

a - Oil pickup tube
b - Oil pickup tube screw
c - Oil strainer
d - Oil strainer and balance shaft assembly screw

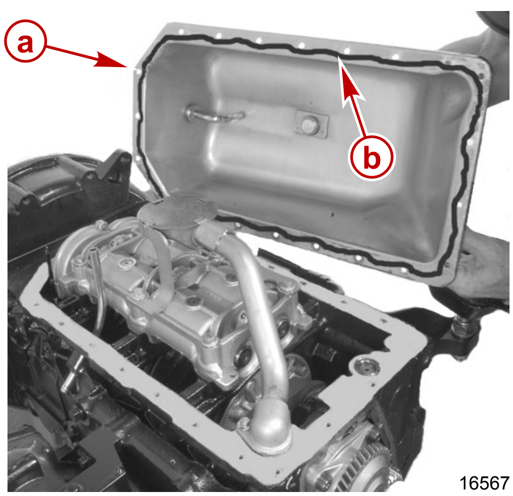
Description	Nm	lb. in.	lb. ft.
Oil pickup tube screw	12.7	112	–
Oil strainer and balance shaft assembly screw	32.4	–	23

OIL PAN

1. Wipe off all excess oil and foreign matter from sealing surface on crankcase and oil pan. Thoroughly degrease all sealing surfaces prior to application of sealant.

IMPORTANT: Excessive sealant can clog the pickup strainer, restricting oil flow and damaging the engine. Apply the minimum effective amount of sealant during installation.

2. Apply a continuous bead of sealant around the oil pan flange on the **inside** of the bolt holes as shown.



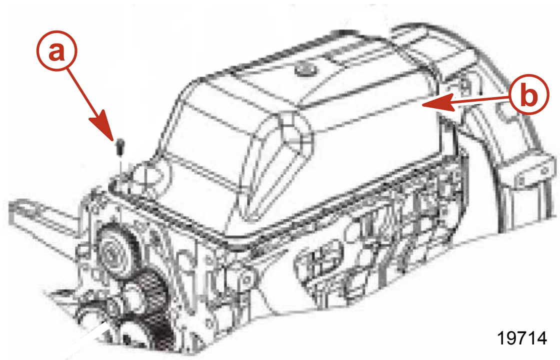
16567

a - Oil pan flange
b - Continuous bead of sealant

Tube Ref No.	Description	Where Used	Part No.
116	RTV 587 Ultra Blue Silicone Sealer	Oil pan flange	92-809825

3. Install the oil pan.

4. Install oil pan screws finger tight.



a - Oil pan screw
b - Oil pan

5. Torque the oil pan screws evenly, in a diagonal pattern.

Description	Nm	lb. in.	lb. ft.
Oil pan screw	12.7	112	–

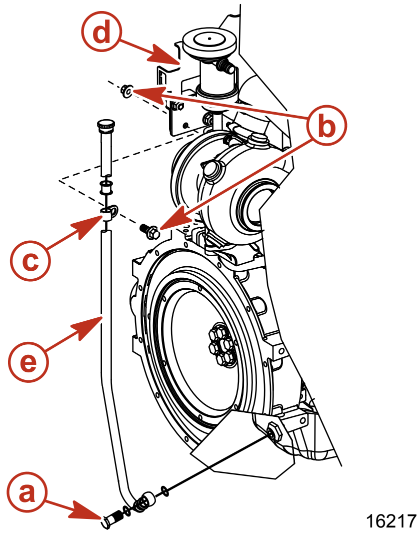
OIL DRAIN HOSE

1. Connect the oil drain hose using two new sealing washers on the oil drain hose hollow bolt fitting.
2. Torque the oil drain hose hollow bolt.

Description	Nm	lb. in.	lb. ft.
Oil drain hose hollow bolt	16.7	147	–

3. Install the protective rubber sleeve and J-clip around the oil drain hose.

4. Attach the J-clip and oil drain hose to the gear lube monitor bracket. Torque the oil drain hose J-clip flange nut and bolt securely.



a - Oil drain hose hollow bolt with sealing washers
b - Flange nut and bolt
c - J-clip
d - Gear lube monitor bracket
e - Oil drain hose

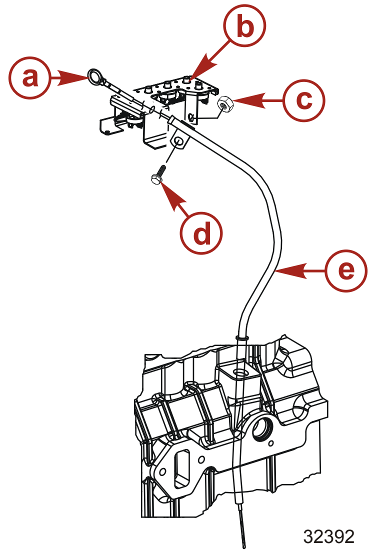
Description	Nm	lb. in.	lb. ft.
Oil drain hose J-clip flange nut	24.5	–	18

OIL DIPSTICK AND TUBE

1. Apply sealant to the lower end of the dipstick tube that fits into the engine block.

Tube Ref No.	Description	Where Used	Part No.
116	RTV 587 Ultra Blue Silicone Sealer	Lower end of the dipstick tube	92-809825

2. Hand press the dipstick tube into the engine block.



a - Oil dipstick
b - Circuit breaker panel
c - Nut
d - Bolt
e - Dipstick tube

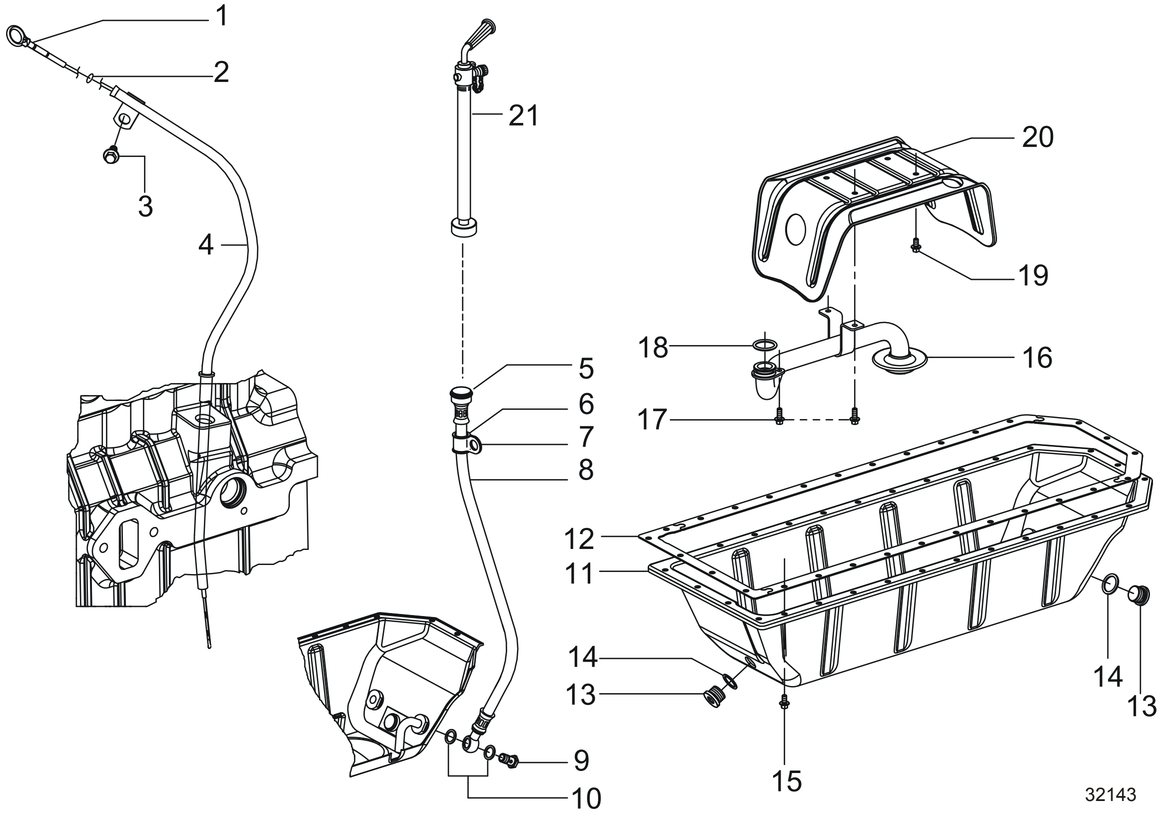
3. Wipe off excess sealant.
4. Attach the dipstick tube to the circuit breaker panel.
5. Torque the dipstick tube flange nut.

Description	Nm	lb. in.	lb. ft.
Dipstick tube flange nut	24.5	–	18

6. Install the oil dipstick.

4.2 Oil Pan, Oil Pickup, and Related Components

Exploded View—4.2 Oil Pan and Related Components



Exploded View—4.2 Oil Pan and Related Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Dipstick			
2	1	O-Ring			
3	1	Screw	12.7	112	–
4	1	Dipstick tube			
5	1	Cap, oil extraction hose			
6	1	Sleeve			
7	1	J-clip			
8	1	Oil extraction hose			
9	1	Hollow bolt	16.7	148	–
10	2	Sealing washer			
11	1	Oil Pan			
12	1	Oil pan gasket			
13	2	Drain plug	37.3	–	28
14	2	Sealing washer			
15	21	Oil pan screw	12.7	112	–
16	1	Oil pickup assembly			
17	2	Screw, M8 x 50 mm	32.4	–	23
18	1	O-ring seal			
19	2	Bolt	12.7	112	–
20	1	Deflector			
21	1	Oil extraction pump (accessory component)			

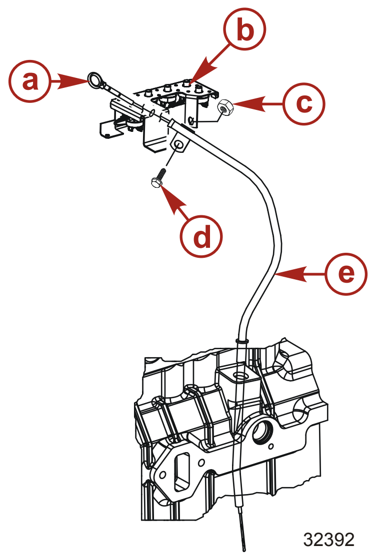
Removal

OIL DIPSTICK AND TUBE

1. Remove the oil dipstick.
2. Remove the dipstick tube nut and bolt from the circuit breaker panel.

NOTE: *The engine oil dipstick tube interference fits into the engine block and is held in place by sealant. Moderate twisting of the oil dipstick tube will break sealant adhesion and ease removal.*

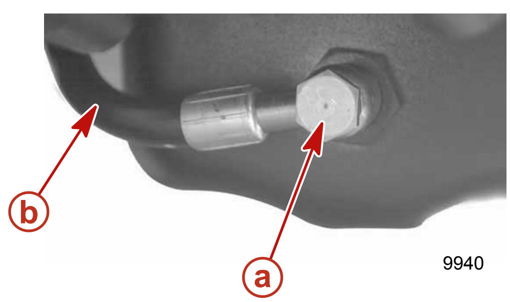
3. Remove the dipstick tube.



a - Oil dipstick
b - Circuit breaker panel
c - Nut
d - Bolt
e - Dipstick tube

OIL DRAIN HOSE

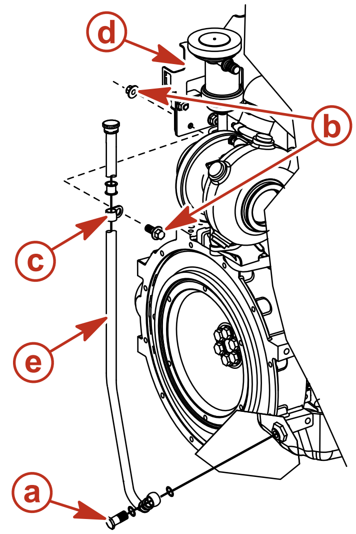
1. Drain or pump the oil out of the engine. See the **Maintenance** section.
2. Remove the hollow bolt with sealing washers and disconnect the oil drain hose from the oil pan.



a - Hollow bolt with sealing washers
b - Oil drain hose

3. Remove the J-clip flange nut and bolt from the gear lube monitor bracket.

4. Remove the oil drain hose.

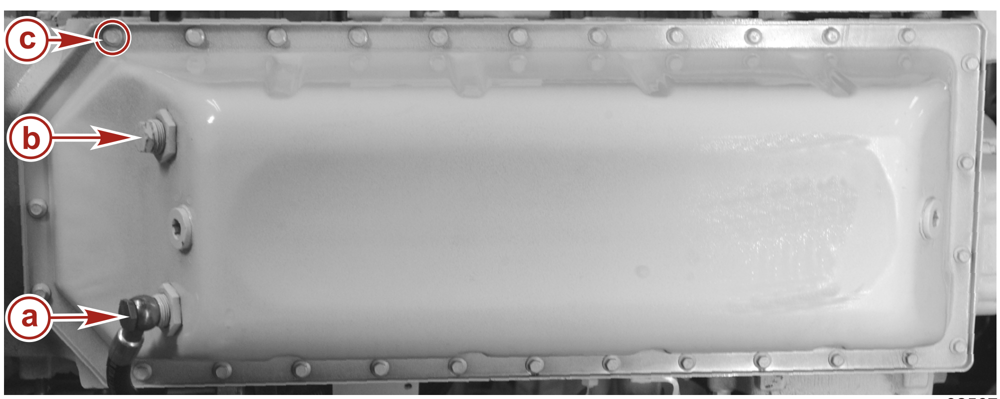


16217

a - Hollow bolt with sealing washers
b - Flange nut and bolt
c - J-clip
d - Gear lube monitor bracket
e - Oil drain hose

OIL PAN

1. Drain or pump the oil out of the engine. Refer to the **Maintenance** section.
2. Remove the oil drain hose from the oil pan



32567

a - Oil drain hose fitting
b - Oil drain plug
c - Oil pan screw

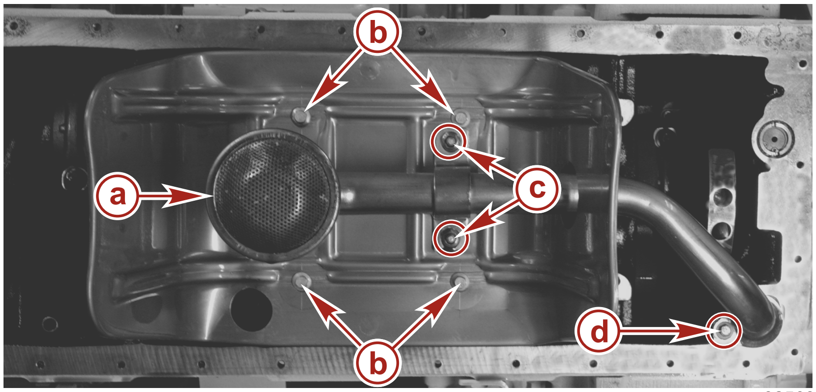
.

3. Remove the oil pan screws.
4. Remove the oil pan.

OIL PICKUP

NOTE: *The Oil pickup tube and strainer is attached to the oil splash shield with 2 nuts and bolts. To simplify installation, remove the oil pickup and splash shield as an assembly unless component replacement is necessary.*

1. Remove the oil pickup tube to block mounting screw.

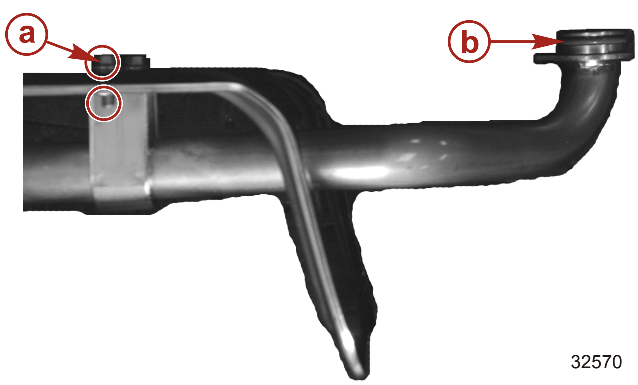


32568

a - Oil pickup strainer
b - Oil splash shield mounting screws
c - Oil strainer mounting screws
d - Oil pickup tube to block screw

NOTE: *The oil pickup tube is fitted into the block with an o-ring seal. Pull the oil pickup tube straight out from the block when removing.*

2. Remove the oil splash shield mounting screws.
3. Remove the oil pickup tube and strainer, and oil splash shield assembly.
4. Remove the old oil pickup tube O-ring.



32570

a - Nut and bolt
b - O-ring

5. If component replacement is necessary, remove the nuts and bolts attaching the oil pickup to the splash shield.

Cleaning

1. Clean the cylinder block bolt holes to ensure that no dirt or oil remain.
2. Clean the sealer from cylinder block and oil pan flange sealing surfaces.
3. Wash the non-rubber parts in cleaning solvent (rubber parts can be damaged by cleaning solvents).

4. Put on safety glasses and dry the parts with compressed air, including the cylinder block bolt holes.
5. Clean the pick up tube seat in the cylinder block.
6. Clean the dipstick tube seat in the cylinder block.

Inspection

1. Inspect the components for fatigue cracks or damage.
2. Check all welds for leaks.
3. Replace parts if necessary.

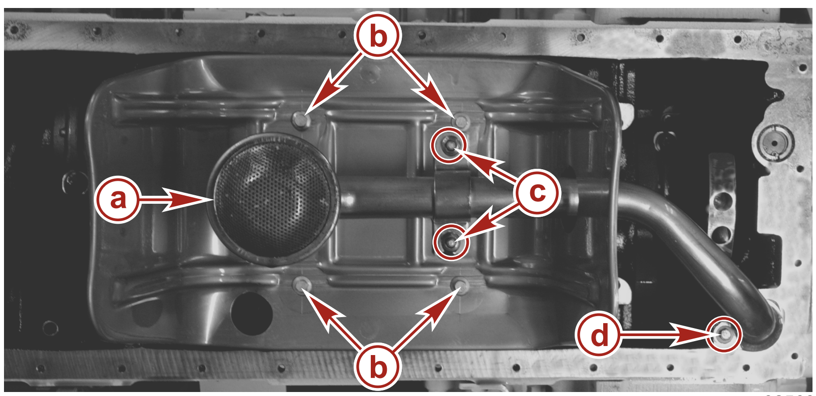
Installation

OIL PICKUP

1. Replace the oil pickup tube O-ring.
2. Lubricate the oil pickup tube O-ring.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Oil pickup tube O-ring	Obtain Locally

3. Install the oil pickup tube and strainer.



32568

a - Oil pickup strainer
b - Oil splash shield mounting screws
c - Oil strainer mounting screws
d - Oil pickup tube to block screw

4. Install the oil pickup tube and strainer screws.
5. Torque the oil pickup tube and strainer screws.

Description	Nm	lb. in.	lb. ft.
Oil pickup tube screw	12.7	112	–
Oil strainer screw	32.4	–	23

OIL PAN

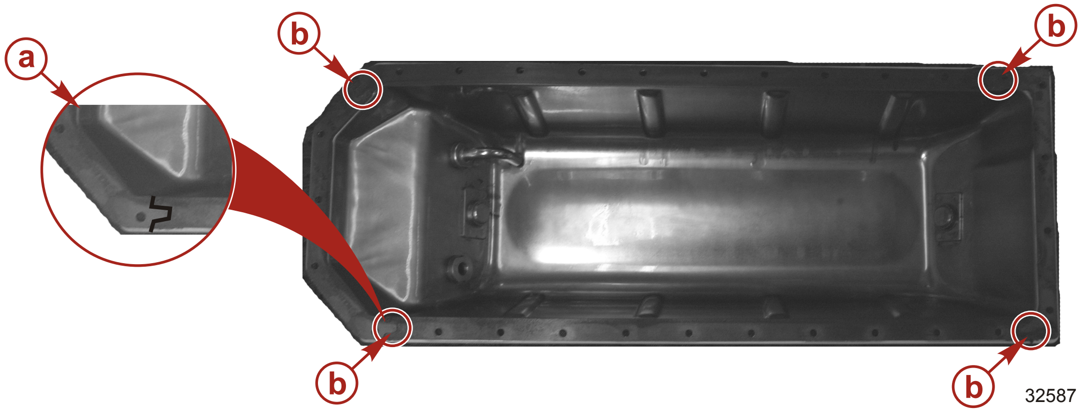
1. Inspect both the cylinder block and oil pan mating surfaces for oil , solvent, old sealant, old gasket material, or any foreign material. Clean as necessary.

NOTE: The oil pan gasket is composed of four separate pieces. Sealant is applied at the gasket joints to prevent leaking.

2. Set the oil pan gasket pieces on the oil pan or the engine block (engine inverted) and note the location of the gasket joints.

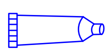
IMPORTANT: Excessive sealant can clog the pickup strainer, restricting oil flow and damaging the engine. Apply the minimum effective amount of sealant during installation.

3. Apply a 6 mm (1/8 in.) bead of sealant across the sealing surface at each oil pan gasket joint.

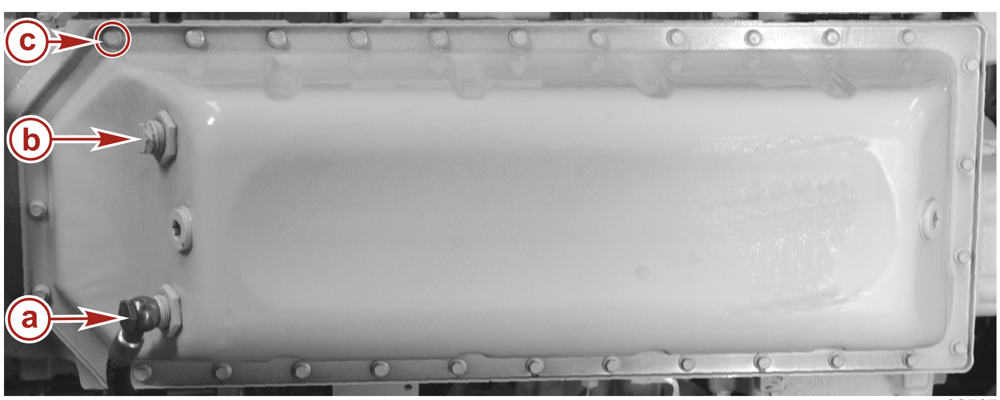


32587

a - Gasket joint detail
b - Sealant application points

Tube Ref No.	Description	Where Used	Part No.
	Dow Corning 7091 Adhesive Sealant	Oil pan gasket joints	Obtain Locally

4. Inspect oil pan gasket alignment and adjust as necessary.
5. Install the oil pan.
6. Install oil pan screws finger tight.



32567

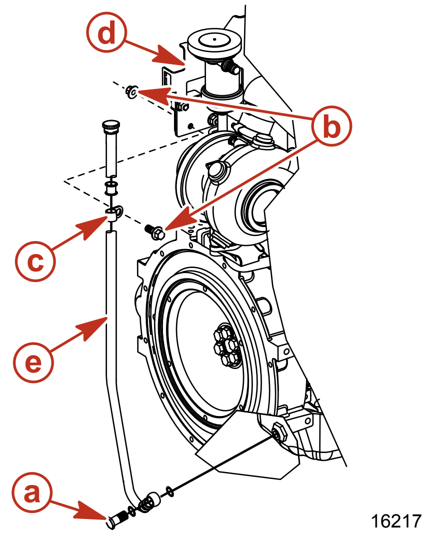
a - Oil drain hose fitting
b - Oil drain plug
c - Oil pan screw

7. Torque the oil pan screws in a diagonal pattern.

Description	Nm	lb. in.	lb. ft.
Oil pan screw	12.7	112	–

OIL DRAIN HOSE

1. Connect the oil drain hose using two new sealing washers on the oil drain hose hollow bolt.



a - Oil drain hose hollow bolt with sealing washers
b - Flange nut and bolt
c - J-clip
d - Gear lube monitor bracket
e - Oil drain hose

2. Position the hose fitting and torque the oil drain hose hollow bolt.

Description	Nm	lb. in.	lb. ft.
Oil drain hose hollow bolt	16.7	147	–

3. Install the protective rubber sleeve and J-clip around the oil drain hose.
4. Attach the J-clip and oil drain hose to the gear lube monitor bracket.
5. Torque the oil drain hose J-clip flange nut and bolt.

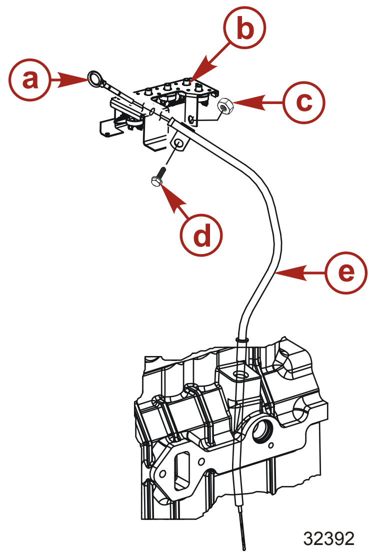
Description	Nm	lb. in.	lb. ft.
Oil drain hose J-clip flange nut	24.5	–	18

OIL DIPSTICK AND TUBE

1. Apply sealant to the lower end of the dipstick tube that fits into the engine block.

Tube Ref No.	Description	Where Used	Part No.
116	RTV 587 Ultra Blue Silicone Sealer	Lower end of the dipstick tube	92-809825

2. Hand press the dipstick tube into the engine block.



a - Oil dipstick
b - Circuit breaker panel
c - Nut
d - Bolt
e - Dipstick tube

3. Wipe off excess sealant.
4. Attach the dipstick tube to the circuit breaker panel.
5. Torque the dipstick tube flange nut.

Description	Nm	lb. in.	lb. ft.
Dipstick tube flange nut	24.5	–	18

6. Install the oil dipstick.

Oil Pressure Relief Valve

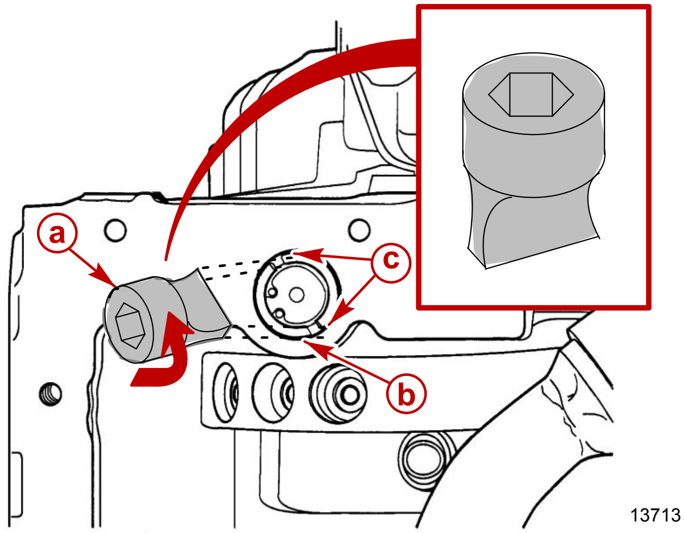
The oil pressure relief valve (oil pressure regulator valve) is installed vertically in the underside of the crankcase.

Removal

1. Remove the oil pan.
2. Clean any old gasket material from the area around the relief valve.
3. **If removing only the relief valve and spring (or springs)**: proceed to **Disassembly**. Observe all precautions and perform all steps except step 1.

4. **If removing the complete pressure relief valve assembly**:
   a. Unscrew the oil pressure relief valve assembly from the crankcase using a suitable tool. The tool should engage the 2 slots opposite each other on the edge of the valve assembly.

NOTE: Locking compound is used during installation of the oil pressure relief valve assembly. The area around the assembly may need to be heated to aid in removal.



Typical

a - Example of suitable tool
b - Valve assembly
c - Slots

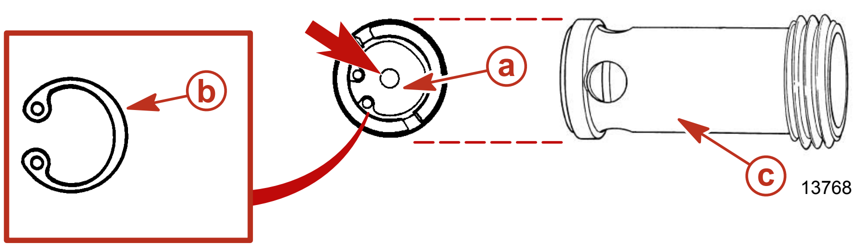
   b. Remove the pressure relief valve assembly from the crankcase.
   c. Proceed to **Disassembly**.

Disassembly

1. If the complete assembly was removed, lock the pressure relief valve assembly in a soft-jawed vise. .

⚠ CAUTION
A sudden release of the oil pressure relief valve assembly can cause injury. The relief valve cap and high pressure spring are retained by a snap-ring. Remove the snap ring with caution and release spring pressure slowly and wear protective eye equipment to prevent injury.

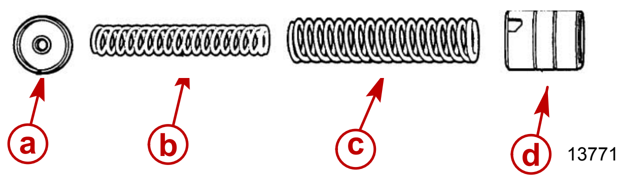
2. Push the cap in against the high pressure spring and hold. Remove snap-ring.
3. Release spring pressure slowly.



a - Cap
b - Snap-ring
c - Valve body

4. Remove the cap, springs and relief valve from the bore of the valve body.

NOTE: Some oil pressure relief valves have only one spring.



a - Cap
b - Spring (inner, if equipped with dual springs)
c - Spring (outer, if equipped with dual springs)
d - Relief valve

Cleaning

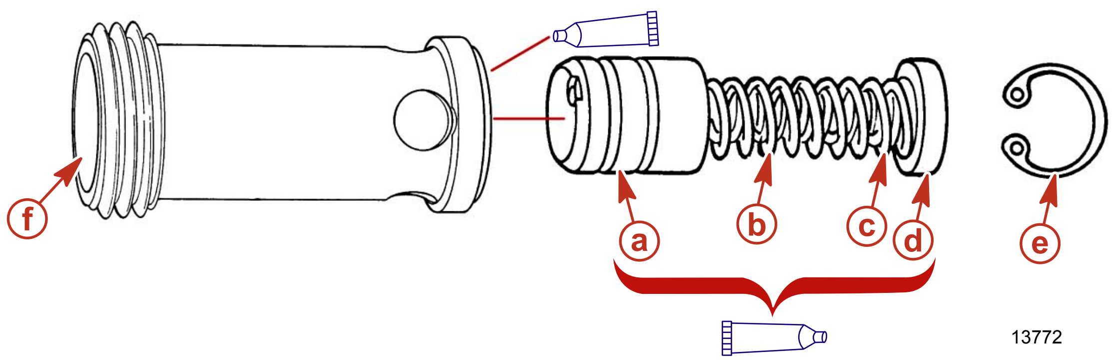
1. Clean any gasket sealing material from the cylinder block and oil pan flanges.
2. Wash all parts in cleaning solvent.
3. Put on safety glasses and dry the parts with compressed air.

Inspection

1. Replace the complete oil pressure valve assembly if the spring is broken.
2. Replace the complete valve assembly if the valve is badly worn or sticking in the bore.
3. Check the valve and seat to determine if pressure could be restored by lapping the valve into the seat using a grinding paste.
4. Ensure that the valve slides freely in the valve seat and valve body when coated with oil.

Assembly

1. Coat the inside of the oil pressure relief valve seat and body bore with lubricant. Liberally coat the remaining components.
2. Assemble the valve, springs, and cap. Install the parts into the valve seat and body.



a - Relief valve
b - Spring (inner, if equipped with dual springs)
c - Spring (outer, if equipped with dual springs)
d - Cap
e - Snap-ring
f - Valve seat and body

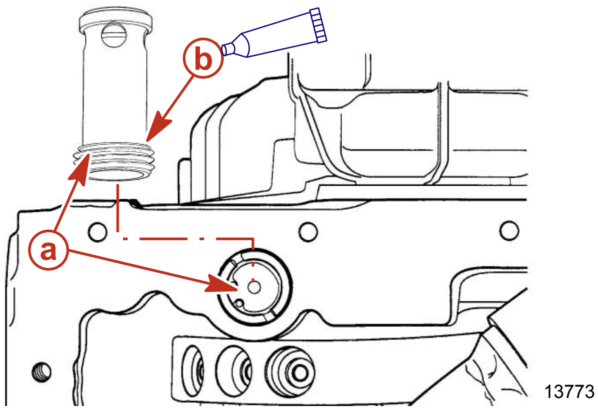
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Inside of oil pressure relief valve seat and body bore and components	Obtain Locally

3. Push the cap in against the high-pressure spring and hold.

4. Install the snap-ring.

Installation

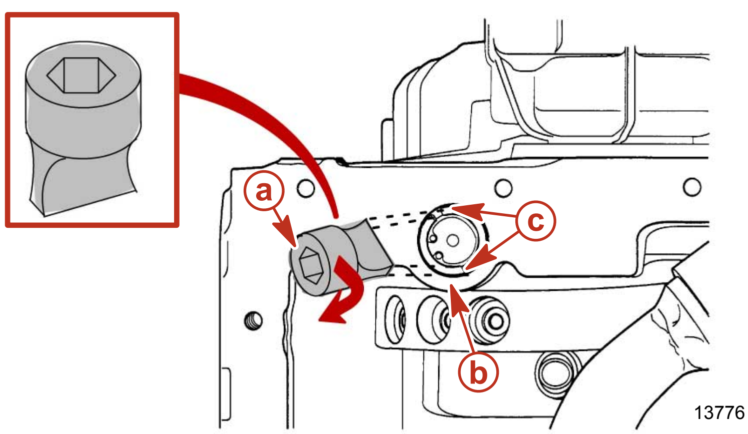
1. **If installing only the oil pressure relief valve and spring, or springs**: see **Assembly**. Observe all precautions and perform all steps with the valve body still in the crankcase.
2. **If installing the complete oil pressure relief valve assembly**:
   a. Apply sealant to the threads when replacing the complete oil pressure relief valve assembly. Screw the complete assembly into the crankcase.



a - Oil pressure relief valve assembly **b -** Threads

Tube Ref No.	Description	Where Used	Part No.
66	Loctite 242 Threadlocker	Oil pressure relief valve assembly threads	92-809821

   b. Using a suitable tool, torque the oil pressure relief valve assembly into the crankcase.



Typical

a - Example of suitable tool **c -** Slots
b - Oil pressure relief valve assembly

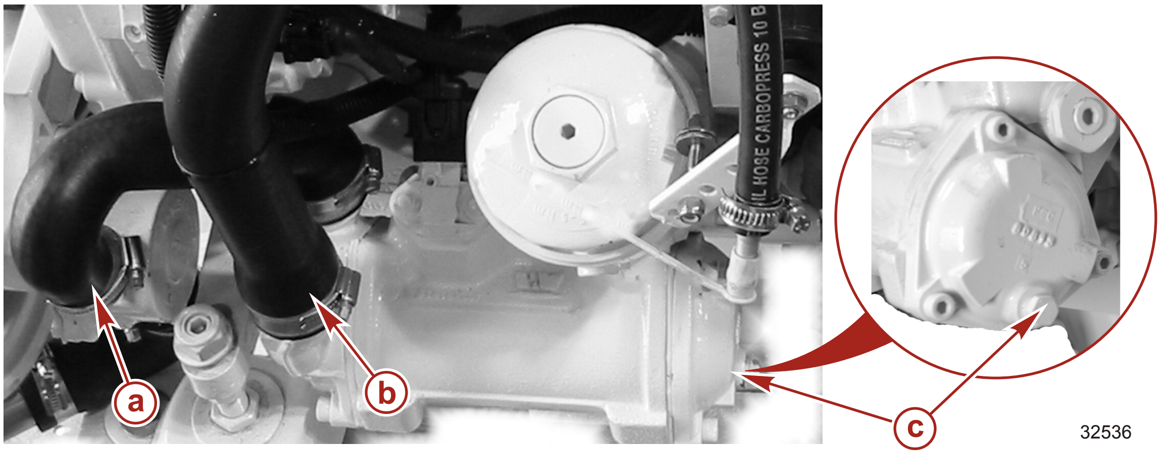
Description		Nm	lb. in.	lb. ft.
Oil pressure relief valve assembly	M27 x 2.5	53.9		39

3. Install the oil pan and related hardware.
4. Check for leaks when you start the engine.

Oil Filter and Oil Cooler Assembly

Removal

1. If the boat is to remain in the water, close the seacock (if equipped) or disconnect and plug the seawater inlet hose.
2. Drain the seawater from the cooling system.
3. Remove the seawater pump outlet hose to the oil cooler assembly.



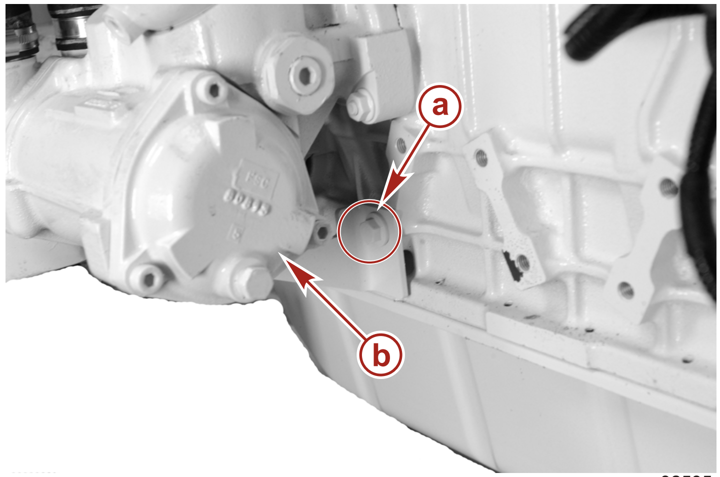
a - Seawater pump outlet hose
b - Oil cooler seawater outlet hose
c - Drain plug

4. Disconnect the oil cooler seawater outlet hose from the oil cooler assembly.
5. Remove the drain plug from the aft end cover of the oil cooler.

NOTICE
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

6. Unscrew and remove the oil filter assembly.

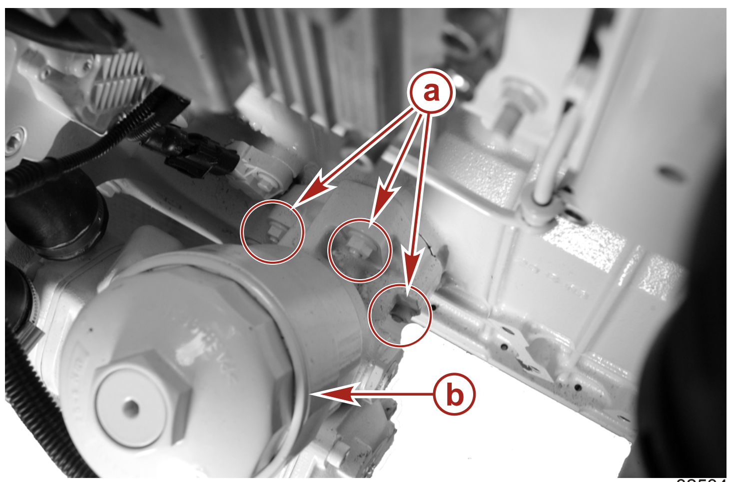
7. Remove the screw (under the oil cooler assembly) that holds the support bracket to the cylinder block.



32535

a - Support bracket screw
b - Oil cooler

8. Remove the three flange nuts holding the oil cooler header to the cylinder block.



32534

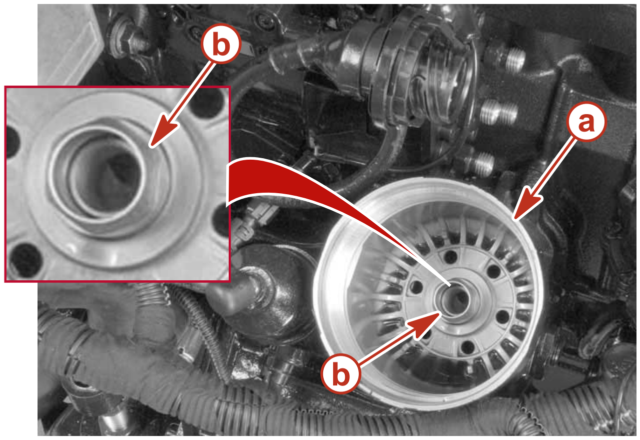
a - Flange nuts
b - Oil filter housing

9. Remove the oil cooler assembly and O-ring seal.
10. Remove the screw that fastens the support bracket to oil cooler and remove the support bracket.

Disassembly

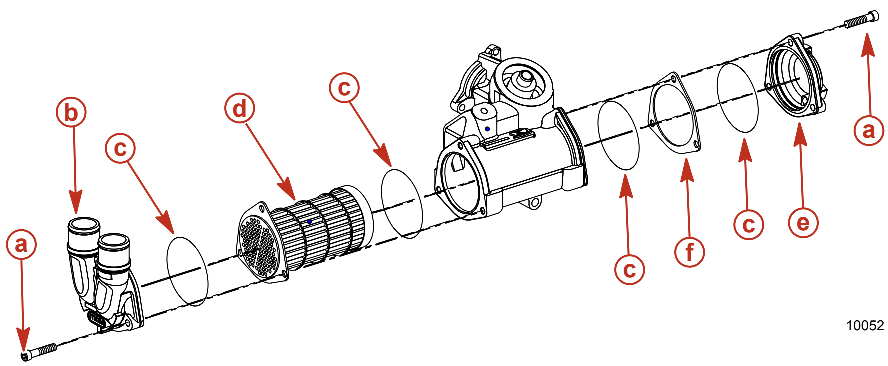
1. Remove the oil thermostat and sealing washer.

2. Loosen the special retaining nut and remove the oil filter housing from the oil cooler assembly.



a - Oil filter housing
b - Special retaining nut

3. Remove the oil cooler front cover screws.
4. Remove the oil cooler front cover and O-ring.
5. Remove the oil cooler rear cover screws.
6. Remove the oil cooler rear cover. Note the position of the first O-ring, gasket and second O-ring.
7. Slide the oil cooler insert out the front of the oil cooler. Note the position of the O-ring.



a - Screw
b - Oil cooler front cover
c - O-ring
d - Oil cooler insert
e - Oil cooler rear cover
f - Gasket

Cleaning And Inspection

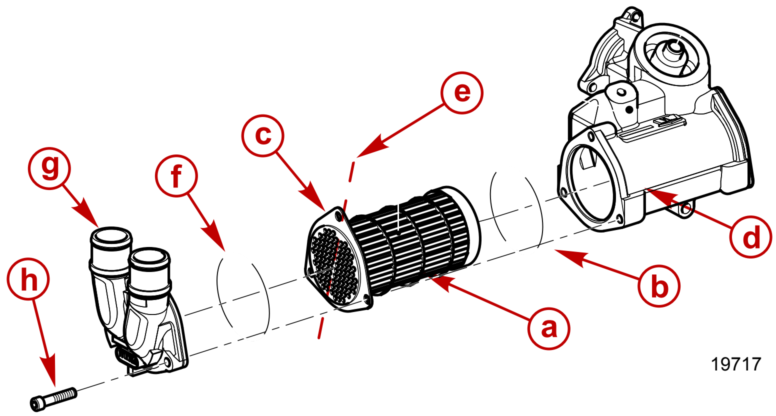
1. Clean the old gasket material and sealant from the flanges. Do not nick or gouge the surfaces which would cause oil or seawater leaks.
2. Use an appropriate rod to clean out the insert tubes, or take the insert to a radiator shop for cleaning.
3. Inspect each part for cracks or other damage which would render it unserviceable.
4. Clean and paint exterior surfaces as required to prevent corrosion.
5. Clean the cylinder block mounting surface.

Assembly

IMPORTANT: Do not roll or twist the 0-rings when installing around the oil cooler insert.

1. Install the O-ring against the front flange of the oil cooler insert.

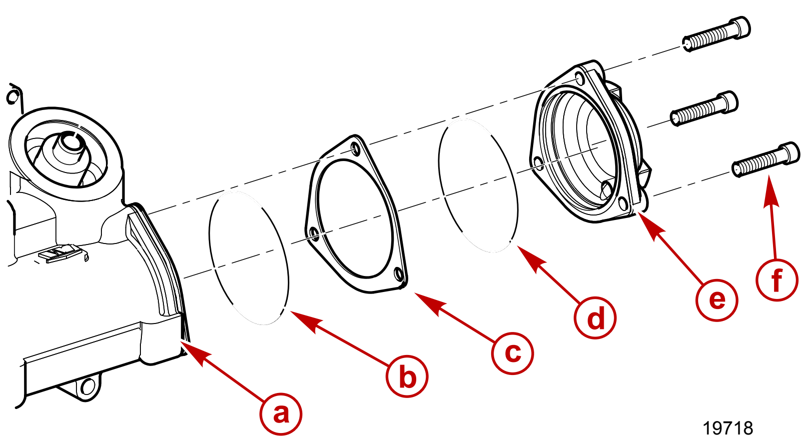
2. Slide the oil cooler insert into the front of the oil cooler.
3. Align the insert passages as shown.
4. Place the O-ring into the groove on the oil cooler front cover.
5. Install the oil cooler front cover. Torque the oil cooler front cover screws.



a - Oil cooler insert
b - O-ring
c - Front flange
d - Oil cooler
e - Passage alignment reference
f - Front cover O-ring (for groove of front cover)
g - Oil cooler front cover
h - Oil cooler front cover screw

Description	Nm	lb. in.	lb. ft.
Oil cooler front cover screw	24.5	–	18

6. Install the O-ring around the oil cooler insert and against the rear of the oil cooler.
7. Install the plate around the oil cooler insert.
8. Install the second O-ring around the oil cooler insert and against the plate.
9. Install the oil cooler rear cover. Torque the oil cooler rear cover screws.



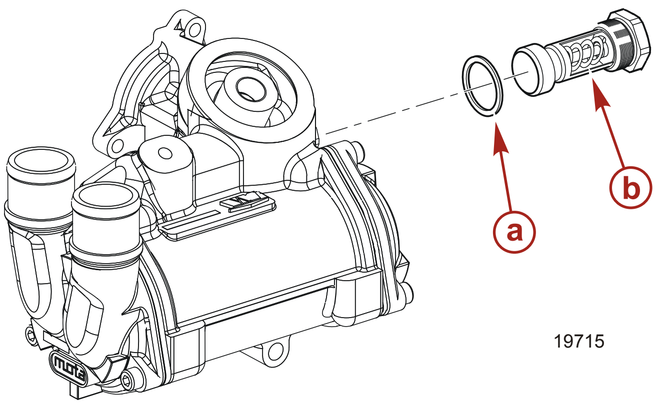
a - Oil cooler
b - O-ring
c - Plate
d - O-ring
e - Oil cooler rear cover
f - Oil cooler rear cover screw

Description	Nm	lb. in.	lb. ft.
Oil cooler rear cover screws	24.5	–	18

10. Apply sealant to the threads of the oil thermostat.

Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	Oil thermostat threads	92-809822

11. Install the oil thermostat using a new sealing washer. Torque the oil thermostat.

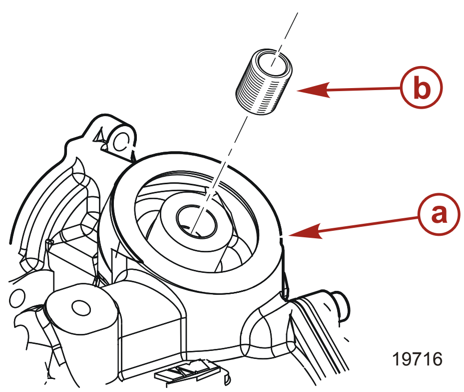


a - Sealing washer

b - Oil thermostat

Description	Nm	lb. in.	lb. ft.
Oil thermostat	88.3	–	65

12. If the oil cooler header (housing) was replaced, install the oil filter assembly threaded fitting.



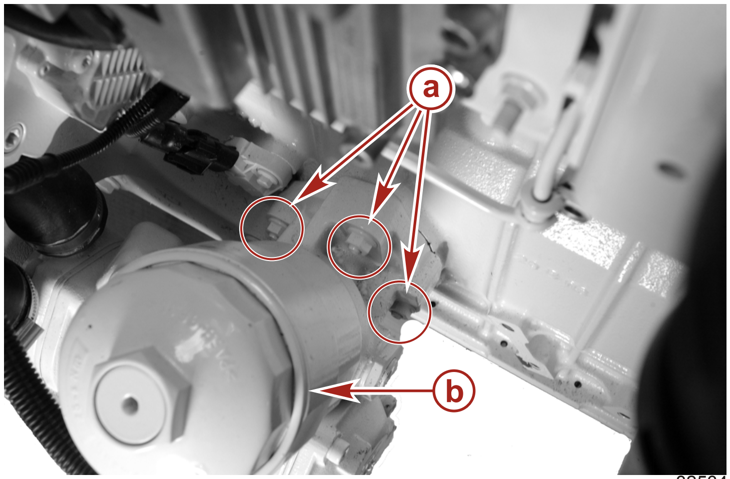
a - Oil cooler assembly

b - Oil filter assembly threaded fitting

Installation

1. Install a new O-ring in the groove on the oil cooler header (housing).

2. Attach the oil cooler assembly to the cylinder block.



a - Flange nuts
b - Oil filter housing

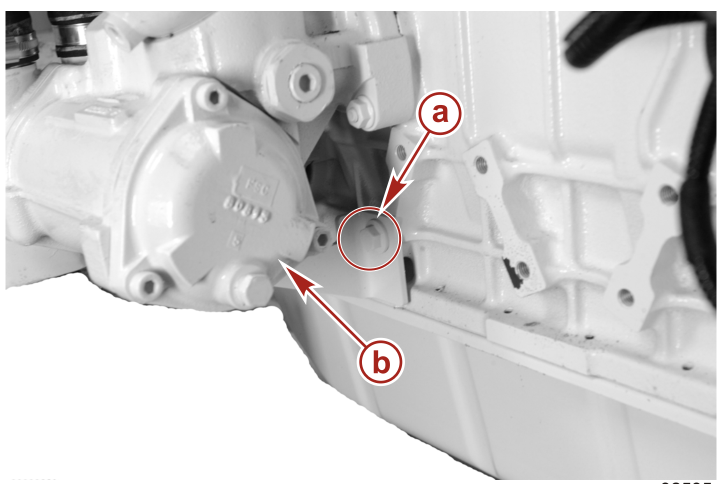
3. Torque the three flange nuts.

Description	Nm	lb. in.	lb. ft.
Oil cooler to cylinder block flange nuts	24.5	–	18

4. Hold the support bracket firmly up and against the oil cooler assembly and install and torque the support bracket to oil cooler assembly screw.

Description	Nm	lb. in.	lb. ft.
Support bracket to oil cooler screw	24.5	–	18

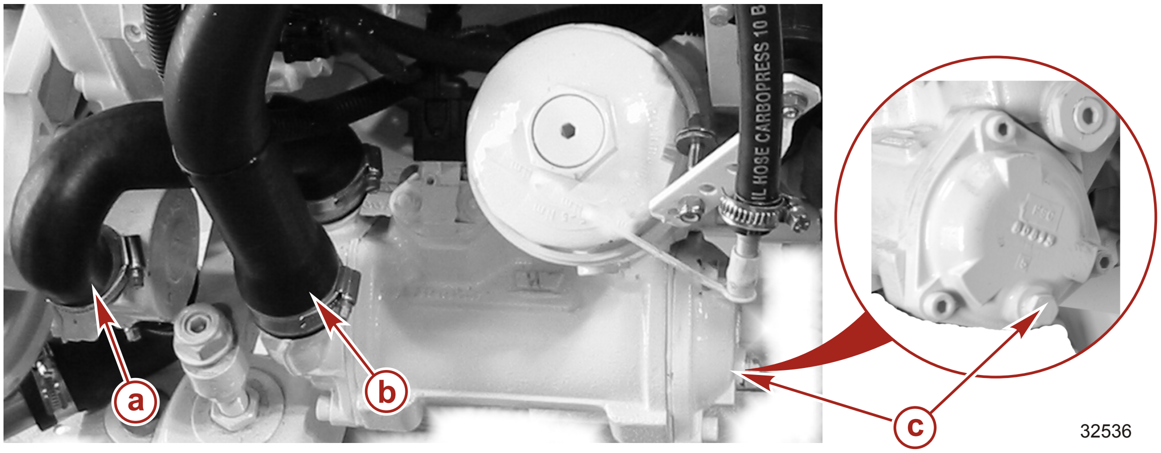
5. Install and torque the support bracket to cylinder block screw.



a - Support bracket screw
b - Oil cooler

Description	Nm	lb. in.	lb. ft.
Support bracket to cylinder block screw	24.5	–	18

6. Install the seawater pump outlet hose to the oil cooler assembly.



a - Seawater pump outlet hose
b - Oil cooler seawater outlet hose
c - Drain plug

7. Connect the oil cooler seawater outlet hose.
8. Install the oil filter assembly.
9. Apply sealant to the threads and install the drain plug in the oil cooler rear cover. Torque the drain plug.

Description	Nm	lb. in.	lb. ft.
Drain plug	19.6	173	–

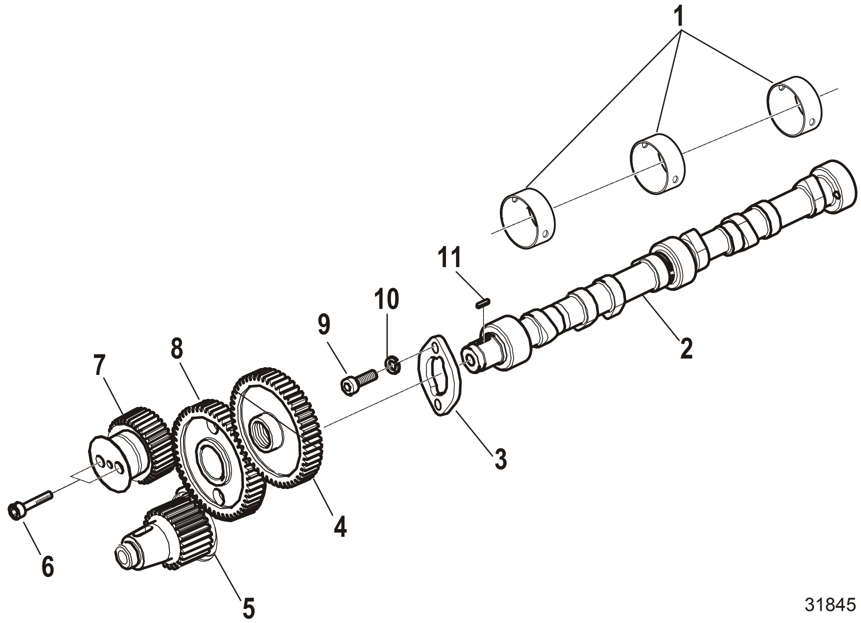
Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	Oil cooler seawater drain plug	92-809822

10. Before first starting the engine, open the seacock if equipped, or unplug and connect the seawater inlet hose.

Notes:

Camshaft

Exploded View—Camshaft



Exploded View—Camshaft

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	3	Bearings			
2	1	Camshaft			
3	1	Thrust plate			
4	1	Injection pump gear			
5	1	Crankshaft gear			
6	2	Idler gear bolts	32.4	–	24
7	1	Idler gear assembly			
8	1	Camshaft gear			
9	2	Camshaft thrust plate mounting screw	27.5	–	20
10	2	Lockwasher			
11	1	Key			

NOTE: Exploded view depicts 2.8 engine, 4.2 is similar.

Testing—Measuring Lobe Lift

1. Remove the rocker arm assemblies.
2. Secure the dial indicator to the cylinder head so the dial indicator plunger rests inside the push rod cup.

Dial Indicator	91-58222A1

3. Turn the crankshaft so that the camshaft lobe is at the bottom of its travel.
4. Set the dial indicator to "0" (zero).
5. Turn the crankshaft two complete revolutions while reading the dial indicator.
6. Measure all lobes of camshaft in the same manner.

IMPORTANT: Camshaft replacement will be necessary if the lobe dimensions are less than the values specified in the following table under Service Limit.

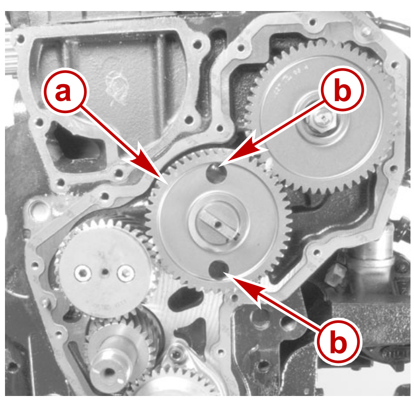
Camshaft			
Lobe lift	Production	Exhaust	7.303 mm (0.2875 in.)
		Intake	6.850 mm (0.2697 in.)
	Service Limit	Exhaust	7.253 mm (0.2855 in.)
		Intake	6.800 mm (0.2677 in.)

Removal

1. Turn the crankshaft to cylinder number 1 TDC of its compression stroke.
2. Remove the timing cover.
3. Remove the mechanical fuel supply pump.

IMPORTANT: Place rocker arm assemblies, valve push rods, and lifters in a rack for reassembly in their original locations.

4. Remove the rocker arm assemblies and valve push rods.
5. Remove the valve roller lifters.
6. Remove the oil level dipstick.
7. Remove the two screws and lockwashers mounting the camshaft thrust plate on the engine block.



16724

a - Camshaft gear

b - Camshaft thrust plate mounting screw with lockwasher

8. Carefully withdraw the camshaft. Take care not to damage the camshaft bearings.
9. Remove the idler gear assembly if complete engine disassembly is required, or if the idler gear assembly is worn or damaged. See **Idler Gear** for procedures.

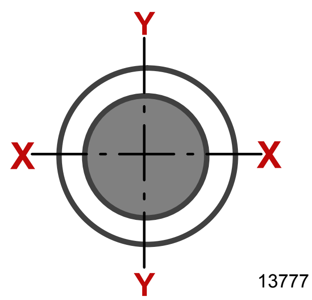
Inspection

GENERAL

1. Inspect the contact surfaces of the valve lifters and pushrods for wear or damage.
2. Inspect the camshaft bearings for wear or damage.
3. Check the camshaft and the gear for wear or damage.
4. Check the idler gear assembly for wear or damage..
5. Replace any worn or damaged components.

CAMSHAFT JOURNAL DIAMETER

1. Use a micrometer to measure each camshaft journal diameter in two directions ("X-X") and ("Y-Y"). If the measured value is less than specified, the camshaft must be replaced.

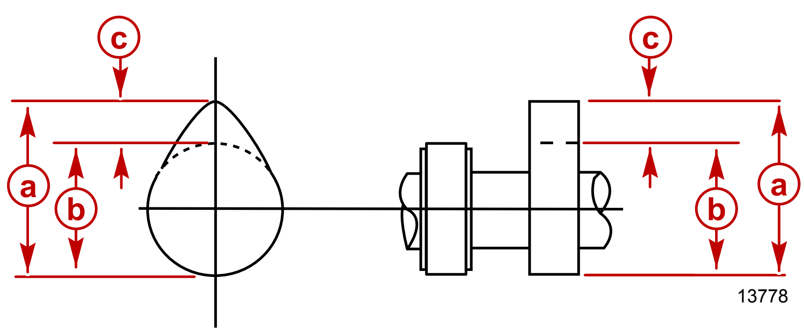


NOTE: Camshaft bearings are available in 0.250 mm (0.0010 in.) undersized.

Camshaft		
Journal diameter	Front	53.495–53.510 mm (2.1061–2.1066 in.)
	Center	53.450–53.470 mm (2.1043–2.1051 in.)
	Rear	53.480–53.500 mm (2.1055–2.1062 in.)

CAMSHAFT HEIGHT

1. Measure the total camshaft height with a micrometer. Subtract the lobe diameter. The difference is lobe lift. If the lobe lift is less than specified, the camshaft must be replaced.



a - Total camshaft height
b - Lobe diameter
c - Lobe lift

Camshaft		
Lobe diameter	Exhaust	38.550–38.650 mm (1.5177–1.5216 in.)
	Intake	39.450–39.550 mm (1.5531–1.5570 in.)
Lobe lift	Exhaust	7.303 mm (0.2875) in.)
	Intake	6.850 mm (0.2697 in.)

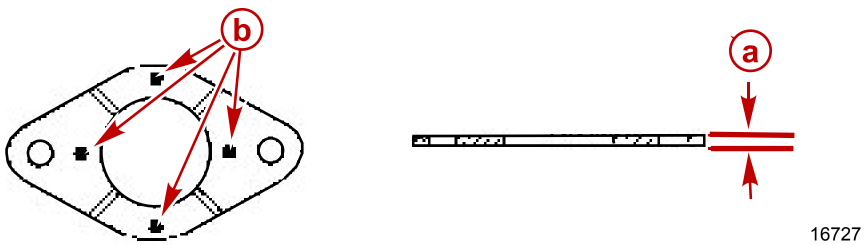
CLEARANCE BETWEEN THRUST PLATE AND CAMSHAFT

1. Measure clearance between thrust plate and camshaft.

Camshaft		
Thrust plate and camshaft clearance	Production	0.030–0.095 mm (0.0012–0.0037 in.)
	Wear limit	0.200 mm (0.0078 in.)

IMPORTANT: The camshaft gear must be pressed onto the shaft of the camshaft. If the camshaft gear is removed, the gear must be heated in an oven to 180-200° C (360-390° F) and pressed on the shaft for reassembly. After installing the proper thrust plate and positioning the key, press the gear until it is tight against the shoulder.

2. If the measured value exceeds specification, remove and inspect the thrust plate thickness at four opposite points. Replace the plate if the assembly clearance is less than specified at any point.



a - Camshaft thrust plate thickness

b - Thickness dimension at four opposite points

Camshaft	
Camshaft thrust plate thickness	3.95–4.05 mm (0.155–0.159 in.)

Installation

1. Install the idler gear, if previously removed. See **Idler Gear**.
2. Lubricate the camshaft lobes with the recommended mixture of 20% SAE 30W engine oil and 80% Needle Bearing Assembly Lubricant, or a mixture of equivalent lubricants.

Tube Ref No.	Description	Where Used	Part No.
4	Needle Bearing Assembly Lubricant	Camshaft lobes (in a specified mixture)	92-802868A1

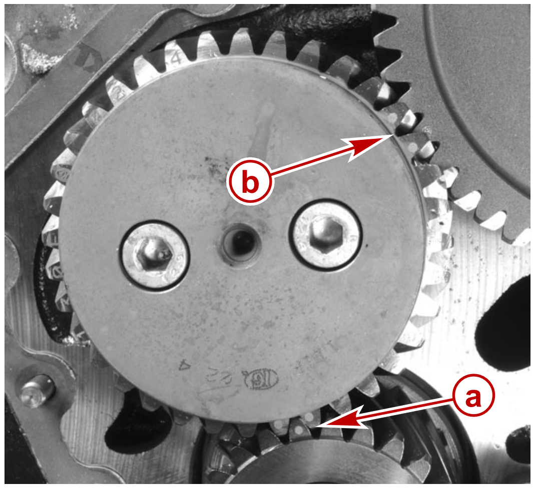
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Camshaft lobes (in a specified mixture)	Obtain Locally

3. Lubricate the camshaft bearings.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Camshaft bearings	Obtain Locally

4. Install the camshaft. Be careful not to damage the bearings.

5. Align the timing marks on camshaft gear and idler gear as shown.

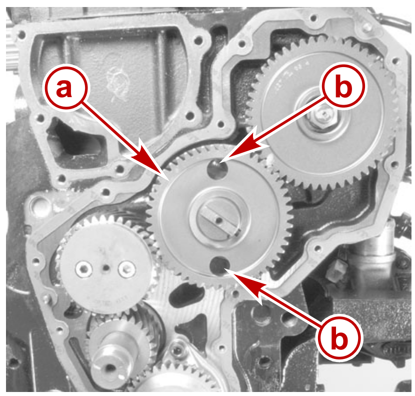


16289

a - Crankshaft and idler gear timing marks aligned

b - Idler gear assembly and camshaft timing marks aligned

6. Install the thrust plate mounting screws using the lockwashers. Torque the screws.



16724

a - Camshaft gear

b - Camshaft thrust plate mounting screw with lockwasher

Description	Nm	lb. in.	lb. ft.
Camshaft thrust plate mounting screw	27.5		20

7. Install all other components removed in the repair process.
8. Check for leaks when you start the engine.

Camshaft Bearings

Inspection

1. Remove the camshaft.
2. Inspect the camshaft bearings. Replace the bearings if they are worn or damaged.
3. Measure the inner diameter of the camshaft bearings and compare to the camshaft journal dimensions. Calculate the bearing clearance.

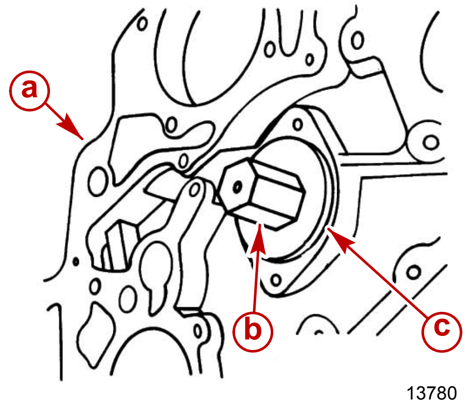
Camshaft		
Bearing clearance	Front	0.030–0.095 mm (0.001–0.0037 in.)
	Center	0.070–0.140 mm (0.0027–0.0055 in.)
	Rear	0.040–0.110 mm (0.0015–0.0043 in.)

4. Replace the camshaft bearings if clearance is not within specifications and camshaft journal diameters are within specifications.
5. Replace the camshaft and the camshaft bearings if lobe lift, journal diameter, or bearing clearance are not within speciofications. See **Section 3A: Engine Specifications**.

Removal

NOTE: Camshaft bearings can only be removed and installed with crankshaft removed.

1. Using the Front Main Bearing and Camshaft Bearing Puller Tool with appropriate hardware, remove the camshaft bearings into the receiver end of the tool (not shown).



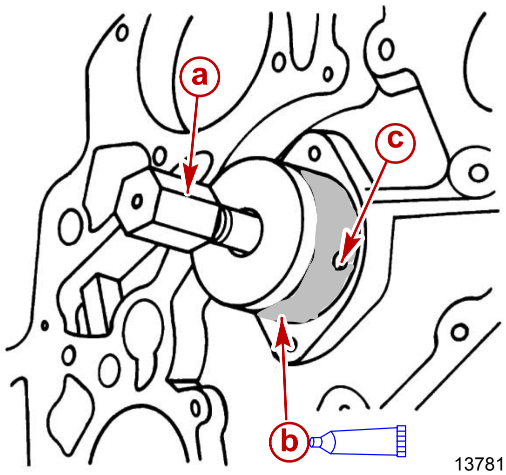
a - Cylinder block
b - Front Main Bearing and Camshaft Bearing Puller Tool
c - Camshaft bearing bore

Front Main Bearing and Camshaft Bearing Puller	**91-801333508**

Installation

1. Clean the camshaft bearing bores in the cylinder block with solvent.
2. Put on safety glasses and blow out the bearing bores with compressed air. Ensure that the drilled oil passages are clean.
3. Lubricate the outer surface of new camshaft bearings to ease installation.
4. Align the camshaft bearing oil supply holes with the drilled oil passages in the cylinder block.

5. Using the Front Main Bearing and Camshaft Bearing Puller Tool with appropriate hardware, install the new camshaft bearings.



a - Special tool
b - Bearing
c - Oil supply hole aligned correctly

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Outer surface of new camshaft bearings	Obtain Locally

Front Main Bearing and Camshaft Bearing Puller	91-801333508

6. Check the position of the oil hole in each bearing and drilling in the block to ensure that the bearings are positioned correctly.
7. Recheck the bearing inner dimensions to verify proper installation.
8. Install the camshaft. See **Camshaft**.
9. Install all other components removed in the repair process.
10. Check for leaks when you start the engine.

Valve Lifters

Important Information

IMPORTANT: Camshafts and valve lifters develop matched wear patterns during engine operation. Changing worn lifter installation location or using worn components with new components can cause rapid and excessive wear resulting in engine component failure. Always use a new camshaft and valve lifters whenever any of the components require replacement.

The hydraulic roller valve lifters are held in position and prevented from rotation by special retainers. Each cylinder head has one retainer. Exercise care when installing the retainers to ensure that the flat portions of the lifters are properly positioned in the retainers.

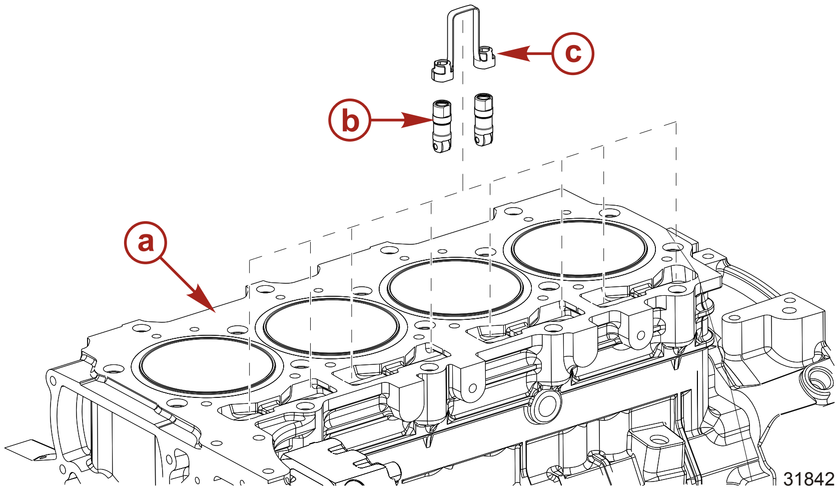
Removal

1. Remove the valve covers. Refer to **Section 3A: Valve Covers**.

IMPORTANT: Organize storage of rocker arm assemblies, pushrods, and valve lifters in sets for reassembly in their original locations.

2. Remove the rocker arm assemblies and valve pushrods. Keep parts in matched sets. Refer to **Section 3A: Rocker Arm**.

3. Remove the cylinder heads. Refer to **Section 3A: Cylinder Heads**.
4. Lift the retainer piece away from around the top of the valve lifters. Do not disturb the valve lifters at this time.



2.8 shown, 4.2 similar

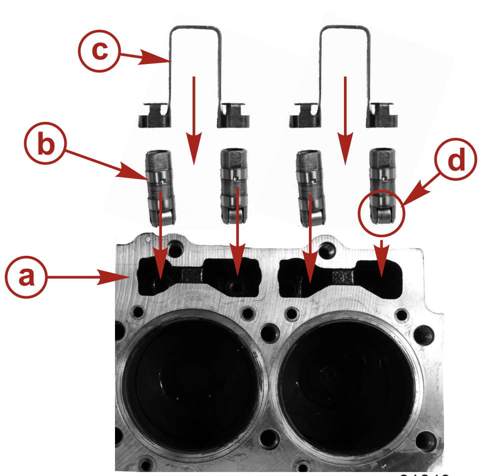
a - Cylinder block
b - Valve lifter
c - Retainer

IMPORTANT: Worn lifters must be installed in their original position and oriented so that the roller will operate in its original direction.

5. Insert the Valve Lifter Tool firmly into the valve lifter. Press downward on the internal spring until the top of the tool is lower than the stop. Turn the tool 90° and remove the valve lifter.

Valve Lifter Tool	91-898282

6. Remove the remaining valve lifters while keeping them organized by installed location and orientation for reassembly.



a - Cylinder block
b - Valve lifter
c - Retainer
d - Roller

Cleaning

1. Except for the valve lifters, clean the parts with cleaning solvent.
2. Put on safety glasses and dry the parts with compressed air.
3. While holding the valve lifters upright wipe them with a clean, oil-saturated, lint-free cloth. Store the lifters upright.

Inspection

1. Inspect the valve push rod seat. If the valve push rod seat is scuffed or worn, inspect the valve push rod.
2. Inspect the outer valve lifter body wall. If the wall is scuffed or worn, inspect the engine block valve lifter bore.
3. Inspect the roller of the valve lifter. If the roller is scuffed or worn, inspect the camshaft lobe.
4. Measure the outer diameter of the valve lifter. If the value is less than specified, replace the valve lifter.

Valve lifter	
Outer diameter	22.195 - 22.212mm (0.8738 - 0.8745 in.)

5. Inspect all parts carefully. If any parts are damaged or worn, the entire valve lifter assembly must be replaced.

Installation

IMPORTANT: Camshafts and valve lifters develop matched wear patterns during engine operation. Changing worn lifter installation location or using worn components with new components can cause rapid and excessive wear resulting in engine component failure. Always use a new camshaft and valve lifter set whenever any of the components require replacement.

IMPORTANT: Before installation, coat the entire valve lifter with engine oil. If installing a new camshaft and valve lifters, coat the valve lifters and camshaft with an oil additive containing EP lube.

1. Drain all of the residual oil in the valve lifter out of the drain hole in the valve lifter by compressing the valve lifter using the Valve Lifter Tool.

Valve Lifter Tool	91-898282

2. **When installing worn components**, coat the entire valve lifter with engine oil.

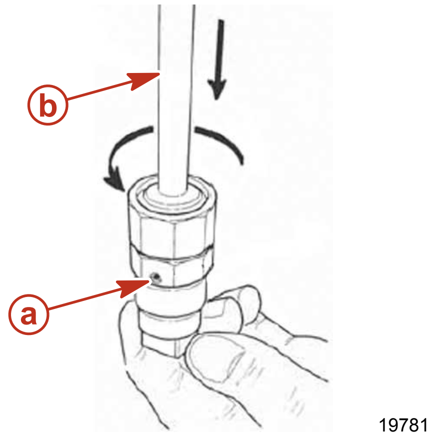
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Valve lifters	Obtain Locally

3. **When installing new components**, coat the valve lifters and camshaft with an oil additive containing EP lube.

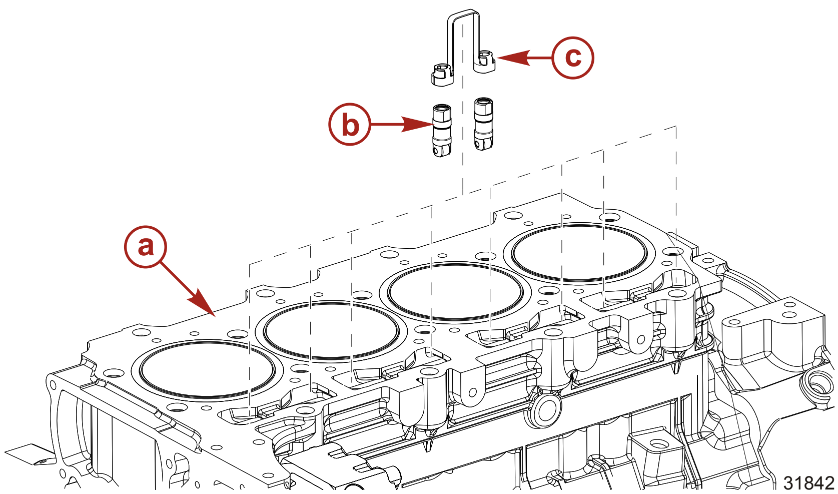
Tube Ref No.	Description	Where Used	Part No.
	Johnson EP Lube, or equivalent	Valve lifters and camshaft lobes - new parts	Obtain Locally

NOTE: Camshafts and valve lifters develop matched wear patterns during engine operation. Changing worn lifter installation location or using worn components with new components can cause rapid and excessive wear resulting in engine component failure.

4. Install the valve lifters in their bores in the order of removal using the Valve Lifter Tool. Align the matching marks made prior to disassembly. Ensure that the valve lifter drain hole is pointing toward the crankshaft.



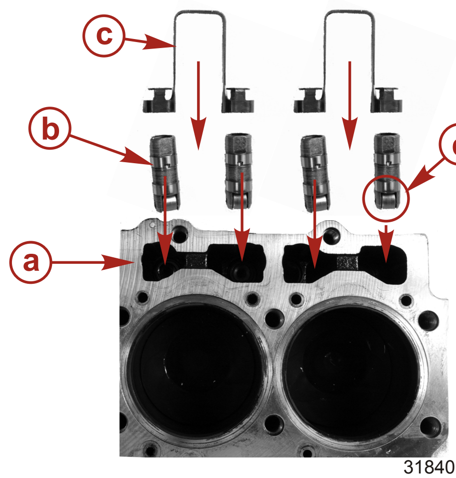
a - Drain hole
b - Valve Lifter Tool



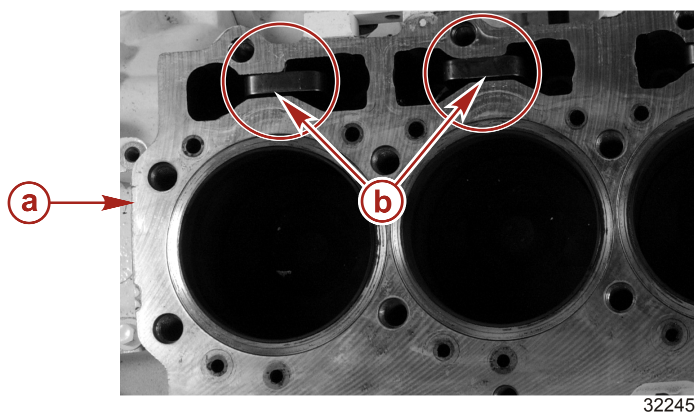
a - Cylinder block
b - Valve lifter
c - Retainer

Valve Lifter Tool	91-898282

5. Install the valve lifter retainers.



a - Cylinder head
b - Valve lifter
c - Retainer
d - Valve lifter roller



a - Cylinder block
b - Installed retainer

6. Lubricate and install the valve pushrods. Ensure that the valve pushrod properly seats in the lifter socket.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Valve lifters	Obtain Locally

7. Install new cylinder head gaskets with the cylinder heads. Refer to **Section 3A: Cylinder Heads**.
8. Install the rocker arm assemblies. Refer to **Section 3A: Rocker Arm**.
9. Install the valve covers. Refer to **Section 3A: Valve Covers**.

IMPORTANT: Engine oil should be changed and a new oil filter be installed whenever servicing valve lifters or camshaft.

10. Change the engine oil and filter.
11. Check for leaks when you start the engine.

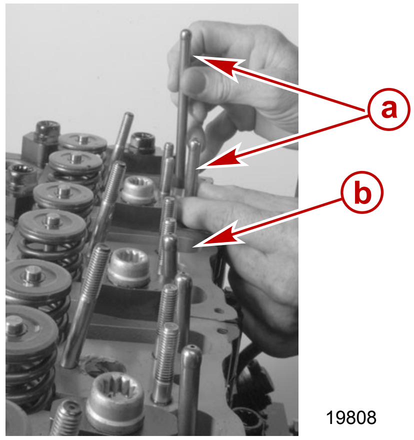
Valve Push Rods

Removal

1. Remove the valve covers.

IMPORTANT: Organize rocker arm assemblies and valve push rods in a rack for reassembly in their original locations.

2. Remove the rocker arm assemblies.
3. Lift the valve push rods from their seat in the valve lifter.



a - Valve push rod **b -** Valve lifter seat (not visible here)

Cleaning

1. Clean the rocker arm assemblies and push rods.
2. Clean the valve push rod oil passages.
3. Put on safety glasses and dry the components with compressed air.

Inspection

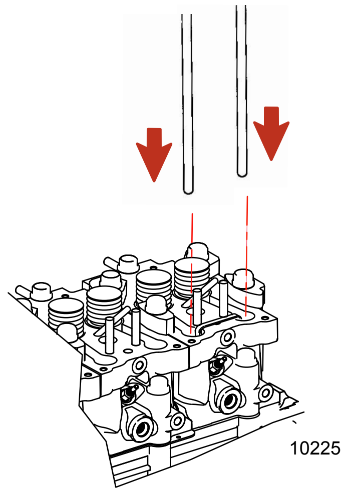
1. Inspect all contact surfaces for excessive wear or scoring.
2. Ensure that the valve push rod oil passage is not restricted.
3. Inspect the shaft for bends by rolling the valve push rod on a flat surface.
4. Replace all damaged parts.

Installation

1. Lubricate the outer surfaces and ends of valve push rods.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Outer surfaces and ends of valve push rods	Obtain Locally

2. Install the valve push rods in their original locations. Ensure that the push rods seat in the valve lifter seat.

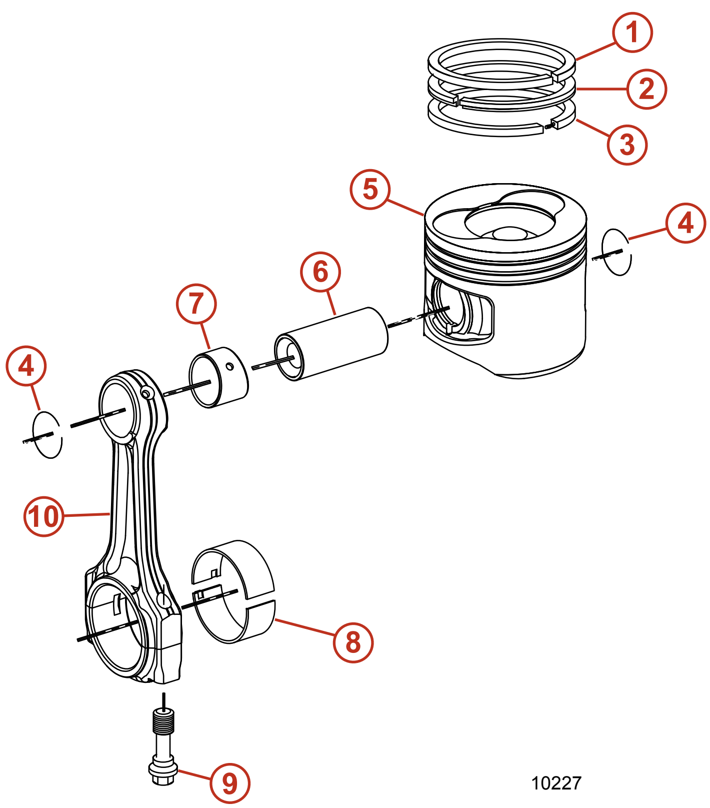


Installing valve push rods

3. Install the rocker arms.
4. Install the valve covers and related components.
5. Check for leaks when you start the engine.

Connecting Rod, Bearings, and Piston Assemblies

Exploded View—Connecting Rod, Bearings, and Piston Assemblies



Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	First compression ring			
2	1	Second (scraper) compression ring			
3	1	Oil control ring			
4	2	Snap ring			
5	1	Piston			
6	1	Piston pin			
7	1	Connecting rod bushing			
8	2	Connecting rod bearing			
9	2	Connecting rod screw	Refer to connecting rod installation procedure.		
10	1	Connecting rod			

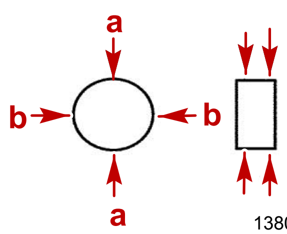
Checking the Connecting Rod Bearing Clearance—Engine Assembled

PREPARATION

1. Remove the oil pan.
2. Remove the oil pickup tube assembly.
3. Remove the balance shaft assembly.
4. Turn the crankshaft to gain access to the connecting rod screws.
5. One cylinder at a time, remove the rod caps and inspect the bearings. See **Bearing Failure**.

CONNECTING ROD JOURNAL DIAMETER

1. Measure the crankshaft connecting rod journal with a micrometer for out of round, taper, or excessive wear. Measure journal diameters at points "a" and "b" on one side of the journal then repeat measurements on the opposite side of the journal.



13800

Connecting Rod Journal	
Journal outside diameter	53.940 - 53.955 mm (2.1236 - 2.1242 in.)
Maximum journal wear	0.1 mm (0.0039 in.)

2. Replace or recondition the crankshaft if any values are less than specified.

CONNECTING ROD BEARING CLEARANCE

1. Ensure that the crankshaft, the connecting rod, the connecting rod cap, and the bearings are clean.
2. Install the bearings onto the connecting rod and the connecting rod cap.

IMPORTANT: Do not allow the crankshaft to move when installing the bearing cap.

3. Prevent the connecting rod from moving. If necessary, remove the starter and install the Flywheel Holder Tool through the starter opening.

Flywheel Holder Tool	91-895472

4. Place a piece of gauging plastic the full width of the crankshaft journal parallel to the crankshaft.
5. Install the connecting rod cap and torque the connecting rod screw.

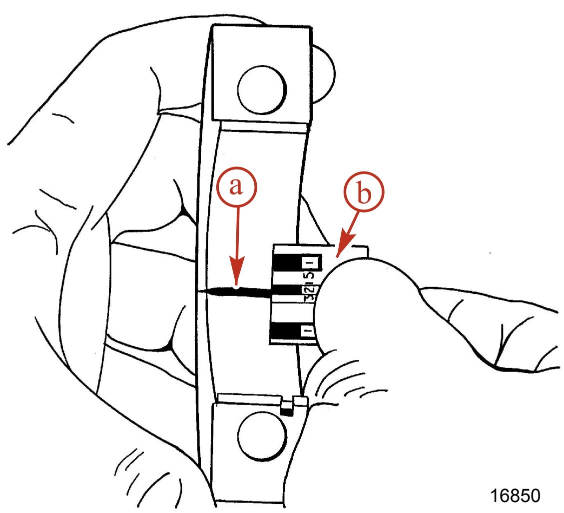
Description		Nm	lb. in.	lb. ft.
Connecting rod screw—after first use	**First pass**	10	88	
	Second pass	30		22
	Final pass (Angle Torque)	+ 40 Degrees		

IMPORTANT: Do not turn the crankshaft while the gauging plastic is in place.

6. Test the torque setting of each connecting rod screw to be no less than the value specified in the following table. This action will verify that the proper torque was achieved. Do not apply more than this specified amount during this validation test.

Description	Nm	lb. in.	lb. ft.
Connecting rod screw torque validation test	88		64

7. Remove the connecting rod cap.
8. The flattened gauging plastic will adhere to either the connecting rod cap or crankshaft journal. Do not remove the gauging plastic.
9. Measure the width of the compressed gauging plastic at the widest point with the graduated scale on the gauging plastic envelope.
10. Compare the measurement to the specification for clearance.



a - Compressed gauging plastic **b -** Graduated scale

Connecting Rod Bearing	
Clearance	0.022–0.076 mm (0.0008–0.0029 in.)

11. If the clearance exceeds specifications, select new bearings of the correct size and determine the clearance.
12. If the clearance is incorrect with the new bearings, recheck the crankshaft journal dimensions.
13. If the clearance is still incorrect, remove the connecting rod and piston assembly and check the dimension of the connecting rod crankshaft journal bore.

14. After obtaining the correct clearance, lubricate the crankshaft journal and connecting rod bearing surfaces and install the connecting rods.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Crankshaft journal and connecting rod bearing surfaces	Obtain Locally

15. Install all other components removed in the repair process.
16. Check for leaks when you start the engine.

Removal

1. Remove the cylinder heads.
2. Remove the oil pan.
3. Remove the oil pickup tube assembly.
4. Remove the balance shaft assembly.
5. Remove any ridge or combustion deposits from the top of the cylinder bore using a ridge reamer.
   a. Install the Crankshaft Rotating (Barring) Tool and turn the crankshaft until the piston is at the bottom of the stroke.

Crankshaft Rotation (Barring) Tool	91-898154

   b. Place a cloth on the top of the piston to collect the cuttings.
   c. Install the Cylinder Bore Ridge Reamer Tool according to the manufacturer and remove the ridge or combustion deposits.

Cylinder Bore Ridge Reamer Tool	**Obtain Locally**

   d. Remove the Cylinder Bore Ridge Reamer Tool.
   e. Turn the crankshaft until the piston is at top of its stroke.
   f. Remove cloth and cuttings.
6. Turn the crankshaft to gain access to the connecting rod screws.

IMPORTANT: Each connecting rod assembly must be reassembled in its original location.

7. Mark or identify each connecting rod assembly to ensure placement in the original cylinder number location during reassembly.
8. Remove the connecting rod cap and rod bearings.

IMPORTANT: The connecting rod can damage the crankshaft journal, the cylinder bore, and the piston cooling jet. Ensure that no components are damaged during connecting rod removal.

9. While protecting the crankshaft journal, cylinder bore, and piston cooling jets from damage, push the piston and connecting rod out of the cylinder.

IMPORTANT: The mating surfaces of the connecting rods and the connecting rod bearing caps form an individual fit and must not be interchanged or damaged under any circumstances. To avoid damage, do not lay connecting rods or connecting rod bearing caps on their mating surfaces.

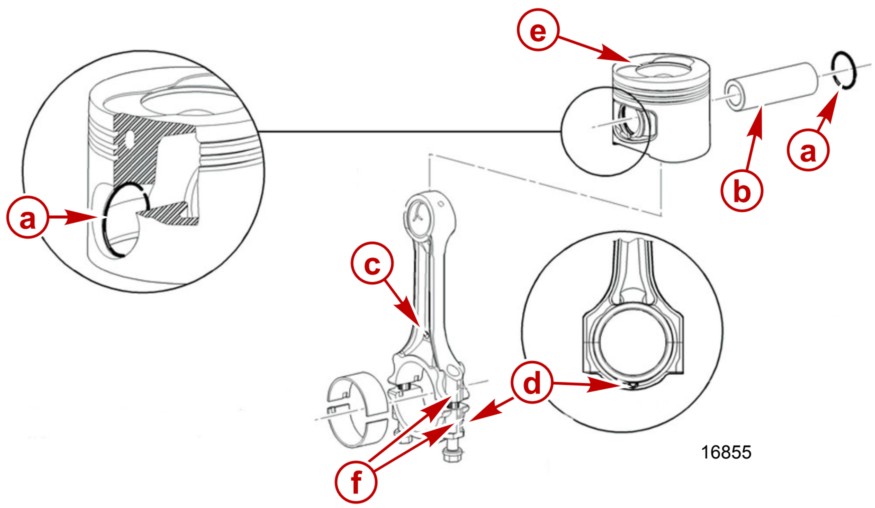
10. Retain the rod cap and bearings with the connecting rod and piston assembly. Do not mix the components.
11. Remove the connecting rod bearings. Keep the bearings, with the original connecting rod and connecting rod cap, together as a matched set.

Disassembly

1. Clamp the connecting rod in a soft-jawed vise.
2. Use the Piston Ring Expander Tool to remove the first and second compression rings and the oil control ring with spring.

Piston Ring Expander Tool	91-24697

3. Remove the snap rings that retain the piston pin. Push the piston pin out of the connecting rod and piston.
4. Note the orientation of the piston combustion chamber recess in relation to the paint mark, the casting node, and the connecting rod number.



a - Snap ring
b - Piston pin
c - Paint mark
d - Casting node
e - Combustion chamber recess orientation
f - Connecting rod number

Cleaning

CONNECTING RODS, PISTON PINS AND PISTON RINGS

1. Wash the components in cleaning solvent.
2. Put on safety glasses and dry the components with compressed air.

CONNECTING ROD BEARINGS

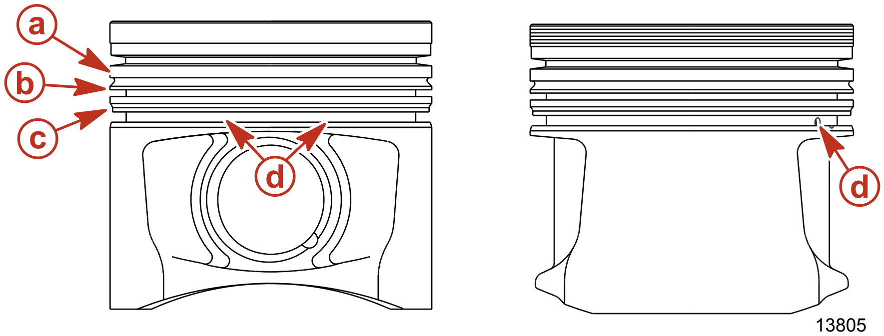
1. Wash the components in cleaning solvent.
2. Wipe the bearings clean with a soft cloth. Do not scratch the bearing contact surfaces.
3. Put on safety glasses and dry the components with compressed air.

PISTONS

IMPORTANT: Do not wire brush on any part of a piston.

1. Wash the components in cleaning solvent.
2. Clean varnish from the piston skirts and pins with a cleaning solvent.
3. Clean the ring grooves.

4. Clean the piston oil lubrication holes and slots.



a - First compression ring groove - (tapered)
b - Second compression ring groove
c - Oil control (lower) ring
d - Oil ring holes

5. Put on safety glasses and dry the components with compressed air.

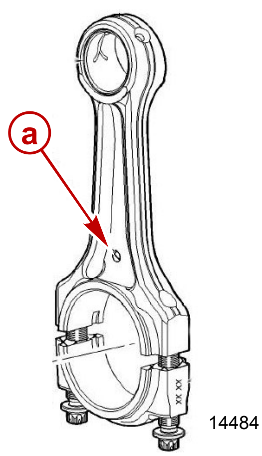
Inspection

IMPORTANT: Measurements should be taken when the components are at room temperature.

CONNECTING ROD AND PISTON PIN

1. Green, blue, white, or yellow paint marks on the connecting rods identify the weight classification. Ensure that all four connecting rods have the same color paint mark. Replace connecting rods that are not the same weight classification and do not have the same color paint mark.

NOTE: All connecting rods provided for service are median weight and class.



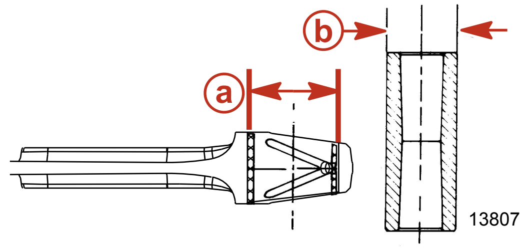
a - Paint mark area

2. Check for twisted or bent connecting rods.

Connecting Rod	
Parallelism deviation between piston pin end and bearing end	0.15 mm (0.006 in.)

3. Inspect for nicks or cracks.
4. Inspect for damage to the bearing cap and bolt threads.
5. Replace damaged connecting rods.
6. Measure connecting rod bushing inner diameter and piston pin outer diameter.

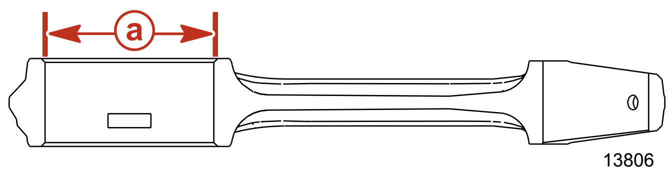
7. Replace the connecting rod bushing if the clearance exceeds the specification.



a - Rod bushing inner diameter **b -** Piston pin outer diameter

Connecting Rod Bushing and Piston Pin		
Bushing inner diameter		30.035–30.050 mm (1.18224–1.1830 in.)
Piston pin outer diameter		31.990–31.996 mm (1.259–1.260 in.)
Clearance	Minimum	0.039 mm (0.0015 in.)
	Limit	0.060 mm (0.0023 in.)

8. Use an inside dial indicator to measure the connecting rod crankshaft journal bore inside diameter, out of round, and taper.



a - Connecting rod crankshaft journal bore

Connecting Rod Crankshaft Journal Bore	
Inner diameter	57.563–57.582 mm (2.2662–2.2670 in.)
Maximum allowable wear or taper	0.01 mm (0.0004 in.)

9. Replace the connecting rod if the measurements exceed the specifications.

CONNECTING ROD BEARING CLEARANCE - MICROMETER METHOD

NOTE: The micrometer method is the preferred method of determining connecting rod bearing clearance.

1. With the connecting rods removed from the engine, wipe both upper and lower connecting rod bearings clean.
2. Install the upper and lower connecting rod bearings.
3. Install the bearing cap. The bearing cap must be torqued to specification for proper reading.
4. Torque the connecting rod screws.

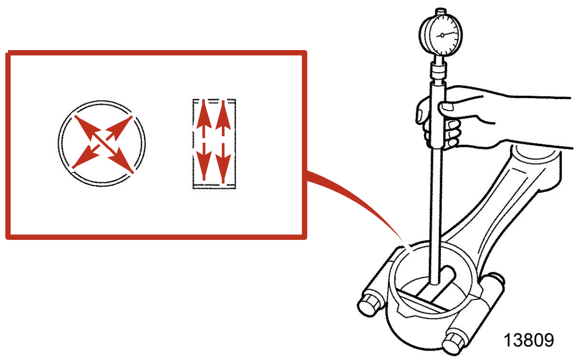
Description		Nm	lb. in.	lb. ft.
Connecting rod screw	**First pass**	10	88	
	Second pass	30		22
	Final pass (Angle Torque)	+ 40 Degrees		

5. Test the torque setting of each connecting rod screw to be no less than the value specified in the following table. this action will verify that proper torque was achieved. Do not apply more than this specified amount during this validation test.

Description	Nm	lb. in.	lb. ft.
Connecting rod screw torque validation test	88		64

6. Use an inside dial indicator to measure the connecting rod bearing inside diameter, out of round, and taper. Measure in several places approximately 90 degrees apart and average the measurements.

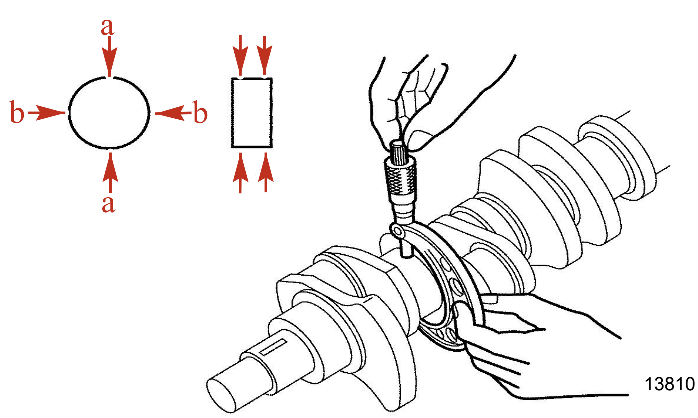
IMPORTANT: Do not measure the diameter close to the split line for the connecting rod and bearings. Bearings are eccentric and false readings could occur.



Measuring connecting rod bearing inside diameter

Connecting Rod Bearing	
Inside Diameter	53.977–54.016 mm (2.1250–2.1266 in.)

7. Record the measurements for use later.
8. Wipe the crankshaft connecting rod journal clean of oil.
9. Using a micrometer, measure the crankshaft connecting rod journal diameters at points "a" and "b" on one side of the journal then repeat measurements on opposite side of journal.



Connecting rod journal measurement - typical crankshaft shown

Crankshaft Connecting Rod Journal	
Outside diameter	53.940–53.955 mm (2.1236–2.1242 in.)
Maximum wear	0.25 mm (0.010 in.)

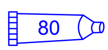
10. If journal diameters are not within specifications, replace or recondition the crankshaft.

NOTICE
Inadequate clearance or interference between the bearing and its mating surface will result in rapid bearing wear and catastrophic component failure. Check all bearing clearances.

11. If journal diameters are within specifications, determine bearing clearance by subtracting the crankshaft connecting rod journal outside diameter from the inner diameter of the bearing recorded previously.

Connecting Rod Bearing	
Clearance	0.022–0.076 mm (0.0008–0.0029 in.)

12. If the clearance exceeds specifications, select a new bearing of the correct size and determine the clearance.
13. After obtaining the correct clearance, apply lubricant to the crankshaft journal. Apply lubricant to the bearing surface and install the connecting rod cap.

Tube Ref No.	Description	Where Used	Part No.
 80	SAE Engine Oil 30W	Crankshaft journal and bearing surface	Obtain Locally

14. Torque the connecting rod screws.

Description		Nm	lb. in.	lb. ft.
Connecting rod screw	**First pass**	10	88	
	Second pass	30		22
	Final pass (Angle Torque)	+ 40 Degrees		

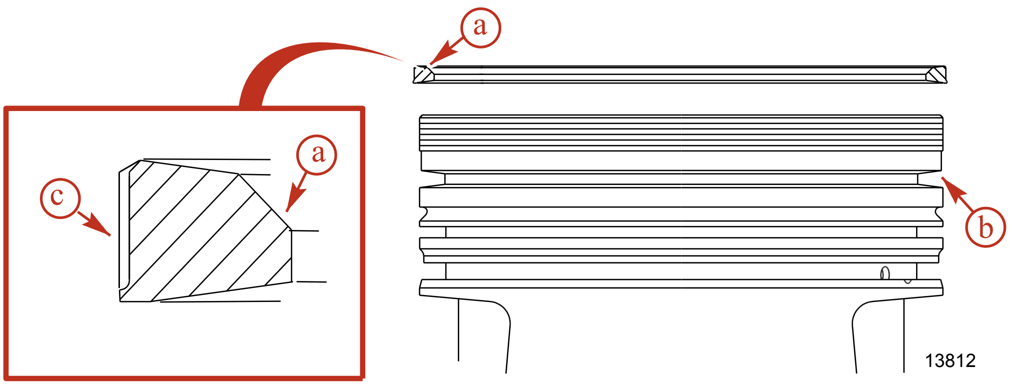
15. Test the torque setting of each connecting rod screw to be no less than the value specified in the following table. this action will verify that proper torque was achieved. Do not apply more than this specified amount during this validation test.

Description	Nm	lb. in.	lb. ft.
Connecting rod screw torque validation test	88		64

PISTONS AND RINGS

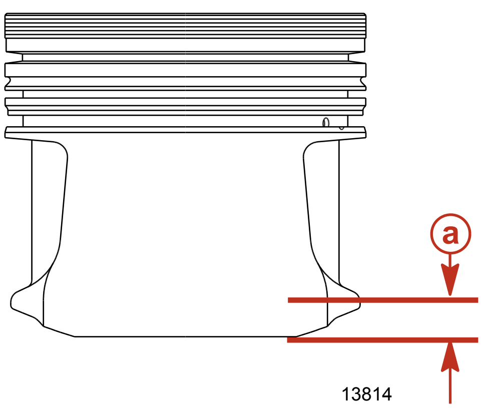
1. Inspect the piston for cracked ring lands, skirts or pin bosses, wavy worn ring lands, scuffed or damaged skirts, or eroded areas at the top of the piston. Replace pistons that are damaged or show signs of excessive wear.

NOTE: *Do not mistake tapered or different ring design characteristics for unusual wear patterns. The first (upper) compression ring is trapezoidal (tapered). That is, it has a taper on both upper and lower surfaces. Correspondingly, the first compression ring groove is tapered on top and bottom. The second (scraper) compression ring and the oil control ring are more typical in design.*



a - First compression ring - trapezoidal (tapered)
b - First compression ring groove - (tapered)
c - Outer edge of first compression ring

2. Measure the piston outer diameter 15 mm (19/32 in.) from the bottom and 90 degrees to the piston pin. Replace the piston if the measurement is less than specified.



a - Outer diameter measurement point

Piston	
Outer diameter	93.898–93.912 mm (3.6967–3.6973 in.)

3. Inspect the piston ring grooves for nicks or burrs that might cause the rings to bind.

4. Except on the upper piston ring groove, insert the edge of the rings into their respective piston ring grooves. Roll the ring entirely around the groove to make sure that ring does not bind. If resistance or binding occurs at any point, determine the cause.
   a. If binding is caused by a distorted ring, recheck with another ring.

IMPORTANT: When using a fine cut file, do not remove excess material. Verify with a feeler gauge and compare to specifications.

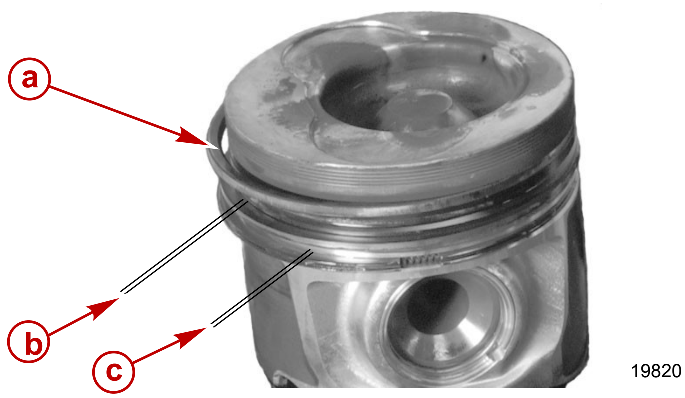
   b. If binding is caused by the ring groove, remove the material causing the binding by dressing the ring groove with a fine cut file.
5. Measure the thickness of the rings. Replace piston rings as a set if out of specification.

Piston Ring Thickness (Production)	
First compression (tapered - outer edge)	2.568–2.597 mm (0.1011–1022 in.)
Second compression	1.970–1.990 mm (0.0775–0.0783 in.)
Oil control	2.970–2.995 mm (0.1169–0.1179 in.)

6. Measure the piston ring groove width.

Piston Ring Groove Width (Production)	
First compression (tapered - outer edge)	2.95 ± 0.015 mm (0.1021 ± 0.0006 in.)
Second compression	2.06–2.08 mm (0.0811–0.0818 in.)
Oil control	3.03–3.05 mm (0.1192–0.1201 in.)

7. Using a feeler gauge, measure the clearance between the serviceable, or new, second compression and oil control piston rings and ring groove at several points around the piston. Replace the piston if the measured values exceed the specification.



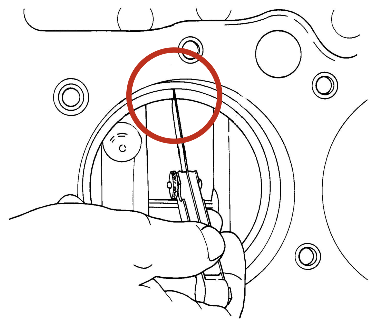
a - Not applicable - first compression ring and groove tapered
b - Second compression ring and groove
c - Oil control ring and groove

Piston Ring Groove		
Clearance	First compression	Not applicable (tapered)
	Second compression	0.10 mm (0.0039 in.)
	Oil control	0.08 mm (0.0031 in.)

8. Check the piston ring end gap:
   a. Position the selected ring in the cylinder bore.

NOTE: The ring must be level (at right angles to the bore surface) for measurement. Push the ring 6 mm (1/4 in.) into the bore with the crown of the piston.

   b. Measure the gap between the ends of the ring with a feeler gauge as shown.



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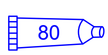
Checking piston ring end gap

Piston Ring End Gap	
First compression	0.5 mm (0.019 in.) maximum
Second compression	0.5 mm (0.019 in.) maximum
Oil control	0.6 mm (0.023 in.) maximum

   c. If the gap between the ends of the piston ring is less than specified, remove the ring and try to fit another. Check the cylinder bore if the specification cannot be met with new rings. See **Cylinder Liners**.
   d. Fit each ring to the cylinder in which it will be installed.

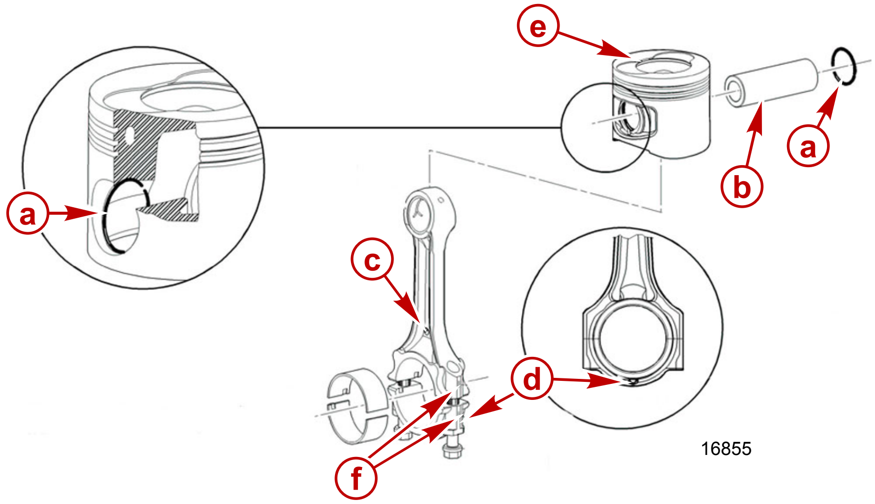
Assembly

1. Lubricate the inside of the connecting rod bushing, piston pin bore, and piston pin.

Tube Ref No.	Description	Where Used	Part No.
	SAE Engine Oil 30W	Connecting rod bushing, piston pin bore, and piston pin	Obtain Locally

2. Assemble the piston to the connecting rod with the combustion chamber recess, the paint mark, the casting node, and the connecting rod number all oriented as noted during disassembly.

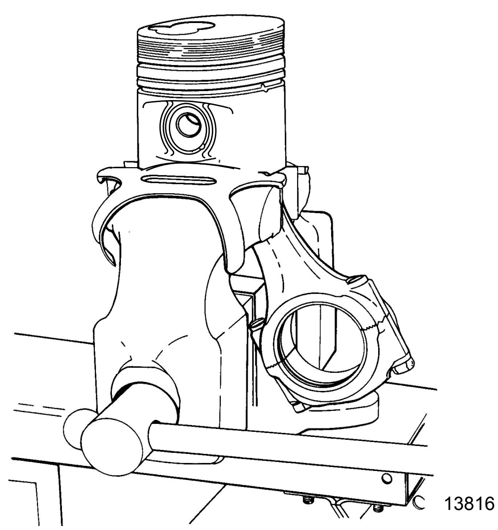
3. Insert the piston pin and install the snap ring.



Piston and connecting rod assembly orientation

a - Snap ring
b - Piston pin
c - Paint mark
d - Casting node
e - Combustion chamber recess orientation
f - Connecting rod number

4. Clamp the connecting rod in a soft-jawed vise as shown.



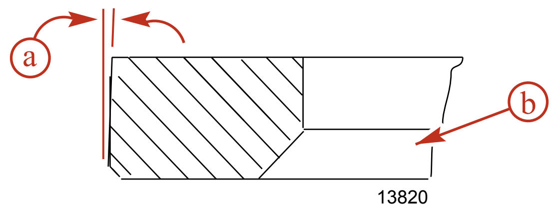
IMPORTANT: Always install rings with ring markings ("CTOP", "PIP" or a dot) facing the top of the piston.

5. Install the oil control ring spring in the lower piston groove.
6. Using the Piston Ring Expander Tool, install the oil control ring.

Piston Ring Expander	91-24697

7. By hand, squeeze the ring into the groove to seat the spring. Check for binding.

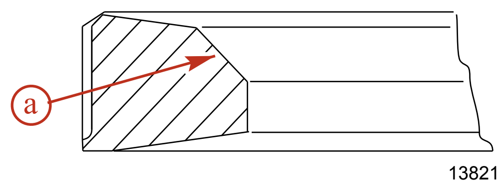
8. Using the tool, install the second compression ring in the center piston groove. The inner taper is toward the bottom of the piston.



Second compression ring

a - Top tapered 2° + or - 30 minutes
b - Inner taper

9. By hand, squeeze the ring into the groove and check for binding.
10. Using the tool, install the first compression ring in the upper piston groove. The 45° inner taper is toward the top of the piston.



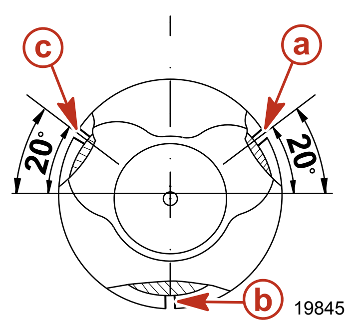
First compression ring

a - Inner taper

11. By hand, squeeze the ring into the groove. Check for binding.

Installation

1. Before installing the pistons into the cylinders, the ring gaps must be positioned as follows:
   a. First compression ring (trapezoidal) gap is 20° to the right of combustion chamber recess.
   b. Second compression ring gap is centered on the combustion chamber recess.
   c. Oil control ring gap is 20° to the left of combustion chamber recess.



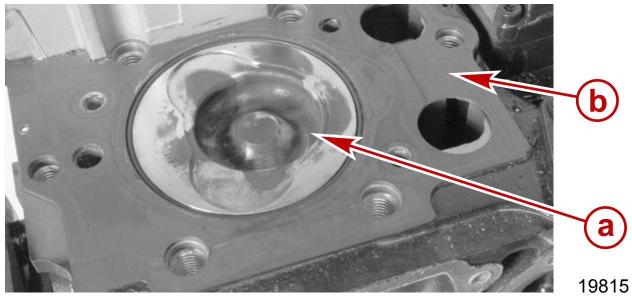
a - First compression ring (trapezoidal) gap
b - Second compression ring gap
c - Oil control ring gap

2. Lubricate the cylinder bores and piston rings.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Cylinder bore and piston rings	Obtain Locally

3. Identify the cylinder from which each piston and connecting rod assembly was removed. Each assembly must be installed in the cylinder from which it was removed.

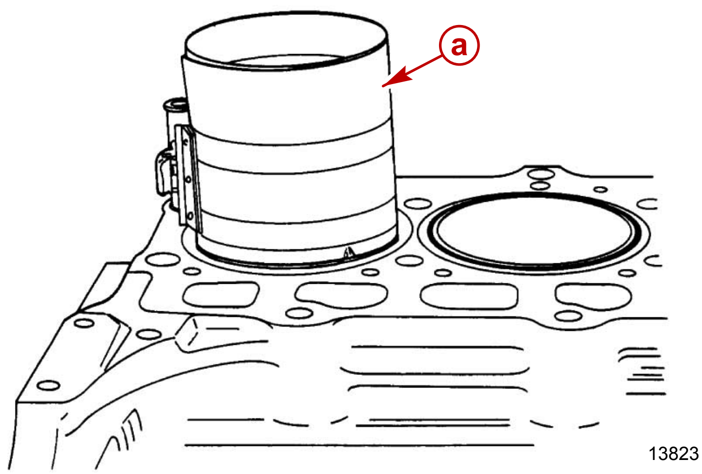
IMPORTANT: The piston combustion chamber recess and the numbers on the connecting rod must be oriented towards the injector and camshaft side of the engine.



Shown installed for visual clarity

a - Combustion chamber recess **b -** Camshaft side

4. Turn the crankshaft to position the crank journal away from the cylinder so the connecting rod will not damage the journal during installation.
5. Using a ring compressor, install the piston by tapping on the piston-top with a suitable device.



a - Ring compressor

6. Insert the connecting rod bearings into the connecting rod and matching connecting rod cap. Lubricate the bearings and crankshaft journal with a lubricant mixture of 20% SAE 30W engine oil and 80% Needle Bearing Assembly Lubricant.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Connecting rod bearings and crankshaft journal	Obtain Locally
4	Needle Bearing Assembly Lubricant	Connecting rod bearings and crankshaft journal	92-802868A1

IMPORTANT: The connecting rod can damage the crankshaft journal, the cylinder bore, and the piston cooling jet. Ensure that no components are damaged during connecting rod installation.

7. Align the connecting rod with the crankshaft journal and tap on the piston top until the connecting rod bearing contacts the journal. Do not scratch or nick the crankshaft journal.

8. Ensure that the matching marks on the connecting rod cap and the connecting rod are the same and that the rod cap numbers point toward the camshaft side. The casting node on the rod cap must point to the rear of the engine.

IMPORTANT: New connecting rod screw threads and the screw head do not generally require lubrication. An anti-friction product should have been applied by the factory. If the screw threads are not stretched, and the top or bottom of the bolt head does not show damage, the connecting rod screws may be reused. When reusing a connecting rod screw, lubricate the threads and bottom of the screw head with the specified lubricant.

9. Lubricate the connecting rod screw threads and the underside of the screw head, unless the screws are being replaced with new screws.

Tube Ref No.	Description	Where Used	Part No.
4	Needle Bearing Assembly Lubricant	Connecting rod screw threads and the underside of the screw head	92-802868A1

10. Apply lubricant to the crankshaft journal and connecting rod bearing surfaces.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Connecting rod crankshaft journal and rod bearing surfaces	Obtain Locally

11. Install the connecting rod cap.
12. Install and torque the connecting rod screws.

Description		Nm	lb. in.	lb. ft.
Connecting rod screw	**First pass**	10	88	
	Second pass	30		22
	Final pass (Angle Torque)	+ 40°		

13. Verify that proper torque was achieved by testing the torque setting of each connecting rod screw to be at least as specified in the following table. Do not apply more than this specified amount during the validation test.

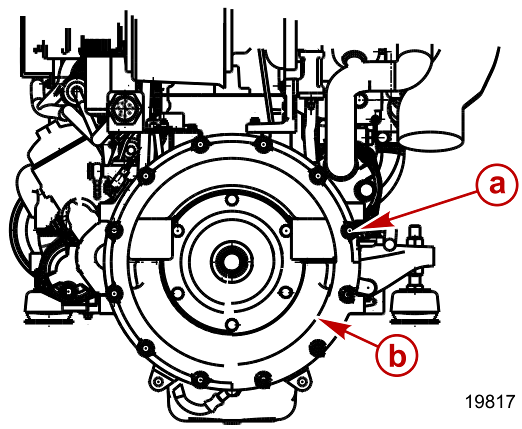
Description	Nm	lb. in.	lb. ft.
Connecting rod screw validation test torque	88		64

14. Ensure that the connecting rod assembly and the crankshaft journal are not binding and that there is proper side-to-side movement.
15. Install the remaining piston and connecting rod assemblies.
16. Measure for head gasket thickness.
17. Complete the engine assembly.

Rear Oil Seal

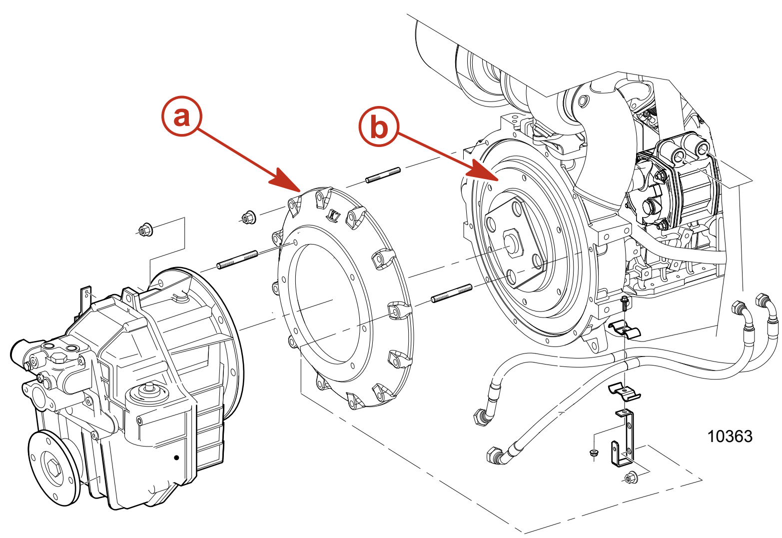
Removal

1. **On Sterndrive Models:**
    a. Remove the flywheel housing cover.



a - Flywheel housing bolt
b - Flywheel housing cover

    b. Remove the coupler.
2. **On Inboard Models:**
    a. Remove the transmission, if required.
    b. Remove the flywheel housing cover.
    c. Remove the drive plate.



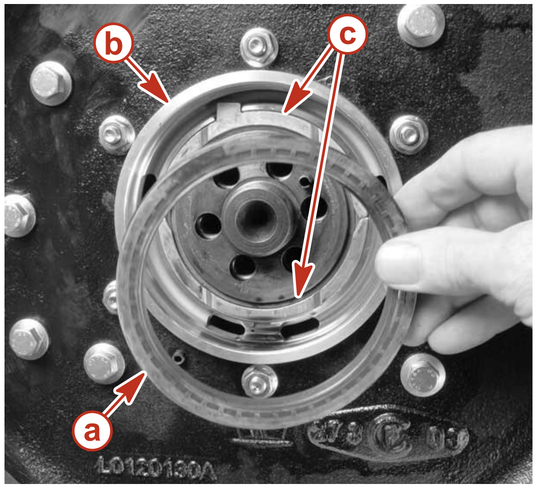
a - Flywheel housing cover
b - Drive plate

3. Remove two opposing flywheel bolts and install the two Flywheel Assembly Guide Pins to assist in removing the flywheel.

Flywheel Assembly Guide Pins	91-898282001

4. Remove the remaining flywheel bolts.
5. Remove the flywheel from the crankshaft and the Flywheel Assembly Guide Pins.

6. Remove the rear main bearing carrier and thrust washers. See **Section 3A: Crankshaft and Main Bearings**.



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a - Rear oil seal
b - Rear main bearing carrier
c - Thrust washers

7. Carefully pry the old seal from the rear main bearing carrier.

Installation

IMPORTANT: The seal is made of special compounds; do not touch or handle the lips of the seal. Do not attempt to install the rear main seal using a hammer or mallet. Damage to the seal or the rear main bearing carrier could result.

1. Press the new rear oil seal into the bearing carrier using an appropriately sized seal installer. The seal will stop when seated.
2. Install the rear main bearing carrier with the new seal and the thrust washers. See **Section 3A: Crankshaft and Main Bearings**.
3. Ensure that there are no scratches, nicks, cracks, or seizure marks on the flywheel mating surface. Only minor scratches, nicks, or seizure marks can be removed. Replace the flywheel if damaged.

NOTE: See Crankshaft End Play (Axial Clearance) to set the crankshaft end play if the flywheel is being replaced.

IMPORTANT: Whenever the flywheel is removed, replace the O-ring.

4. Lubricate a new flywheel O-ring with clean grease to hold it in place during assembly.

Tube Ref No.	Description	Where Used	Part No.
91	Engine Coupler Spline Grease	Flywheel O-ring	92-802869A1

5. Install a new O-ring into the groove of the flywheel to seal the crankshaft.
6. Lubricate the threads of the flywheel bolts.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Flywheel retaining bolts	Obtain Locally

7. Install the two Flywheel Assembly Guide Pins opposite to each other to assist in installing the flywheel.

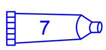
Flywheel Assembly Guide Pins	91-898282001

8. Align the flywheel with the rolled pin and install the flywheel with O-ring onto the crankshaft using the Flywheel Assembly Guide Pins for alignment.
9. Install the lubricated flywheel bolts hand tight.
10. Remove the Flywheel Assembly Guide Pins and install the 2 opposing flywheel bolts hand tight.
11. Torque the flywheel bolts evenly, in a crosswise pattern as specified.

IMPORTANT: The flywheel bolts may be used a maximum of three times within the prescribed torque limits. If the bolts have been torqued for three previous installations or if the service history is unknown, replace the flywheel bolts.

Description		Nm	lb. in.	lb. ft.
Flywheel bolt	**First pass**	50		36
	Second pass - loosen one bolt at a time and torque to:	20 Nm (14 lb. ft.) + 75° angular torque		

12. Apply sealant to bolt threads and install the sterndrive coupler or inboard drive plate assembly.

Tube Ref No.	Description	Where Used	Part No.
	Loctite 271 Threadlocker	Sterndrive coupler or inboard drive plate bolt	92-809819

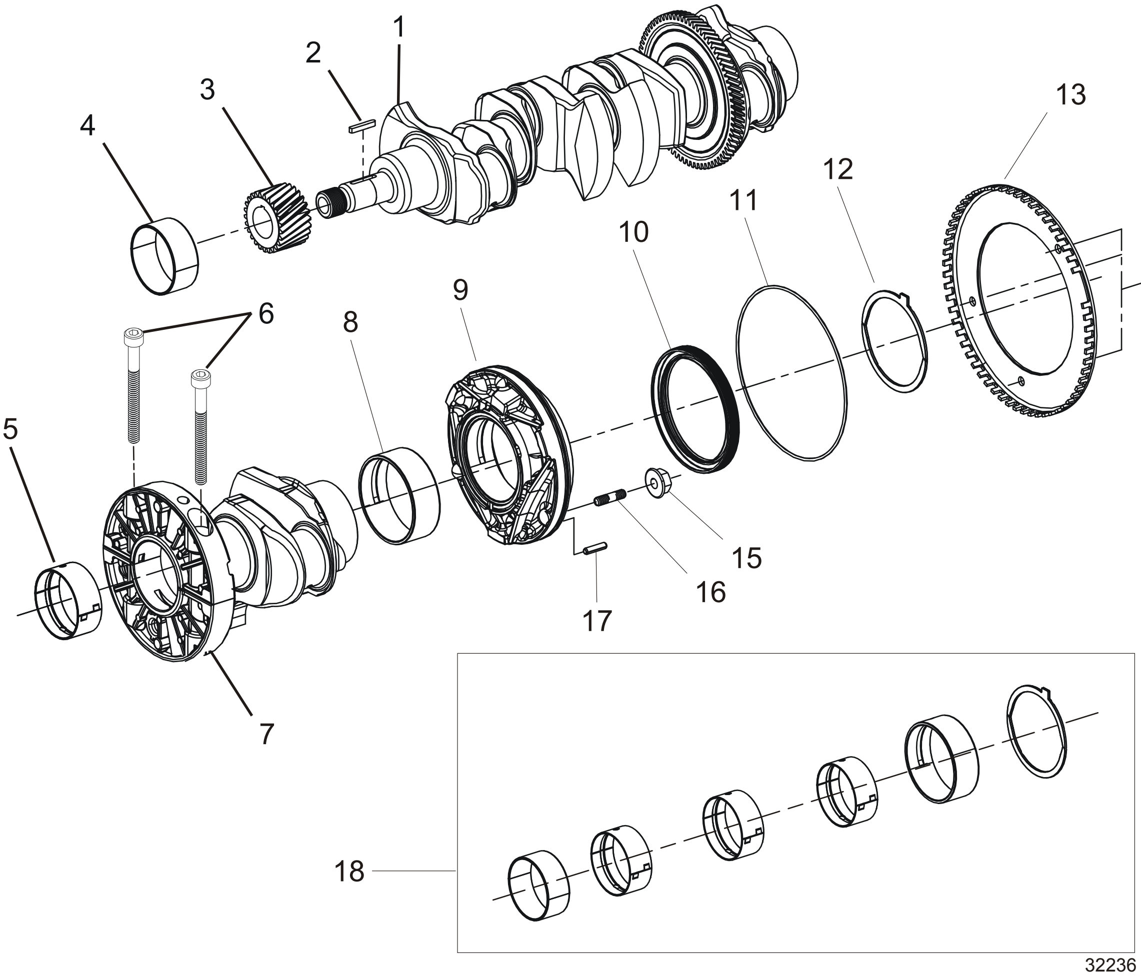
13. Torque the sterndrive coupler or inboard drive plate bolts.

Description	Nm	lb. in.	lb. ft.
Sterndrive coupler bolt	30	–	22
Inboard drive plate bolt	30	–	22

14. Install the flywheel housing cover and related components. See **Section 3A: Flywheel, Coupler or Drive Plate, and Flywheel Housing**.
15. Install all other components removed.
16. Start the engine and check for leaks.

Crankshaft and Main Bearings

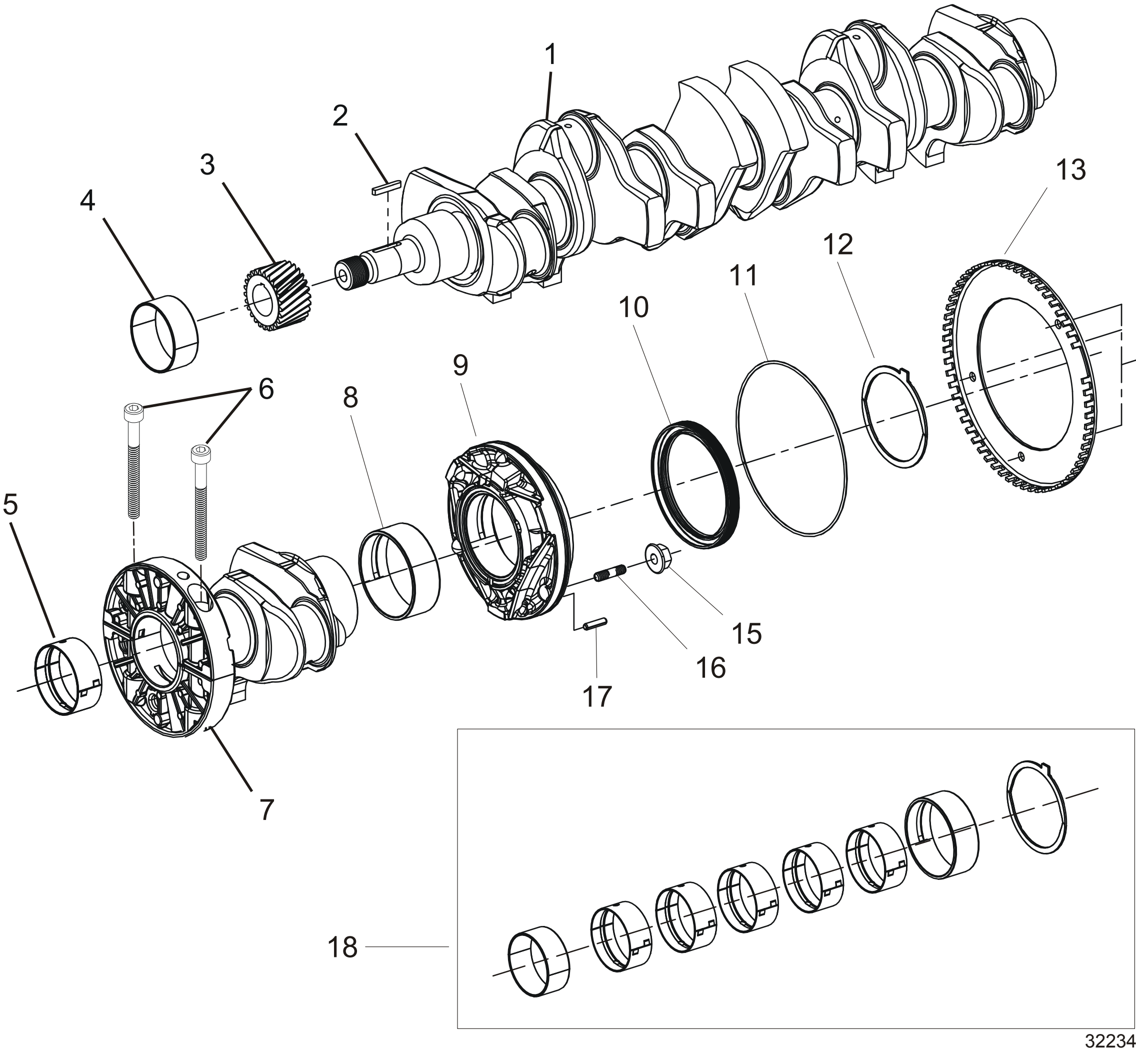
Exploded View—2.8 Crankshaft and Main Bearings



Exploded View—2.8 Crankshaft and Main Bearings

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Crankshaft			
2	1	Key			
3	1	Timing gear			
4	1	Front main bearing			
5	3	Main bearing			
6	6	Main bearing carrier screw	44.1	–	32
7	3	Main bearing carrier			
8	1	Rear main bearing			
9	1	Rear main bearing carrier			
10	1	Rear main seal			
11	1	O-ring seal			
12	1	Thrust bearing			
13	1	Reluctor ring			
14	3	Reluctor ring bolt	14.6	129	–
15	6	Nut	24.5	–	18
16	6	Stud			
17	1	Pin			
18	1	Crankshaft bearing set			

Exploded View—4.2 Crankshaft and Main Bearings



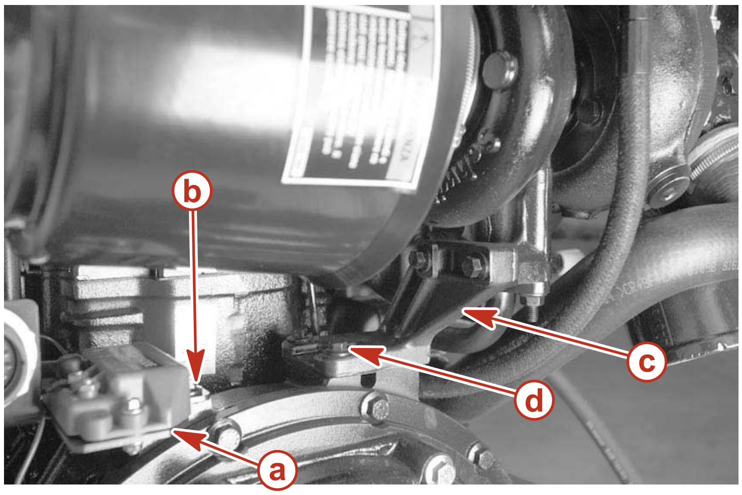
Exploded View—4.2 Crankshaft and Main Bearings

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Crankshaft			
2	1	Key			
3	1	Timing gear			
4	1	Front main bearing			
5	5	Main bearing			
6	10	Main bearing carrier screw	44.1	–	32
7	5	Main bearing carrier			
8	1	Rear main bearing			
9	1	Rear main bearing carrier			
10	1	Rear main seal			
11	1	O-ring seal			
12	1	Thrust bearing			
13	1	Reluctor ring			
14	3	Reluctor ring bolt	14.6	129	–
15	6	Nut	24.5	–	18
16	6	Stud			
17	1	Pin			
18	1	Crankshaft bearing set			

Removal

REAR MAIN BEARING CARRIER AND BEARING

1. Remove the starter.
2. Remove the timing gear cover.
3. Remove the camshaft and lifters.
4. Remove the oil pump.
5. Remove the connecting rods and pistons.
6. Remove the two screws retaining the engine harness connector bracket and MerCathode controller, if equipped, to the flywheel housing.
7. Remove the two turbocharger support bracket screws.



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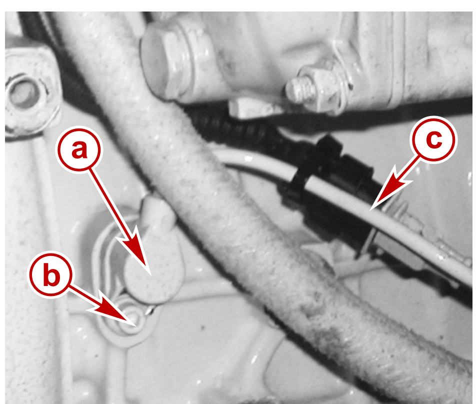
Sterndrive model, Inboard similar

a - Engine harness connector bracket
b - Engine harness connector bracket screw
c - Turbocharger support bracket
d - Turbocharger support bracket screw

8. Remove the crankshaft speed sensor.

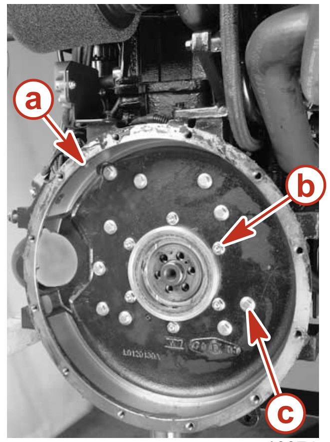


30128

a - Crank shaft speed sensor
b - Retaining screw
c - Electrical connector

9. Remove the flywheel.

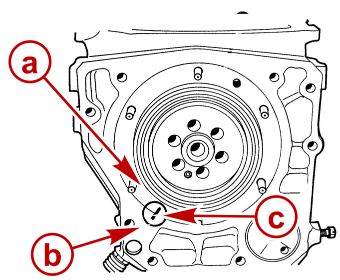
10. Remove the flywheel housing bolts and the rear main bearing carrier flange nuts.
11. Remove the flywheel housing.



10374

a - Flywheel housing
b - Rear main bearing carrier flange nuts
c - Flywheel housing bolts

12. Reference mark the position of the rear main bearing carrier in relation to the cylinder block.

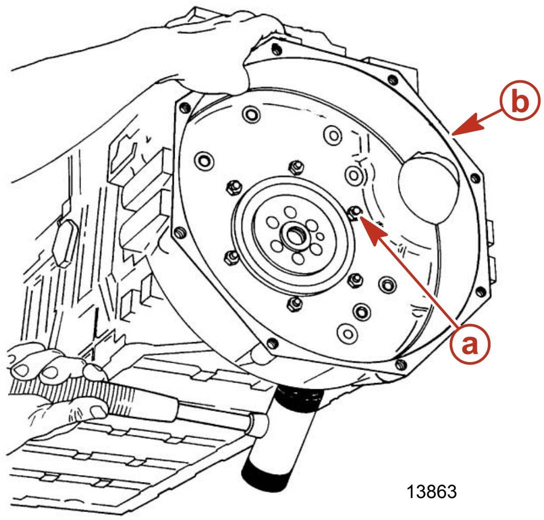


16732

a - Rear main bearing carrier
b - Cylinder block
c - Reference mark

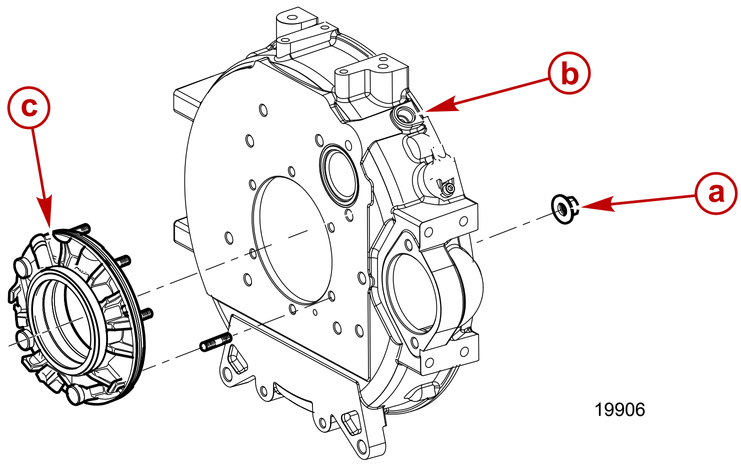
13. To assist in removing the bearing carrier, temporarily reinstall the flywheel housing using only the six nuts on the bearing carrier studs.

14. Using a rubber mallet, tap evenly around the housing. The carrier and thrust plate will be pulled from the cylinder block.



a - Rear main bearing carrier flange nuts
b - Flywheel housing

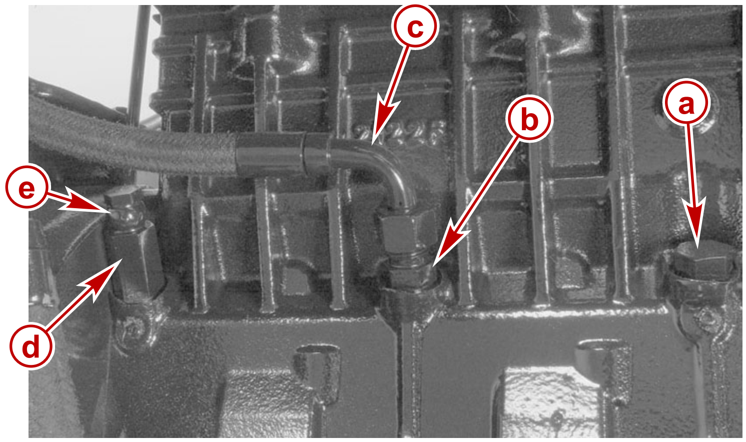
15. Remove the rear main bearing carrier flange nuts and separate the flywheel housing and the rear main bearing carrier.



a - Rear main bearing carrier flange nuts
b - Flywheel housing
c - Rear main bearing carrier

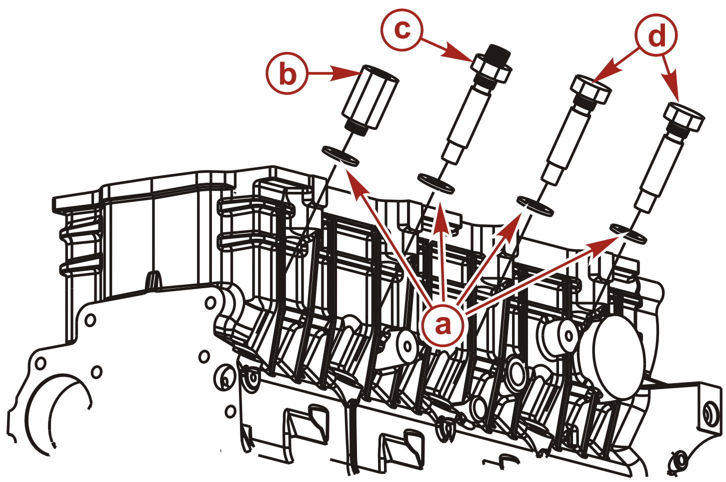
CRANKSHAFT, MAIN BEARINGS, AND MAIN BEARING CARRIERS

1. Remove the oil supply hose and pipe from their fittings on the main bearing carrier locating screws.



a - Main bearing carrier locating screws (standard)
b - Locating screw with fitting
c - Oil supply hose, turbocharger
d - Locating screw with adaptor
e - Oil supply pipe, rocker arms

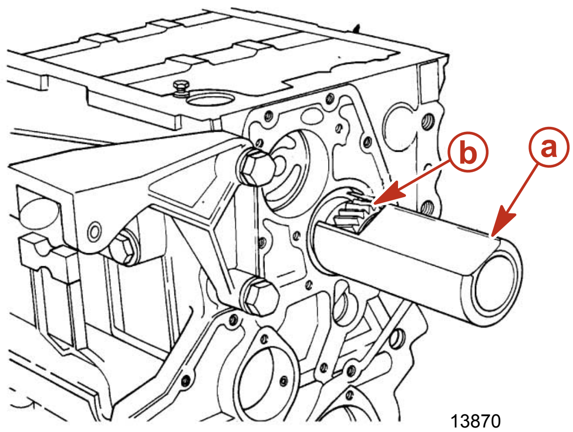
2. Remove the main bearing carrier locating screws and the special locating screws that hold the main bearing carriers in cylinder block.



Starboard side of engine — 2.8 shown, 4.2 similar

a - Seal
b - Fitting
c - Locating screw (with adaptor)
d - Locating screw

3. Install the Crankshaft Gear Cover Assembly Tool over the timing gear to protect the front main bearing.



a - Crankshaft Gear Cover Assembly Tool
b - Timing gear

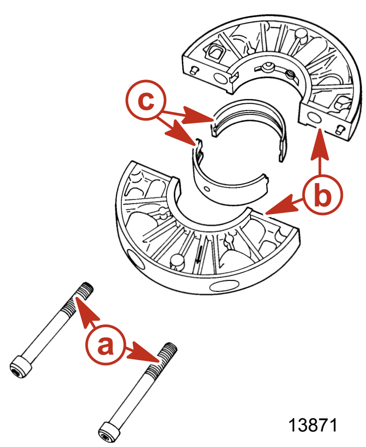
Crankshaft Gear Cover Assembly Tool	91-801333504

4. Turn the engine vertical with the front facing down.
5. Using a hoist and a suitable sling attached to the crankshaft, lift the crankshaft out of the cylinder block.

MAIN BEARING CARRIERS AND BEARINGS

IMPORTANT: Before removing the bearing carriers from the crankshaft, number or mark them according to the journal upon which they are fitted. Also make matching marks on both bearing carrier halves for correct reassembly. Do not mix parts.

1. After marking the bearing carriers, remove the bearing carrier screws and separate the carrier halves. Remove the bearing carriers with bearings from the crankshaft journals.

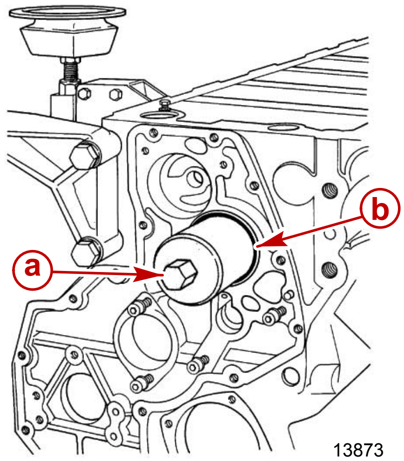


a - Bearing carrier screw
b - Bearing carrier
c - Main bearings

FRONT MAIN BEARING

NOTE: If bearings are being inspected prior to replacement, see Inspection before removing front main bearing. If all bearings are being replaced, proceed.

1. Assemble the Front Main Bearing and Camshaft Bearing Puller into the front main bearing.



a - Bearing puller tool
b - Front main bearing

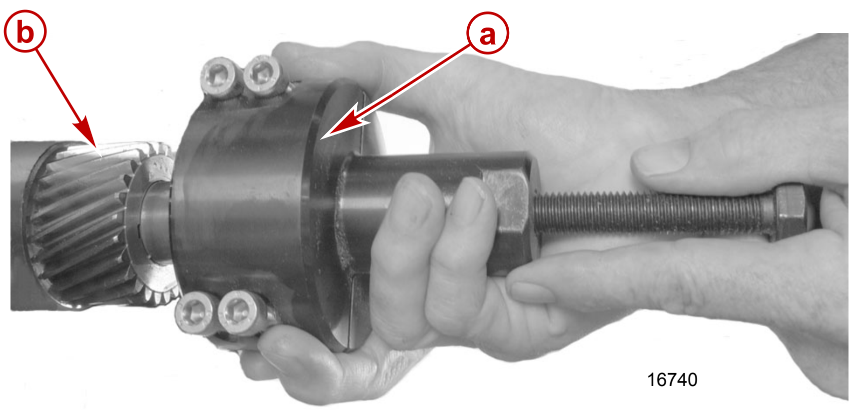
Front Main Bearing and Camshaft Bearing Puller Tool	91-801333508

2. Remove the front main bearing.

TIMING GEAR

NOTE: Replace the timing gear only if worn or damaged.

1. Install the Crankshaft Gear Puller onto the timing gear. Tighten the four clamping screws securely.
2. Turn the Crankshaft Gear Puller screw and remove the timing gear.



a - Crankshaft gear puller with clamping screws
b - Timing gear

Crankshaft Gear Puller	91-898210

Cleaning

CRANKSHAFT

1. Clean the crankshaft in cleaning solvent. Ensure that the oil passages are clear of all sludge and restrictions.
2. Put on safety glasses.
3. Clear the crankshaft oil passages with compressed air.
4. Dry the components with compressed air.

MAIN BEARING CARRIERS

1. Clean the main bearing carriers in cleaning solvent. Ensure that the oil passages are clear of all sludge and restrictions
2. Put on safety glasses and dry the components with compressed air.

MAIN BEARINGS

1. Clean the main bearings in cleaning solvent.
2. Wipe the crankshaft bearings clean with a soft cloth. Do not scratch the crankshaft bearing surfaces.
3. Put on safety glasses and dry the components with compressed air.

Inspection

CRANKSHAFT

1. Inspect the crankshaft for deep grooves, scratches, pitted surfaces, or uneven wear.
2. Inspect the crankshaft rear oil seal surface for scoring or damage.
3. Inspect the crankshaft oil passages for restrictions.
4. Inspect the crankshaft threaded bolt holes for damage.
5. Inspect the crankshaft balancer keyway for damage.
6. After a seizure, overheating, or grinding, the crankshaft must be Magnafluxed to verify no surface cracks are present.
7. Measure the journals of the crankshaft to determine if replacement or grinding is necessary. See Inspection - Main Bearings.

MAIN BEARINGS

1. Inspect the main bearings; replace if needed. See **Examples of Bearing Failures**.

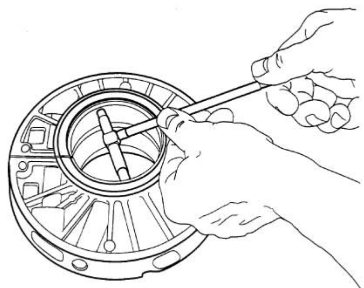
2. Measure the center main bearing clearance.
    a. Install bearings, if removed, in their original bearing carrier halves.
    b. Lubricate the bearing carrier bolts and washers.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Bearing carrier bolts and washers	Obtain Locally

    c. Observing the marks made earlier, assemble the bearing carriers. Torque the bolts with washers.

Description		Nm	lb. in.	lb. ft.
Bearing carrier bolt	M10 x 1.5	44.1		32

    d. Measure the inside diameter of the center bearing. Replace the bearing if any value is greater than specified.



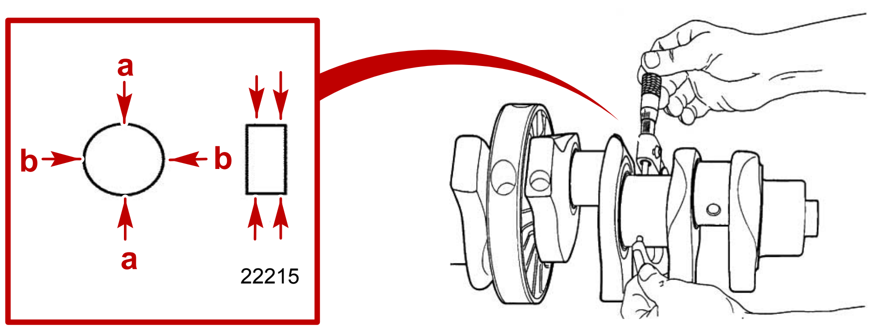
13876

Measuring the inside diameter of a center bearing

Center Main Bearing	
Inside diameter	63.050 - 63.093 mm (2.4822 - 2.4840 in.)

    e. Measure the outside diameter of the matching crankshaft journal. Repair or replace the crankshaft if any measured value is greater than specified.

NOTE: *Measure journal diameters at points "a" and "b" on one side of the journal then repeat measurements on the opposite side of the journal.*



13877

Measuring the outside diameter of a crankshaft main bearing journal

Center Main Bearing Crankshaft Journal	
Outside diameter	63.005 - 63.020 mm (2.4805 - 2.4810 in.)
Maximum wear	0.1 mm (0.0039 in.)

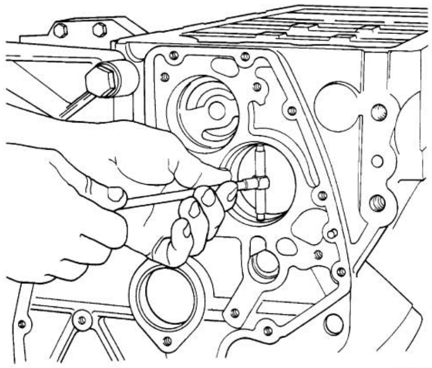
    f. Calculate the difference between the measurements taken in steps d and e to obtain the center main bearing clearance.

Center Main Bearing	
Clearance	0.030 - 0.088 mm (0.0011 - 0.0034 in.)

g. If the main bearing clearance exceeds the specified limit, the bearings, the crankshaft, or both must be replaced.

3. Measure the front main bearing clearance:

a. Measure the inside diameter of the main bearing in the cylinder block. Replace the bearing if any value is greater than specified.



Measuring the inside diameter of the front main bearing

Front Main Bearing	
Inside diameter	63.088 - 63.043 mm (2.480 - 2.482 in.)

b. Measure the outside diameter of the matching crankshaft journal. Repair or replace the crankshaft if any value is greater than specified.

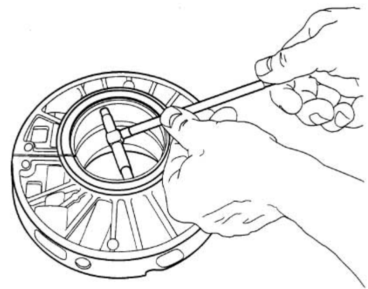
Crankshaft Front Main Bearing Journal	
Outside diameter	62.985 - 63.000 mm (2.479 - 2.480 in.)
Maximum wear	0.1 mm (0.0039 in.)

c. Calculate the difference between the measurements taken in steps a and b to obtain the main bearing clearance.

Front Main Bearing	
Clearance	0.055 - 0.095 mm (0.0022 - 0.0037 in.)

d. If the main bearing clearance exceeds the specified limit, the bearings, the crankshaft, or both must be replaced.

4. Measure the rear main bearing clearance:
    a. Measure the inside diameter of the bearing. Replace the bearing if any value is greater than specified.



Typical bearing carrier shown, rear bearing carrier similar

Rear Main Bearing	
Inside diameter	80.045 - 80.070 mm (3.1514 - 3.1524 in.)

    b. Measure the outside diameter of the matching crankshaft journal. Repair or replace the crankshaft if any value is greater than specified.

NOTE: Measure the journal diameters at points on one side of the journal then repeat measurements on the opposite side of the journal.

Rear Main Bearing Crankshaft Journal	
Outside diameter	79.985 - 80.000 mm (3.1490 - 3.1496 in.)
Maximum wear	0.1 mm (0.0039 in.)

    c. Calculate the difference between measurements taken in steps a and b to obtain the main bearing clearance.

Rear Main Bearing	
Clearance	0.045 - .085 mm (0.0018 - 0.0033 in.)

    d. If the main bearing clearance exceeds the specified limit, the bearings, the crankshaft, or both must be replaced.

TIMING GEAR

1. Remove slight indentations in the gear or gear teeth with a very fine grade Carborundum stone.
2. Replace the timing gear if the teeth are worn or damaged.
3. Inspect and replace the spacer if worn or damaged

FLYWHEEL

1. Check the flywheel ring gear for worn and missing teeth. Replace if worn or damaged.
2. Clean mating surfaces of flywheel and crankshaft. Remove any burrs. The mating surfaces must be clean, bare metal.

Installation

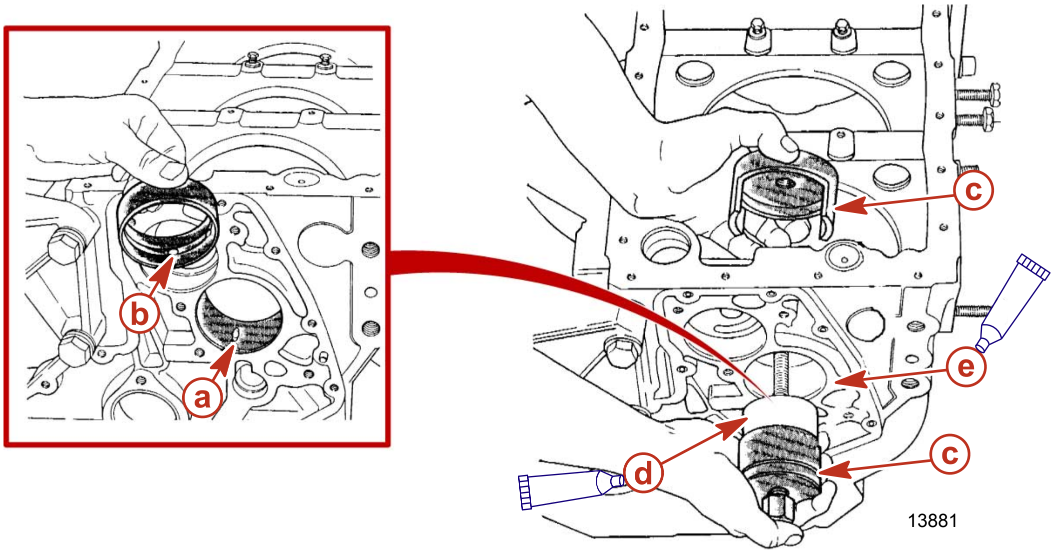
FRONT MAIN BEARING

1. Align the oil passage in the engine block with the hole of the new bearing.

NOTE: To aid installation, hold the bearing halves on the tool with a rubber band or something similar.

2. Lubricate the bearing bore and the bearing outer surface.

3. Position the Bearing Removal and Instillation Tool in the bearing bore and thread the puller screw into the tool.



a - Oil passage
b - Bearing hole
c - Bearing Removal and Instillation Tool
d - Bearing halves (on tool)
e - Bearing bore

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Bearing bore and bearing outer surface	Obtain Locally

Bearing Removal And Installation Tool	91-801333508

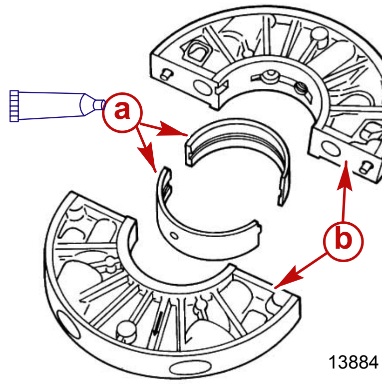
NOTE: *The Bearing Removal and Instillation Tool will install the bearing to the correct depth.*

4. Using two wrenches, hold the puller screw; then turn the nut until the bearing has been pulled into position.
5. Remove the Bearing Removal and Instillation Tool and ensure that the oil hole in the bearing is positioned correctly. The oil hole in the bearing must be aligned with the oil passage in the engine block for proper lubrication.

MAIN BEARING CARRIERS AND MAIN BEARINGS

1. Install main bearings halves into matching main bearing carrier halves.

2. Lubricate the bearing inner surface.



a - Main bearing halves
b - Main bearing carrier matching halves

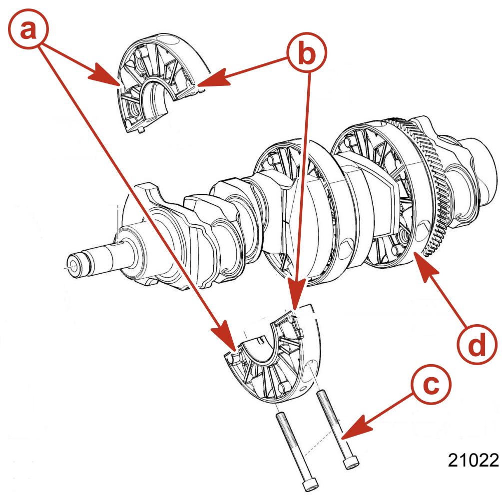
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Bearing inner surface	Obtain Locally

3. Lubricate the crankshaft journal main bearing surfaces.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Crankshaft journal main bearing surfaces	Obtain Locally

4. Install the matching main bearing carrier halves on the crankshaft journals in their original locations (marked during disassembly) or by referencing the factory paint marks on the side that must face the pulley end (front) of the crankshaft.

5. Lubricate the main bearing carrier screws. Install and torque the screws.



a - Main bearing carrier halves
b - Factory paint markings—facing pulley end of crankshaft
c - Main bearing carrier screw
d - Main bearing carrier installed

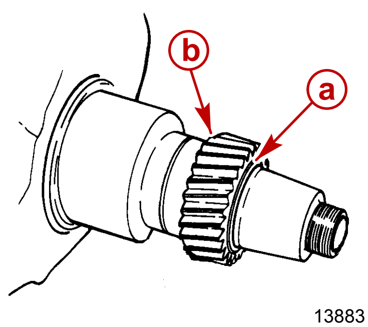
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Main bearing carrier screw	Obtain Locally

Description	Nm	lb. in.	lb. ft.
Main bearing carrier screw	44.1		32

6. Ensure that all carriers were positioned so that the front of the carrier halve is toward the pulley end (front) of the engine after installing them on the journal.

TIMING GEAR

1. Warm the timing gear in a suitable oven to 180-200° C (356-392° F).
2. Ensure that the timing reference dots are facing the **front** of the crankshaft.
3. Ensure that the crankshaft keyway and woodruff key are aligned.
4. Install the timing gear.

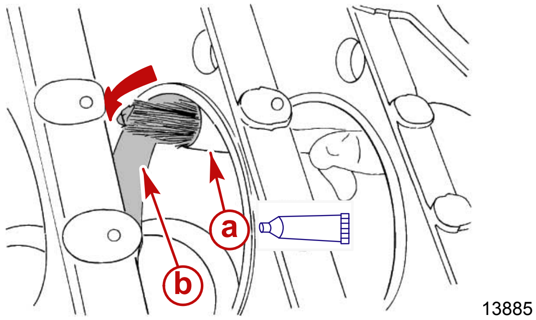


Typical

a - Timing gear
b - Timing reference dots (not visible in this view)

CRANKSHAFT

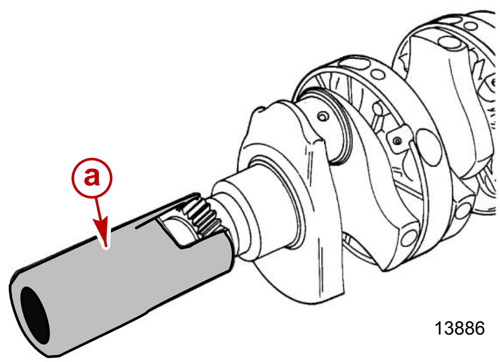
1. Lubricate the main bearing bores in the cylinder block.



a - Brush dipped in lubricant
b - Main bearing bore

Tube Ref No.	Description	Where Used	Part No.
	Molykote	Main bearing bores	Obtain Locally

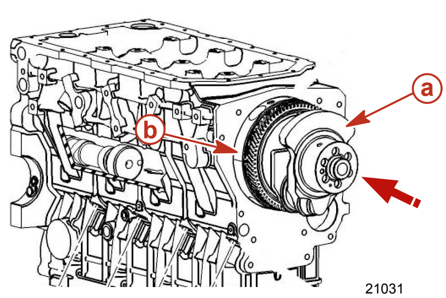
2. Install the Crankshaft Gear Cover Assembly Tool over the timing gear to protect the front main bearing.



a - Crankshaft Gear Cover Assembly Tool

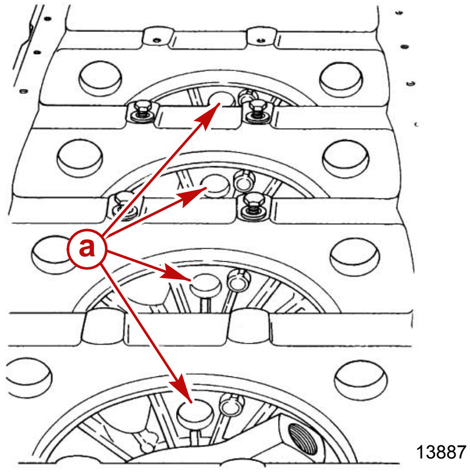
Crankshaft Gear Cover Assembly Tool	91-801333504

3. Position the engine cylinder block horizontal with the oil pan flange facing up.
4. Carefully insert the crankshaft with the main bearing carriers attached into the cylinder block.



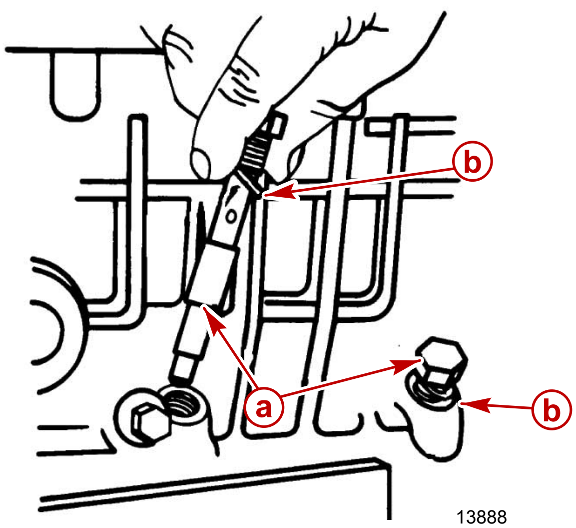
a - Crankshaft assembly
b - Main bearing carrier entering cylinder block

5. Rotate the bearing carriers to align with the marks made during disassembly. If no marks are present, position the bearing carriers with the round hole through the casting pointing toward the oil pan flange.



a - Round holes through the castings

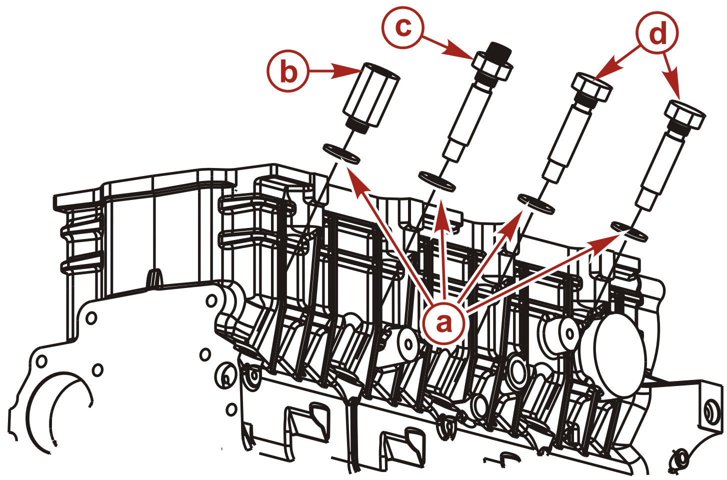
6. Install new sealing washers on all main bearing locating screws and special locating screws.
7. To avoid damaging the threads, **hand-thread** the main bearing locating screws and special locating screws into the bearing carriers.



Typical

a - Bearing carrier locating screw
b - Sealing washer

8. Torque all main bearing carrier locating screws.

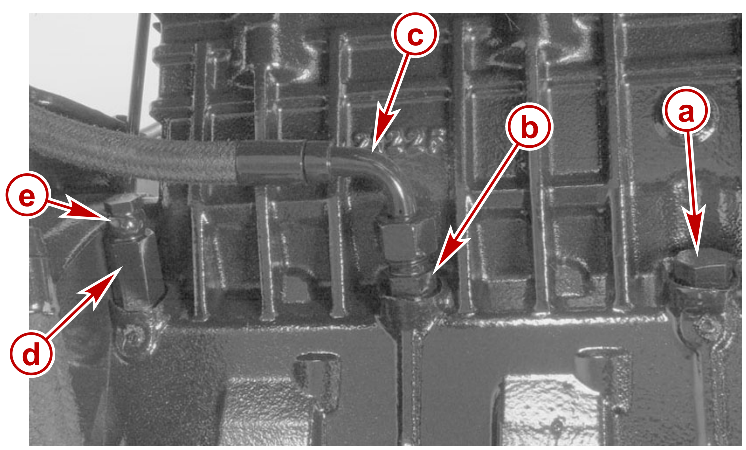


Starboard side of engine 2.8 shown, 4.2 similar

a - Seal
b - Fitting
c - Locating screw (with adaptor)
d - Locating screw

Description		Nm	lb. in.	lb. ft.
Bearing carrier locating and special locating screw	M14 x 1.5	53.9	–	39

9. Reinstall the oil drain pipe and oil supply pipe on the special locating screws. Tighten both securely.



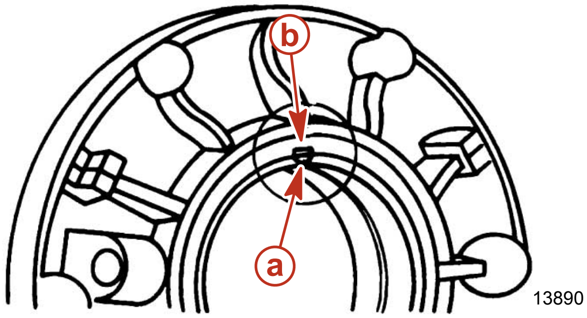
a - Main bearing carrier locating screws (standard)
b - Locating screw with fitting
c - Oil supply hose, turbocharger
d - Locating screw with adaptor
e - Oil supply pipe, rocker arms

REAR MAIN BEARING

IMPORTANT: Carefully press the bearing into the rear main bearing carrier to prevent damage to the notch arrangement in the carrier where the bearing tab aligns.

1. Using a suitable mandrel, press the rear main bearing out of the carrier.

2. Align the tab of a new rear main bearing with the notch in the rear main bearing carrier and press the new bearing into the carrier.

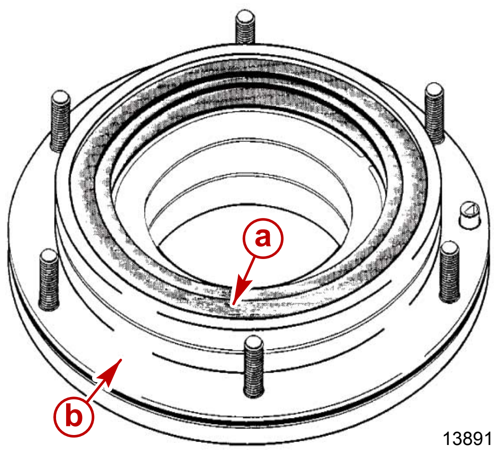


Typical

a - Bearing tab
b - Notch in carrier

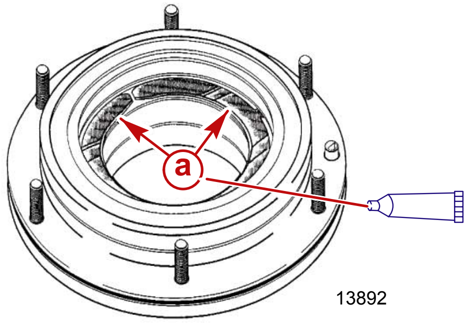
REAR MAIN BEARING CARRIER

1. Install a new rear main oil seal in the rear main bearing carrier. See **Rear Oil Seal—Installation.**



a - Rear main oil seal
b - Rear main bearing carrier

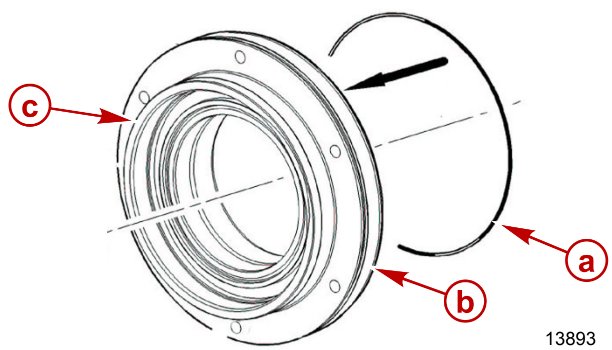
2. Install standard-size thrust washers into the rear (flywheel) side of the rear carrier. Use lubricant to keep the thrust washers positioned.



a - Standard size thrust washers—flywheel side

Tube Ref No.	Description	Where Used	Part No.
4	Needle Bearing Assembly Lubricant	Rear bearing carrier thrust washer	92-802868A1

3. Install a new O-ring into the groove around the rear bearing carrier. Lubricate the O-ring to assist during installation.



a - O-ring
b - Groove
c - Rear main bearing carrier

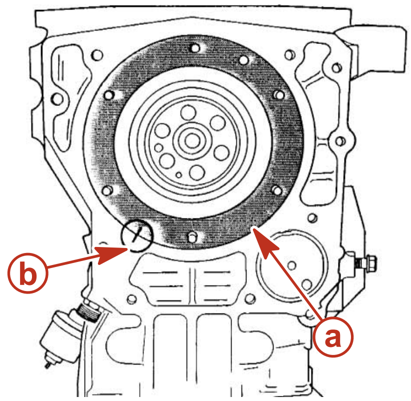
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Rear bearing carrier O-ring	Obtain Locally

4. Lubricate the rear crankshaft journal and rear main bearing.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Rear crankshaft journal and rear bearing	Obtain Locally

5. Install the rear main bearing carrier into the cylinder block. Align the marks made previously.

6. Ensure that lubrication holes on the block and carrier align, especially if the reference marks are not present.

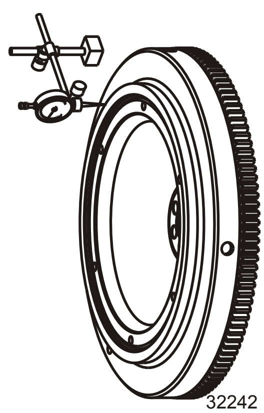


a - Rear main bearing carrier
b - Marks aligned

7. Install the flywheel housing and flywheel. See **Flywheel, Coupler or Drive Plate, and Flywheel Housing—Installation.**
8. Check the flywheel runout. See **Flywheel Runout**.
9. Check the crankshaft end play. See **Crankshaft End Play (Axial Clearance)**.

FLYWHEEL RUNOUT

1. Attach a dial indicator to the engine block.
2. Record the measurements around the outer edge of the flywheel.
3. If the flywheel runout exceeds the specified limit, replace the flywheel.



Dial indicator position

Flywheel	
Runout	0.10 mm (0.004 in.)

CRANKSHAFT END PLAY (AXIAL CLEARANCE)

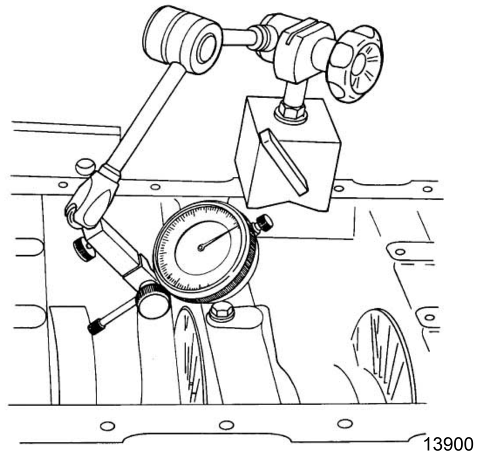
NOTE: *Ensure crankshaft runout is within specifications before setting crankshaft end play (axial clearance).*

1. Attach the Dial Indicator to the cylinder block to check the installed crankshaft end play (axial clearance). Take measurement at the crankshaft counter weight.

Dial Indicator	91-58222A1

2. Firmly force the crankshaft rearward. Record the measurement.

3. Firmly force the crankshaft forward. Record the measurement.
4. Subtract the measurements to determine the crankshaft end play (axial clearance).



Measuring crankshaft end play (axial clearance)

Crankshaft	
End play (axial clearance)	0.080 - 0.280 mm (0.0031 - 0.0110 in.)

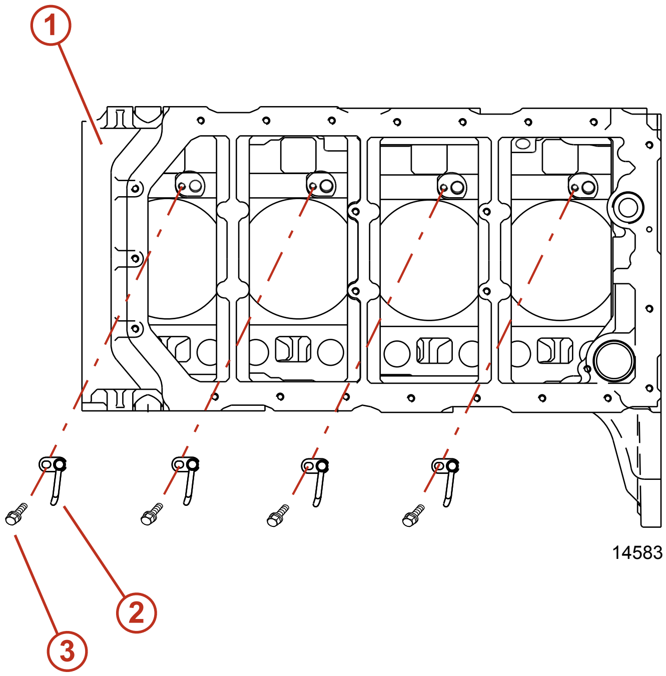
5. If the end play (axial clearance) is incorrect, calculate the necessary thickness of the thrust washers needed.
6. Install the thrust washers and recheck the end play (axial clearance).

Thrust Washer	
Standard	2.310 - 2.360 mm (0.0909 - 0.0929 in.)
First oversized	2.410 - 2.460 mm (0.0948 - 0.0968 in.)
Second oversized	2.510 - 2.560 mm (0.0988 - 0.1007 in.)

7. Repeat the steps until the proper end play (axial clearance) is reached.

Piston Cooling Jets (Oil Spray Nozzles)

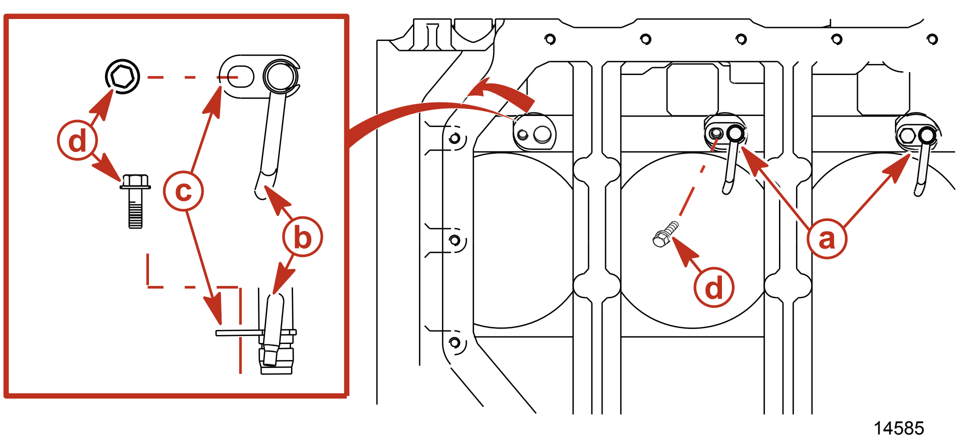
Exploded View—Piston Cooling Jets (Oil Spray Nozzles)



Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Cylinder block			
2	4	Piston cooling jet assembly			
-	4	O-ring seal (on piston cooling jet assembly)			
3	4	Piston cooling jet assembly screw	12.7	112	–

Removal

1. With the crankshaft removed, remove the piston cooling jet assembly from near the cylinder bore.



a - Cooling jet assembly
b - Nozzle
c - Plate
d - Bolt

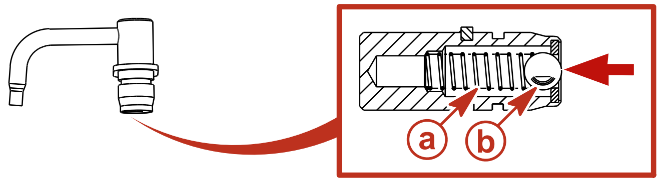
2. Remove and discard the O-ring seal on the piston cooling jet.

Cleaning

1. Clean the passages of the piston cooling jet and cylinder block.
2. Put on safety glasses.
3. Blow out any debris from cleaning using compressed air.

Inspection

1. Ensure that the check valve ball moves freely against the spring in the bore.



14586

a - Spring **b -** Check valve ball

2. Check for a cracked, bent, or damaged tube or nozzle.

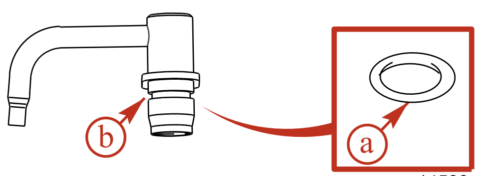
14587

a - Tube **b -** Nozzle

3. Replace if necessary.

Installation

1. Install a new O-ring in the piston cooling jet groove.



14588

a - O-ring **b -** Piston cooling jet groove

2. Lubricate the piston cooling jet O-ring.

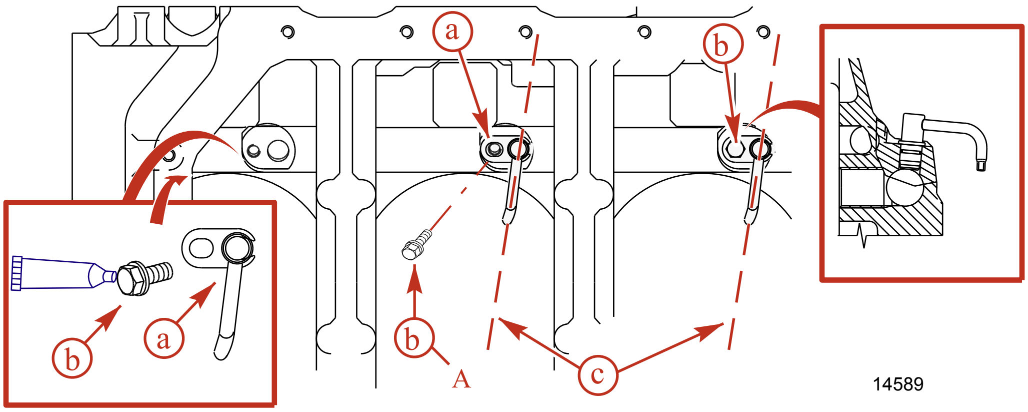
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Piston cooling jet O-ring	Obtain Locally

3. Insert the piston cooling jet assembly into the cylinder block.
4. Ensure that the piston cooling jet assembly is correctly seated.

NOTICE
Clogged or incorrectly installed piston cooling jets can damage the engine. The cooling jets lubricate and cool the piston and other engine components. Ensure the oil spray nozzles are clean and install the piston cooling jet assemblies correctly to allow proper oil distribution.

5. Position the tube and nozzle as shown.

6. Apply sealant to the piston cooling jet assembly screw threads.
7. Install and torque the piston cooling jet assembly screw.



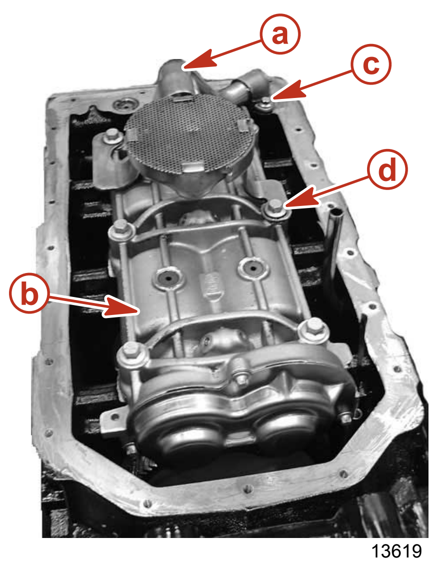
a - Piston cooling jet assembly
b - Piston cooling jet assembly screw
c - Tube and nozzle position

Description	Nm	lb. in.	lb. ft.
Piston cooling jet assembly screw	12.7	112	

Balance Shaft Assembly (2.8 Only)

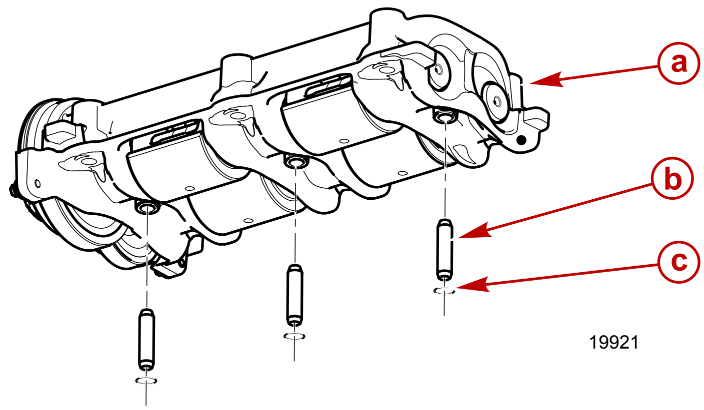
Removal

1. Position the engine at cylinder number 1 TDC. See **Establishing TDC (Top Dead Center)**.
2. Remove the oil pan.
3. Remove the bolts retaining the oil pickup and the balance shaft assembly to the cylinder block.



a - Oil pickup
b - Balance shaft assembly
c - Oil pickup bolt (1)
d - Balance shaft assembly bolt (6)

4. Lift the balance shaft assembly from the cylinder block. Note the position of the oil supply tubes and O-ring seals between the engine block and balance shaft assembly.



a - Balance shaft assembly
b - Oil supply tube
c - O-ring seal

Cleaning

1. Wash the balance shaft assembly in cleaning solvent.
2. Remove and discard the O-rings on the oil supply tubes.
3. Wash the oil supply tubes in cleaning solvent.
4. Put on safety glasses and dry the components with compressed air.

Inspection

NOTE: There are no individual replacement components for the balance shaft assembly. If worn, cracked, or damaged, the complete balance shaft assembly must be replaced.

1. Inspect the gears on the crankshaft and balance shaft assembly for wear or damage.
2. Inspect the balance shaft assembly housing for cracks or damage.
3. Replace the crankshaft and balance shaft assembly if worn, cracked, or damaged.

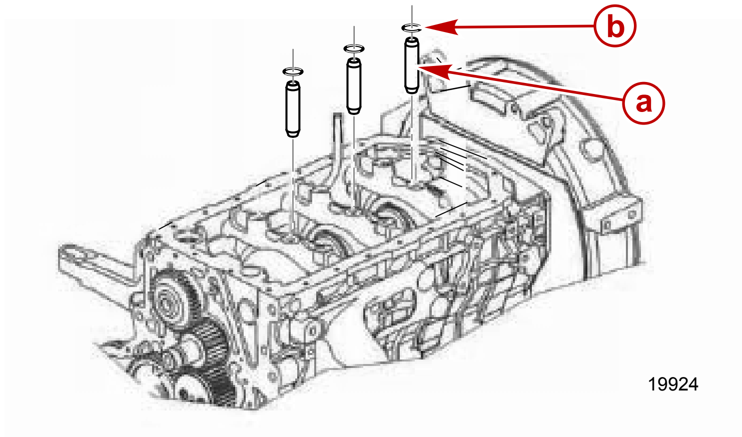
Installation

1. Set cylinder number 1 at TDC using the Flywheel TDC Pin Tool. Refer to **Section 3A: General Information**.

Flywheel TDC Pin Tool	91-889331001

2. Position a new O-ring seal around the center of each of the three oil supply tubes.

3. Insert the three oil supply tubes with O-ring seals into the cylinder block counterbores.



a - Oil supply tube **b -** O-ring

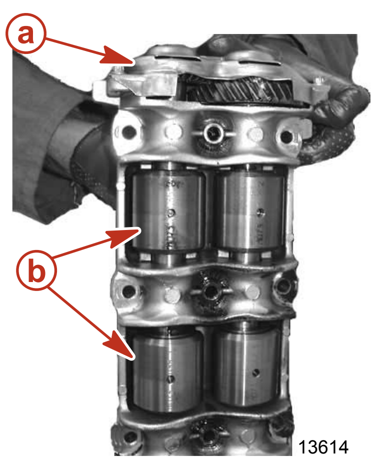
4. Thoroughly lubricate the balance shaft assembly.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Balance shaft assembly	Obtain Locally

NOTICE

The engines covered in this manual use a pair of crankshaft-driven, counterweighted shafts to balance the engine. Failure to align the balance shaft assembly will result in engine damage. When assembling the balance shaft assembly, properly align the shafts using the appropriate tools.

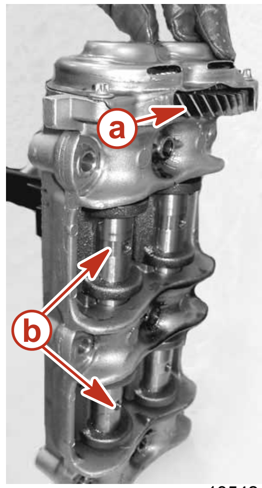
5. Do not align the counterweights as shown. In this view the counterweights are **not properly** aligned. See step 8 for proper counterweight alignment.



Improperly aligned counterweights

a - Balance shaft assembly **b -** Counterweights - improperly align

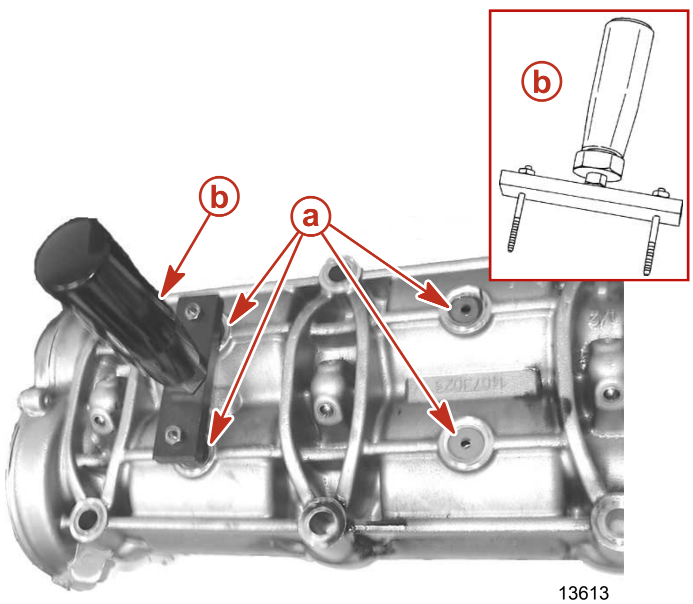
6. Turn the balance shaft assembly gear and align the counterweights as shown. In this view the counterweights are **properly** aligned.



Properly aligned counterweights

a - Balance shaft assembly gear **b -** Counterweights - properly aligned

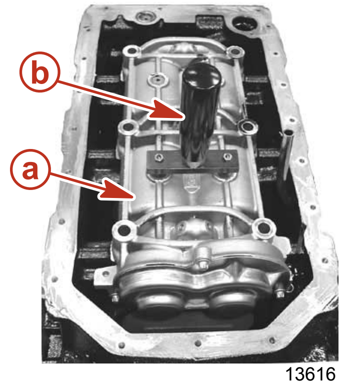
7. Insert the special Balance Shaft Installation Tool into either the front or rear set of 2 holes in the balance shaft assembly housing, to keep the counterweights aligned during installation.



a - Front and rear set of 2 holes **b -** Balance Shaft Instillation Tool

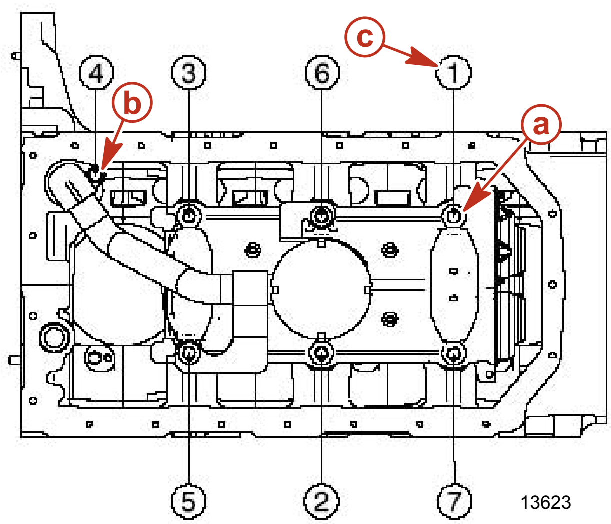
Balance Shaft Installation Tool	91-898155

8. Ensure that the engine is set on cylinder number 1 TDC with the Flywheel TDC Pin Tool installed. Mesh the balance shaft assembly gear with the crankshaft gear and install the balance shaft assembly onto the cylinder block.



a - Balance shaft assembly **b -** Balance Shaft Instillation Tool

9. Remove the Balance Shaft Installation Tool.
10. Install a new O-ring on the oil pickup tube.
11. Install the oil pickup.
12. Install the bolts retaining the balance shaft assembly and oil pickup to the cylinder block. Torque the oil pickup bolt and the balance shaft assembly bolts in the numbered sequence shown.



a - Balance shaft assembly bolt (6) **c -** Torque sequence
b - Oil pickup bolt (1)

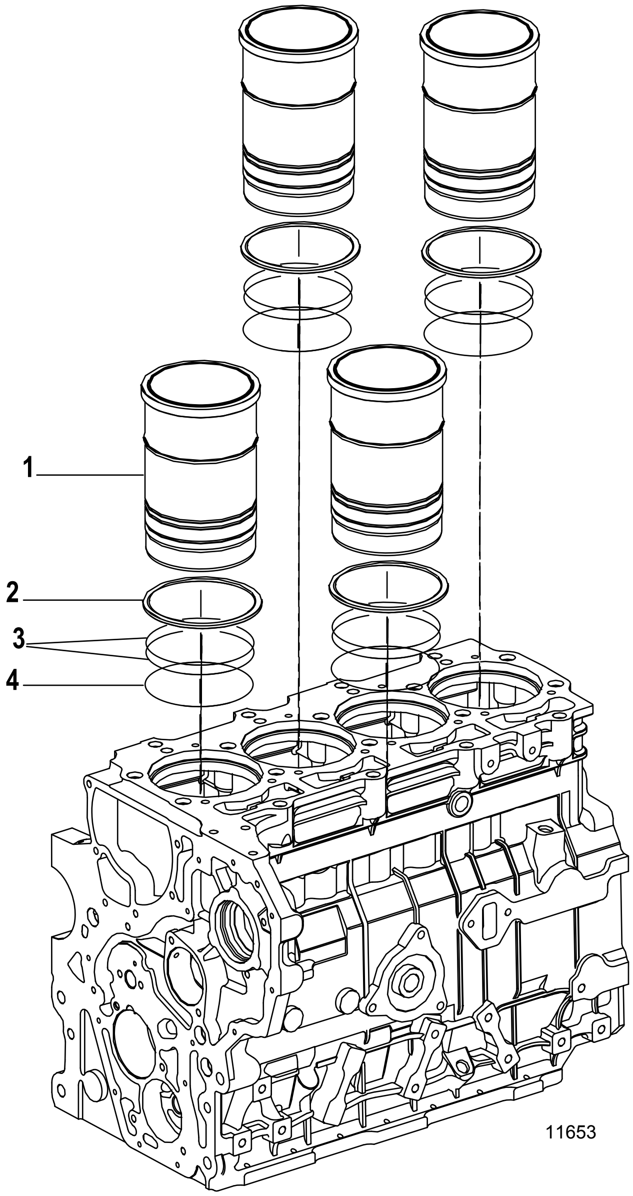
Description	Nm	lb. in.	lb. ft.
Balance shaft assembly bolts	32.4	–	23
Oil pickup bolt	12.7	112	–

13. Install the oil pan. See **Oil Pan, Oil Pickup, And Related Components**.
14. Remove the Flywheel TDC Pin Tool.

Notes:

Cylinder Liners

Exploded View—Cylinder Liners

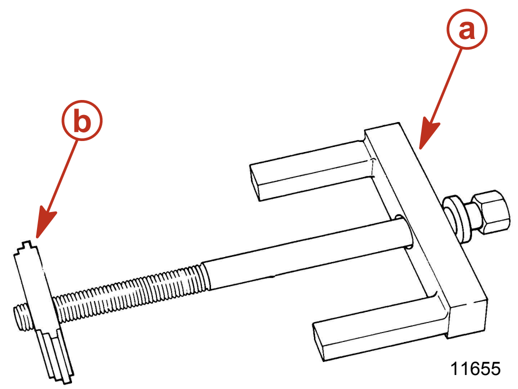


Exploded View—Cylinder Liners

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	4	Cylinder liner			
2	4	Compensation shim			
3	8	Upper O-ring (Black color)			
4	4	Lower O-ring (Brown color)			

Removal

1. Remove engine components as needed, including pistons.
2. Remove the piston cooling jets (oil spray nozzles).
3. Remove the plate from the Cylinder Liner Puller.

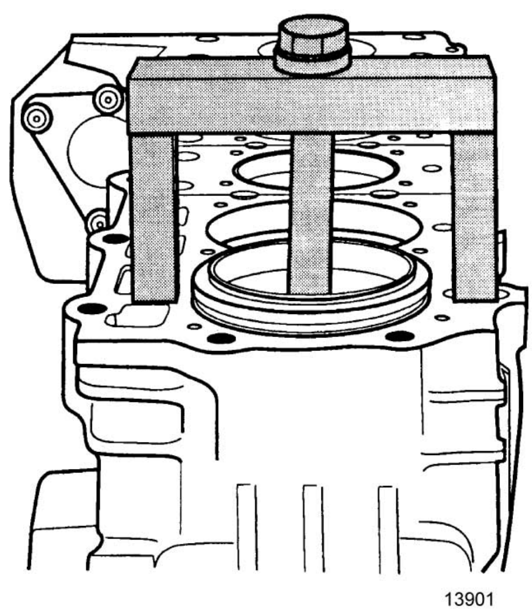


a - Cylinder Liner Puller **b -** Plate

Cylinder Liner Puller	91-801333502

IMPORTANT: To avoid mismatching cylinder liners and pistons upon reassembly, mark the liners as to the cylinder number and orientation in the cylinder block.

4. Install the Cylinder Liner Puller into the cylinder liner and attach the plate to the tool at the bottom of the cylinder liner.
5. Remove the cylinder liners. Note the location of the shim between the cylinder liner and the crankcase bore relief. Also, note the O-rings on the cylinder liner lower part.



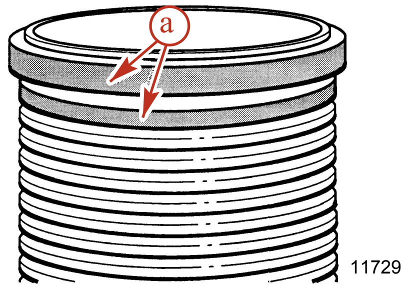
Removing a cylinder liner

Cleaning and Inspection

CYLINDER LINERS

1. Remove old sealant from the cylinder liners.

2. Clean the cylinder liners, especially in the areas shown, and in the areas where the O-rings fit.



a - Areas for special cleanliness

3. Wash the liners in cleaning solvent.
4. Put on safety glasses and dry the components with compressed air.
5. Inspect the cylinder liners for abnormal wear or cracks. Replace as needed with those parts for your specific model.
6. Inspect the cylinder liners for a ridge at the top of the ring travel. Remove the ridge if the cylinder liners are within specification.
7. Measure the cylinder liners for taper and out of round using a dial indicator or inside micrometer. If wear exceeds specifications, replace the cylinder liners.

NOTE: *Carefully move the gauge up and down in the cylinder liner bore to determine taper. Measure the taper at three different vertical positions and at opposite sides of the cylinder liner bore. Turn the gauge to different points around the cylinder liner wall to determine the out of round condition. Maximum measurement depth is 108 mm (4.25 in.) down from the top edge of the cylinder liner.*

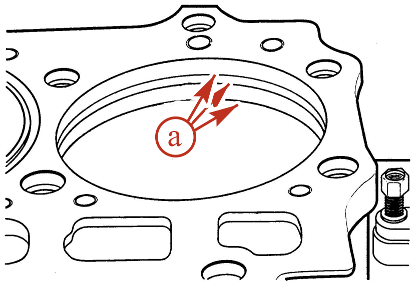
Cylinder Liner	
Production diameter	93.995 - 94.015 mm (3.7006 - 3.7011 in.)
Production out of round or taper	0.008 mm (0.0003 in.)
Maximum out of round or taper	0.10 mm (0.004 in.)

8. When the cylinder liner wear is within specifications, light honing of the cylinder liner bore is allowed.

CYLINDER BLOCK LINER BORES

1. Thoroughly clean the cylinder block with a suitable solvent.
2. Put on safety glasses and dry the components with compressed air.
3. Inspect the cylinder block for cracks or flaws.
4. Check the cylinder head mating surfaces of the block and the area around the cylinder liner bores for abnormal wear or damage.

5. Check the cylinder block bores for damage and cleanliness, especially the flanges and counterbores for cylinder liners.



a - Areas for special cleanliness

Installation

Cylinder liners on all engines are required to protrude, or rise, a specified distance above the surface of the cylinder block. This specified protrusion can be obtained by adding the thickness of one of the five compensation shims between the liner flange and the cylinder block.

1. Determine the correct compensation shim thickness needed for each liner.

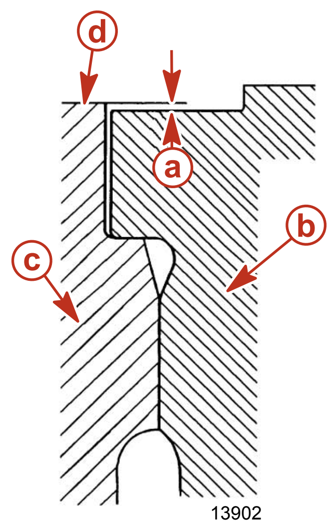
NOTICE

Cylinder liner protrusion can only be correctly measured with the cylinder liners fully seated in the cylinder block. Incorrect measurements will result in engine performance problems or severe engine damage. Ensure the cylinder liners are fully seated in the cylinder block before measuring cylinder liner protrusion.

NOTE: *The cylinder liners will rotate freely in the bore when the cylinder block and cylinder liner are completely clean and ready for assembly.*

a. Unless being replaced, install the cylinder liners in the same cylinder block bore as marked or noted upon disassembly **without compensation shims or O-rings**.

b. Using a precision depth gauge, measure and record the amount of cylinder liner recess (the depth below the cylinder head mounting surface of the cylinder block) of each liner.



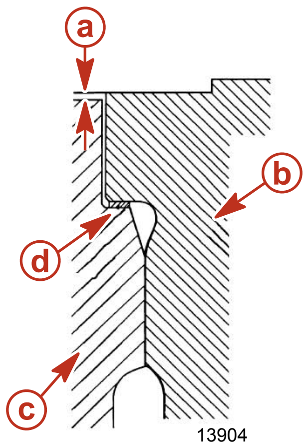
a - Cylinder liner recess
b - Cylinder liner
c - Cylinder block
d - Cylinder head mounting surface

c. Use the following chart to determine and select the compensation shim thickness required to produce the correct cylinder liner protrusion:

Cylinder liner protrusion		
Liner recess below block surface (without compensation shim)	Compensation shim to be used (thickness)	Liner protrusion above block (with compensation shim)
0.12 - 0.10 mm (0.0047 - 0.0039 in.)	0.15 mm (0.0059 in.)	0.01–0.06 mm (0.0004–0.0023 in.)
0.14 - 0.12 mm (0.0055 - 0.0047 in.)	0.17 mm (0.0067 in.)	
0.17 - 0.15 mm (0.0067 - 0.0059 in.)	0.20 mm (0.0078 in.)	
0.20 - 0.18 mm (0.0079 - 0.0070 in.)	0.23 mm (0.0090 in.)	
0.22 - 0.20 mm (0.0086 - 0.0078 in.)	0.25 mm (0.0098 in.)	

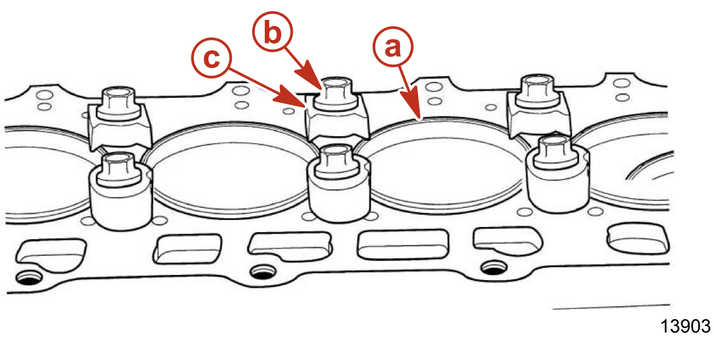
d. Remove the cylinder liner and install the compensation shim selected. Refit the cylinder liner.

e. Measure the protrusion above the block surface. Adjust using an alternate compensation shim, if not within specification.



a - Cylinder liner protrusion (height above block surface)
b - Cylinder liner
c - Cylinder block
d - Shim

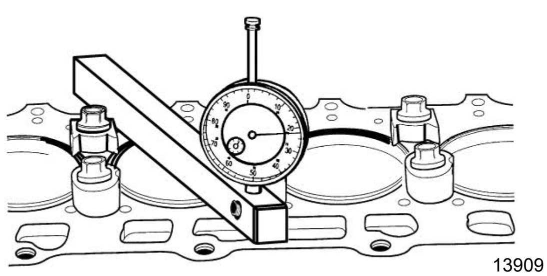
2. Install the cylinder liners with the appropriate shims and hold in place with formed spacer washers. Temporarily torque the formed spacer-washer bolts.



a - Cylinder liner
b - Bolt
c - Formed spacer washer

Description	Nm	lb. in.	lb. ft.
Formed spacer washer bolt	30		22

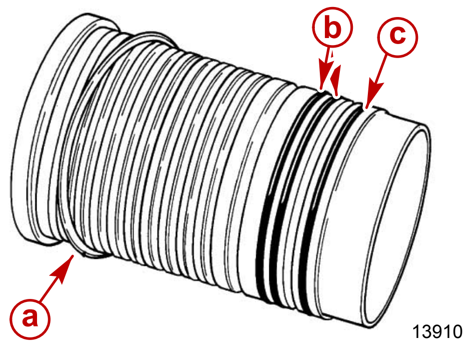
3. Recheck the cylinder liners for the proper amount of protrusion using the liner gauge bar and an appropriate dial gauge.



Checking Liner Protrusion

Support Block	91-814812A 1

4. Measured value must be as specified in chart given in step 1. If not, adjust until each liner is within liner protrusion specification.
5. Remove the cylinder liners in order, keeping the appropriate shims matched to liners.
6. Install two black O-rings in the grooves near the neck of the cylinder liner and one brown O-ring in the groove near the bottom.

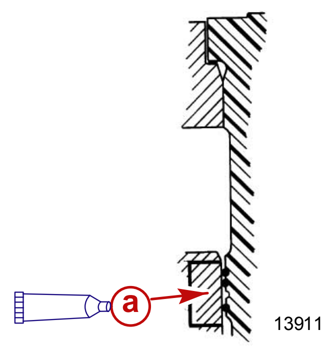


a - Shim
b - Black O-rings (two)
c - Brown O-ring (one)

7. Lubricate the lower centering collars in the cylinder block (those areas where lower liner O-rings seal against the bore) with one of the specified lubricants.

IMPORTANT: Do not lubricate upper bore area where sealant will be applied later.

NOTE: *Cylinder liner shown fitted only for visual clarity. Do not install cylinder liners in this step.*

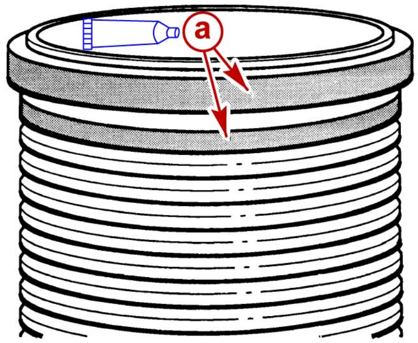


a - Lower centering collar area of cylinder block

Tube Ref No.	Description	Where Used	Part No.
4	Needle Bearing Assembly Lubricant	Lower centering collars in cylinder block	92-802868A1
80	SAE Engine Oil 30W	Lower centering collars in cylinder block	Obtain Locally

8. Select and apply one of the two specified sealants to the liner surfaces.

IMPORTANT: Do not apply sealant to shim or shim contact surfaces.

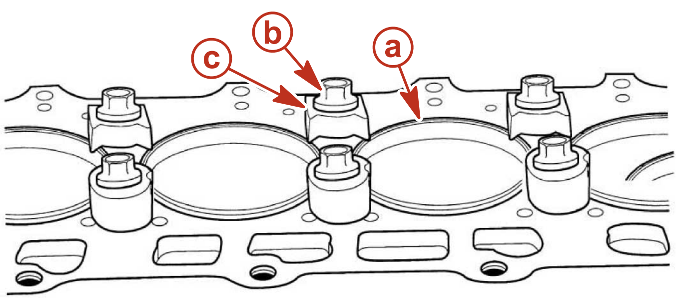


a - Sealant area

Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Cylinder liner surfaces	92-12564 2

Tube Ref No.	Description	Where Used	Part No.
	Loctite 620 or 986	Cylinder liner surfaces	Obtain Locally

9. Install the cylinder liners in the cylinder block, being careful not to damage the O-rings or distort the compensation shims.
10. Hold the liners securely in position with the bolts and formed spacer-washers. Temporarily torque the bolts and allow the sealant to dry.



a - Cylinder liner

b - Suitable bolt

c - Formed spacer washer

Description	Nm	lb. in.	lb. ft.
Spacer washer bolt	49		36

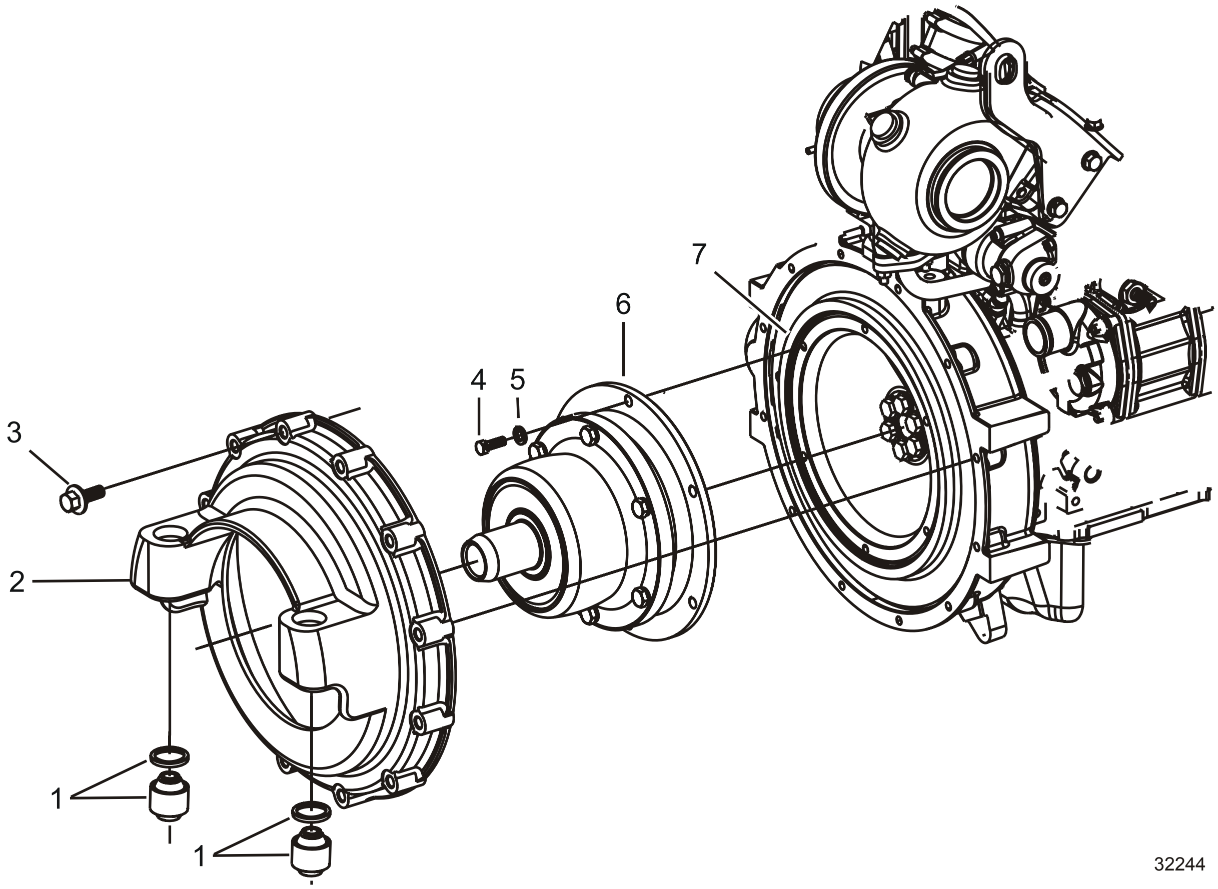
IMPORTANT: If the cylinder heads are not installed within one hour, the cylinder liners must remain clamped by the spacer washers and bolts for roughly 8 hours, so that the sealant can properly cure. After eight hours the spacer washers and bolts can be removed and the cylinder heads can be installed.

11. After the sealant is dry, verify the cylinder liner protrusion and adjust with appropriate compensation shims, if required.
12. Continue the engine assembly.

Notes:

Flywheel, Coupler Or Drive Plate, and Flywheel Housing

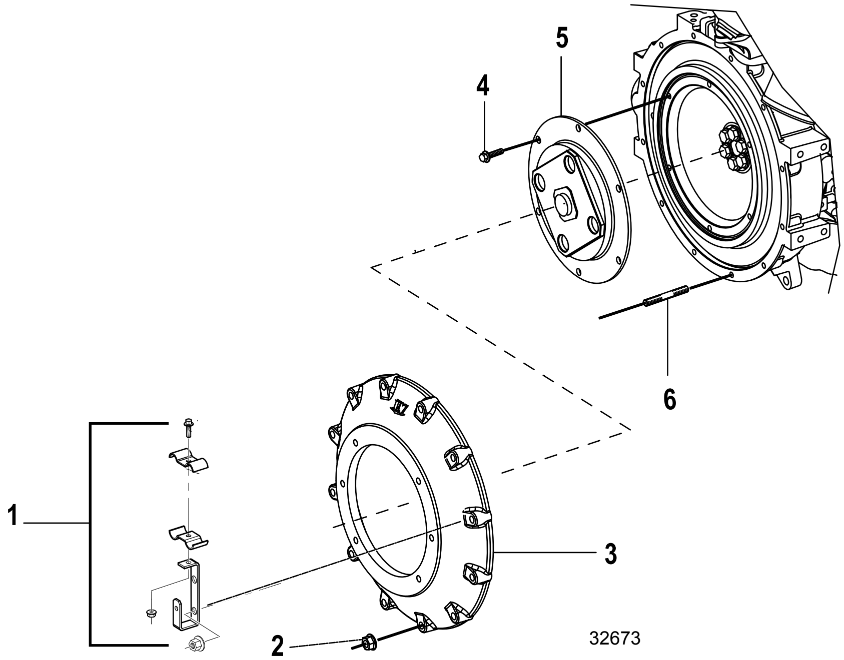
Exploded View—Sterndrive Flywheel Cover and Coupler



Exploded View—Sterndrive Flywheel Cover and Coupler

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	2	Rear mount bushings			
2	1	Flywheel housing cover			
3	12	Flywheel housing cover bolt	47.1	–	34
4	6	Coupler bolt	47.1	–	34
5	6	Washer			
6	1	Sterndrive Coupler			
7	1	Flywheel			

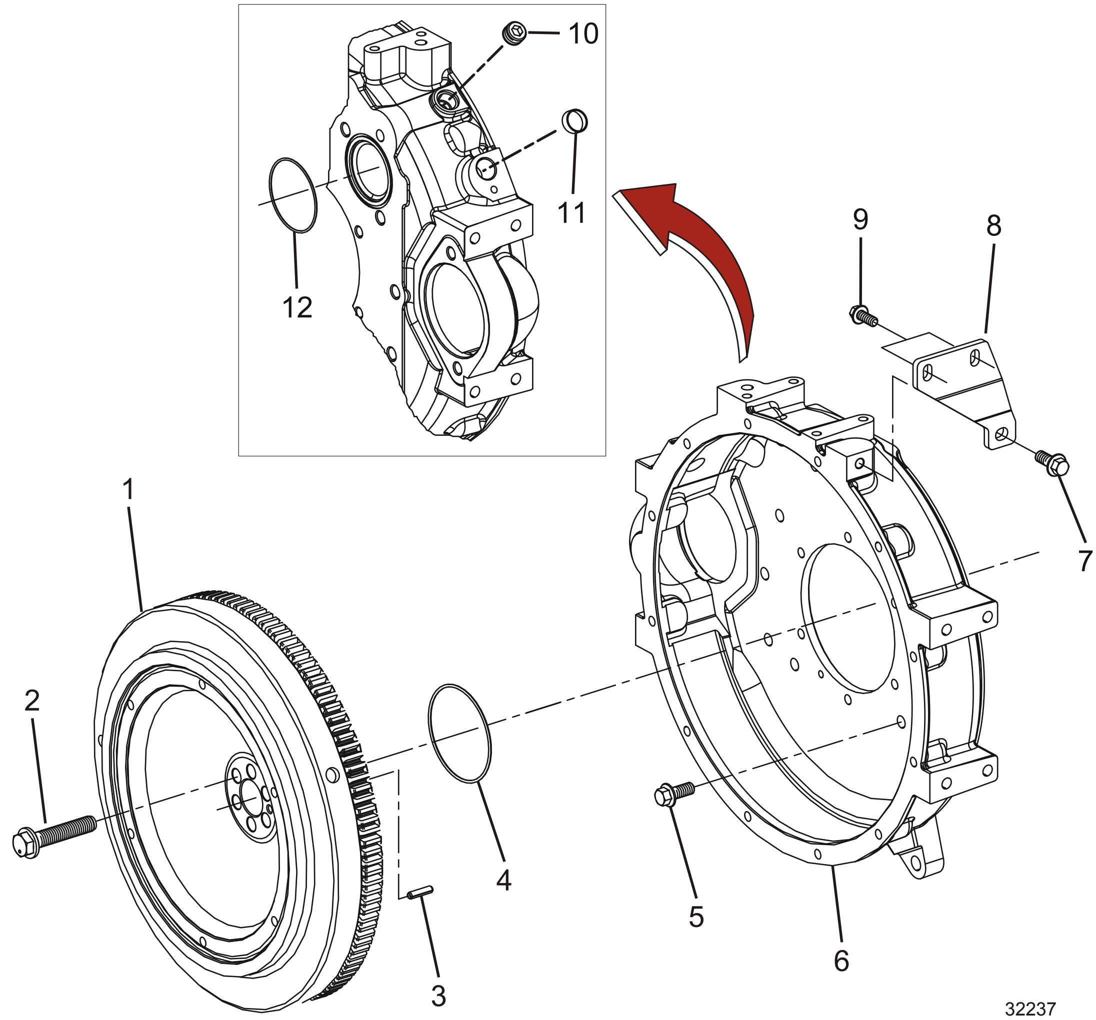
Exploded View—Inboard Flywheel Cover and Drive Plate



Exploded View—Inboard Flywheel Cover and Drive Plate

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Hose support bracket assembly			
2	12	Flywheel housing cover flange nut	47.1	–	34
3	1	Flywheel housing cover			
4	6	Drive plate bolt	47.1	–	34
5	1	Drive plate			
6	12	Stud			

Exploded View—Flywheel Housing

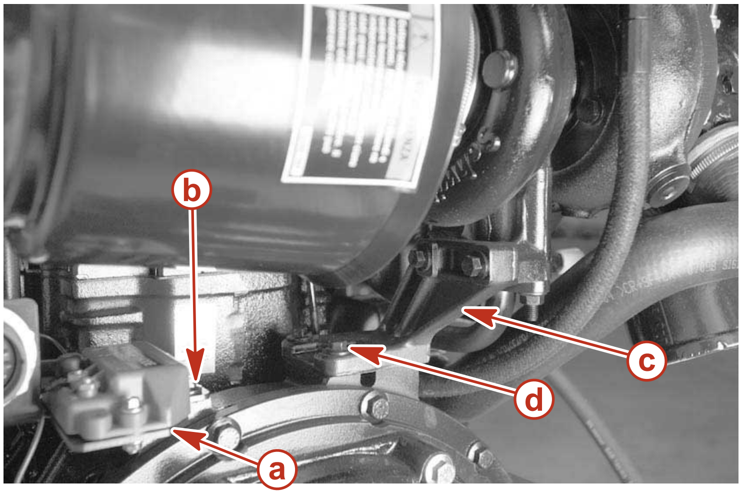


Exploded View—Flywheel Housing

Ref. No.	Qty.	Description		Torque Nm	Torque lb. In.	Torque lb. ft.
1	1	Flywheel				
2	6	Flywheel bolt	First pass	32.4	–	24
			Second pass	+ 75 degrees		
3	1	Pin				
4	1	Flywheel housing O-ring				
5	10	Flywheel housing screw	Grade 8.8	47	–	34
			Grade 10.9	69	–	50
6	1	Flywheel housing				
7	1	Turbocharger support bracket flange screw		47	–	34
8	1	Support bracket				
9	2	Screw, M8 x 60 mm		27.5	–	20
10	1	Plug		49	–	36
11	1	Expansion plug				
12	1	O-ring				

Removal

1. Remove the starter.
2. Remove the two flange screws retaining the engine harness connector bracket and MerCathode controller if equipped, to the flywheel housing.
3. Remove the two turbocharger support bracket screws.



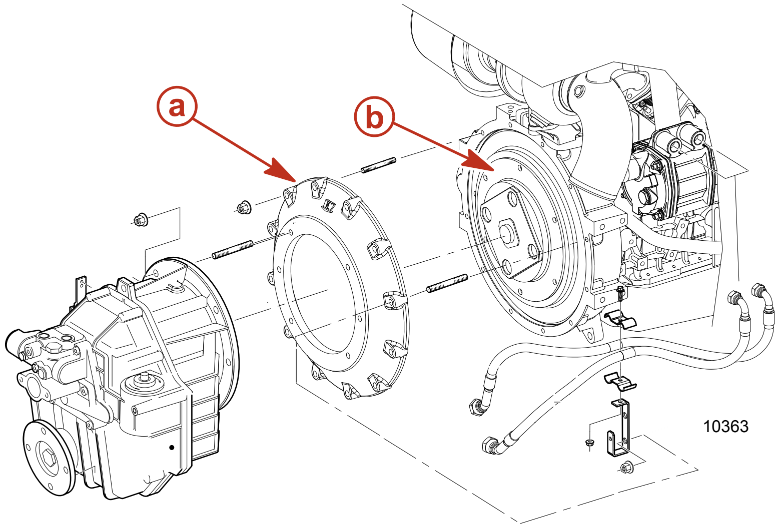
10376

Sterndrive model, Inboard similar

a - Engine harness connector bracket
b - Engine harness connector bracket screw
c - Turbocharger support bracket
d - Turbocharger support bracket screw

4. **On Sterndrive Models:**
   a. Remove the flywheel housing cover.
   b. Remove the coupler.

5. **On Inboard Models:**
   a. Remove the flywheel housing cover with the transmission, or remove the transmission, if required.
   b. Remove the flywheel housing cover.
   c. Remove the drive plate.

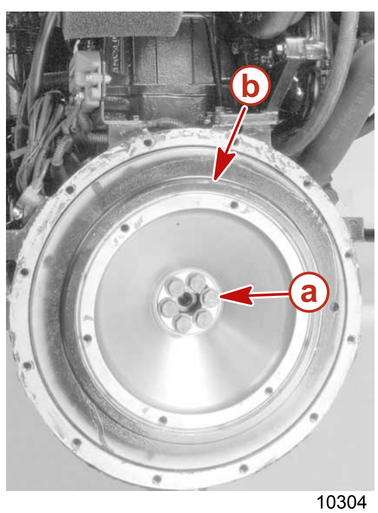


a - Flywheel housing cover
b - Drive plate

6. Remove two of the flywheel bolts and install the Flywheel Assembly Guide Pins.

Flywheel Assembly Guide Pins	91-898282001

7. Remove the remaining flywheel bolts and the flywheel.



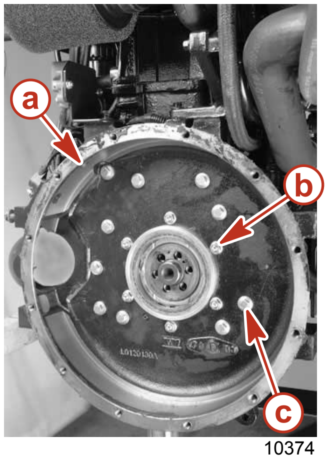
Sterndrive model, inboard similar

a - Flywheel bolts
b - Flywheel

8. Remove the Flywheel Assembly Guide Pins.
9. Remove the remaining flywheel housing bolts and the six rear main bearing carrier flange nuts.

10. Remove the flywheel housing.

NOTE: *Upon removal, note the position of the O-ring between the flywheel housing and the engine block.*



a - Flywheel housing
b - Rear main bearing carrier flange nut
c - Flywheel housing bolt

Cleaning

1. Wash the flywheel housing cover, flywheel, and flywheel housing in cleaning solvent.
2. Put on safety glasses and dry the components with compressed air.
3. Clean the mating surfaces of the flywheel and crankshaft. Remove any burrs. Mating surfaces must be clean, bare metal.

Inspection

1. Inspect the rear mounts in the flywheel housing cover. Replace the rear mounts as a matched pair if damaged.
2. Inspect the flywheel housing cover and flywheel housing for cracks or damage.
3. Inspect the splines in the sterndrive coupler or the inboard drive plate for wear.
4. Clean the flywheel with a non-caustic solvent, then visually inspect the flywheel for cracks or heat checks which would make it unfit for further service.
5. Check the flywheel ring gear for worn and missing teeth.
6. Repair or replace worn or damaged components.

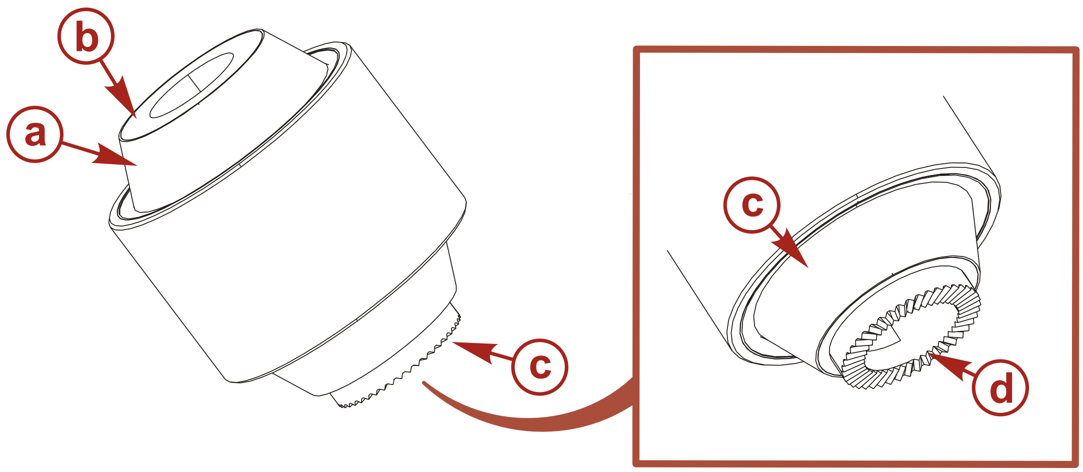
Repair

NOTE: *The rear mounts pressed into the flywheel housing cover and the flywheel ring gear can be serviced. Replace the other components, such as the flywheel housing, coupler, and drive plate, if worn or damaged.*

REAR MOUNTS

1. Replace the rear mounts in the sterndrive flywheel housing cover as follows:
   a. With the flywheel housing cover in the upright position, remove the rear engine mounts and spacers using a suitable arbor and press.
   b. Clean the flywheel housing cover rear mount bores.
   c. Turn the flywheel housing cover upside down and install the spacer inside the rear mount bore.

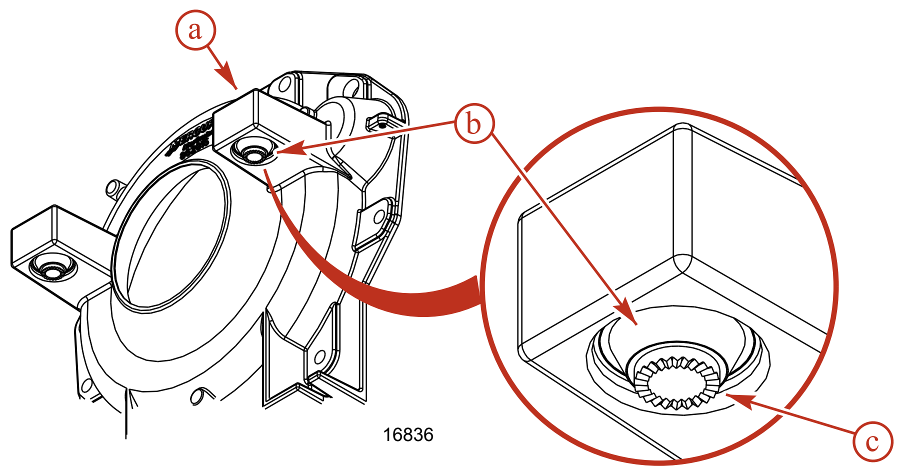
IMPORTANT: The yellow paint identifies the top of the mount assembly (865330). The bottom has the knurled edge.



16835

a - Painted top
b - Smooth edge
c - Bottom end
d - Knurled edge

   d. Press the mount into the flywheel housing cover so that the painted end will be facing up and the knurled edge of the mount bottom will be facing down when installed on the engine.



Typical sterndrive flywheel housing cover, all similar

a - Painted end (not visible)
b - Mount bottom
c - Knurled edge

IMPORTANT: Because of the bottom knurled edge on these mounts, the double-wound lockwashers, if equipped, are no longer required.

FLYWHEEL RING GEAR

1. Heat the ring gear with a torch on the engine side of the ring gear.

2. Once heated, knock the ring gear off the flywheel. Do not strike the flywheel when removing the ring gear.

IMPORTANT: Some components are made of steel that has been heat treated to increase hardness. Applying excessive heat to the hardened steel will alter the hardness and make the steel weaker. Do not heat any portion of these hardened steel components, such as a flywheel ring gear, to a temperature higher than 278 °C (500 °F).

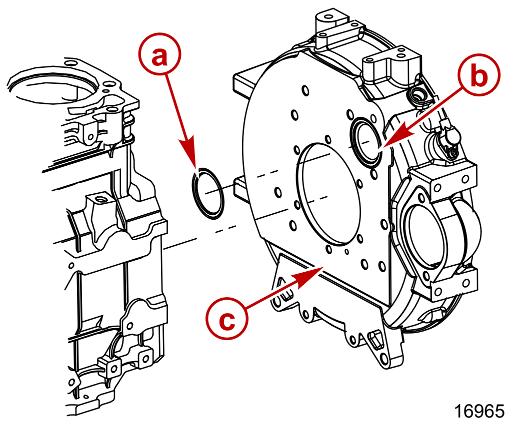
3. Heat the new ring gear for 20 minutes in an oven preheated to 127° C (260° F), or heat evenly until the gear expands enough to slip onto the flywheel. Do not overheat the ring gear.

IMPORTANT: The ring gear must be installed so the bevel on the teeth is toward the crankshaft side of the flywheel.

4. Install the ring gear. Ensure that the ring gear is seated properly against the flywheel shoulder.

Installation

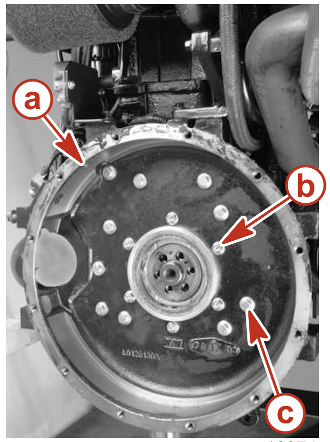
1. Install a new O-ring into the groove of the flywheel housing. A small amount of grease, such as Molykote, may be used to hold the O-ring in position during installation.



a - O-ring
b - Groove
c - Flywheel housing

2. Install the flywheel housing.
3. Install and torque the flywheel housing bolts.

4. Install the 6 rear main bearing carrier flange nuts. Torque the flange nuts evenly in a diagonal pattern.



10374

a - Flywheel housing
b - Rear main bearing carrier flange nut
c - Flywheel housing bolt

Description		Nm	lb. in.	lb. ft.
Flywheel housing bolts	Grade 8.8	47	–	35
	Grade 10.9	69	–	50
Rear main bearing carrier flange nuts		24.5	–	18

5. Ensure that there are no scratches, nicks, cracks, or seizure marks on the flywheel mating surface. Only minor scratches, nicks, or seizure marks can be removed. Replace the flywheel if damaged.

IMPORTANT: Whenever the flywheel is removed, replace the O-ring.

6. Install a new O-ring into the groove on the flywheel.
7. Install the two Flywheel Assembly Guide Pins.

Flywheel Assembly Guide Pins	91-898282001

8. Align the flywheel with the rolled pin and install the flywheel with O-ring onto the crankshaft using the Flywheel Assembly Guide Pins.
9. Lubricate the threads of the flywheel bolts.

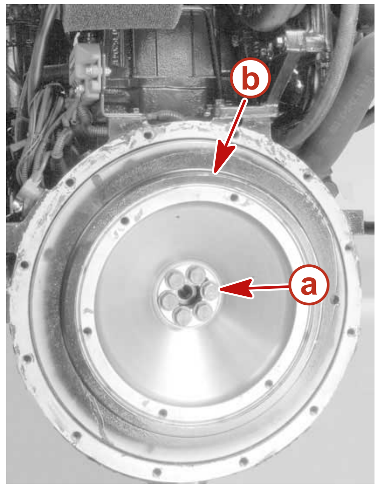
Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Flywheel bolt threads	Obtain Locally

10. Install and hand-tighten four of the flywheel bolts.
11. Remove the Flywheel Assembly Guide Pins and install the remaining flywheel bolts.

12. Torque the flywheel bolts evenly in a clockwise cross pattern as specified.

Description	Nm	lb. in.	lb. ft.
Flywheel bolts	50	–	37

IMPORTANT: The flywheel bolts may be reused up to three times. Replace them if their service history is unknown.



10304

a - Flywheel bolts
b - Flywheel

13. Loosen one flywheel bolt at a time and tighten as specified.

Description		Nm	lb. in.	lb. ft.
Flywheel bolt	First pass	20	177	–
	Second pass	+ 75°		

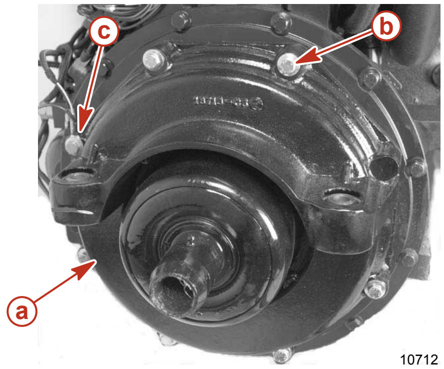
14. Apply sealant to the bolt threads and install the sterndrive coupler or inboard drive plate assembly.

Tube Ref No.	Description	Where Used	Part No.
7	Loctite 271 Threadlocker	Sterndrive coupler or inboard drive plate bolt	92-809819

15. Torque the sterndrive coupler or inboard drive plate bolts.

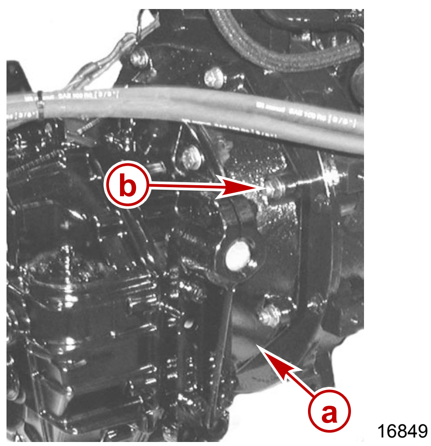
Description	Nm	lb. in.	lb. ft.
Sterndrive coupler bolt	47.1	–	35
Inboard drive plate bolt	47.1	–	35

16. Install the flywheel housing cover. Connect the ground (–) wires, if equipped. Torque the sterndrive flywheel cover bolts or the inboard flywheel cover nuts.



Typical sterndrive

a - Flywheel cover
b - Flywheel cover bolt
c - Ground (–) wires



Typical inboard

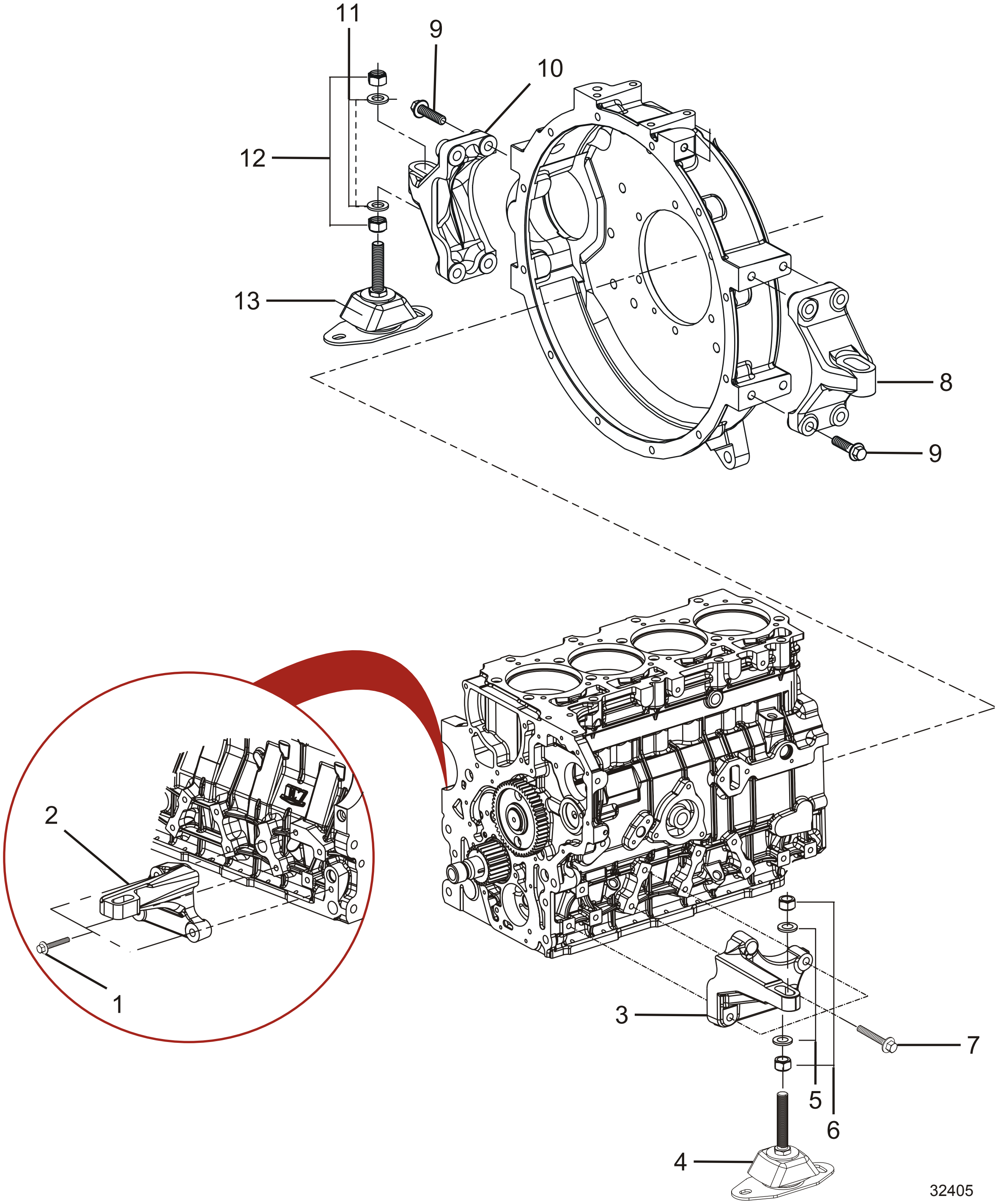
a - Flywheel cover
b - Flywheel cover nut

Description	Nm	lb. in.	lb. ft.
Sterndrive flywheel housing cover bolt	47.1	–	35
Inboard flywheel housing cover nut to flywheel housing	47.1	–	35

17. Remove the Flywheel Holder Tool, if installed.
18. Install all other components removed.
19. Start the engine and check for leaks.

Engine Mounts and Brackets

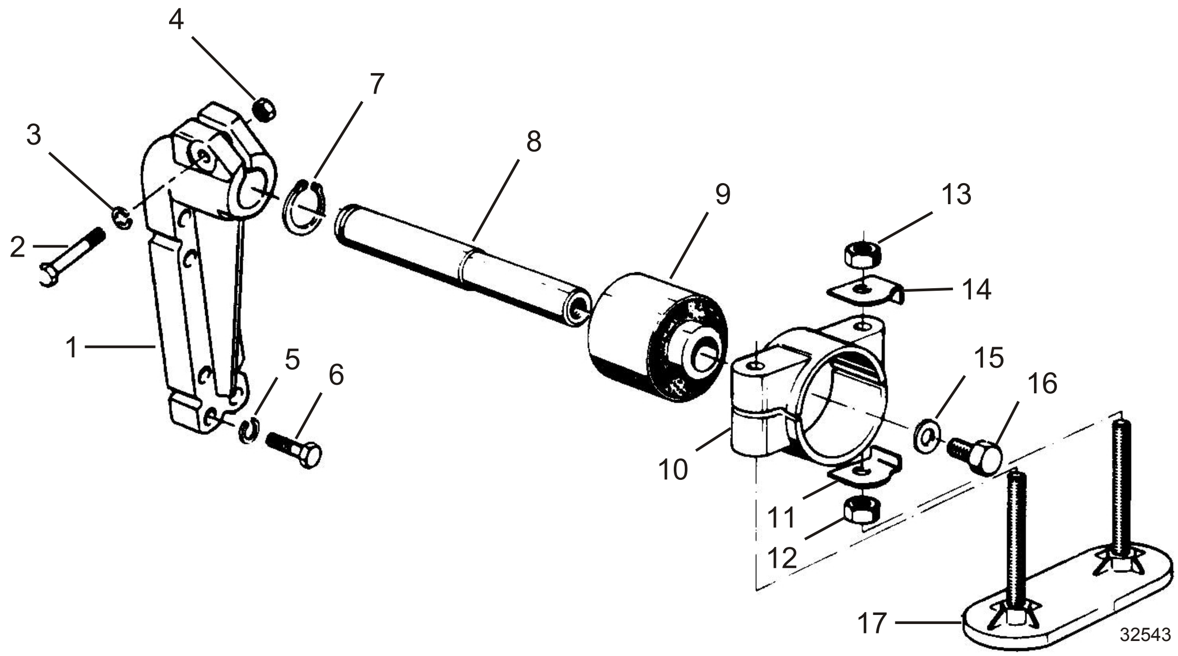
Exploded View—Engine Mounts and Brackets



Exploded View—Engine Mounts and Brackets

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	3	Screw	78.5	–	58
2	1	Starboard front mount bracket			
3	1	Port front mount bracket			
4	2	Engine mount			
5	4	Lockwasher			
6	2	Adjustment and locking (jam) nut	80	–	59
7	3	Screw	78.5	–	58
8	1	Rear mount bracket			
9	8	Rear mount bracket screw (use sealant)	75	–	55
10	1	Rear mount bracket			
11	4	Washer			
12	2	Adjustment and locking (jam) nut	80	–	59
13	2	Rear engine mount			

Exploded View—V-drive Rear Engine Mounts



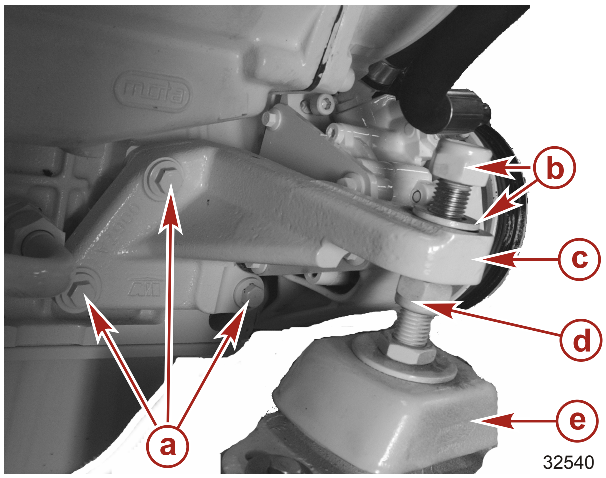
Exploded View—V-drive Rear Engine Mounts

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	2	Rear mount bracket			
2	2	Trunnion clamp bolt			
3	2	Lockwasher			
4	2	Nut	68	–	50
5	2	Lockwasher			
6	4	Rear mount bracket screw (use sealant)	75	–	55
7	2	Snap-ring			
8	2	Trunnion pin			
9	2	Isolator bushing			
10	2	Isolator bushing housing			
11	4	Tab washer			
12	4	Locking jam nut	80	–	59
13	4	Locking jam nut	80	–	59
14	4	Tab washer			
15	2	Washer			
16	2	Bushing center screw	52	–	38
17	2	Rear mount base			

Front Mounts

REMOVAL

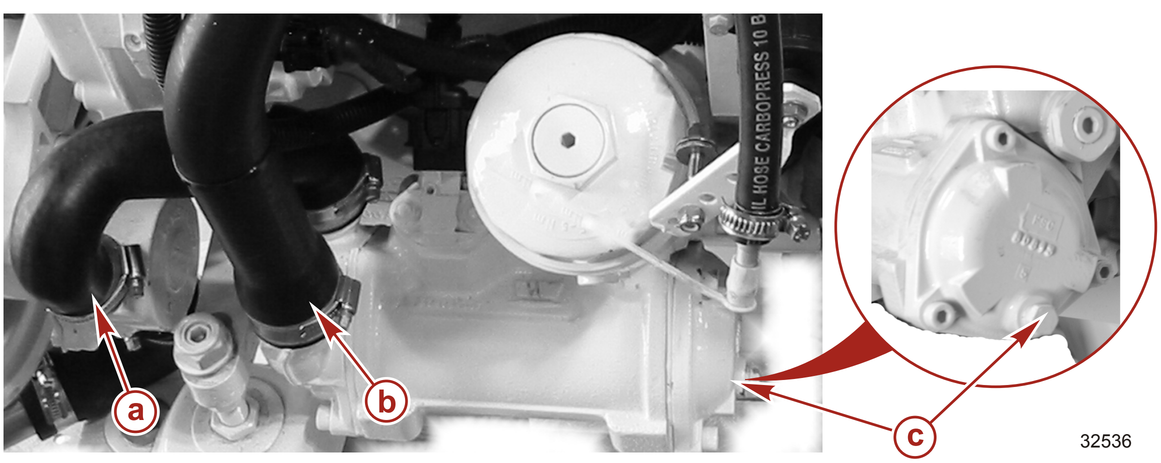
1. Remove the front engine mount to engine bed fasteners and hardware.
2. Support the front part of the engine with a hoist, or put suitable blocks under the engine.
3. Remove the three engine mount bracket to cylinder block attaching screws from the starboard engine mount bracket.



Starboard side shown, port attachment similar

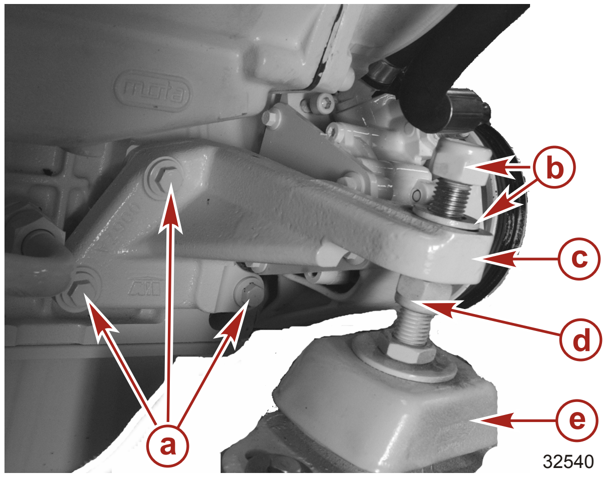
a - Engine mount attaching screws
b - Isolator to mount nut and lock washer
c - Engine mount bracket
d - Adjusting nut
e - Engine mount

4. If the boat is to remain in the water, close the seacock (if equipped) or disconnect and plug the seawater inlet hose.
5. Drain the seawater system.
6. Remove the two seawater hoses from the oil cooler to ease access to the port side engine mount bracket.



a - Seawater pump outlet hose
b - Oil cooler seawater outlet hose
c - Drain plug

7. Remove the three engine mount bracket to cylinder block attaching screws from the port engine mount bracket.



Port side shown, starboard attachment similar

a - Engine mount attaching screws
b - Isolator to mount nut and lock washer
c - Engine mount bracket
d - Adjusting nut
e - Engine mount

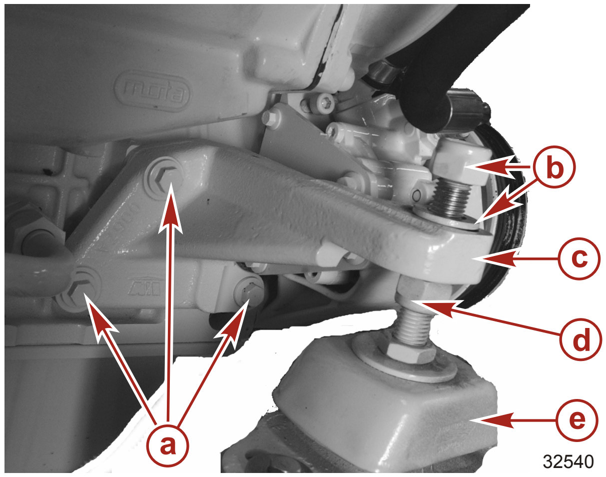
CLEANING AND INSPECTION

1. Except for rubber portions of the mounts, clean the components in cleaning solvent.
2. Put on safety glasses and dry the components with compressed air.
3. Inspect the mounts for cracks or damage.
4. Inspect the rubber portions of the mount for deterioration or wear.
5. Replace deteriorated, worn, cracked, or damaged components.

INSTALLATION

1. Install the starboard front mount bracket to the cylinder block.
2. Install the port front mount bracket to the cylinder block.

3. Torque the front mount bracket screws.

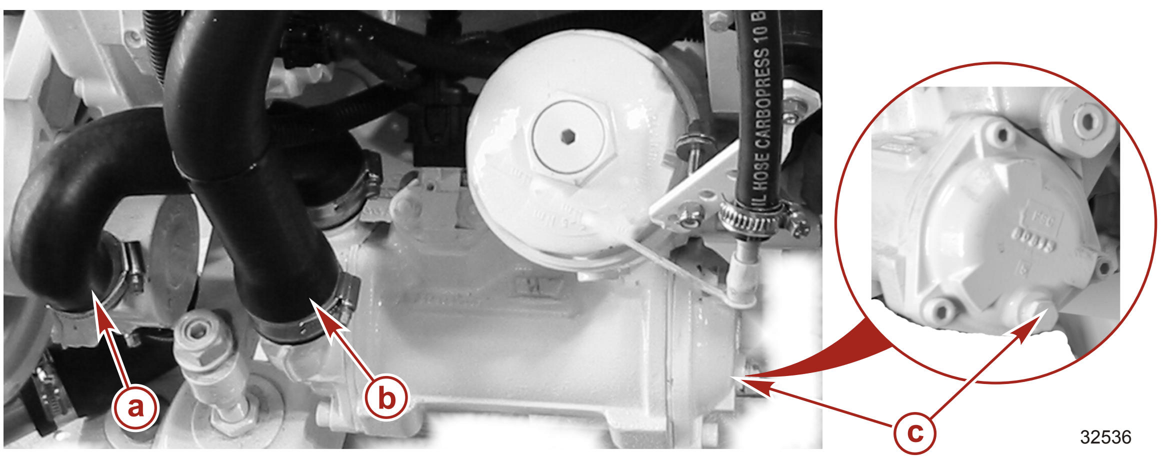


Port side shown, starboard attachment similar

a - Engine mount attaching screws
b - Isolator to mount nut and lock washer
c - Engine mount bracket
d - Adjusting nut
e - Engine mount

Description	Nm	lb. in.	lb. ft.
Front mount screw	78.5	–	58

4. Install the two seawater hoses on the oil cooler.



a - Seawater pump outlet hose
b - Oil cooler seawater outlet hose
c - Drain plug

5. Remove the engine's secondary support and lower the engine with a hoist.
6. Install the front engine mount to engine bed fasteners and hardware. Tighten securely.
7. Align the engine and drive. Adjust the mounts as needed. See **Section 2B: Engine Installation**.

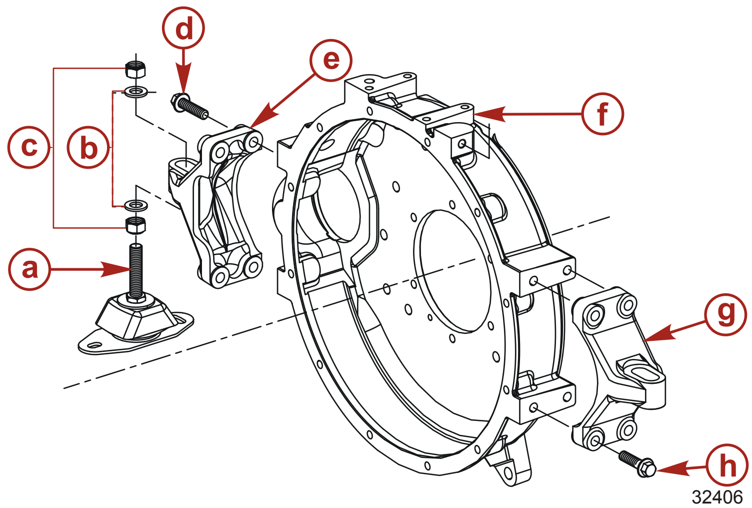
Sterndrive Models

NOTE: For rear mount information and procedures about sterndrive model, see ***Flywheel, Coupler Or Drive Plate, and Flywheel Housing*** *or the appropriate Mercury MerCruiser Sterndrive Service Manual.*

Inboard Rear Engine Mounts

REMOVAL

1. Remove the rear engine mount to engine bed fasteners and hardware.
2. Support the rear part of the engine or the transmission with a hoist, or put suitable blocks under the flywheel housing or transmission.
3. Remove the port and starboard rear engine mount brackets.



a - Engine mount
b - Lockwashers
c - Adjustment and locking (jam) nut
d - Engine mount bracket screws
e - Port engine mount bracket
f - Flywheel housing
g - Starboard engine mount bracket
h - Engine mount bracket screws

CLEANING AND INSPECTION

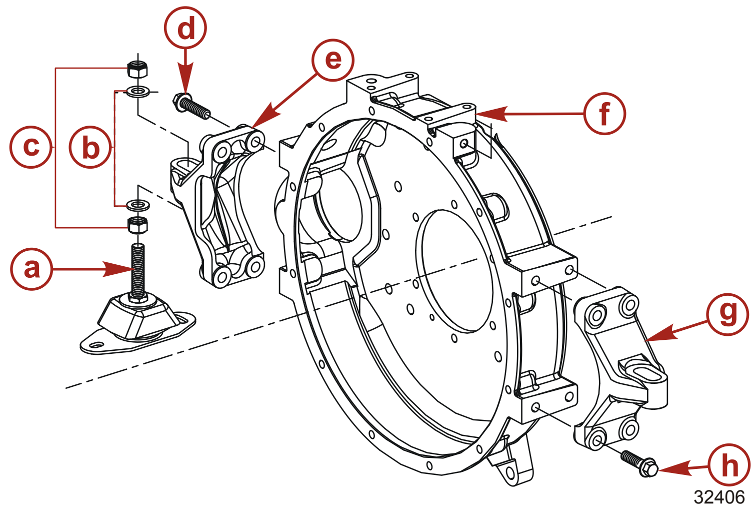
1. Except for rubber portions of the mount, clean the components in cleaning solvent.
2. Put on safety glasses and dry the components with compressed air.
3. Inspect the mounts for cracks or damage.
4. Inspect the rubber portions of the mount for deterioration or wear.
5. Replace deteriorated, worn, cracked, or damaged components.

INSTALLATION

1. Apply sealant to the threads of the rear mount bracket screws.

Tube Ref No.	Description	Where Used	Part No.
51	Loctite 222 Threadlocker	Rear mount bracket screws	92-809818

2. Install the rear mount brackets.



a - Engine mount
b - Lockwashers
c - Adjustment and locking (jam) nut
d - Engine mount bracket screws
e - Port engine mount bracket
f - Flywheel housing
g - Starboard engine mount bracket
h - Engine mount bracket screws

3. Torque the rear mount bracket screws.

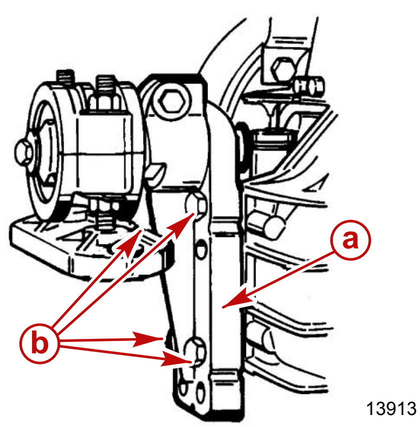
Description	Nm	lb. in.	lb. ft.
Rear mount bracket screw	75	–	55

4. Remove the suitable blocks under the flywheel housing or transmission and lower the rear part of the engine or the transmission with a hoist.
5. Install the rear engine mount to engine bed fasteners and hardware. Tighten the fasteners securely.
6. Align the engine and drive. Adjust the mounts as needed. See **Section 2.**

V-drive Rear Engine Mounts

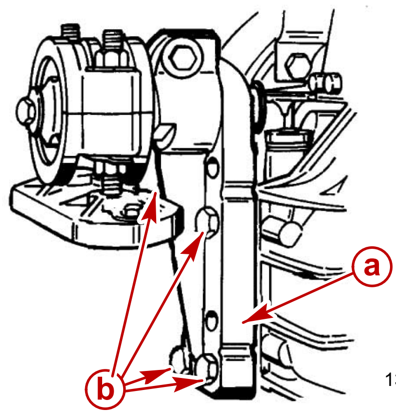
INSTALLATION POSITION

Depending on the installation angle, the inboard model rear mount bracket can be bolted to the transmission in the standard or alternate mount position as shown.



Standard Mount Position

a - Mount bracket
b - Bolts



Alternate Mount Position

a - Mount bracket **b -** Bolts

REMOVAL

1. Remove the rear engine mount to engine bed fasteners and hardware.
2. Support the rear part of the engine or the transmission with a hoist, or put suitable blocks under the flywheel housing or transmission.
3. Remove the port and starboard rear mount brackets, with base and trunnion.

CLEANING AND INSPECTION

1. Except for rubber portions of the mount, clean the components in cleaning solvent.
2. Put on safety glasses and dry the components with compressed air.
3. Inspect the mounts for cracks or damage.
4. Inspect the rubber portions of the mount for deterioration or wear.
5. Replace deteriorated, worn, cracked, or damaged components.

INSTALLATION

1. Apply sealant to the threads of the rear mount bracket screws.

Tube Ref No.	Description	Where Used	Part No.
51	Loctite 222 Threadlocker	Rear mount bracket screws	92-809818

2. Install the rear mount brackets in the standard or alternate mount position as required. Torque the rear mount bracket screws with lockwashers.

Description	Nm	lb. in.	lb. ft.
Rear mount bracket screw	75	–	55

3. Remove the suitable blocks under the flywheel housing or transmission and lower the rear part of the engine or the transmission with a hoist.
4. Install the four rear engine mount to engine bed fasteners and hardware. Tighten the fasteners securely.
5. Align the engine and drive. Adjust the mounts as needed. See **Section 2.**

Notes:

Electrical System

Section 4A - Starting System

Table of Contents

Starter Specifications

Starter

IMPORTANT: The starter can operate only for a short time because of the heat it generates. Do not operate the starter for more than 15 seconds at a time. Before retrying, wait at least 2 minutes to avoid damaging the starter.

Starter—QSD 2.8 and 4.2	
Identification number	0 001 0EA 1TE
Starter draw (under load)	60 amperes
Battery rating (minimum)	750 CCA, 950 MCA or 180 Ah

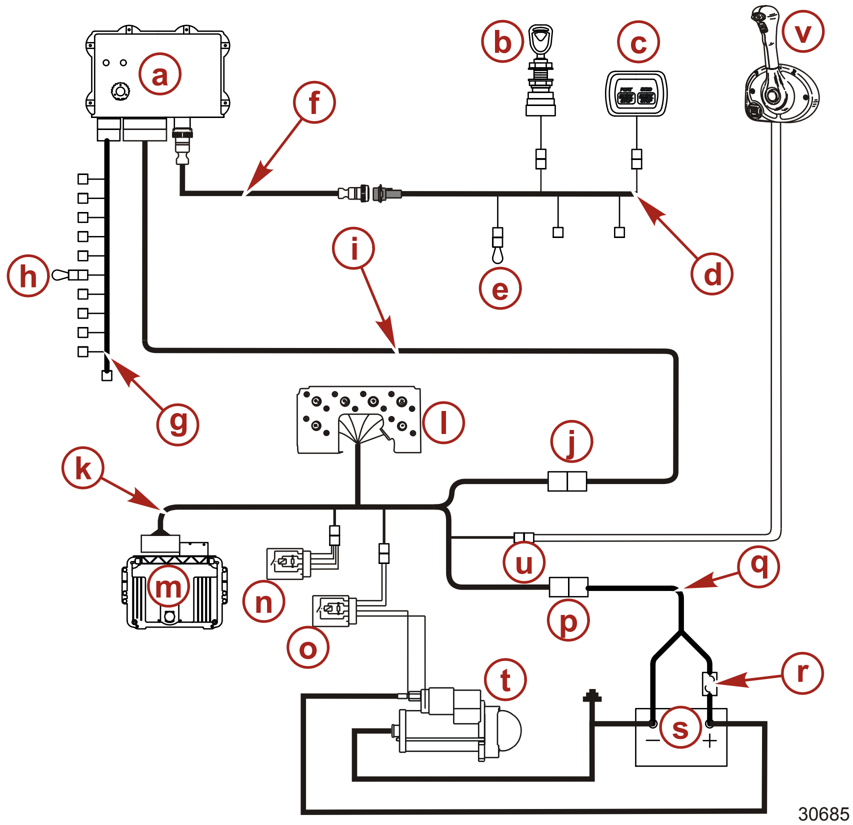
Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Exposed electrical terminals and connections	92- 25711 3
95	2-4-C Marine Lubricant with Teflon	Starter mounting surfaces and mounting fasteners	92-802859A1

Wire Color Code Abbreviations

Wire Color Abbreviations				
BLK	Black		BLU	Blue
BRN	Brown		GRY	Gray
GRN	Green		ORN or ORG	Orange
PNK	Pink		PPL or PUR	Purple
RED	Red		TAN	Tan
WHT	White		YEL	Yellow
LT or LIT	Light		DK or DRK	Dark

Starting System Components



a - VIP	**l -** Circuit breaker panel
b - Key switch	**m -** ECM
c - Start stop buttons, if equipped	**n -** Main relay
d - Main station helm harness	**o -** Start relay
e - Halon breakout	**p -** Engine power harness connection
f - Station extension harness	**q -** Engine power harness
g - Vessel sensor harness	**r -** 30-amp fuse
h - Halon breakout	**s -** Battery
i - Engine to VIP harness	**t -** Starter
j - Engine to VIP harness engine connection	**u -** Neutral safety switch connection at engine harness "K"
k - Engine interface harness "K"	**v -** Remote control neutral safety switch

IMPORTANT: The key switch circuit is connected to the halon breakouts in the helm harness and vessel sensor harness before being routed to the engine. If the halon breakout connection is broken, the engine will not start.

Starter Inspection

Periodic Inspection

The starter, consisting of a starter motor with solenoid, is completely enclosed when mounted to the drive housing to prevent entrance of moisture and dirt. However, periodic inspection is required.

1. Inspect the terminals for corrosion and loose connections.

2. Inspect the wiring for frayed and worn insulation.
3. Ensure that the retaining fasteners are tight.
4. Ensure that the mounting surfaces under the starter motor and the retaining fasteners are free of paint and corrosion.
5. Treat the mounting surfaces under the starter motor and the retaining fasteners with lubricant to prevent corrosion.

Testing Voltage

IMPORTANT: Battery voltage or supply voltage below 9.5 volts can cause the starter to overheat. Check the battery voltage to ensure the voltage supplied to the starter is greater than 9.5 volts.

1. Ensure that the battery is fully charged.
2. Connect the voltmeter positive (+) lead to the terminal on the starter solenoid.
3. Connect the voltmeter negative (–) lead to the starter motor case. Ensure that there is good metal contact to prevent a false voltage reading.
4. Crank the engine for 10 seconds and record the voltmeter reading.
5. A reading of 9.5 volts or more verifies the starter motor is getting sufficient voltage.

NOTE: If the starter is getting at least 9.5 volts and the engine is not cranking properly, remove the glow plugs, or glow plug hole plugs, and try turning the engine over by hand. If the engine turns over freely by hand, the starter motor could have a problem.

6. A reading below 9.5 volts suggests a voltage loss between the battery and the starter. Refer to Testing Voltage Drop.

Testing Voltage Drop

This test should be done anytime a voltage drop is suspected.

1. Ensure that the battery is fully charged.
2. Connect the voltmeter positive (+) lead to the battery positive (+) post.
3. Connect the voltmeter negative (–) lead to the starter solenoid terminal where the positive (+) battery cable connects.

NOTE: Connect the voltmeter leads to the battery post, not to the battery cable end.

IMPORTANT: Remove one voltmeter lead before the starter motor stops cranking in the following steps to prevent the possibility of voltmeter damage.

4. Crank the engine and record the voltmeter reading. The reading should not exceed 0.5 volt. A reading over 0.5 volt suggests excessive resistance.
5. Test the negative (–) battery cable by connecting the voltmeter negative (–) lead to the battery negative (–) post.
6. Connect the voltmeter positive (+) lead to the starter motor case. Ensure that there is good contact with metal.
7. Repeat step 4.
8. If either reading was above 0.5 volt, start with the battery cable and work toward the starter checking each connection for resistance.

NOTE: Always ensure that paint or corrosion is not causing the high resistance. The mounting surface under the starter motor and the mounting fasteners should be free from paint and corrosion.

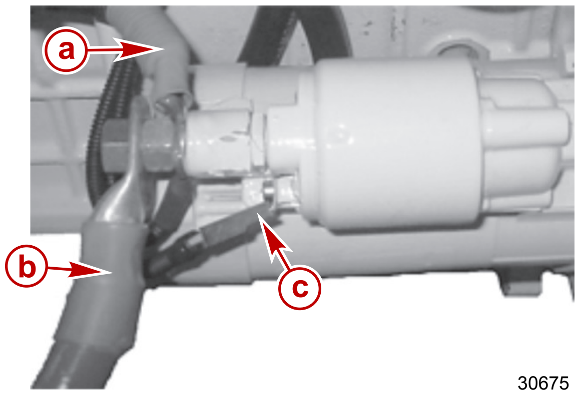
Starter

Starter Removal

⚠ WARNING

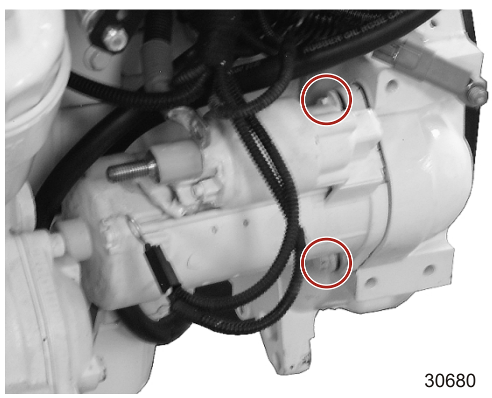
Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

1. Disconnect the battery cables from the battery.
2. Slide the protective rubber boot, if equipped, off of the cable ends.
3. Disconnect the positive (+) battery cable and wires from the starter solenoid.



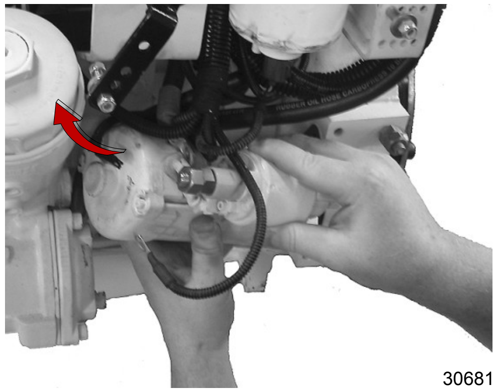
a - Alternator wire
b - Positive (+) battery cable
c - Solenoid wire

4. Remove the upper and lower starter mounting screws.



Starter mounting screws

5. Remove the starter from the engine.



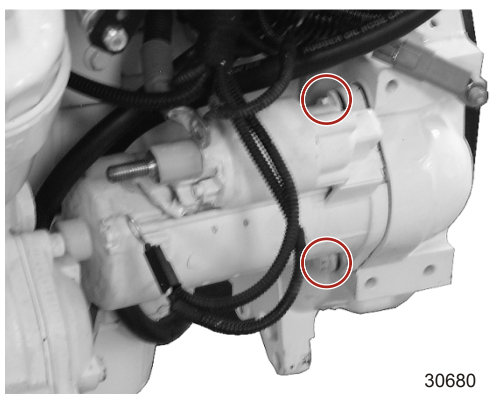
Lift starter up and away from the flywheel housing to remove.

Starter Installation

1. Lightly lubricate the starter mounting surfaces and the mounting screws before installation.

Tube Ref No.	Description	Where Used	Part No.
95	2-4-C Marine Lubricant with Teflon	Starter mounting surfaces and mounting fasteners	92-802859A1

2. Position the starter on the engine.
3. Install the upper and lower starter mounting screws.

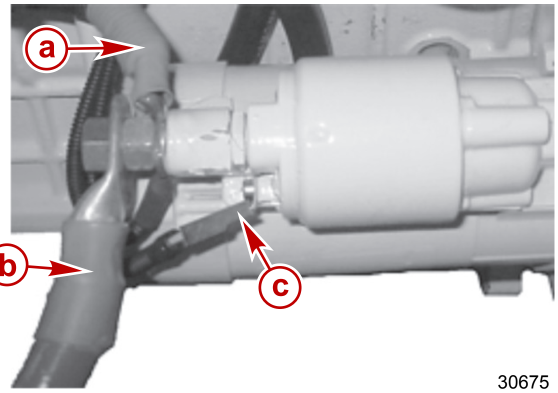


Starter mounting screws

4. Torque the starter mounting screws.

Description	Nm	lb. in.	lb. ft.
Starter mounting screw	47.1	–	35

5. Connect the positive (+) battery cable and wires to the starter solenoid. Tighten the fasteners securely.



a - Alternator wire
b - Positive (+) battery cable
c - Solenoid wire

6. Torque the positive (+) battery cable nut.

Description	Nm	lb. in.	lb. ft.
Positive (+) battery cable nut	10.8	96	–

7. Apply sealant to the exposed electrical terminals and connections.

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Exposed electrical terminals and connections	92- 25711 3

8. Slide the protective rubber boot, if equipped, over the positive (+) terminal connection after the sealant has dried.
9. Connect the battery cables to the battery.

Notes:

Electrical System

Section 4B - Charging System

Table of Contents

4
B

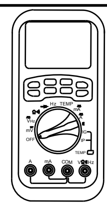
Alternator Specifications

Alternator—Bosch		
Identification number		0 124 325 052
Current output (alternator RPM)	1800 RPM	50 amperes
	6000 RPM	90 amperes
Voltage set point		14 volts
Drive belt tension		Automatic tensioning

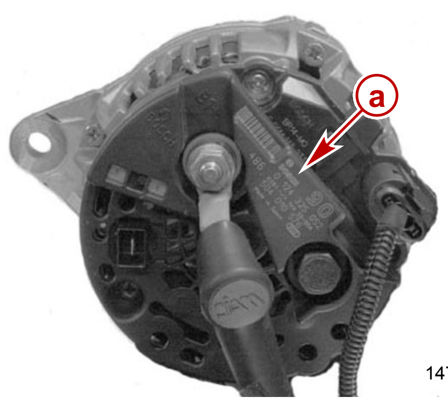
Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Exposed electrical terminals and connections	92- 25711 3
95	2-4-C with Teflon	Battery terminal bolts	92-802859A1

Special Tools

DMT 2004 Digital Multimeter	91-892647A01
 4516	Measures RPM on spark ignition (SI) engines, ohms, amperes, AC and DC voltages; records maximums and minimums simultaneously, and accurately reads in high RFI environments.

Alternator Identification



14783

a - Identification number location on alternator

⚠ WARNING
Failure to comply with regulations can result in injury from fire or explosion. Electrical system components on this engine are not rated as external ignition–protected (EIP). Do not store or use gasoline on boats equipped with these engines, unless provisions have been made to exclude gasoline vapors from the engine compartment (REF: 33 CFR).

Wire Color Code Abbreviations

Wire Color Abbreviations				
BLK	Black		BLU	Blue
BRN	Brown		GRY	Gray
GRN	Green		ORN or ORG	Orange
PNK	Pink		PPL or PUR	Purple
RED	Red		TAN	Tan
WHT	White		YEL	Yellow
LT or LIT	Light		DK or DRK	Dark

Battery Precautions

⚠ WARNING

An operating or charging battery produces gas that can ignite and explode, spraying out sulfuric acid, which can cause severe burns. Ventilate the area around the battery and wear protective equipment when handling or servicing batteries.

When charging batteries, an explosive gas mixture forms in each cell. Part of this gas escapes through holes in vent plugs and may form an explosive atmosphere around battery if ventilation is poor. This explosive gas may remain in or around battery for several hours after it has been charged. Sparks or flames can ignite this gas and cause an internal explosion which may shatter the battery.

The following precautions should be observed to prevent an explosion:

1. Do not smoke near batteries being charged or which have been charged very recently.
2. Do not break live circuits at terminals of batteries because a spark usually occurs at the point where a live circuit is broken. Always be careful when connecting or disconnecting cable clamps on chargers. Poor connections are a common cause of electrical arcs which cause explosions.
3. Do not reverse polarity of battery terminal to cable connections.

Charging a Discharged Battery

⚠ WARNING

An operating or charging battery produces gas that can ignite and explode, spraying out sulfuric acid, which can cause severe burns. Ventilate the area around the battery and wear protective equipment when handling or servicing batteries.

The following basic rules apply to any battery charging situation:

1. Any battery may be charged at any rate (in amperes) or as long as spewing of electrolyte (from violent gassing) does not occur and for as long as electrolyte temperature does not exceed 52 °C (125 °F). If spewing of electrolyte occurs, or if electrolyte temperature exceeds 52 °C (125 °F), charging rate (in amperes) must be reduced or temporarily halted to avoid damage to the battery.

2. Battery is fully charged when, over a 2 hour period at a low charging rate (in amperes), all cells are gassing freely (not spewing liquid electrolyte), and no change in specific gravity occurs. Full charge specific gravity is 1.260 - 1.275, corrected for electrolyte temperature with electrolyte level at 4.8 mm (3/16 in.) over plate, unless electrolyte loss has occurred (from age or overfilling) in which case specific gravity reading will be lower. For most satisfactory charging, lower charging rates in amperes are recommended.
3. If, after prolonged charging, specific gravity of at least 1.230 on all cells cannot be reached, battery is not in optimum condition and will not provide optimum performance; however, it may continue to provide additional service, if it has performed satisfactorily in the past.
4. To check battery voltage while cranking engine with electric starting motor at ambient air temperature of 23.8 °C (75 °F), place red (+) lead of tester on positive (+) battery terminal and black (–) lead of tester on negative (–) battery terminal. If the voltage drops below 10-1/2 volts while cranking, the battery is weak and should be recharged or replaced.

Winter Storage of Batteries

Battery companies are not responsible for battery damage either in winter storage or in dealer stock if the following instructions are not observed:

1. Remove battery from its installation as soon as possible and remove all grease, sulfate and dirt from top surface by running water over top of battery. Be sure, however, that vent caps are tight beforehand and blow off all excess water thoroughly with compressed air. Check water level, making sure that plates are covered.
2. When adding distilled water to battery, be extremely careful not to fill more than 4.8 mm (3/16 in.) above perforated baffles inside battery. Battery solution or electrolyte expands from heat caused by charging. Overfilling battery will cause electrolyte to overflow (if filled beyond 4.8 mm [3/16 in.] above baffles).
3. Grease terminal bolts well with 2-4-C with Teflon and store battery in a cool-dry place. Remove battery from storage every 30 - 45 days, check water level and put on charge for 5 or 6 amperes. Do not fast charge.

Tube Ref No.	Description	Where Used	Part No.
95	2-4-C with Teflon	Battery terminal bolts	92-802859A1

4. If specific gravity drops below 1.240, check battery for reason and recharge. When gravity reaches 1.260, discontinue charging. To check specific gravity, use a hydrometer, which can be purchased locally.
5. Repeat preceding charging procedure every 30 - 45 days, as long as battery is in storage, for best possible maintenance during inactive periods to ensure a good serviceable battery in spring. When ready to place battery back in service, remove excess grease from terminals (a small amount is desirable on terminals at all times), recharge again as necessary and reinstall battery.

Charging System Precautions

IMPORTANT: Failure to observe the following precautions may result in damage to the charging system or alternator .

1. Do not attempt to polarize the alternator.
2. Do not short across or ground any of the terminals on the alternator, except as specifically instructed in the **Troubleshooting Tests**.

3. Never disconnect the alternator output lead or battery cables while the alternator is operating.
4. Never disconnect the regulator lead from the alternator regulator terminal while the alternator is operating.
5. Always remove the negative (–) battery cable from the battery before working on the charging system.
6. When installing the battery, be sure to connect the positive (+) battery cable to the positive (+) battery terminal and the negative (–) battery cable to the negative (–) battery terminal.
7. If using a charger or booster battery, connect it in parallel with the existing battery (positive to positive; negative to negative).

Battery Isolators

⚠ WARNING

Improper design and installation of the electrical system can result in serious injury or death. Adhere to all applicable marine regulations (United States Coast Guard [USCG], European Union–Recreational Craft Directive [EU-RCD], etc.) and the standards they reference (American Boat and Yacht Council [ABYC], Society of Automotive Engineers [SAE], International Standards Organization [ISO], etc.) for the market in which the boat will be sold.

A battery isolator can be installed to allow the charging of an auxiliary battery for use in operating accessories. The battery isolator will allow the alternator to charge both the cranking battery and auxiliary battery at the same time, while preventing accessories connected to the auxiliary battery from discharging the cranking battery.

The alternators used on Cummins MerCruiser Diesel products are equipped with a special external sensing circuit to ensure optimum charging performance in these types of applications by compensating for the voltage drop across the isolator. The manufacturer's instructions should be carefully followed when making the installation.

IMPORTANT: Cummins MerCruiser Diesel cannot be responsible for problems resulting from the installation of the isolator. The installer and the isolator manufacturer must ensure that the installation and any modifications to the Cummins MerCruiser Diesel product comply with all applicable standards/regulations, including (but not limited to) wire size, type, routing, terminals, overcurrent protection).

A special isolator is required for multiple-engine installations where the cranking batteries are to be charged from a common source.

Refer to the appropriate Cummins MerCruiser Diesel Product Applications Manual.

Alternator Description

The alternator employs a rotor that is supported in twoend frames by ball bearings, and is belt-driven by the engine. The rotor contains a field winding enclosed between two multiple-finger pole pieces. The ends of the field winding are connected to two brushes which make continuous sliding contact with the slip rings. The current flowing through the field winding creates a magnetic field that causes the adjacent fingers of the pole pieces to become alternate north and south magnetic poles.

The 3-phase stator is mounted directly over the rotor pole pieces and between the two end frames. It consists of three windings wound 120º electrically out of phase on the inside of a laminated core.

The rectifier bridge contains six diodes, allowing current to flow from ground through the stator and to the output terminal, but not in the opposite direction.

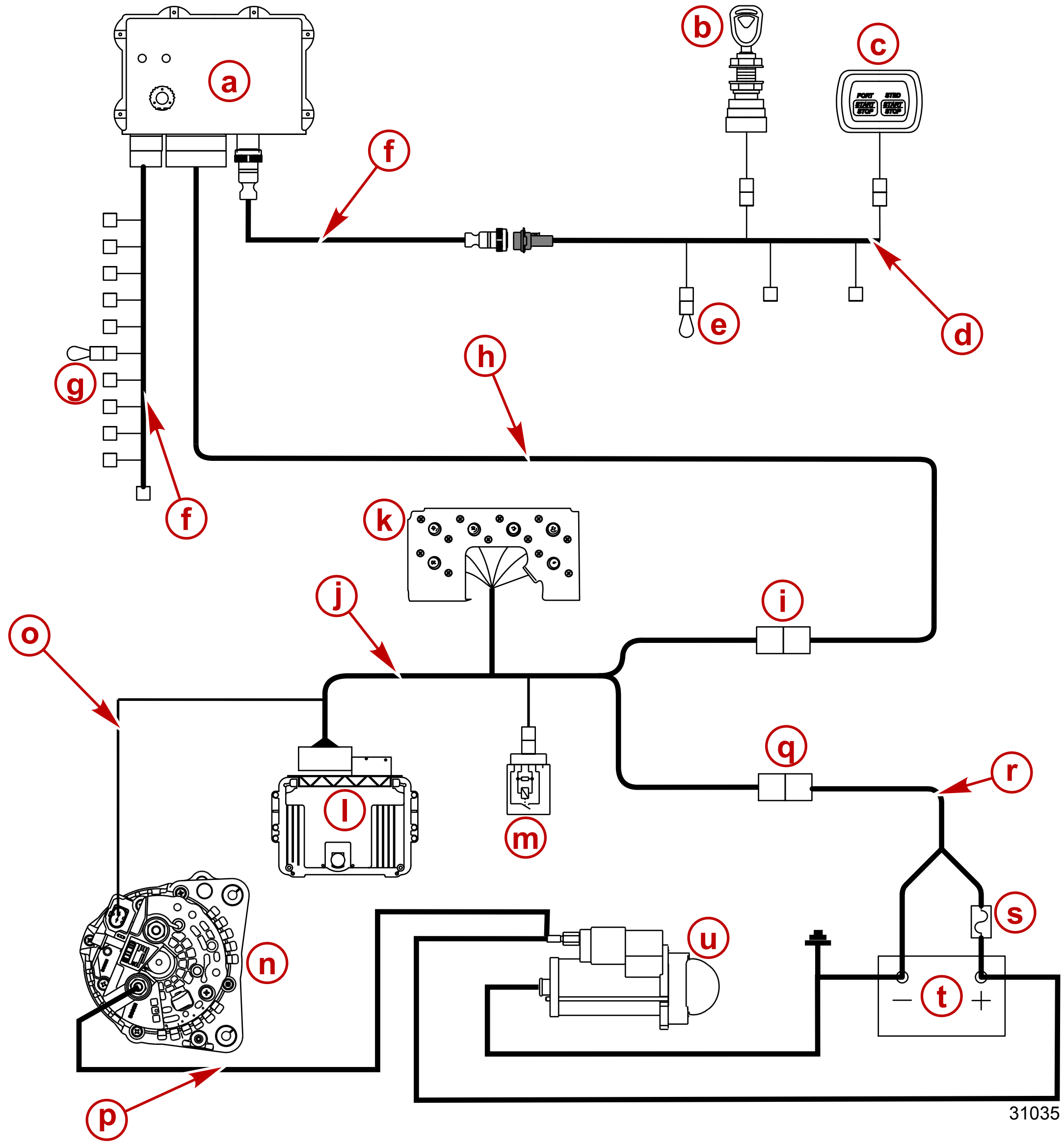
When current is supplied to the rotor field winding and the rotor is turned, the movement of the magnetic fields created induces an alternating current into the stator windings. The rectifier bridge changes this alternating current to direct current, which appears at the output terminal. The diode trio is connected to the stator windings to supply current to the regulator and the rotor field during operation.

Voltage output of the alternator is controlled by a transistorized voltage regulator that senses the voltage at the battery and regulates the field current to maintain alternator voltage for properly charging the battery. Current output of the alternator does not require regulation, as maximum current output is limited by the design of the alternator. When the voltage is regulated within the prescribed limits, the alternator cannot produce excessive current. A cutout relay in the voltage regulator is not required, because the rectifier diodes prevent the battery from discharging back through the stator.

A small amount of current is supplied by the excitation circuit in the regulator to the rotor field to start the alternator charging. After the alternator has begun to produce output, field current is supplied solely by the diode trio.

The alternator is equipped with two fans that induce air flow through the alternator to remove heat created by the rectifier and stator.

Alternator System Components



- **a -** Vessel interface panel (VIP)
- **b -** Key switch
- **c -** Start stop button panel
- **d -** Main station helm harness
- **e -** Halon breakout
- **f -** Helm extension harness
- **g -** Vessel sensor harness
- **h -** Engine to VIP harness
- **i -** Engine to VIP harness engine connection
- **j -** Engine interface harness "K"
- **k -** Circuit breaker panel
- **l -** ECM
- **m -** Main relay
- **n -** Alternator
- **o -** Alternator excitation wire
- **p -** Alternator output cable
- **q -** Engine power harness connector
- **r -** Power harness
- **s -** 30-amp fuse
- **t -** Battery
- **u -** Starter

IMPORTANT: The alternator excitation circuit is powered by the key switch. The key switch circuit is dependent on the halon breakout connections. If a halon breakout connection is broken the alternator excitation circuit will not function.

Periodic Maintenance

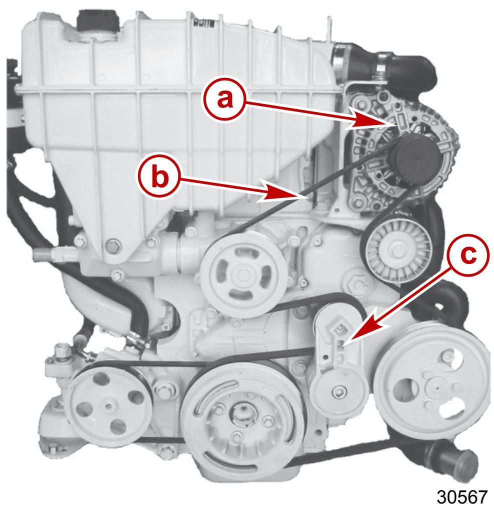
⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

1. Disconnect both battery cables.
2. Inspect the entire alternator system for corroded or loose connectors.
3. Check the wiring for frayed or worn insulation.
4. Check the alternator drive belt for excessive wear, cracks, fraying and glazed surfaces.
5. Check the drive belt tension and adjust, if necessary.
6. Check the alternator mounting bolts for adequate torque.

Drive Belt Tension Adjustment

- An automatic belt tensioner assembly maintains proper tension on the serpentine belt of the alternator.



2.8 shown, 4.2 similar

a - Alternator
b - Serpentine belt
c - Automatic tensioner assembly

Troubleshooting, Alternator On the Engine

Troubleshooting

For additional diagnostic procedures see **Section 1C: Troubleshooting**.

Preparation

IMPORTANT: Observe all applicable precautions to prevent damage to the electrical system.

Perform these initial diagnostic checks to eliminate possible causes of system failure.

1. Ensure that an undercharged battery condition has not been caused by:
    a. Extended low speed engine operation
    b. Lighting or accessories left on when the engine is not operating
    c. Lighting or accessories draw excessive current
    d. Extended vessel storage
2. Check the physical condition of the battery and its state of charge. The battery must have at least 75% (1.230 specific gravity) of a full charge to obtain valid results in the following tests. If not, charge the battery before testing the system.
3. Inspect the entire charging system for wiring defects. Check all connections for tightness and cleanliness, particularly the battery cable clamps and battery terminals.
4. Check the alternator drive belt for excessive wear, cracks, fraying, and glazed surfaces. Replace if necessary.
5. Check the drive belt tensioner. Replace if necessary.

Circuitry Test

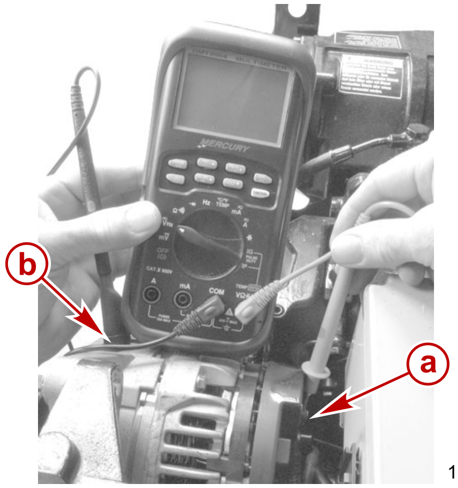
Perform the following tests, using the DMT 2004 Digital Tachometer Multi-meter or equivalent 0–20 volt DC voltmeter, to ensure that all the circuits between the alternator and the other components within the charging system are in good condition.

DMT 2004 Digital Multimeter	91-892647A01

OUTPUT CIRCUIT

1. Connect the DMT positive (+) lead to the battery positive (+) post.
2. Connect the DMT negative (–) lead to the battery negative (–) post.
3. Supply cooling water to all water inlets.
4. Start the engine and increase engine speed to approximately 1300 RPM.
5. Observe the voltage reading.
6. If the reading is between 13.5 and 14.8 volts, switch the DMT to the AC volt position. A reading of 0.25 AC volt or less indicates that the alternator diodes are fully functional. A reading above 0.25 AC volt indicates that the diodes are faulty and the alternator must be replaced.
7. If the reading is below 13.5 volts:
    a. Connect the positive (+) DMT lead to the alternator output post.
    b. Connect the negative (–) DMT lead to a clean, unpainted ground (–) area or to the ground post on the alternator.
    c. Wiggle the engine wiring harness while observing the voltmeter. The meter should indicate the approximate battery voltage and should not vary. If no reading is obtained or if the reading varies, inspect the wiring harness for loose connections, corrosion, breaks, or shorts. Repair or replace the harness as required.

8. If the reading is above 15 volts at the battery, the alternator is overcharging and must be replaced.



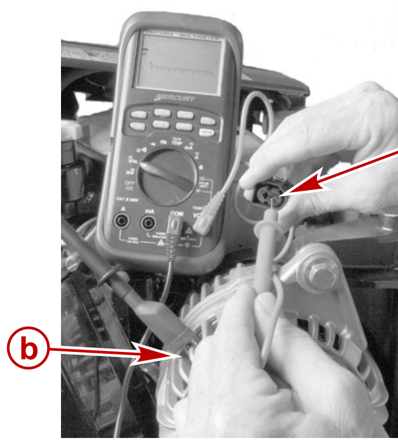
19973

a - Alternator output post

b - Ground (–), or ground post (not shown)

EXCITATION CIRCUIT

1. Disconnect the excitation circuit 2-pin connector from the alternator.
2. Turn the key switch to the on position, do not start the engine.
3. Connect the positive (+) DMT lead to the excitation circuit pin and the negative (–) DMT lead to a clean, unpainted ground (–) area or to the ground post on the alternator.
4. The DMT should indicate battery voltage. If battery voltage is not present, check the excitation circuit for loose or dirty connections or damaged wiring.



19950

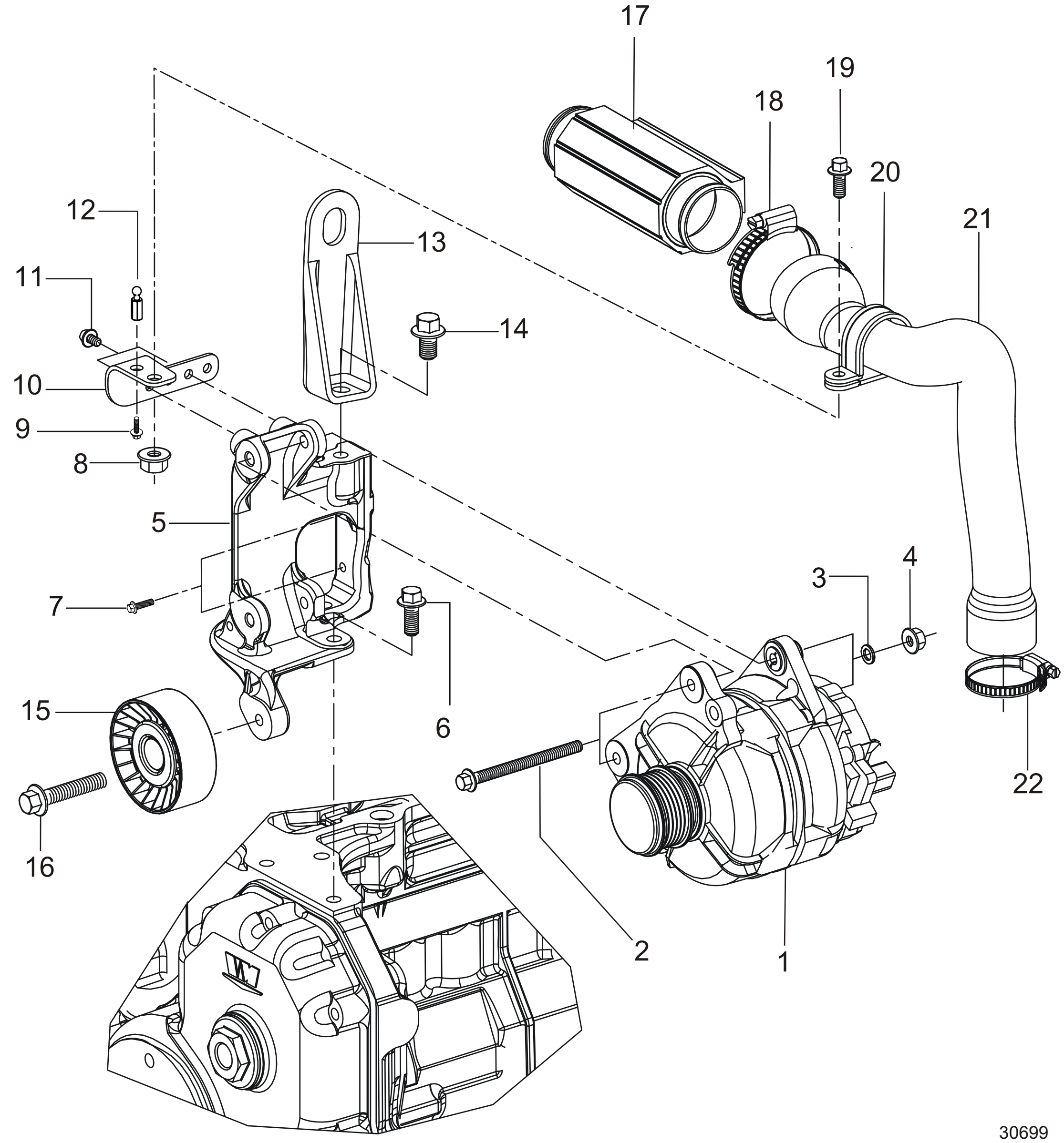
a - Excitation circuit pin (brown wire)

b - Ground (–), or ground post (not shown)

5. Turn the key switch to the off position.

Notes:

Exploded View, Alternator



Exploded View, Alternator

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Alternator			
2	2	Alternator mounting bolt	27.5	–	20
3	2	Washer			
4	2	Alternator mounting bolt nut			
5	1	Alternator bracket			
6	3	Alternator bracket screws	47.1	–	35
7	2	Alternator bracket screws	47.1	–	35
8	1	J-clip nut			
9	1	Engine cover stud screw	24.5	–	18
10	1	J-clip bracket			
11	2	J-clip bracket screw	24.5	–	18
12	1	Engine cover stud			
13	1	Front lifting eye bracket			
14	1	Front lifting eye bracket screw	83.4	–	62
15	1	Idler pulley			
16	1	2.8 Idler pulley screw	47.1	–	35
		4.2 Idler pulley screw	32.4	–	24
17	1	Fuel cooler			
18	1	Clamp	5.6	50	–
19	1	J-clip bolt	16.7	148	–
20	1	J-clip			
21	1	Seawater hose			
22	1	Clamp	5.6	50	–

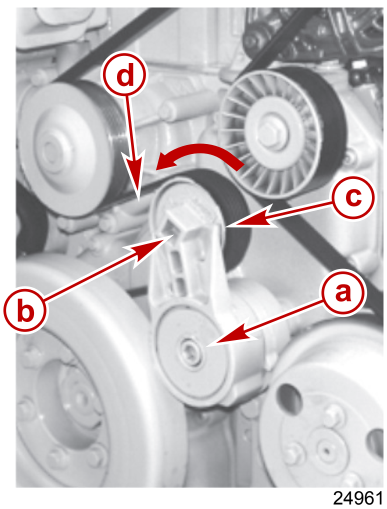
Alternator Removal

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

NOTE: *The alternator mounting hardware and electrical connections can be difficult to access. Remove the seawater hose between the oil and fuel coolers if necessary to gain access to the mounting hardware and electrical connections. Refer to* ***Section 6A*** *for information on removing the seawater hose.*

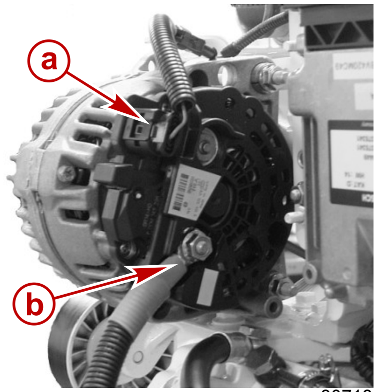
1. Disconnect both battery cables from the battery.
2. Position a suitable tool in the tensioner release slot and rotate the tensioner pulley to relieve serpentine belt tension.
3. Remove the serpentine belt.



a - Tensioner
b - Tensioner release slot
c - Tensioner pulley
d - Serpentine belt

4. Slowly release the tensioner and return to original position.
5. Remove the protective rubber boot, if equipped, from the alternator output lead.
6. Disconnect the output lead.

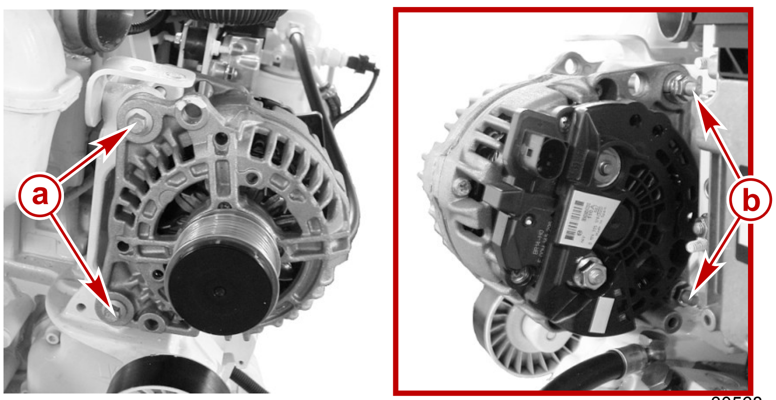
7. Disconnect the excitation circuit 2-pin connector.



Seawater hose removed for visual clarity

a - Two-way connector
b - Output lead

8. Remove the upper and lower alternator mounting bolts, flange nuts, and washers.



Seawater hose removed for visual clarity

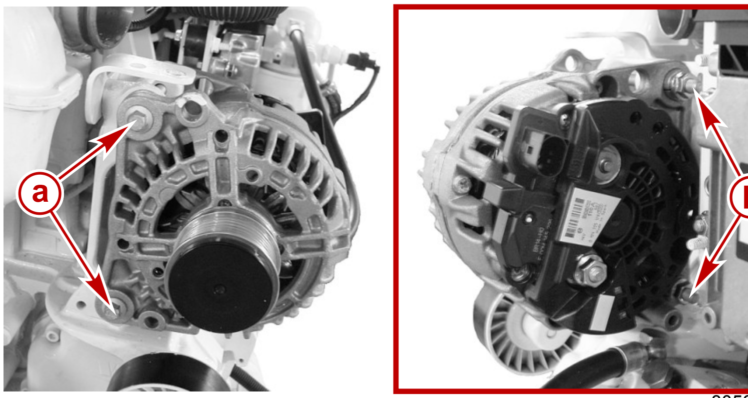
a - Mounting bolt
b - Flange nut and washer

9. Remove the alternator.

Alternator Installation

1. Position the alternator in the mounting bracket.

2. Install and tighten the alternator mounting bolts, washers and flange nuts.



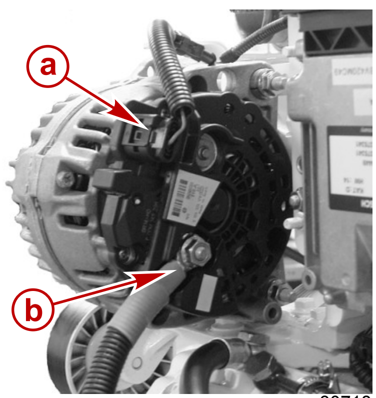
30568

a - Mounting bolt
b - Flange nut and washer

3. Torque the alternator mounting bolts.

Description	Nm	lb. in.	lb. ft.
Alternator mounting bolt	47.1	–	35

4. Connect the output lead. Ensure the output lead (positive [+] cable) is positioned as shown.
5. Connect the excitation circuit 2-pin connector to the alternator.



30718

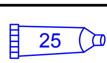
Seawater hose removed for visual clarity

a - Two-way connector
b - Output lead

6. Torque the output lead nut.

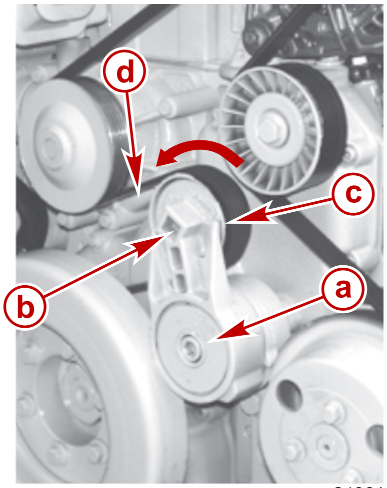
Description	Nm	lb. in.	lb. ft.
Output lead nut	15	132	–

7. Apply sealant to any exposed electrical terminals and connections.

Tube Ref No.	Description	Where Used	Part No.
 25	Liquid Neoprene	Exposed electrical terminals and connections	92- 25711 3

8. When the sealant is dry, install the protective rubber boot, if equipped, over the output lead.

9. Position a suitable tool in the tensioner release slot and rotate the tensioner pulley in the direction of the arrow.
10. Install the serpentine belt.



24961

a - Tensioner
b - Tensioner release slot
c - Tensioner pulley
d - Serpentine belt

11. Slowly release the tensioner returning it to the original position.
12. Connect the battery cables.

Notes:

Electrical System

Section 4C - Instrumentation

Table of Contents

Tools

Kent-Moore Tools

Kent-Moore Tools, Inc.29784 Little MackRoseville, MI 48066Phone: (313) 774-9500	
Description	**Part Number**
Connector Test Adapter Kit	J-35616-A

Wire Color Code Abbreviations

Wire Color Abbreviations				
BLK	Black		BLU	Blue
BRN	Brown		GRY	Gray
GRN	Green		ORN or ORG	Orange
PNK	Pink		PPL or PUR	Purple
RED	Red		TAN	Tan
WHT	White		YEL	Yellow
LT or LIT	Light		DK or DRK	Dark

Precautions

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

IMPORTANT: It may be necessary to remove the instrument panel from the dashboard to gain access to instruments and switches. Do not allow wires to come in contact with metal or other wires.

IMPORTANT: When conducting tests using a heat source, be sure to follow all instructions of the manufacturer of the heat source.

General Information

IMPORTANT: If all instrument readings appear suspicious, an electrical overload may have occurred. A fuse may be defective or a circuit breaker may be tripped open. Find and correct the cause before replacing the fuse or resetting the circuit breaker.

Before testing individual instruments, check the following:

- All wires in the circuit are connected.
- The plug-in connectors are fully engaged.
- The battery is fully charged.
- All connections are tight and corrosion-free.

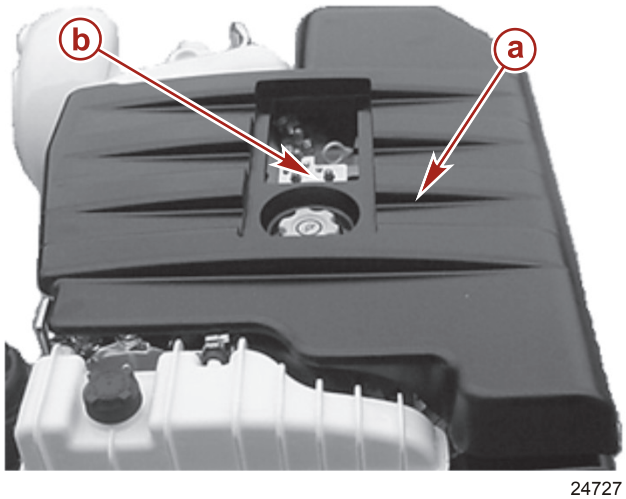
Electrical Overload Protection

Engine Electrical System Overload Protection

If an electrical overload occurs, a fuse will burn out (blow) or a circuit breaker will trip open. Find and correct the cause for the electrical overload before replacing the fuse or resetting the circuit breaker.

NOTE: In an emergency, when the engine must be operated and the cause for the high current draw cannot be located and corrected, turn off or disconnect all the accessories connected to the engine and instrumentation wiring. Reset the circuit breaker. If the breaker remains open, the electrical overload has not been eliminated. Further checks must be made on the electrical system. Contact your Cummins MerCruiser Diesel Authorized Repair Facility.

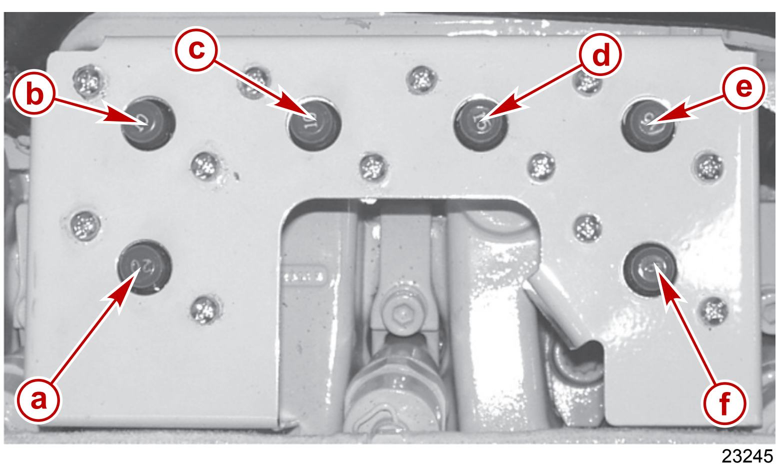
Circuit breakers provide protection for the engine electrical system as indicated. The circuit breaker panel is located beneath a small access panel in the engine cover on top of the engine.



Typical engine cover with access panel

a - Engine cover **b -** Circuit breakers

After finding and correcting the cause of the overload, reset the circuit breaker by pressing the reset button.



Circuit breakers

Reference	Circuit breaker rating	Protection	Location on fuse panel
a	20-amp	Key unswitched power to helm	Lower left
b	10-amp	Switched power to ECM	Upper left
c	10-amp	Key switch to ECM	Middle left
d	15-amp	Switched power to ECM	Middle right
e	15-amp	ECM switched power to SIM	Upper right
f	5-amp	Power—diagnostic connector	Lower right

Vessel Integration Panel (VIP) Overload Protection

The Vessel Integration Panel (VIP) contains 2 circuit breakers that help protect the engine harness, vessel sensor harness, and helm harness.

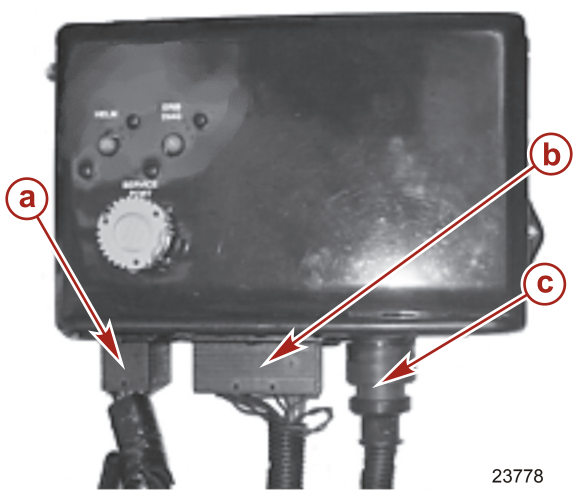
Vessel Integration Panel (VIP) circuit breakers

Reference	Circuit breaker rating	Protection	Location on fuse panel
a	5-amp	VIP Diagnostic	Left
b	10-amp	Helm	Right

Vessel Interface Panel (VIP)

Removal

1. Disconnect the vessel sensor harness from the VIP (24-pin connector).
2. Disconnect the engine to VIP harness from the VIP (40-pin connector).
3. Twist the locking ring and disconnect the 14-pin helm extension harness from the VIP.



Vessel Interface Panel (VIP)

a - Vessel sensor harness connector
b - Engine to VIP harness connector
c - 14-pin helm extension harness connector

4. Remove the VIP mounting screws and remove the VIP.

VOP mounting screws (6 total, 2 not visible)

Installation

The Vessel Interface Panel (VIP) is intended for mounting on the inner transom of the vessel in the engine compartment.

IMPORTANT: Mount the VIP with the connectors oriented downward, to the port or starboard side, or laid down. Do not mount the VIP with the connectors facing upward.

Consider the following if the VIP is mounted in a new location:

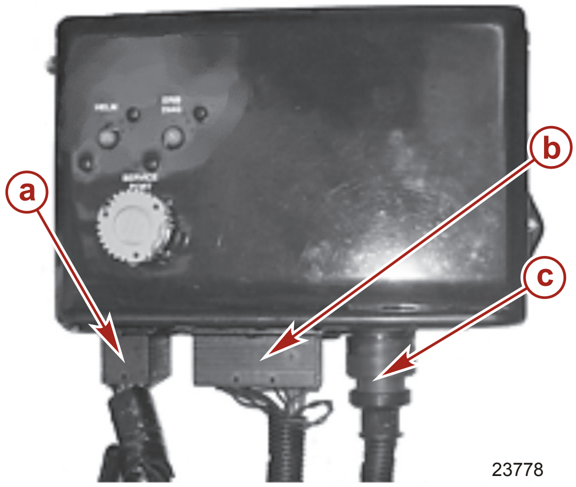
- it is in an accessible location.
- it is above the waterline at rest and is not near any moving parts.
- it is clear of deck water run-off and engine compartment water spray.
- the circuit breakers are easily accessible.
- it is in an area that is free of excessive heat and minimum 305 mm (12 in.) distance from all exhaust components.
- it allows a minimum of 229 mm (9 in.) of free space directly below the VIP for wire harness routing.
- it is not mounted directly or indirectly to the engine and is free from excessive vibration.

1. Mount the VIP using the mounting screws.

VOP mounting screws (6 total, 2 not visible)

2. Connect the vessel sensor harness to the VIP (24-pin connector).
3. Connect the engine to VIP harness to the VIP (40-pin connector).

4. Connect the 14-pin helm extension harness to the VIP and twist the locking ring into position.



Vessel Interface Panel (VIP)

a - Vessel sensor harness connector
b - Engine to VIP harness connector
c - 14-pin helm extension harness connector

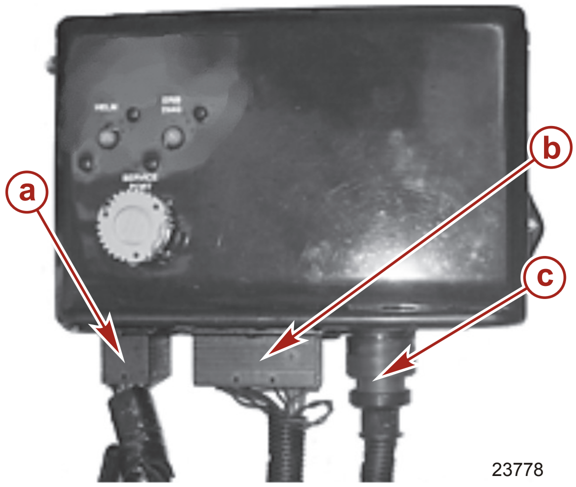
Extension Harness

When routing any wiring harness to or from the engine compartment:

IMPORTANT: Ensure that the harness can not be pinched or chaffed.

- Confirm that all connectors are secure.
- Anchor the harness at least every 460 mm (18 in.) using appropriate fasteners.
- Minimize exposure to moisture.
- Install in a location away from hot or moving components.
- Install the harness following the most direct route possible to minimize voltage drop due to wire resistance.
- Protect the harness from sharp edges.

- Follow all ABYC guidelines that govern the installation of signal and DC power wiring in marine vessels.



Vessel Interface Panel (VIP)

a - Vessel sensor harness connector
b - Engine to VIP harness connector
c - 14-pin helm harness connector

VesselView

Important Information

The VesselView display is not field serviceable. If the VesselView is identified as the malfunctioning component, confirm operation with a properly functioning unit. Replace the VesselView if it is faulty.

Faulty units can be sent to Mototron for repair or exchange.

Removal

1. Disconnect the battery cables.

IMPORTANT: Use care when working around or handling the VesselView so that the display screen is not scratched or damaged.

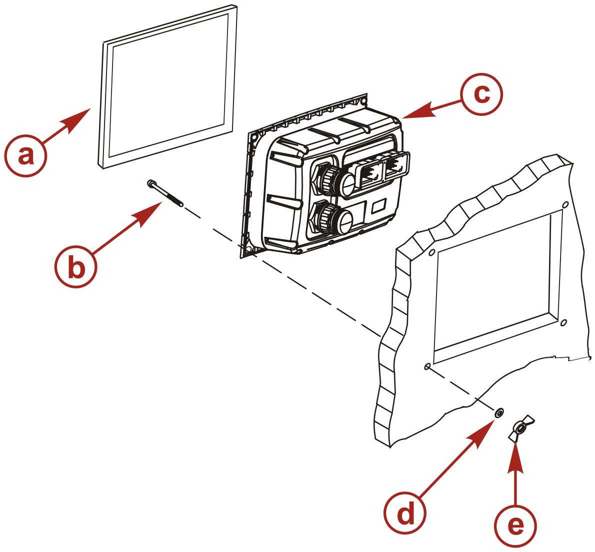
2. Disconnect the harness from the VesselView head unit.

NOTE: The VesselView bezel snaps on to the display face using plastic locking tabs. Use care during removal.

3. Carefully remove the VesselView bezel.
    a. The VesselView has four access slots at the bottom of the bezel.
    b. Use a small plastic trim-stick (preferred) or an angled flat head screwdriver inserted into the slots to gently pry the bezel up. Start removal at the inner slots and work outward..

27440

    c. Continue working the slots until the bottom of the bezel is loose.
    d. Carefully pry up the sides of the bezel until the bezel releases.
4. Remove the four screws securing the VesselView to the vessel.



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a - Bezel
b - Mounting Screw
c - VesselView
d - Washer
e - Wing nut

5. Pull the VesselView out through the front of the panel opening to remove.

Cleaning

Clean the VesselView screen with a soft cloth and mild soap and water. An abrasive cloth will scratch and damage the VesselView screen.

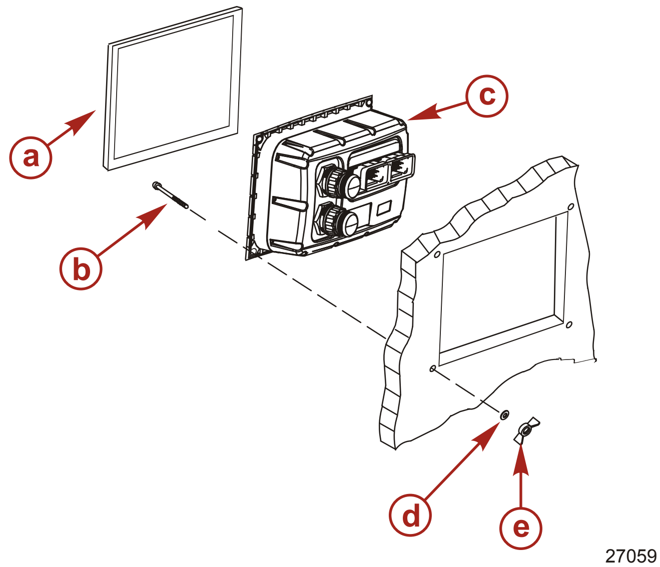
Clean the body and keypad of the VesselView with a soft cloth, a detailing brush, or a canned-air duster.

Inspection

1. Inspect for screen damage.
2. Inspect for housing separation and exposed or protruding water seals.
3. Inspect the connector locks and electrical pins.
4. Inspect the keypad covers for perforations.
5. Replace or return a damaged VesselView for service.

Installation

1. Insert the VesselView into the opening.



a - Bezel
b - Mounting Screw
c - VesselView
d - Washer
e - Wing nut

2. Secure the VesselView with the four mounting screws, washers, and wing nuts. Do not overtighten the wing nuts.
3. The back of the bezel is labeled "TOP" and "BOTTOM".

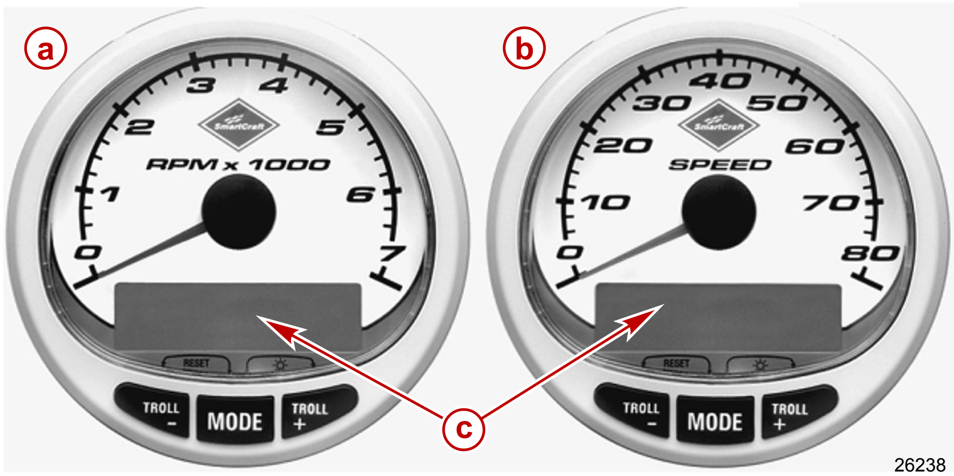
NOTE: *Ensure the bezel is aligned correctly to avoid damaging the bezel or VesselView.*

4. Snap the bezel onto the VesselView.

SmartCraft Gauges

Basic Operation

Refer to the appropriate Mercury MerCruiser SmartCraft documentation for additional diagnostics and troubleshooting information.

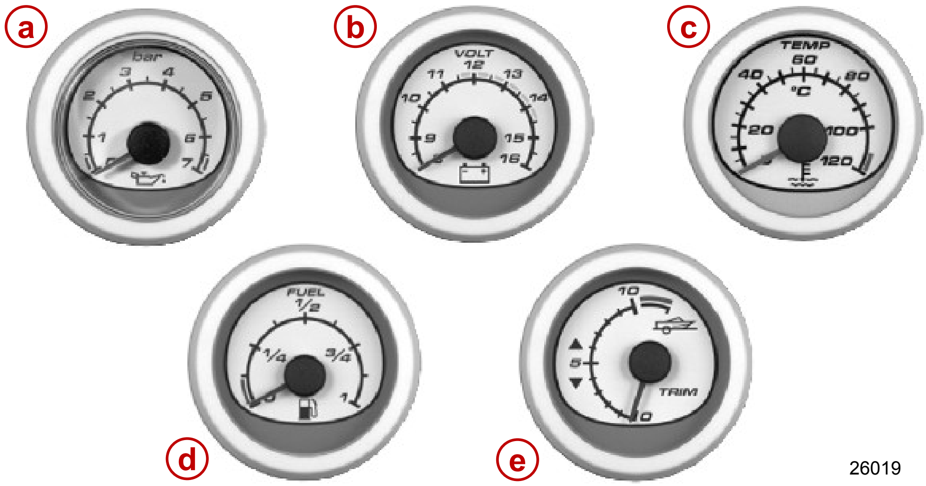


a - System Tachometer (required)
b - System Speedometer (optional)
c - LCD display

- **Power up:** Gauges receive power when the ignition is turned on.
- **Lights:** The brightness and contrast are adjustable.
- **Buttons:** The "MODE" button is used for selecting information screens. The "+" and "–" buttons are for user input and setting gauge calibrations.
- **Troll Control:** Allows the operator to set and control the idle speed of the engine for trolling without using the throttle.
- **Engine Guardian System:** Monitors the critical sensors on the engine for any early indications of problems. The system will respond to a problem by reducing engine speed in order to maintain a safe operating condition.
- **Warning System:** The system will sound the warning horn and display the warning message.
- **Digital Display Screen:** Displays the following engine information.

SC1000 System Tachometer Display Screen (depending on engine type):	SC1000 System Speedometer Display Screen (depending on engine type):
Engine RPM	Speed
Engine Temperature	Trim and RPM Synchronizer
Engine Oil Pressure	Trip Odometer
Trim and RPM	Fuel Range
Trim and Water Pressure	Fuel Economy
Water Pressure	Instant and Average Fuel Economy
Battery Voltage and Engine Hours	Fuel Used
Fuel Flow and Fuel Used	Fuel Tank Levels
Depth	Oil Tank Levels
Engine Break-in	Fresh Water Tank Level

SC1000 System Tachometer Display Screen (depending on engine type):	SC1000 System Speedometer Display Screen (depending on engine type):
	Waste Water Tank Level
	Clock and Air/Sea Temp
	Distance and fuel to waypoint if waypoint programmed into optional GPS
	Optional GPS Input Display



Optional System Link (gauges typical)

- **a -** Oil pressure
- **b -** Battery voltage
- **c -** Water temperature
- **d -** Fuel level
- **e -** Trim

The System Link digital gauges are connected in series and receive their data from the System Tachometer.

Removal

1. Tachometer and speedometer removal:

NOTE: Use care to not pull or stress any wiring attached the instrument panel during removal.

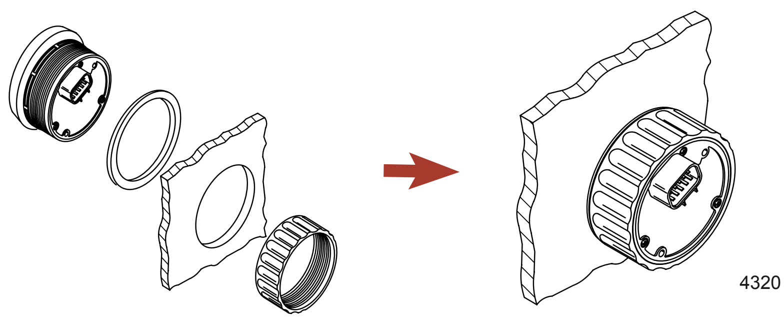
   a. Remove or gain access to the back of the instrument panel.

   b. Disconnect the harness connector from the back of the gauge.

IMPORTANT: Remove gauges by hand. The use of large jawed tools may damage the gauges.

   c. Support and hold the face of the gauge stationary during removal.

   d. Turn the retaining ring on the back of the gauge counterclockwise and remove it from the the gauge.



System Tachometer or Speedometer panel installation

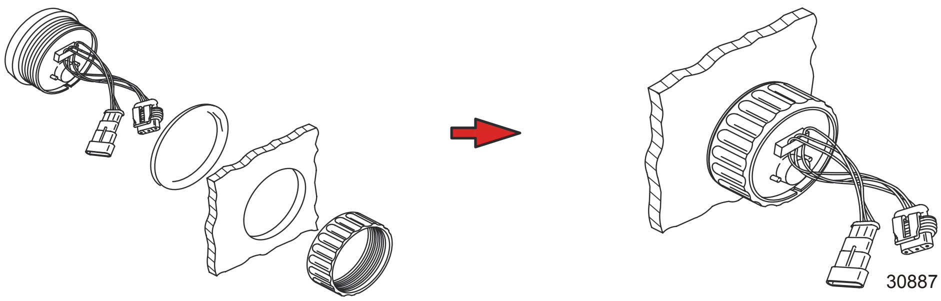
   e. Remove the gauge from the front of the instrument panel.

   f. Reassemble the loose gauge, seal, and retaining ring to keep the components together.

2. System Link gauge removal:
   a. Remove or gain access to the back of the instrument panel.
   b. Disconnect the harness connector from the back of the gauge.

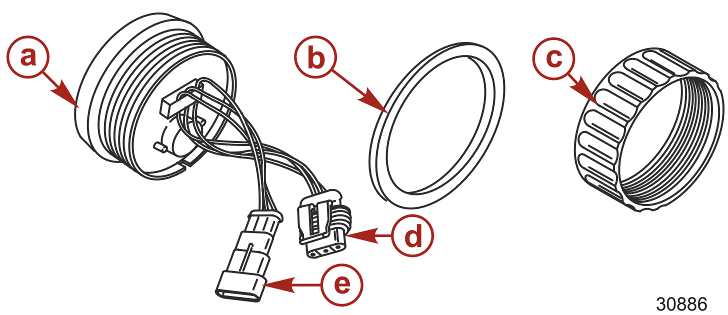
IMPORTANT: Remove gauges by hand. The use of large jawed tools may damage the gauges.

   c. Support and hold the face of the gauge stationary during removal.
   d. Turn the retaining ring on the back of the gauge counterclockwise and remove it from the the gauge.
   e. Remove the gauge from the front of the instrument panel.



System Link gauge panel installation

   f. Reassemble the loose gauge, seal, and retaining ring to keep the components together.



a - System Link gauge
b - Seal
c - Retaining ring
d - Male connector
e - Female connector

Cleaning

1. Clean the gauge lens with a soft cloth suitable for optical lens cleaning and mild soap and water.
2. Rinse and dry the lens completely to avoid water spots.
3. The System Tachometer and Speedometer keypad area can be cleaned with a soft cloth, a small detailing brush, and a canned-air duster.

Inspection

1. Inspect the gauge for damaged electrical connectors or locks.
2. Inspect the gauge seal for excessive compression scaring and cuts or tears.
3. Inspect the gauge body threads for damage.
4. Inspect the retaining ring for cracks or damaged threads.
5. Repair or replace the gauge or components that prevent it from being secured to the instrument panel and remaining watertight.

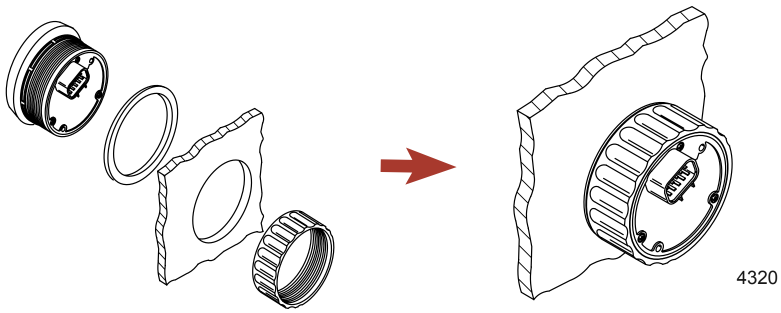
Installation

1. Tachometer and speedometer installation:

IMPORTANT: Install gauges by hand. Applying uneven force or overtightening the retaining ring will damage the gauge.

NOTE: Use care to not pull or stress any wiring attached the instrument panel during installation.

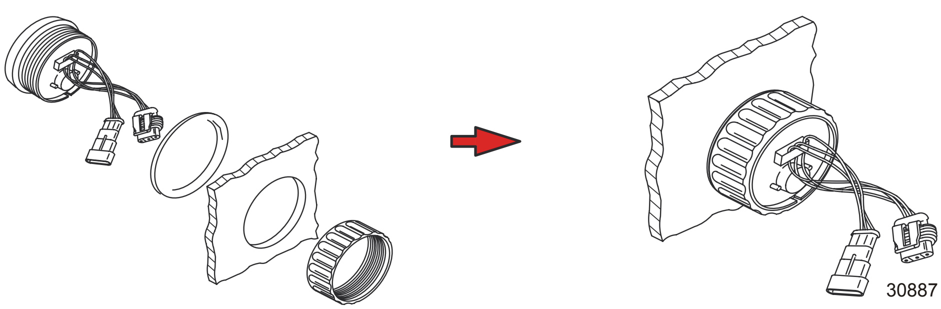
   a. Gain access to the back of the instrument panel.
   b. Remove the retaining ring from the back of the gauge.
   c. Confirm that the seal is properly positioned flat against the back of the gauge face.
   d. Insert the gauge through the front of the instrument panel.
   e. Support and hold the face of the gauge stationary.
   f. Turn the retaining ring on the back of the gauge clockwise until the seal is moderately compressed and the gauge is secure. Do not overtighten.



System Tachometer or Speedometer panel installation

   g. Connect the harness connector to the back of the gauge.
   h. Reinstall the instrument panel (if removed).

2. System Link gauge installation:
   a. Gain access to the back of the instrument panel.
   b. Remove the retaining ring from the back of the gauge.
   c. Confirm that the seal is properly positioned flat against the back of the gauge face.
   d. Insert the gauge and wiring through the front of the instrument panel.
   e. Support and hold the face of the gauge stationary.
   f. Turn the retaining ring on the back of the gauge clockwise until the seal is moderately compressed and the gauge is secure. Do not overtighten.



System Link gauge panel installation

   g. Connect the harness connectors. Weather cap the last unused connector.
   h. Reinstall the instrument panel (if removed).

CAN Bus Testing

1. Turn off the vessel's main power.

2. Disconnect the harness being tested from the engine and any peripherals.
3. Measure resistance across connector pins "J" and "K" (WHT and BLU wires in the harness).
4. Measured resistance should be approximately 60 ohms.
5. A harness with either to little or excessive resistance will be unable to support a CAN data signal.
6. Repair or replace the harness as required.

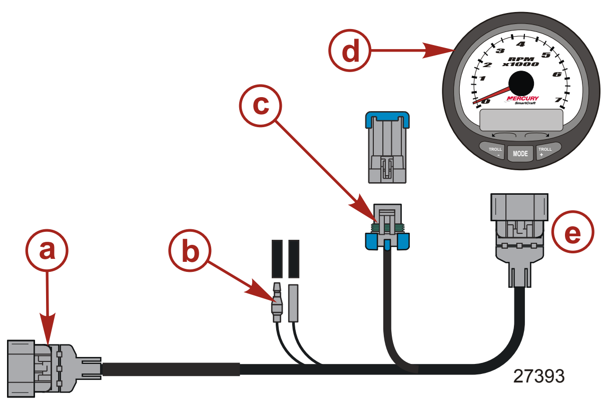
System Link Test

System link connector	Logic Probe	Wire Color	Color gauges
1	HI LED (12 volts DC positive)	PUR/WHT	Red
2	LO LED (ground)	BLK	Blue
3	HI/LO frequency (VDO data)	YEL (single),YEL/PUR (starboard),YEL/WHT (port)	Yellow

SmartCraft Gauge Connections

System Tachometer Harness

The System Tachometer receives its signal from the 14-pin helm harness CAN P (1) bus and is connected to a junction box with a SmartCraft 10-pin male-to-male harness. Each helm station has a System Tachometer will have one System Tachometer for each engine.

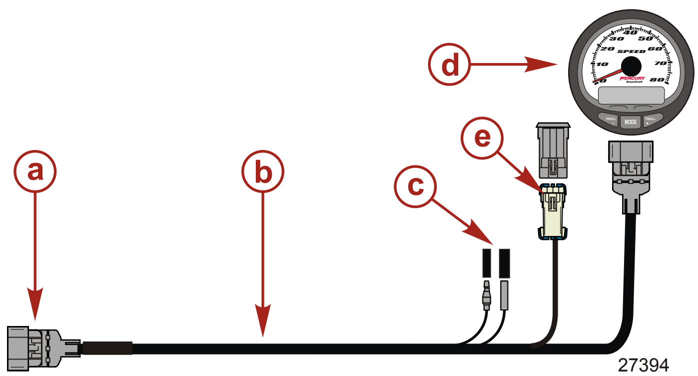


System tachometer harness

a - 10-pin junction box connector
b - Audio warning (weather cap)
c - Smart Link connector (weather cap)
d - System Tachometer
e - Gauge connector

System Speedometer Harness

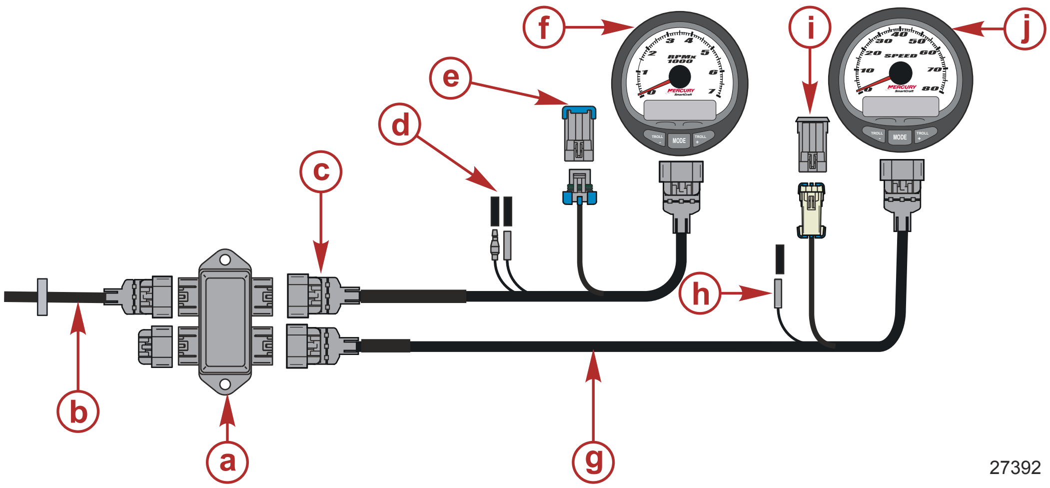
The System Speedometer receives its signal from the 14-pin helm harness CAN P (1) bus and is connected to a junction box with a SmartCraft 10-pin male-to-male harness. In single engine applications it is connected to the junction box. For multiple engine applications only one System Speedometer is connected to the junction box networked to the VIP and vessel sensor harness connected to the paddle wheel speed sensor. One System Speedometer can be installed at each helm.



a - 10-pin junction box connector
b - System speedometer harness
c - NMEA connectors
d - System speedometer
e - Temperature sensor connector

SC1000 System Tachometer and Speedometer Installation (Single Engine)

In single engine applications the System Tachometer and Speedometer share a junction box connected to the helm harness. In single engine, dual helm applications, the System Tachometer and Speedometer connect through a junction box connected to each stations' helm harness.

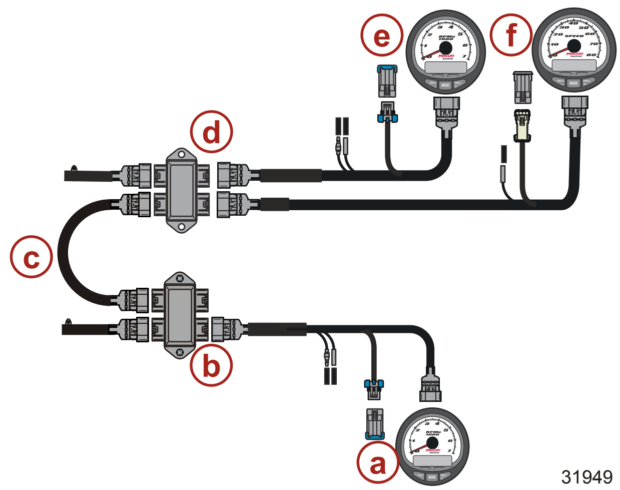


Single engine installation

- **a -** Junction box
- **b -** 10-pin SmartCraft connector from helm harness
- **c -** System tachometer harness
- **d -** Audio Warning
- **e -** System Link Connector
- **f -** System Tachometer
- **g -** System Speedometer harness
- **h -** NMEA connector
- **i -** Air temperature sensor connector
- **j -** System Speedometer

Dual Engine Installation SC1000 System Tachometer and Speedometer

In dual engine applications there is a System Tachometer installed for each engine. They are connected to a junction box that is attached to each engine's helm harness. The System Speedometer is connected to the junction box networked to the VIP and vessel sensor harness connected to the paddle wheel speed sensor. For dual engine, dual helm applications this basic installation is repeated at the secondary helm.

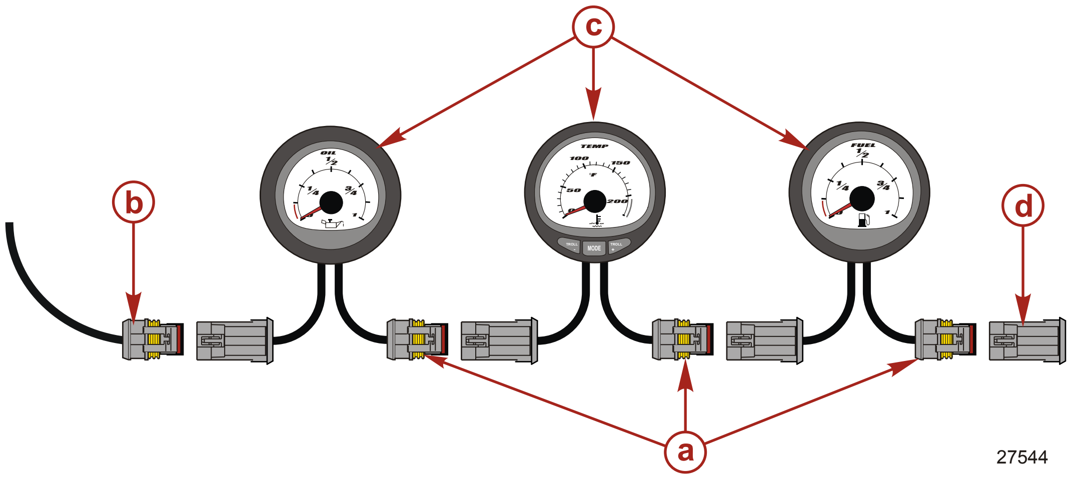


Duel engine installation

- **a -** Starboard engine tachometer and harness connection to junction box
- **b -** Starboard engine helm harness connection to junction box
- **c -** CAN P jumper harness
- **d -** Port engine helm harness connection to junction box
- **e -** Port engine tachometer and harness connection to junction box
- **f -** System Speedometer and harness

System Link Gauge Connections

System Link gauges are slaved off and receive their data signal from a master gauge, either a System Monitor, System Tachometer, or VesselView. This enables System Link gauges to be used in a variety of situations and in a wide range of configurations. The System Link gauges are linked together in series. The System Link connector of the final gauge in a series is sealed with a weather cap.

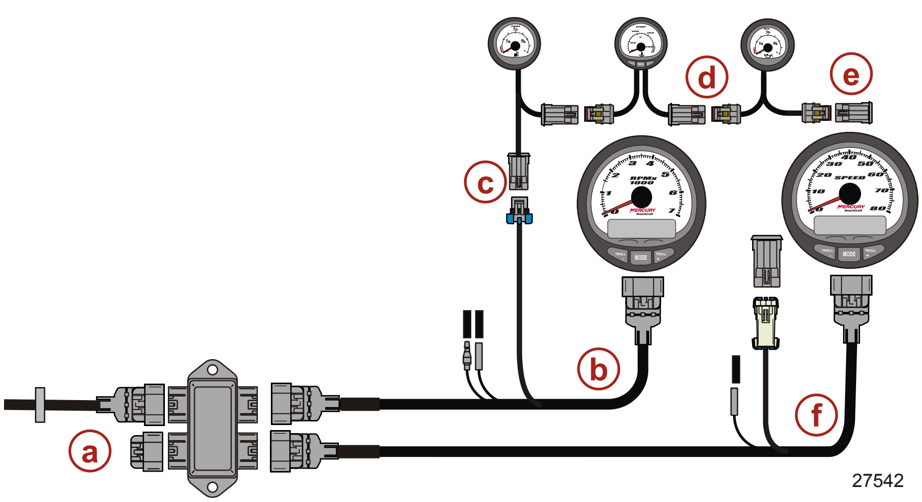


System Link gauges (typical)

- **a -** System Link connectors in series
- **b -** System Link connector to master gauge
- **c -** System Link gauges
- **d -** Weather cap

Each set of System Link gauges will monitor one engine. In multiple engine applications a System Link gauge set must be installed for each engine. In all cases the System Link gauges are connected to a master gauge connected to each engine's junction box. For multiple helm applications the secondary helm instrumentation will connect to the secondary helm harness in the same manner.

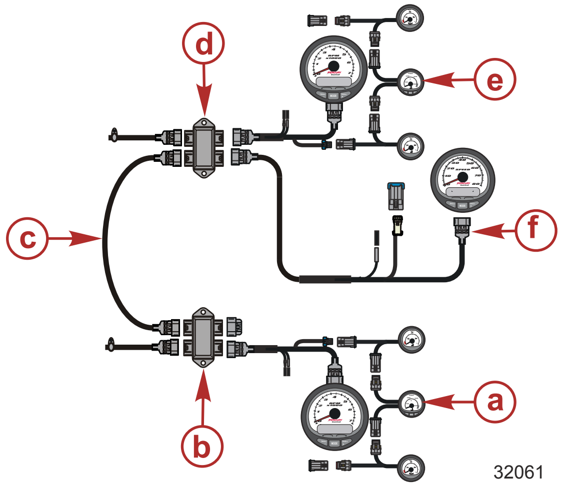
1. Single engine System Tachometer with System Link gauges.



Single helm installation

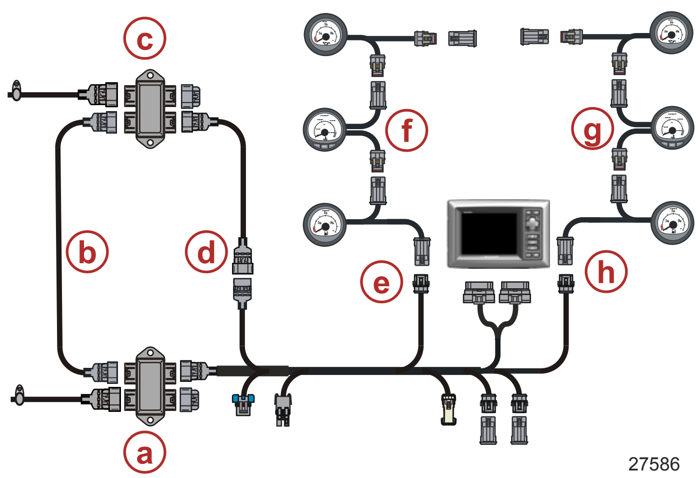
a - Junction box	**d -** System Link gauges (typical)
b - System Tachometer harness	**e -** Weather cap
c - System Link connector	**f -** System Speedometer and harness

2. Dual engine System Tachometer with System Link gauges.



a - Starboard System Link gauges
b - Starboard engine junction box
c - CAN P Jumper harness
d - Port engine junction box
e - Port System Link gauges
f - System Speedometer and harness

3. VesselView with System Link gauges



Duel engine Vessel View with System Link gauges

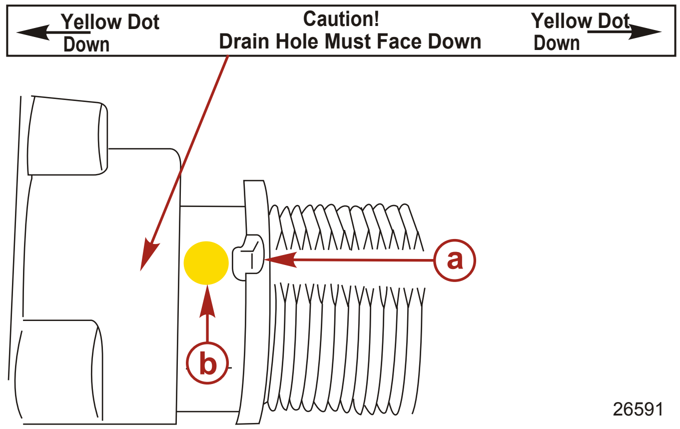
a - Starboard engine junction box
b - CAN P Jumper harness
c - Port engine junction box
d - 8-pin to 10-pin ignition adaptor harness
e - Port System Link connector
f - Port System Link gauges
g - Starboard System Link gauges
h - Starboard System Link connector

Primary Station Switches

4 Position Key Switch Mounting - With Bezel

1. Cut or drill a 54 mm (2-1/8 in.) diameter hole through the dashboard at the selected location.
2. Install the key switch housing assembly onto the key switch assembly.

3. Align the upper notch of the key switch assembly and housing. Following the instructions on the decal, ensure the drain hole with the yellow dot points down for proper draining after installation.



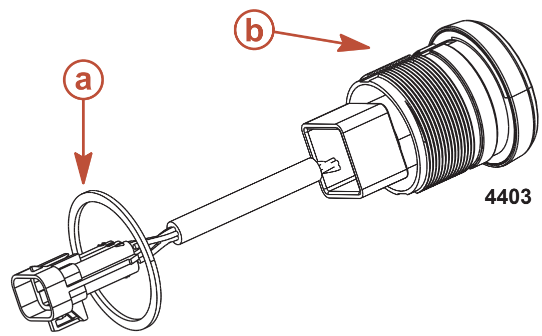
a - Drain hole

b - Yellow dot

4. Install the key switch nut and tighten to the specified torque.

Description	Nm	lb. in.	lb. ft.
Key switch nut	2.2	20	

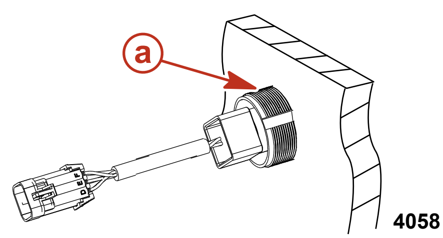
5. Install the cover and the bezel onto the key switch housing.
6. Install the gasket onto the key switch housing.



a - Gasket

b - Key switch housing

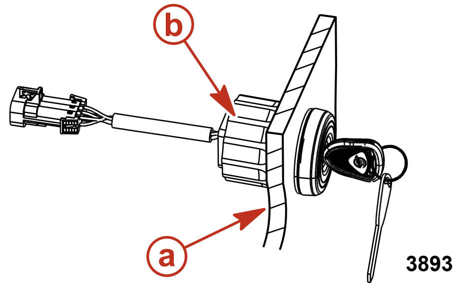
7. Insert the key switch assembly through the dash opening.



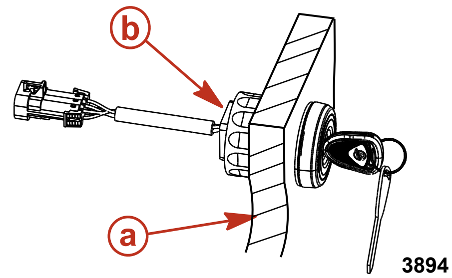
a - Key switch housing

NOTE: *The ring mounting nut is threaded so that it can be installed to fit a thick or thin dashboard.*

8. Install the ring mounting nut, depending on dash thickness, so that the most threads are engaged when threaded onto the key switch housing.



a - Thin dashboard
b - Ring mounting nut orientation



a - Thick dashboard
b - Ring mounting nut orientation

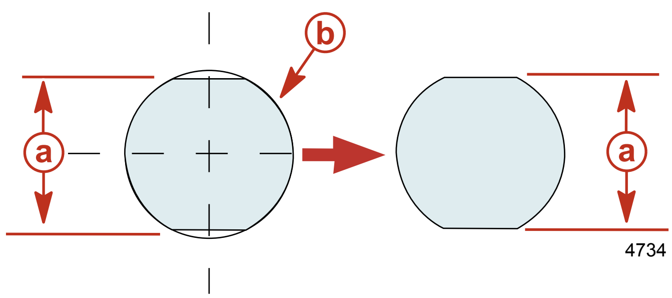
9. Position the key switch properly in the dash.

NOTE: *The ring mounting nut must be tight so the assembly will not rotate during use.*

10. Tighten the ring mounting nut securely.
11. Connect the key switch electrical connector to the command module harness.

4 Position Key Switch Mounting - Without Bezel

1. Cut a 22.5 mm (7/8 in.) oblong shaped hole that matches the key switch assembly threaded end with the opposing top and bottom flat surfaces. The shape of the hole will keep the assembly from rotating during use.

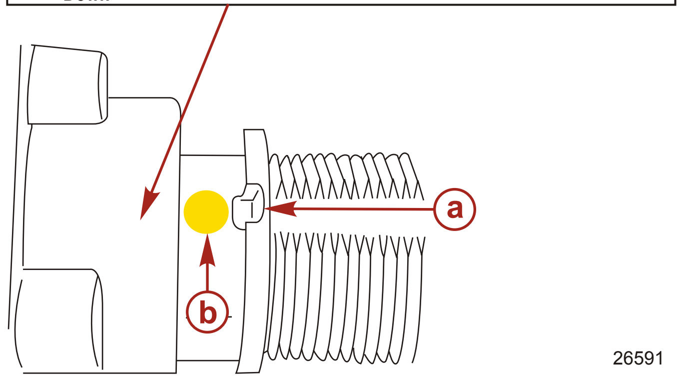


a - Distance between the flat surfaces - 20 mm (25/32 in.)
b - Diameter of the hole - 22.5 mm (7/8 in.)

2. Install one nut onto the key switch assembly with the flat flange of the nut toward the key end of the switch. Thread this nut on as needed until the key switch will extend through the dashboard with enough threads exposed for the second nut to be installed.

IMPORTANT: There are two notches in the key switch assembly. The notch with white plastic showing and the yellow dot next to it is a drain hole. To properly drain the key switch, this notch must point down when installed.

3. Install the key switch assembly into the dashboard oblong hole. Following the instructions on the decal, ensure the drain hole with the yellow dot points down for proper draining after installation.



a - Drain hole
b - Yellow dot

4. Install the second key switch nut and tighten to the specified torque.

Description	Nm	lb. in.	lb. ft.
Key switch nut	2.2	20	

5. Connect the key switch electrical connector to the command module harness.

Four Position Key Switch Test

a - Pin A
b - Pin B
c - Pin C
d - Pin D
e - Pin E
f - Pin F

Ref. No.	Pin	Wire Color	Description
a	A	Red	12 volts
b	B	Black	Ground
c	C	Purple/white	Accessory
d	D	Purple	Run
e	E	Black/yellow	Stop
f	F	Yellow/red	Start

Meter Test Leads		Key Position	Reading (Ω)
Red	Black		
Pin B	Pin E	Off	Continuity

Meter Test Leads		Key Position	Reading (Ω)
Pin A	Pin C	Accessories	Continuity
Pin A	Pin F	Run	Continuity
Pin A	Pin C		
Pin A	Pin F	Start	Continuity
Pin F	Pin D		Continuity
Pin A	Pin D		Continuity
Pin A	Pin C		Continuity

Start-Stop Panel Installation

The Start-Stop Panel allows the operator to start and stop the engines with the press of a single button. For the Start-Stop Panel to function, the key switch must be in the ON position. A start-stop switch is optional at the main helm station. A start-stop switch is required at the second helm station where no key switches are installed. Each engine is controlled independently in dual engine applications.

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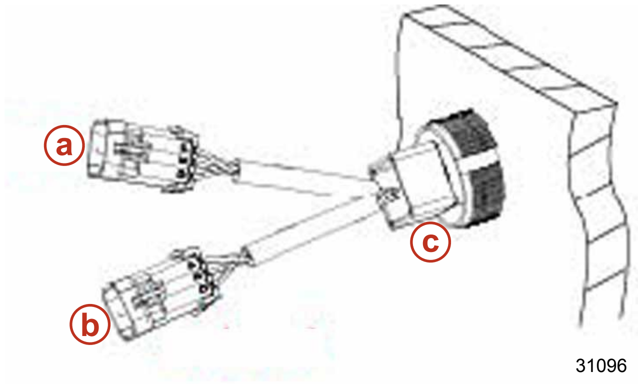
Dual engine start-stop switch

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

1. Ensure battery cables are disconnected.

2. Insert the Start-Stop Panel electrical connector, wiring, and Start-Stop Panel housing through the dash opening.



Behind the dashboard or instrument panel

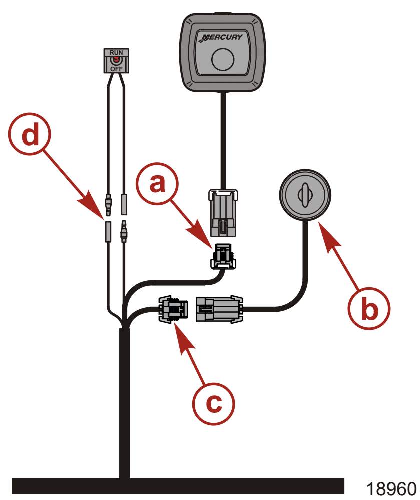
a - Port connector
b - Starboard connector
c - Back of switch housing

NOTE: The mounting nut is designed so that it can be reversed to maximize thread engagement depending on the thickness of the mounting surface.

3. Install the mounting nut to engage the maximum number of threads.
4. Correctly orientate the Start-Stop Panel.
5. Tighten the mounting nut securely.
6. Connect the Start-Stop Panel electrical connectors to their respective "START/STOP" connections on the helm harness.

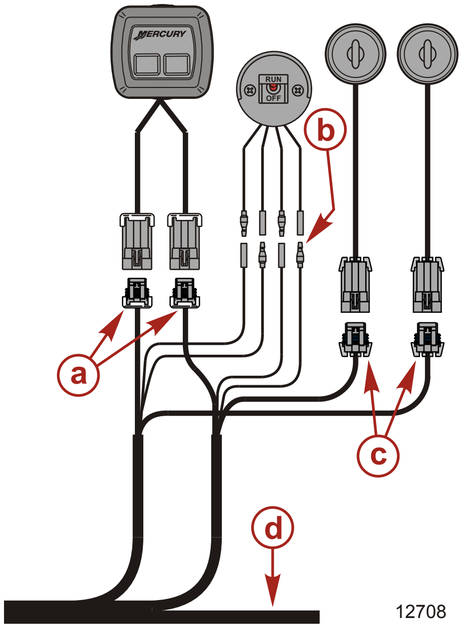
Start-Stop Switch Wiring

IMPORTANT: In dual helm applications, a start-stop switch is optional at the main helm station. The second helm station requires a start-stop switch. Seal the second station ignition key switch connector with a weathercap.



Single engine applications

a - Start-stop switch connector
b - Ignition key switch
c - Ignition key switch connector (weather cap at helm 2)
d - Lanyard stop switch connectors



Dual engine applications

a - Start-stop switch connector
b - Lanyard stop switch connector
c - Ignition key switch connector (weather cap at helm 2)
d - Helm harness

Engine and Helm Configuration

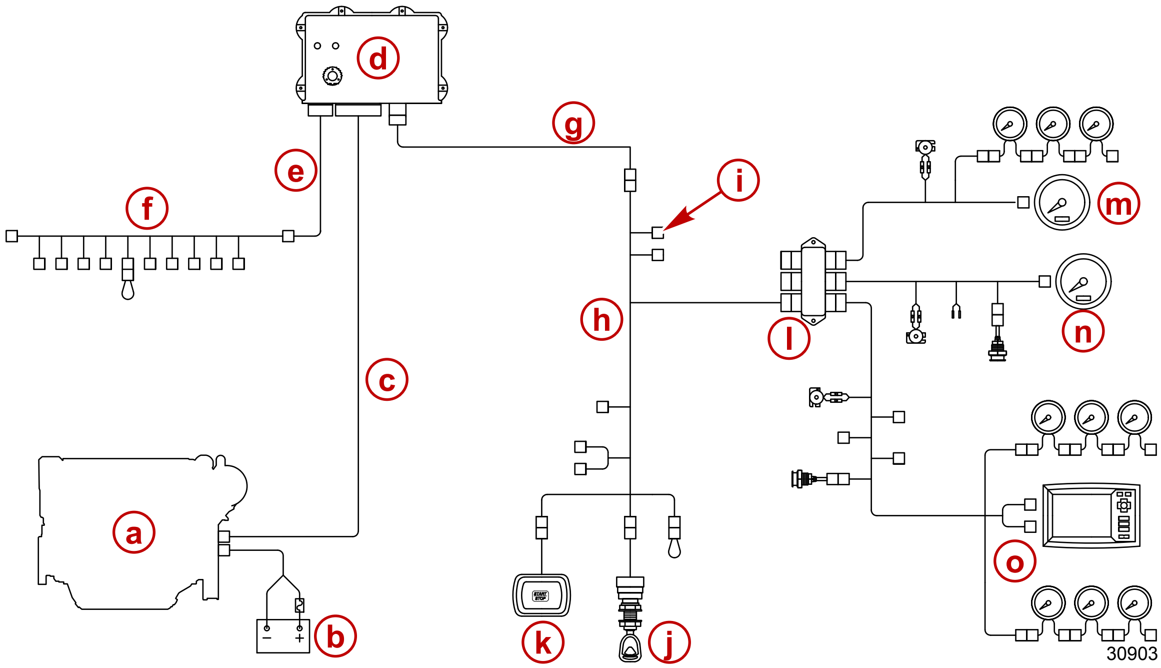
IMPORTANT: Connectors must be fully engaged and secure.

1. Connect and tighten the threaded collars of the helm extension harnesses and second station T harness, if equipped, and the non-DTS helm harnesses.
2. Connect the second station instrument harness or extension harness to the Y-harness connector tagged or titled "2nd STATION".
3. Connect the primary station instrument harness or extension harness to the Y-harness connector tagged or titled "MAIN STATION".
4. Connect the extension harness from the engine harness to the Y-harness connector tagged or titled "ENGINES"

IMPORTANT: When routing any wiring harness, ensure that the harnesses do not rub or get pinched.

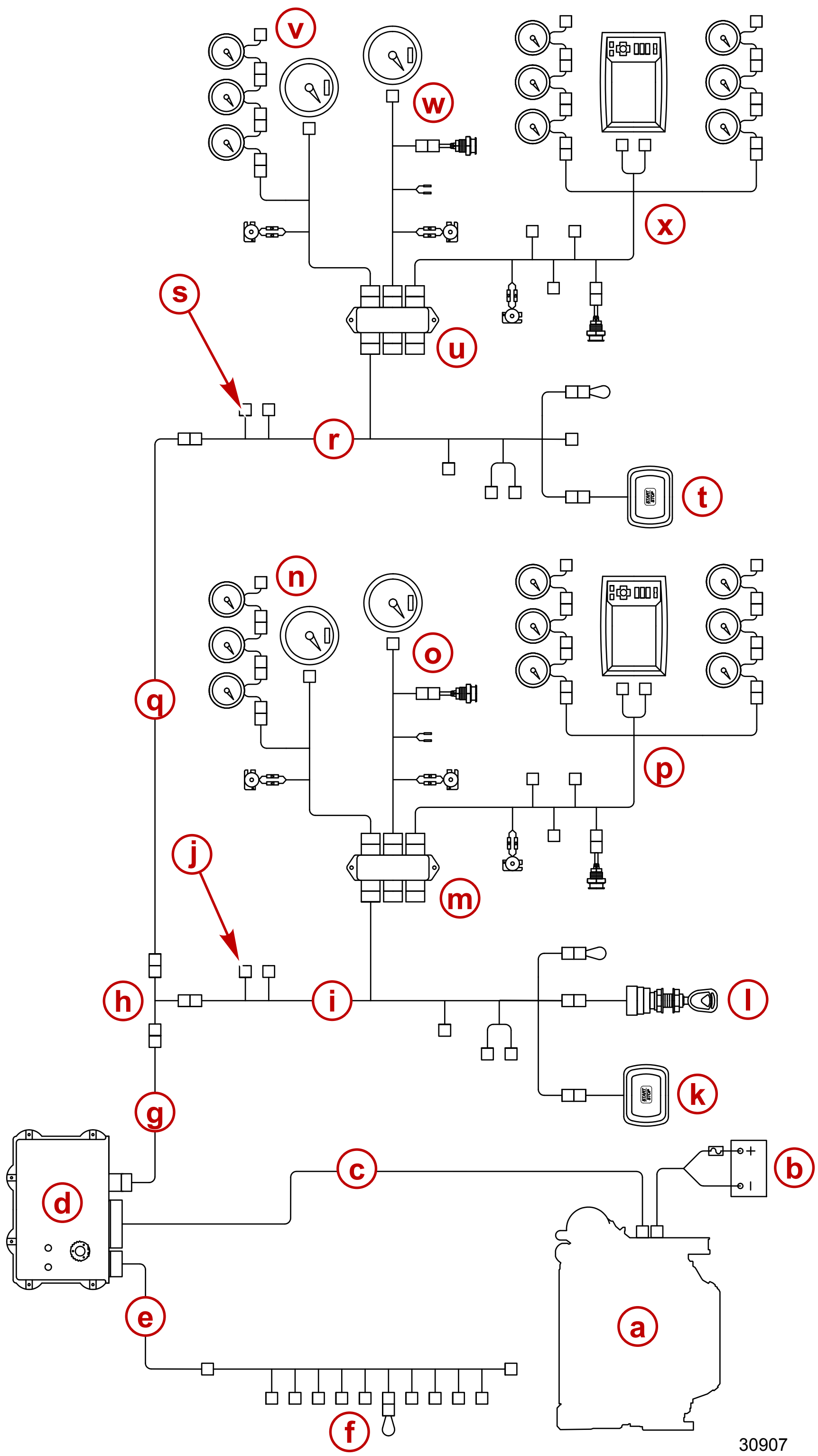
5. Secure the harnesses to the boat at least every 460 mm (18 in.) using appropriate fasteners.

Single Engine—Single Helm



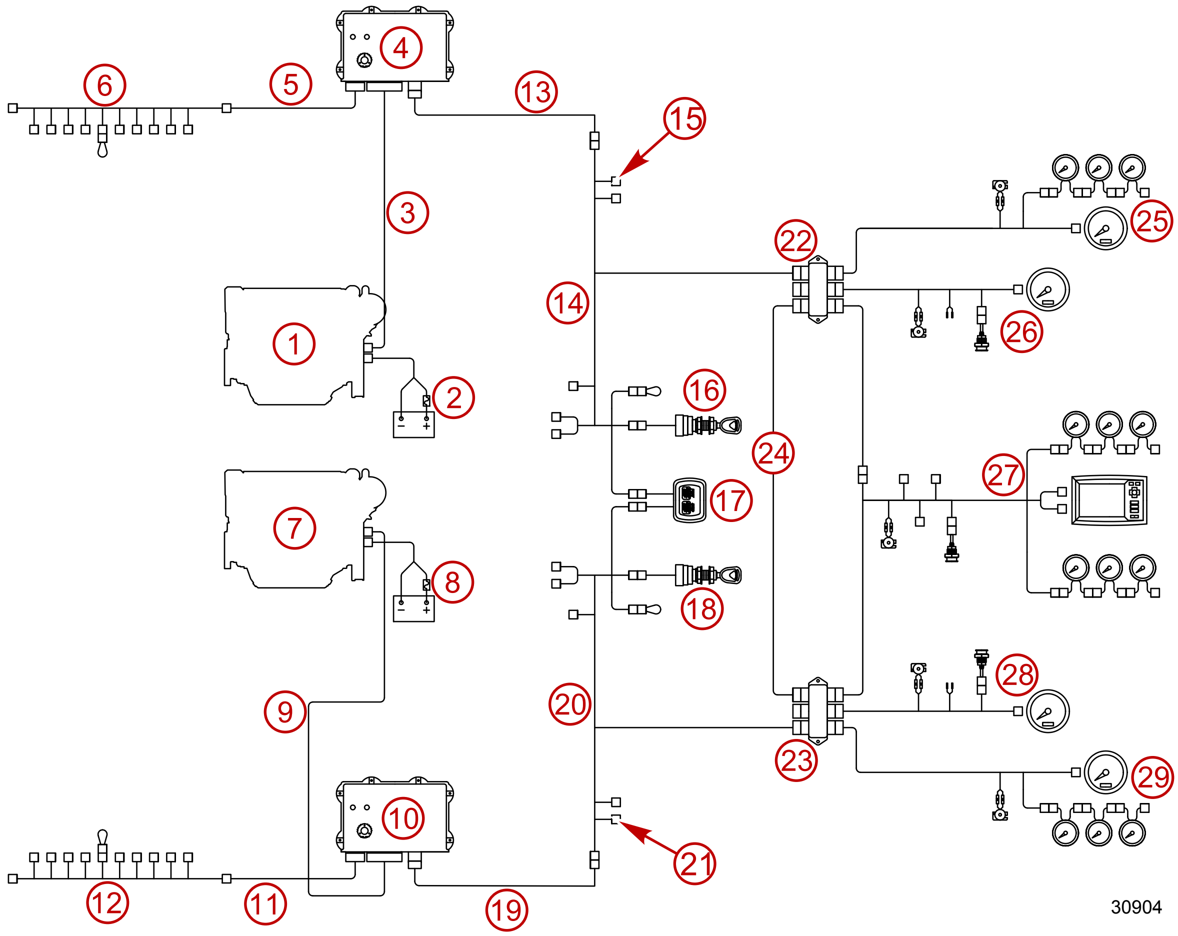
Reference	Description
a	Engine
b	Battery and power harness
c	Engine to VIP extension harness
d	Vessel Interface Panel (VIP)
e	Vessel sensor extension harness (if equipped)
f	Vessel sensor harness
g	14-pin helm extension harness
h	Non-DTS helm harness
i	CAN P termination resistor
j	Key switch
k	Start-stop panel (if equipped)
l	Junction box
m	System tachometer, harness, and link gauges
n	System speedometer and harness (if equipped)
o	VesselView display and harness (if equipped)

Single Engine—Dual Helm



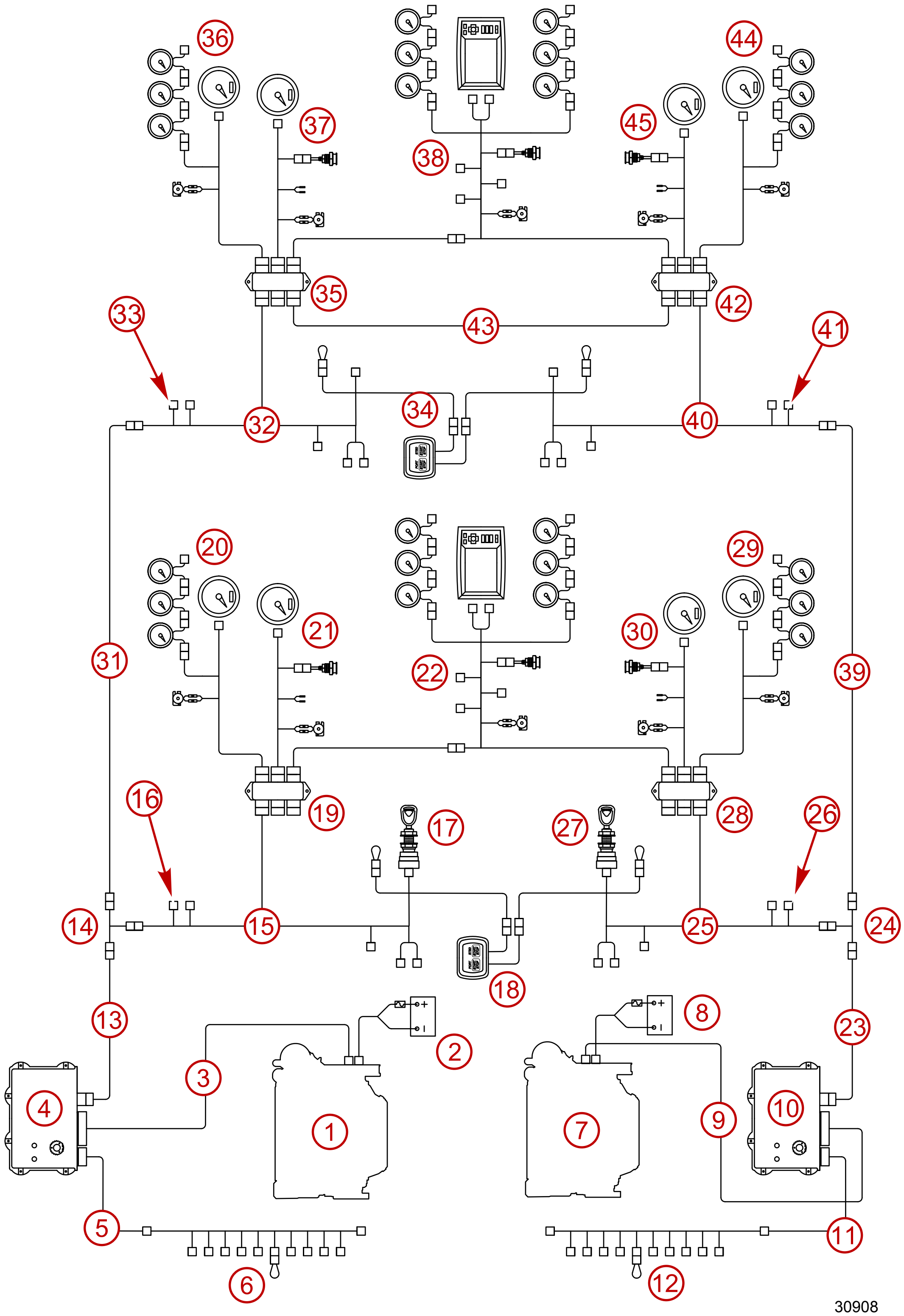
Reference	Description
a	Engine
b	Battery and power harness
c	Engine to VIP extension harness
d	Vessel Interface Panel (VIP)
e	Vessel sensor extension harness (if equipped)
f	Vessel sensor harness
g	14-pin helm extension harness
h	Second station adaptor harness
i	Primary station non-DTS helm harness
j	Primary station CAN P terminal with weather cap
k	Primary station start-stop panel (if equipped)
l	Primary station key switch
m	Primary station junction box
n	Primary station system tachometer, harness, and link gauges
o	Primary station system speedometer and harness (if equipped)
p	Primary station VesselView display and harness (if equipped)
q	Secondary station helm extension harness
r	Secondary station non-DTS helm harness
s	Secondary station CAN P termination resistor
t	Secondary station start-stop panel (if equipped)
u	Secondary station junction box
v	Secondary station system tachometer, harness, and link gauges
w	Secondary station system speedometer and harness (if equipped)
x	Secondary station VesselView display and harness (if equipped)

Dual Engine—Single Helm



Reference	Description
1	Port side engine
2	Port engine battery and power harness
3	Port engine to VIP harness
4	Port engine VIP
5	Port vessel sensor extension harness (if equipped)
6	Port vessel sensor harness
7	Starboard engine
8	Starboard engine battery and power harness
9	Starboard engine to VIP harness
10	Starboard engine VIP
11	Starboard vessel sensor extension harness (if equipped)
12	Starboard vessel sensor harness
13	Port engine 14-pin helm extension harness
14	Port engine non-DTS helm harness
15	CAN P connector with weather cap
16	Port engine key switch
17	Start-stop panel (if equipped)
18	Starboard engine key switch
19	Starboard engine 14-pin helm extension harness
20	Starboard engine non-DTS helm harness
21	CAN P terminal with weather cap
22	Port engine junction box
23	Starboard engine junction box
24	CAN P crossover harness
25	Port engine system tachometer, harness, and link gauges
26	Port engine system speedometer and harness (if equipped)
27	VesselView display and harness (if equipped)
28	Starboard engine system speedometer and harness (if equipped)
29	Starboard engine system tachometer, harness, and link gauges

Dual Engine—Dual Helm



Reference	Description
1	Port engine
2	Port engine battery and power harness
3	Port engine to VIP harness
4	Port engine VIP

Reference	Description
5	Port vessel sensor extension harness (if equipped)
6	Port vessel sensor harness
7	Starboard engine
8	Starboard engine battery and power harness
9	Starboard engine to VIP harness
10	Starboard engine VIP
11	Starboard vessel sensor extension harness (if equipped)
12	Starboard vessel sensor harness
13	Port engine 14-pin helm extension harness
14	Port engine second station adaptor harness
15	Port engine primary station non-DTS helm harness
16	Port engine primary station CAN P connector with weathercap
17	Port engine primary station key switch
18	Primary station start-stop panel (if equipped)
19	Port engine primary station junction box
20	Port engine primary station system tachometer, harness, and link gauges
21	Port engine primary station system speedometer and harness (if equipped)
22	Primary station VesselView display and harness (if equipped)
23	Starboard engine 14-pin helm extension harness
24	Starboard engine second station adaptor harness
25	Starboard engine primary station non-DTS helm harness
26	Starboard engine primary station CAN P connector with weathercap
27	Starboard engine primary station key switch
28	Starboard engine primary station junction box
29	Starboard engine primary station system tachometer, harness, and link gauges
30	Starboard engine primary station system speedometer and harness (if equipped)
31	Port engine secondary station 14-pin helm extension harness
32	Port engine secondary station non-DTS helm harness
33	Port engine secondary station CAN P connector with weathercap
34	Secondary station start-stop panel (if equipped)
35	Port engine secondary station junction box
36	Port engine secondary station system tachometer, harness, and link gauges
37	Port engine secondary station system speedometer and harness (if equipped)
38	Secondary station VesselView display and harness (if equipped)
39	Starboard engine-secondary station 14-pin helm extension harness
40	Starboard engine-secondary station non-DTS helm harness
41	Starboard engine-secondary station CAN P connector with weathercap
42	Starboard engine-secondary station junction box
43	Secondary station CAN P crossover harness
44	Starboard engine-secondary station system tachometer, harness, and link gauges
45	Starboard engine-secondary station system speedometer and harness (if equipped)

Remote Control Neutral Start Safety Circuit

⚠ WARNING

Starting the engine with the drive in gear can cause serious injury or death. Never operate a boat that does not have a neutral-safety-protection device.

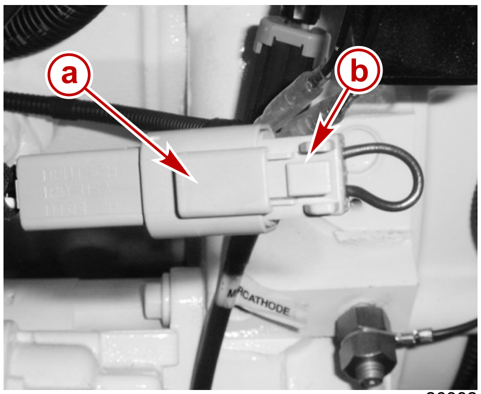
The neutral safety switch connection prevents the engine from starting while the remote control is in either the forward or reverse gear.

Primary Station

⚠ WARNING

Improperly installing the remote control can result in serious injury or death. Always remove the jumper plug from the neutral safety connection on the engine and install it correctly to the remote control.

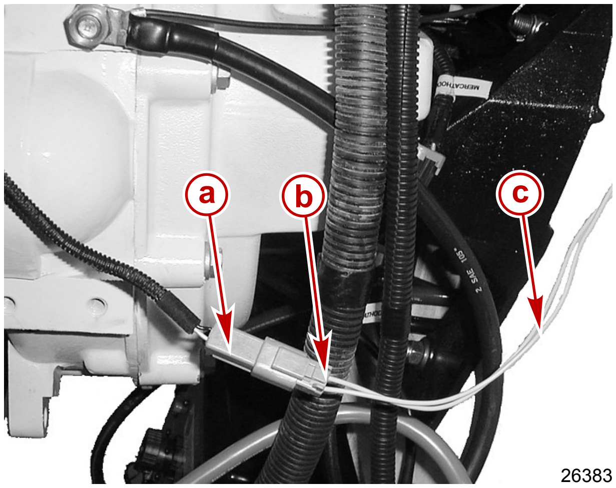
1. Disconnect the jumper plug from the neutral safety switch connector located on the engine if necessary.



a - Neutral safety switch connector
b - Jumper plug

2. Install a proper connector to the neutral switch wires leading to the remote control.

3. Connect the neutral switch wires from the remote control to the neutral safety switch connector on the engine.



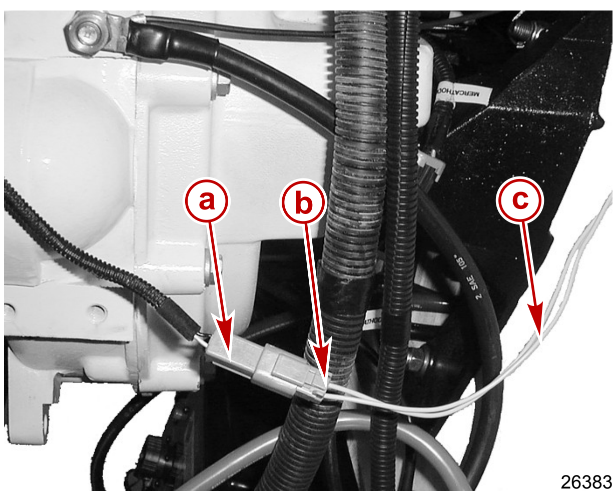
Typical

a - Neutral safety switch connector
b - Proper connector for wires from the remote control
c - Neutral switch wires leading to the remote control

Secondary Station

IMPORTANT: The remote control neutral safety wires from the secondary station remote control must be wired in series with the primary station remote control and neutral safety switch connection on the engine for the neutral safety feature to function properly.

1. Route the neutral safety switch wires from the second station remote control to the primary station remote control.
2. Connect the output wire from the second station remote control to the input wire on the primary station remote control.
3. Connect the neutral switch wires from the remote control to the neutral safety switch connector on the engine.



Typical

a - Neutral safety switch connector
b - Proper connector for wires from the remote control
c - Neutral switch wires leading to the remote control

Engine Monitoring Features

Audio Warning System

Your Cummins MerCruiser Diesel power package may be equipped with an audio warning system. The audio warning system will not protect the engine from damage. It is designed to warn the operator that a problem has occurred.

The audio warning system will sound if the Engine Control Module (ECM) detects a malfunction. Your power package may be equipped with one of the following system views that can be used to indicate the fault codes.

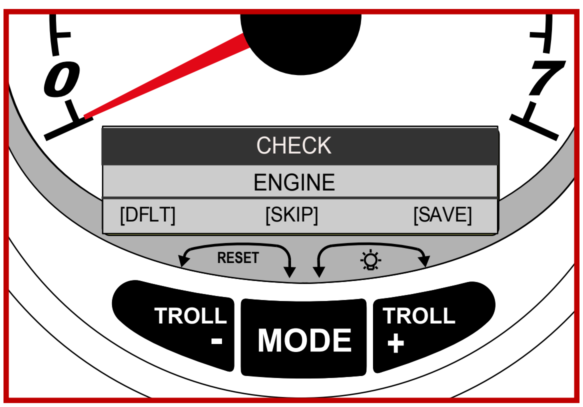
- System Tachometer or Speedometer

NOTICE
A continuous horn indicates a critical fault. Operating the engine during a critical fault can damage components. If the warning horn emits a continuous beep, do not operate the engine unless avoiding a hazardous situation.

If the alarm sounds, stop the engine immediately if you are not in a hazardous situation. Investigate the cause and correct it, if possible. If you cannot determine the cause, consult your Cummins MerCruiser Diesel Authorized Repair Facility.

System Tachometer or Speedometer

The LCD on the system tachometer, if equipped, displays active fault codes. To indicate an active fault code is present the following screen appears on the tachometer display.



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Typical system tachometer fault code display

After pressing the "MODE" button, a blinking "AL" also appears in the upper right hand corner of each menu on the digital display screen to signify an active fault. A major fault is also accompanied by the audio warning system.

To view the active faults, you must press the "MODE" button until you reach the total engine hours screen. In the event of an active fault code, the total engine hours is only displayed for 30 seconds after key-on. After this 30-second period, the digital display screen outputs the active fault codes in 3-second intervals in place of the total engine hour value.

The following is a list of faults displayed by the Smart Tach that also activates the audio warning system.

Smart Tach Display	Warning Indication
"LOW OIL PRESS"	The oil pressure has dropped below the critical engine protection limit
"OVERHEAT"	The engine coolant temperature has risen above the engine protection limit.
"WATER IN FUEL"	Water has been detected in the fuel filter housing.
"FAULT THROTTLE"	There is a fault in the throttle sensor.
"FAULT BATTERY"	The ECM battery voltage is out of range.
"CHECK ENGINE"	The "CHECK ENGINE" code corresponds to a number of different engine related faults. Refer to your Cummins MerCruiser Diesel Authorized Repair Facility.

Senders

NOTE: *Refer to Section 5 for information on the engine coolant temperature (ECT) and engine oil pressure (EOP) sensors.*

NOTE: *Refer to the appropriate Mercury MerCruiser sterdive service manual for information on the trim pump sender, steering angle sender, and paddle wheel speed sender.*

Notes:

Electrical System

Section 4D - Wiring Diagrams

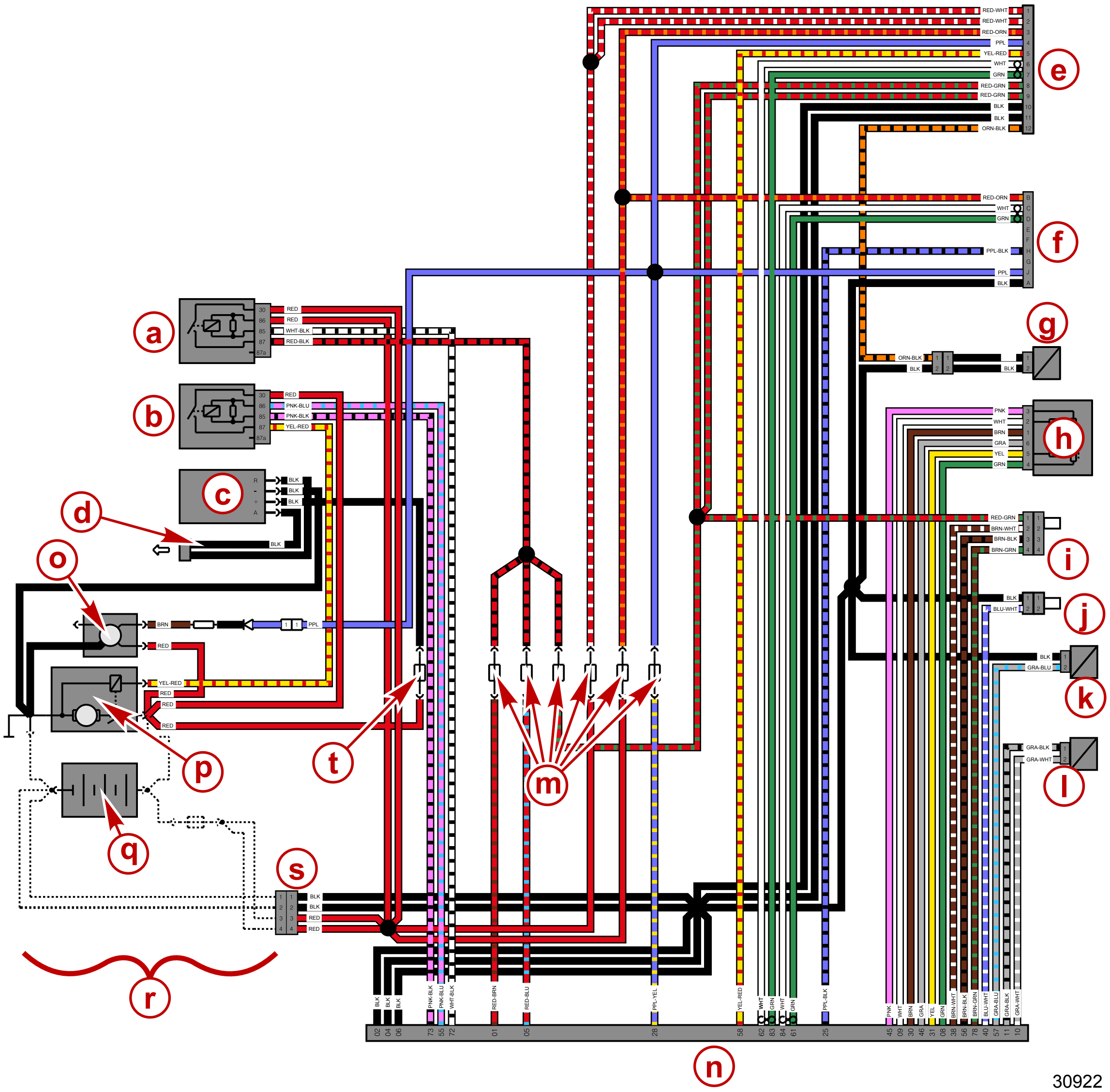
Table of Contents

Notes:

Notes:

Engine Harness Wiring Diagrams

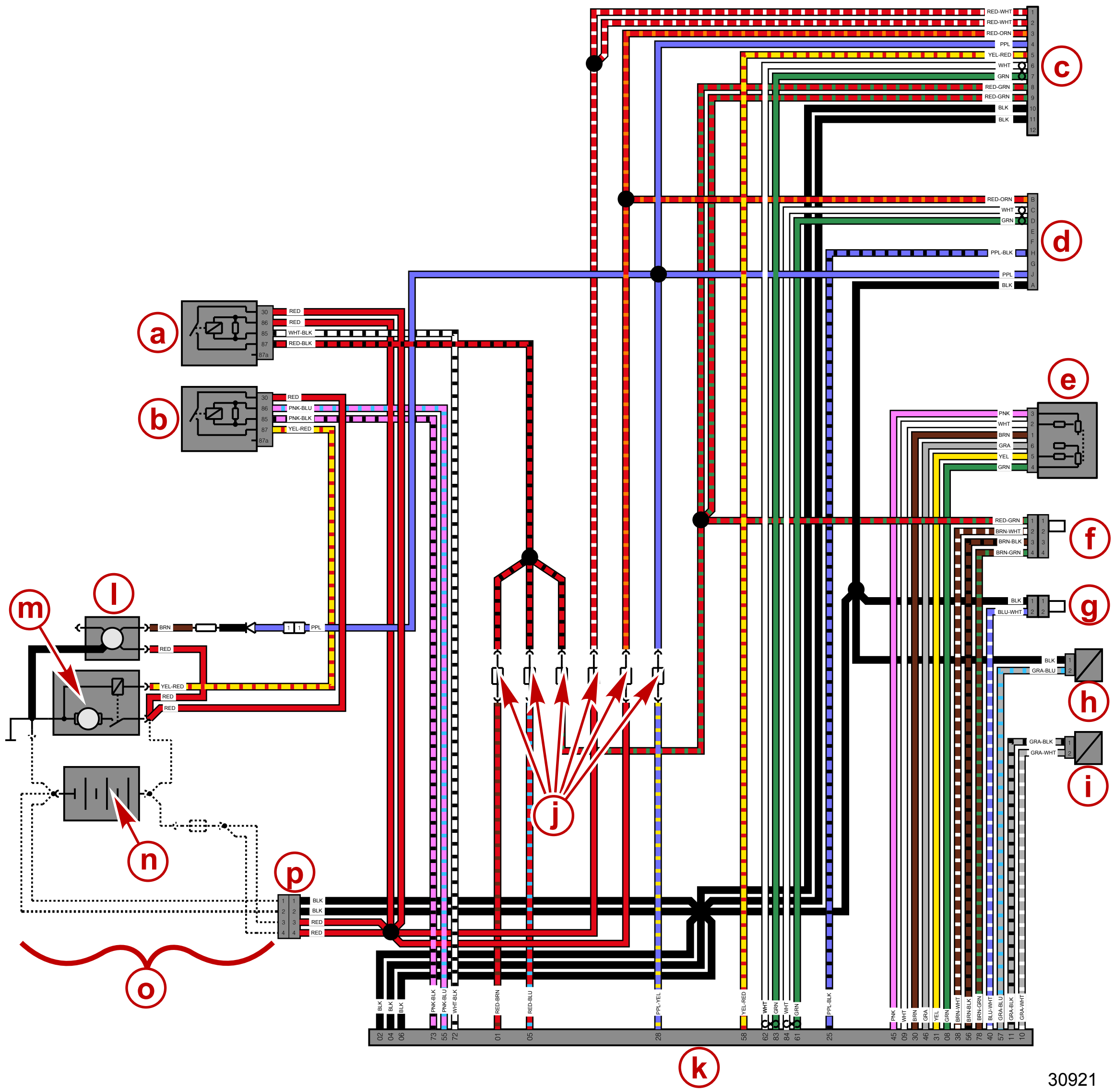
Engine Interface Harness K—Sterndrive Models



- **a -** Main relay
- **b -** Starter relay
- **c -** MerCathode
- **d -** MerCathode connections to transom
- **e -** Engine interface connection
- **f -** CDS diagnostic tool connection
- **g -** Sterndrive gear lube level sensor connection
- **h -** Throttle position sensor (TPS) connection
- **i -** MUS ID jumper connection
- **j -** Neutral safety switch connection
- **k -** Water in fuel (WIF) sensor connection
- **l -** Engine fuel temperature (EFT) sensor connection
- **m -** Engine circuit breakers
- **n -** ECM connection
- **o -** Alternator
- **p -** Starter
- **q -** Battery
- **r -** Engine power harness
- **s -** Engine power harness connection
- **t -** Mercathode 20-amp in-line fuse

Notes:

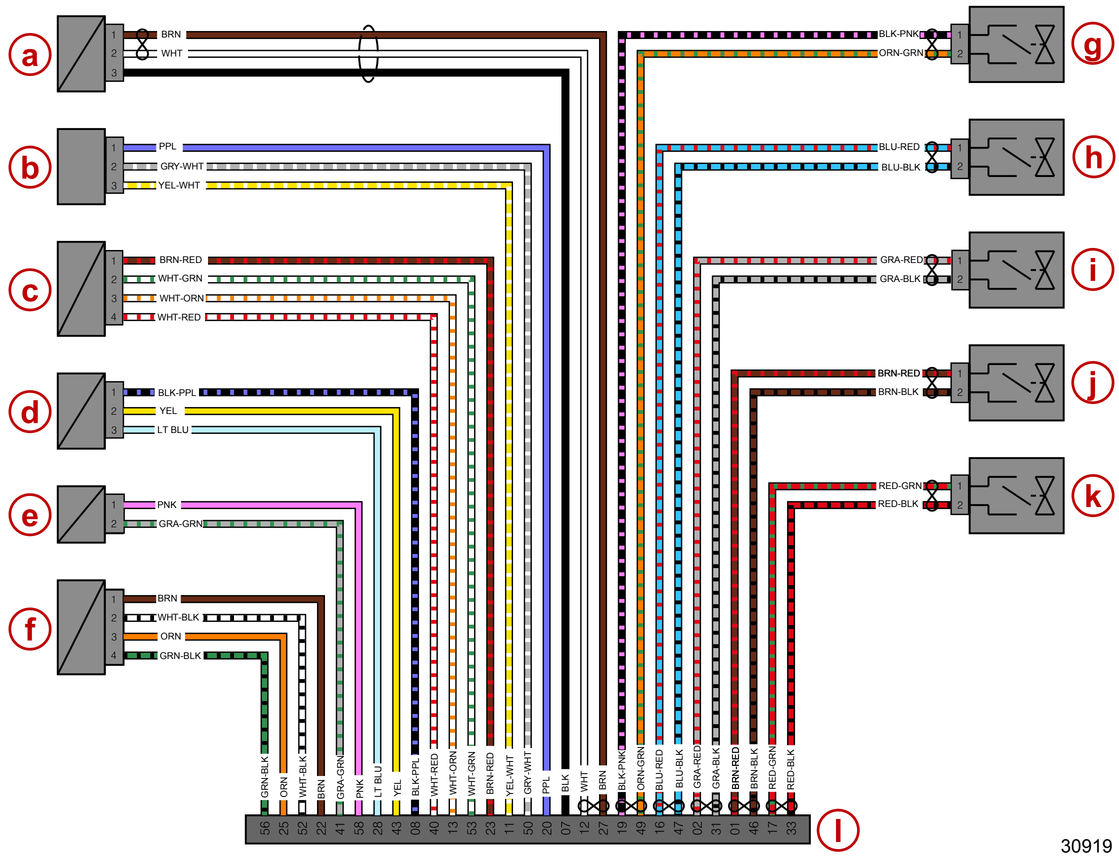
Engine Interface Harness K—Inboard Models



a - Main relay
b - Starter relay
c - Engine interface connection
d - CDS diagnostic tool connection
e - Throttle position (TP) sensor connection
f - MUS ID jumper connection
g - Neutral safety switch connection
h - Water in fuel (WIF) sensor connection
i - Engine fuel temperature (EFT) sensor connection
j - Engine circuit breakers
k - ECM connection
l - Alternator
m - Starter
n - Battery
o - Engine power harness
p - Engine power harness connection

Notes:

2.8 Engine Fuel System Harness A



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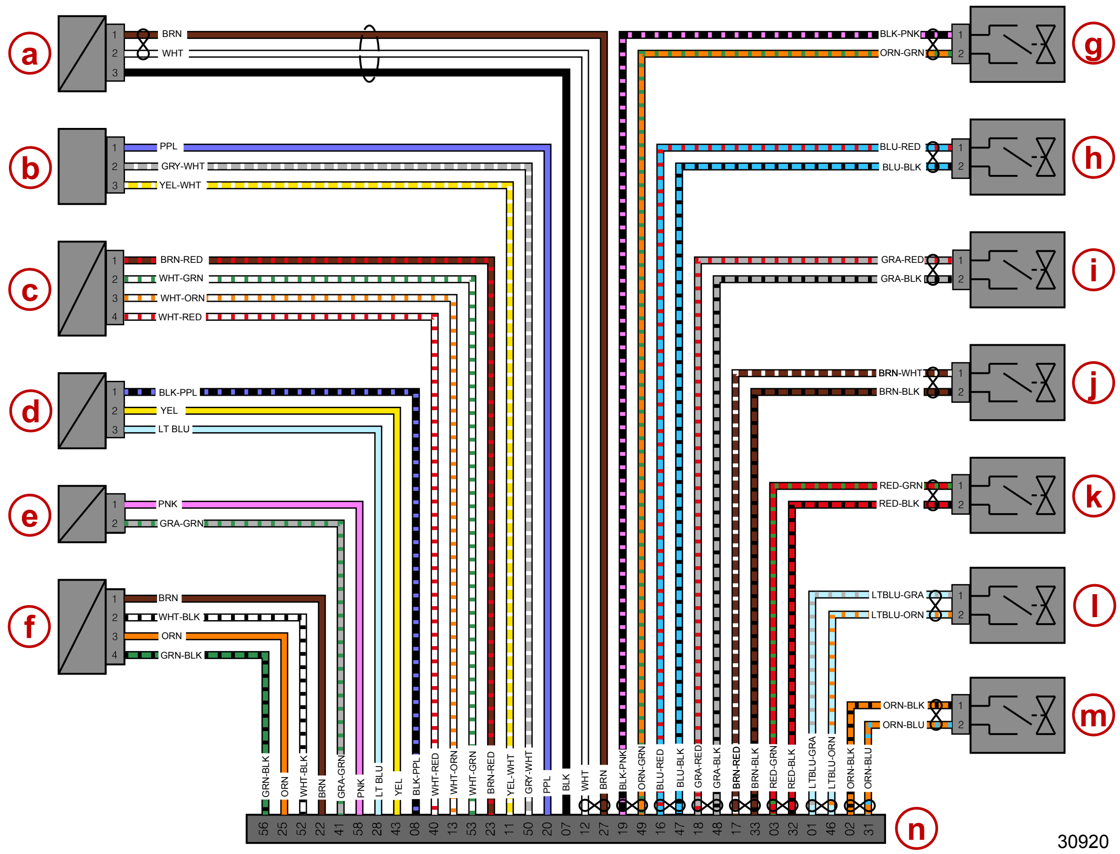
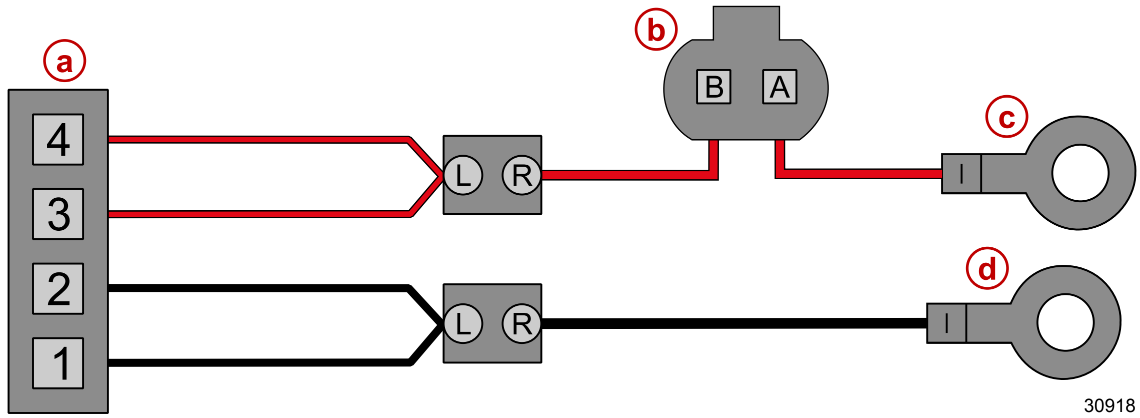
a - Crankshaft speed sensor connection
b - Camshaft position sensor connection
c - Manifold absolute pressure and temperature (IMP and MAP) sensor connection
d - Rail fuel pressure sensor connection
e - Engine coolant temperature (ECT) sensor
f - Engine oil pressure and temperature (EOP and EFT) sensor connection
g - High pressure fuel pump sensor connection
h - Injector 1
i - Injector 2
j - Injector 3
k - Injector 4
l - ECM connection

4.2 Engine Fuel System Harness A



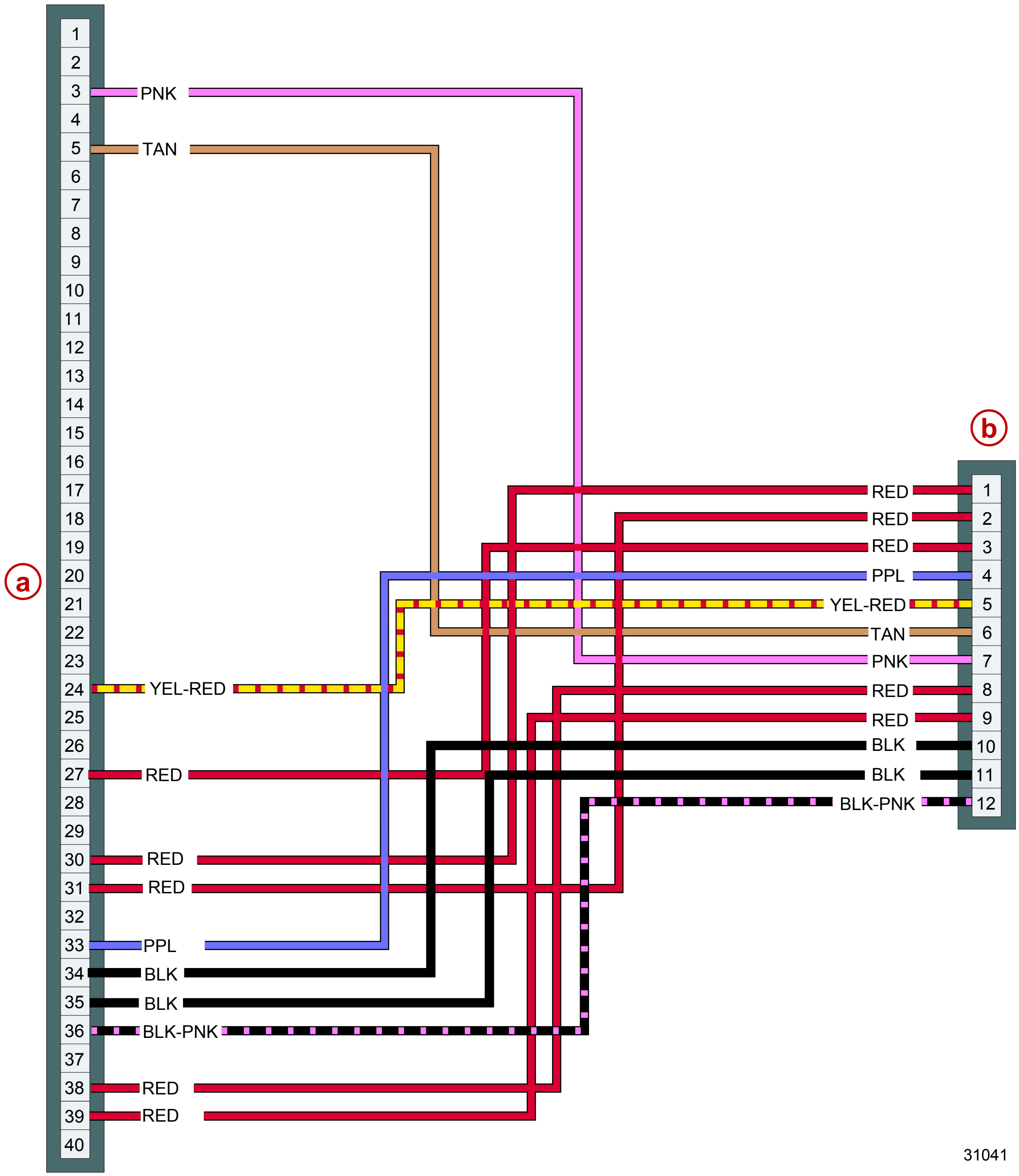
a - Crankshaft speed sensor connection
b - Camshaft position sensor connection
c - Manifold absolute pressure and temperature (IMP and MAP) sensor connection
d - Rail fuel pressure sensor connection
e - Engine coolant temperature (ECT) sensor
f - Engine oil pressure and temperature (EOP and EFT) sensor connection
g - High pressure fuel pump sensor connection
h - Injector 1
i - Injector 2
j - Injector 3
k - Injector 4
l - Injector 5
m - Injector 6
n - ECM connection

Engine Power Harness



a - Engine power connector
b - 30-amp fuse
c - Positive (+) battery terminal connection
d - Negative (–) battery terminal connection

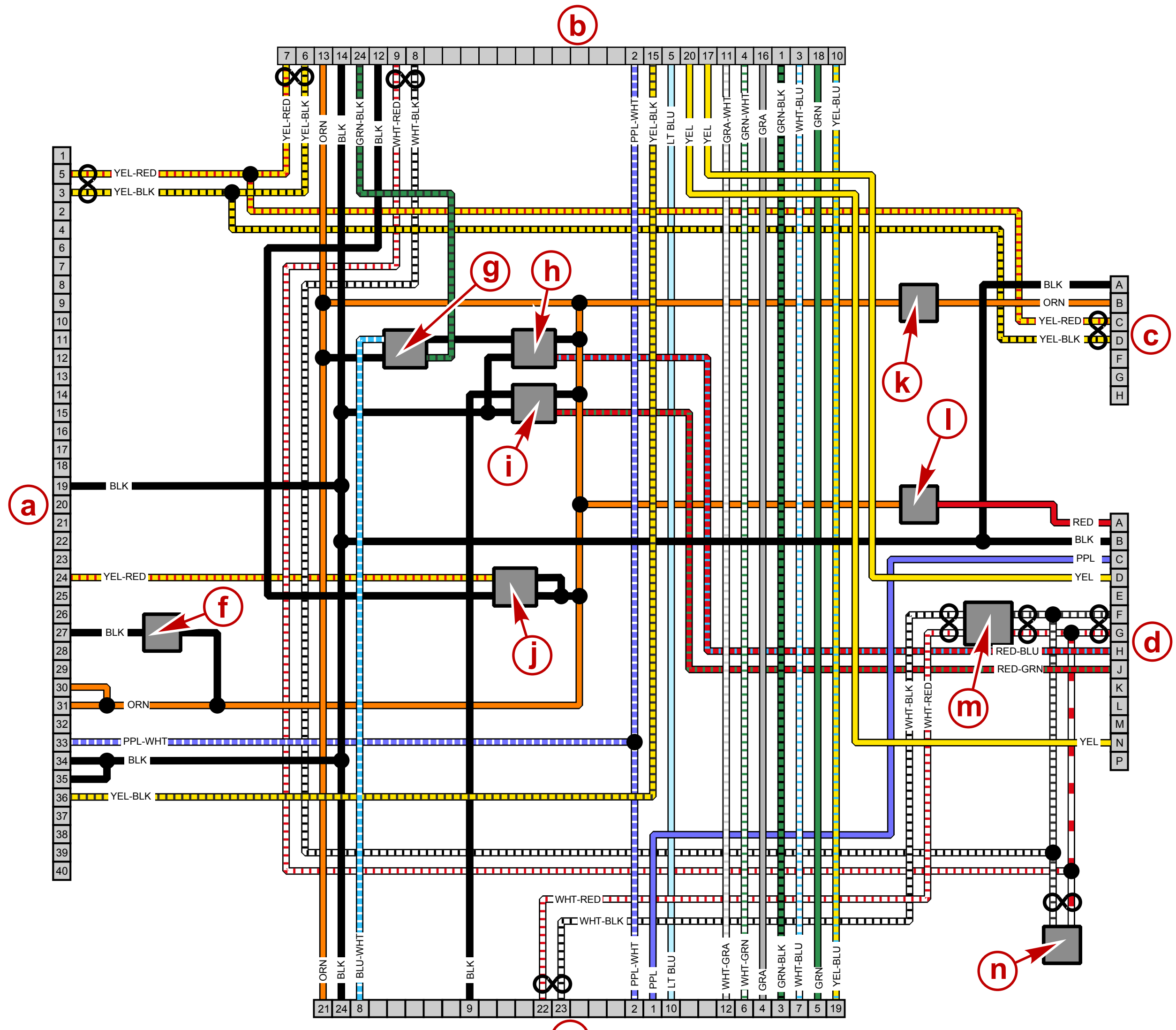
Engine to VIP Wiring Harness



a - 40-pin VIP connector

b - 12-pin engine interface

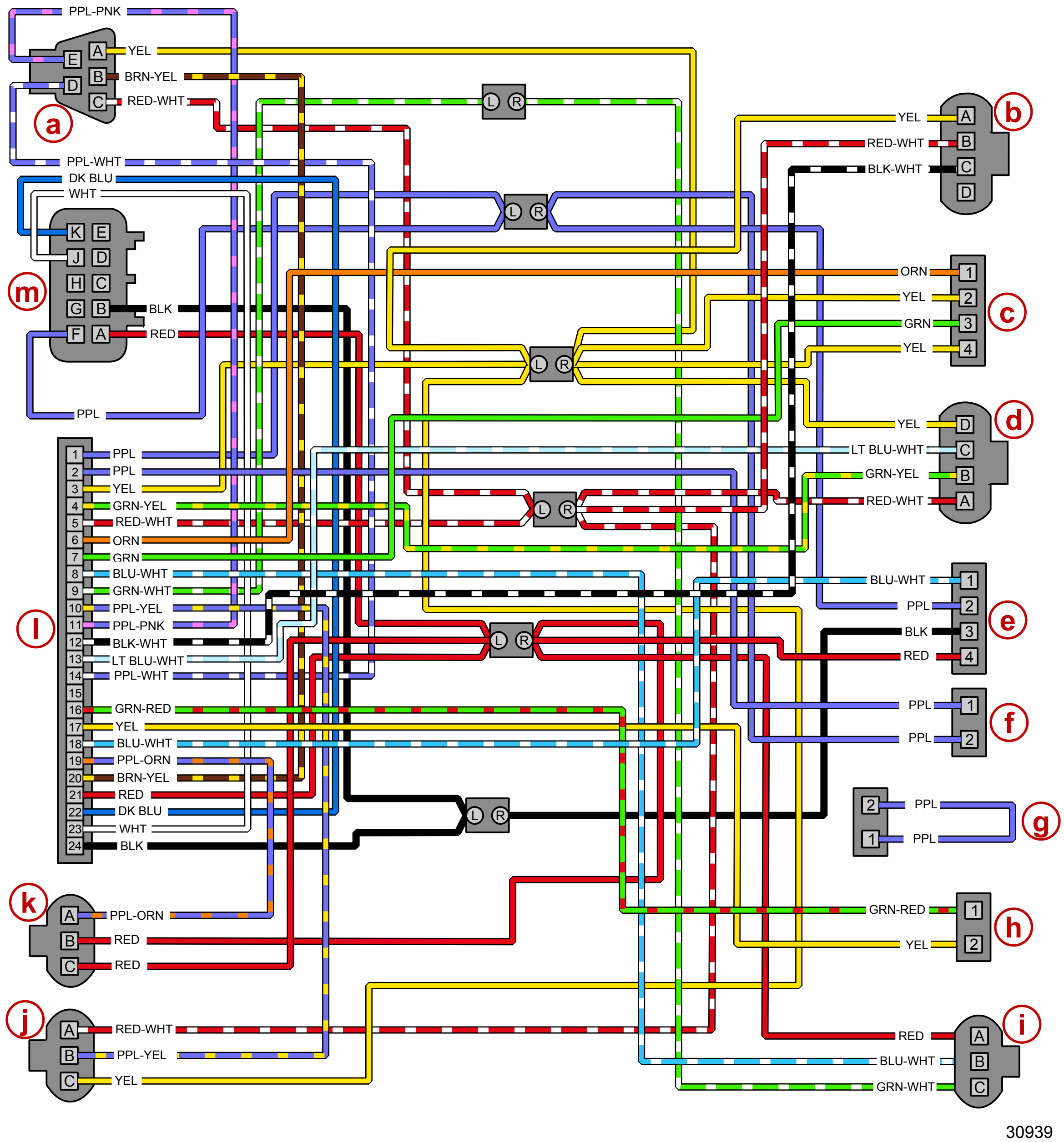
Vessel Interface Panel Wiring Diagram



a - 40-pin engine to VIP harness connector
b - SIM connections
c - 9-pin diagnostic connector
d - 14-pin helm harness connector
e - 24-pin vessel sensor harness connector
f - 5-amp circuit breaker
g - Trim limit relay
h - Trim up relay
i - Trim down realy
j - Start relay
k - 5-amp circuit breaker
l - 10-amp circuit breaker
m - Default switch position
n - 120-ohm CAN P terminator resistor

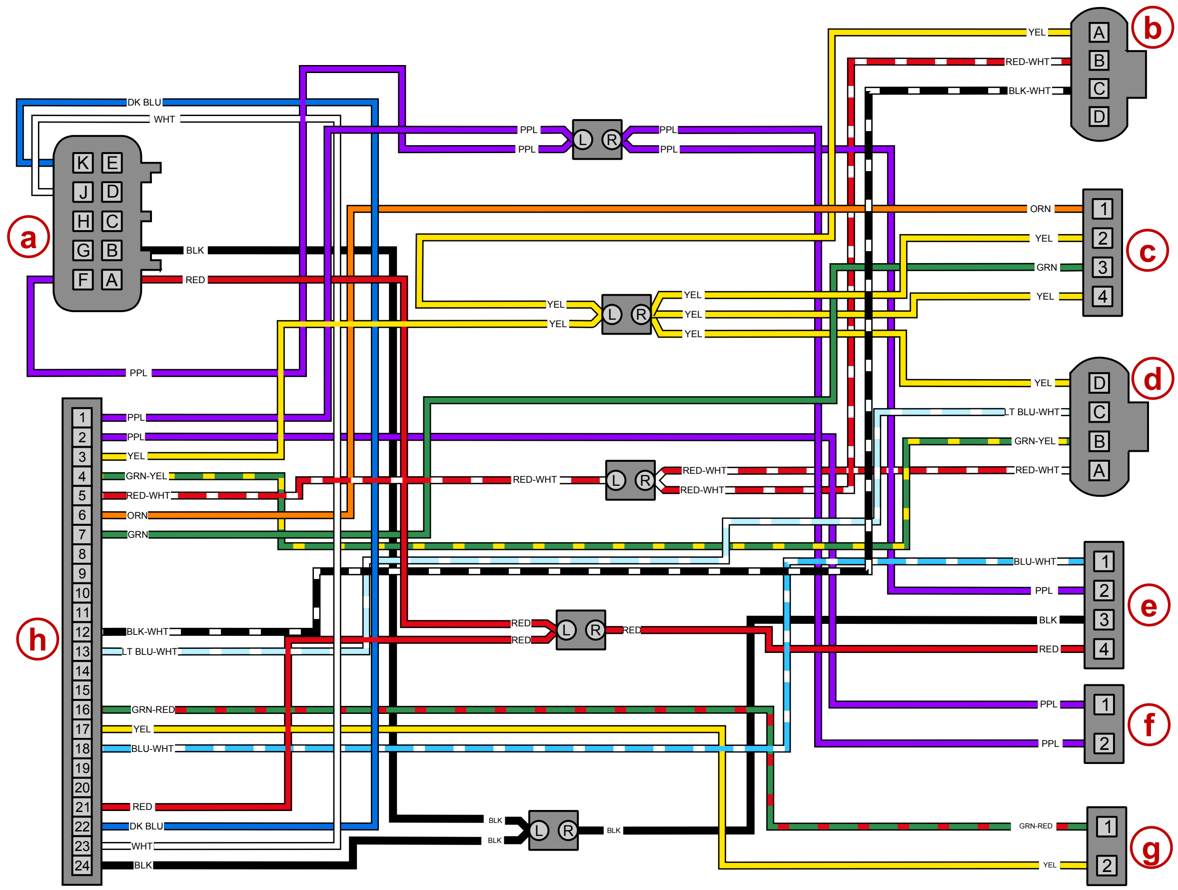
Vessel Sensor Harness Wiring Diagrams

Sterndrive Vessel Sensor Harness



a - Shift actuator connector
b - Paddle wheel speed sensor connector
c - Fuel tank quantity sensor connector
d - Fuel tank quantity sensor connector
e - Accessory relay drive connector
f - Halon breakout connector
g - Halon breakout jumper plug
h - Water in fuel (WIF) connection
i - Trim pump connection
j - Trim position sensor connection
k - Shift anticipation connection
l - 24-pin VIP connection
m - CAN P connector

Inboard Vessel Sensor Harness



a - CAN P connector

b - Paddle wheel speed sensor connector

c - Fuel tank quantity sensor connector

d - Steering position connector

e - Accessory relay drive connector

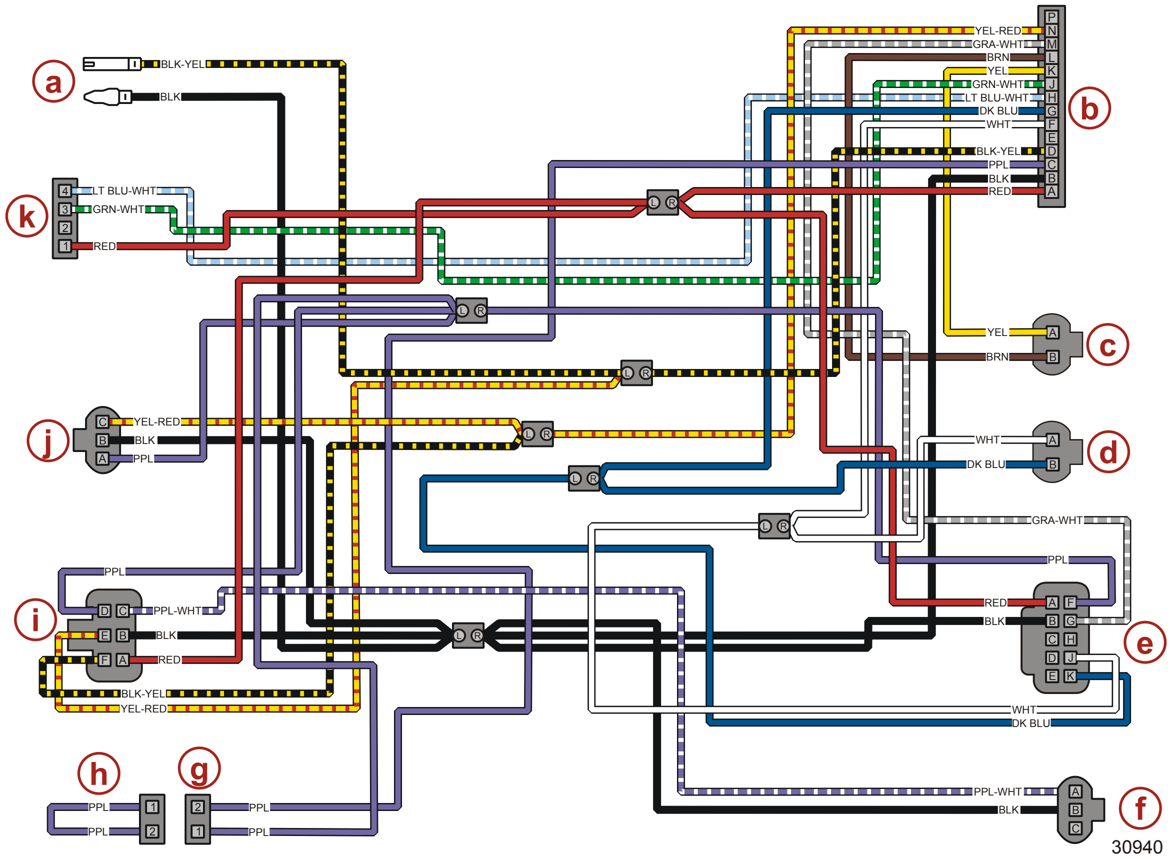
f - Halon breakout connector (jumper plug not shown)

g - Water in fuel (WIF) extension connection

h - 24-pin VIP connection

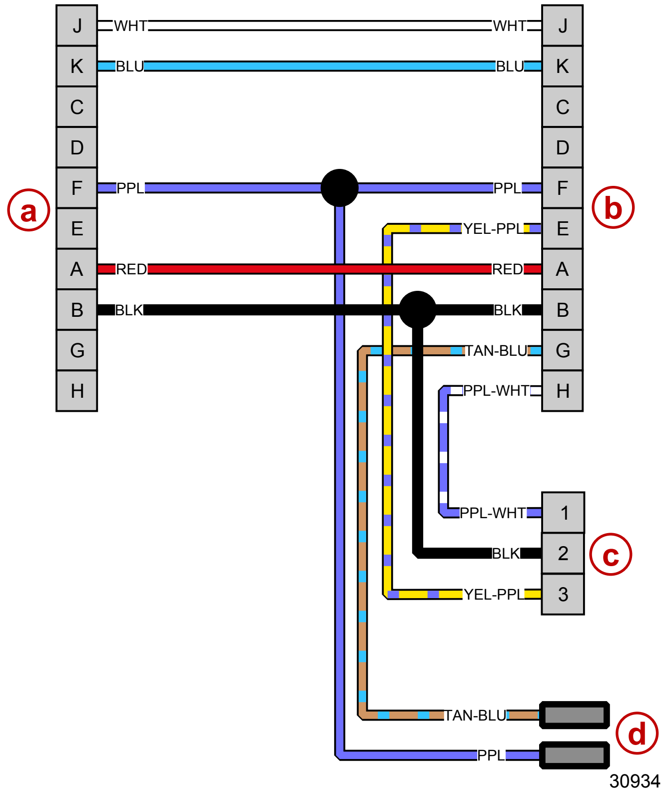
Instrumentation Wiring Diagrams

Non-DTS helm harness



a - Lanyard connections
b - 14-pin helm extension harness or VIP connection
c - CAN X termination resistor connector (weather capped)
d - CAN P termination resistor connector
e - Junction block connection
f - Switched load connection
g - Halon breakout connection
h - Halon breakout jumper plug
i - Key switch connection
j - Start-stop panel connector
k - Power trim control connection

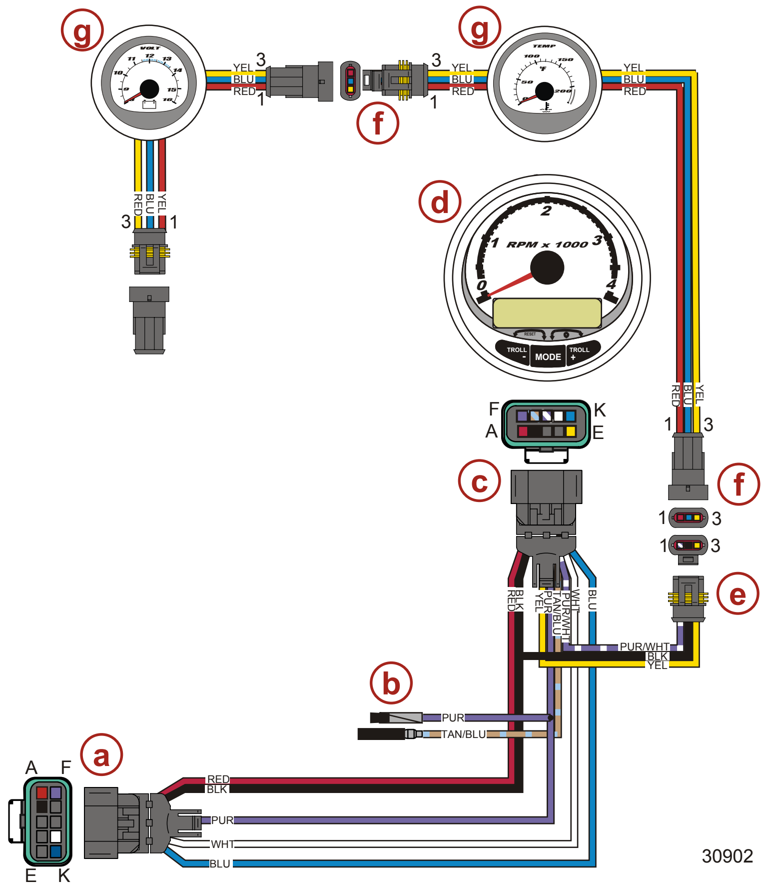
SmartCraft System Tachometer



a - Junction block connection
b - System tachometer connection
c - Link gauges connection
d - Alarm horn connections

SmartCraft System Tachometer

IMPORTANT: Seal all unused connectors with weather caps.

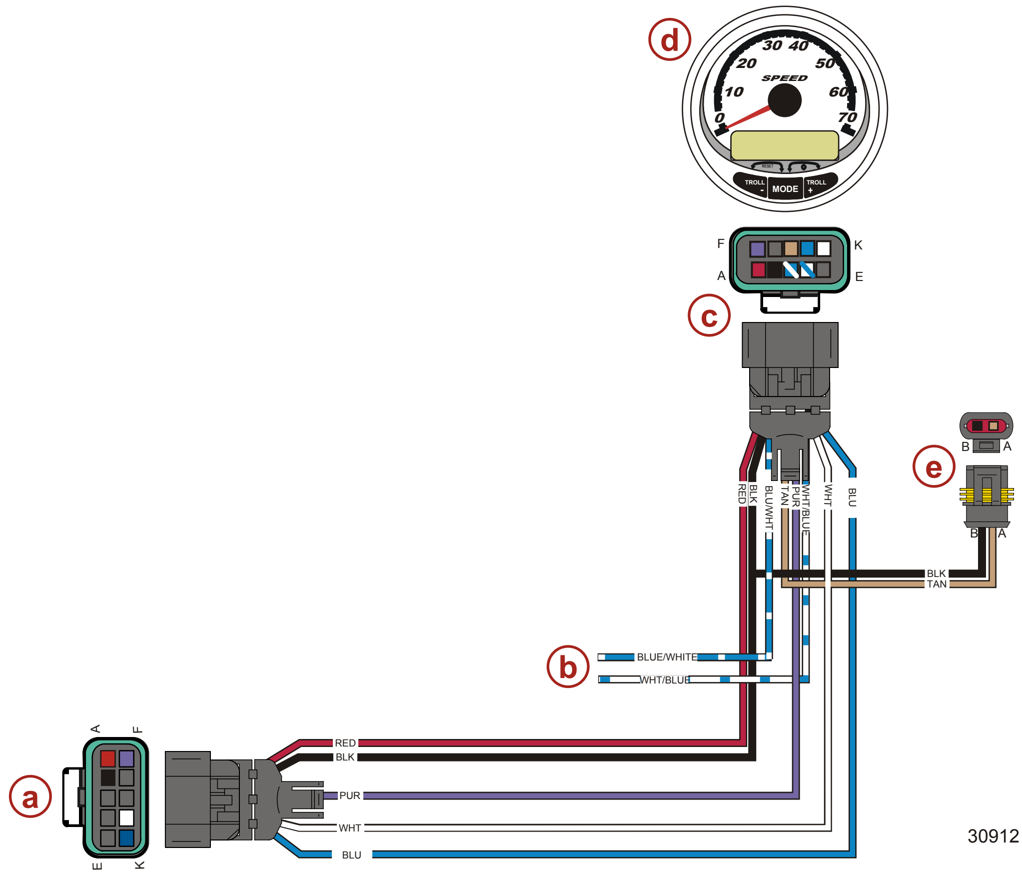


a - 10-pin SmartCraft connector
b - Audio warning wiring
c - Tachometer connector
d - System Tachometer
e - System Link Gauge connector
f - System Link Gauge wiring
g - System Link Gauge

Tachometer Connector		
Pin	Wire Color	Function
A	RED	Positive 12 volts (un-switched)
B	BLK	Ground
C	–	Empty
D	–	Empty
E	YEL	System Link Data
F	PUR	Wake (key on battery power)
G	TAN/BLU	Audio warning
H	PUR/WHT	System Link Power
J	WHT	CAN P +
K	BLU	CAN P -

SmartCraft System Speedometer

IMPORTANT: Seal all unused connectors with weather caps.



a - 10-pin SmartCraft connector

b - GPS NEMA connection

c - Speedometer connector

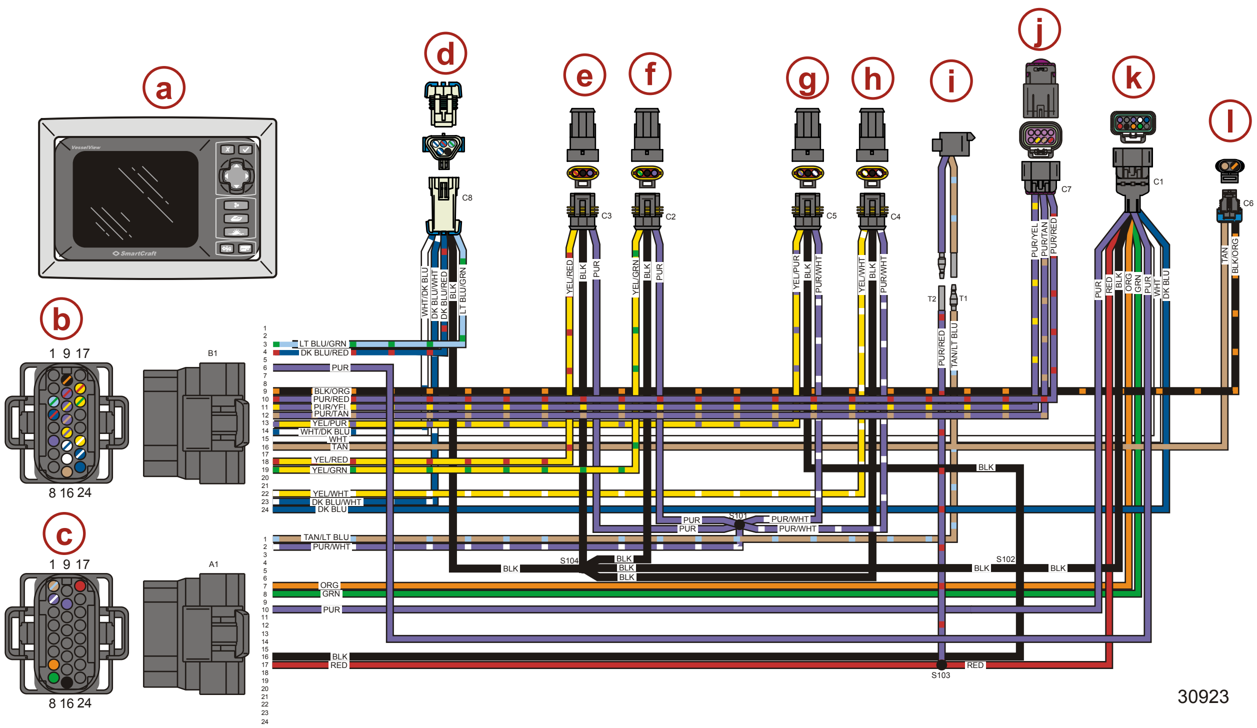
d - System Speedometer

e - Air temperature connector

Pin	Wire Color	Function
A	RED	Positive 12 volts
B	BLK	Ground
C	BLU/WHT	NEMA -
D	WHT/BLU	NEMA +
E	–	Empty
F	PUR	Wake (key on battery voltage)
G	–	Empty
H	TAN	Air Temperature
J	BLU	CAN P +
K	WHT	CAN P -

VesselView Harness Wiring Diagram

VesselView Harness Diagram



a - VesselView
b - VesselView connector "B"
c - VesselView connector "A"
d - NMEA connection
e - System link (starboard 2)
f - System link (port 2)
g - Starboard system link
h - Port system link
i - Warning horn
j - Ignition connector
k - Junction box connector
l - Air temperature sensor

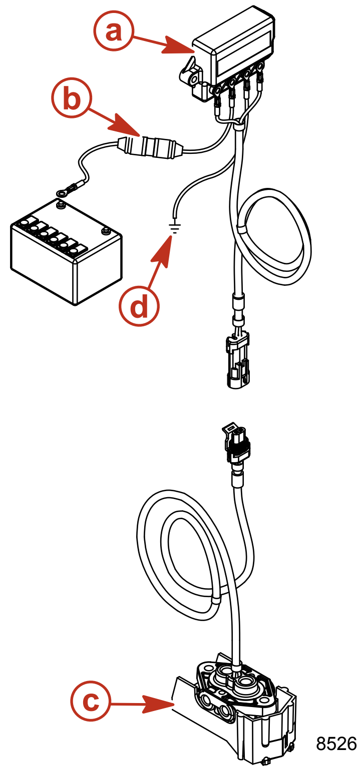
IMPORTANT: Seal all unused connectors with weather caps.

VesselView Harness Pinout Table

Vessel View Connector "A"		
Pin	Wire Color	Function
1	TAN/LT BLU	Audio warning signal
2	PUR/WHT	Audio warning power
3 – 6	–	Empty
7	ORG	Reserved
8	GRN	Reserved
9	–	Empty
10	PUR	Wake (key on battery power)
11 – 15	–	Empty
16	BLK	Ground
17	RED	Positive 12 volts (un-switched)
18 – 24	–	Empty

Vessel View Connector "B"		
Pin	Wire Color	Function
1 – 2	–	Empty
3	LT BLU/GRN	NMEA out (+)
4	DK BLU/RED	NMEA out (–)
5	–	Empty
6	PUR	Wake (key on battery power)
7 – 8	–	Empty
9	BLK/ORG	Air temperature ground
10	PUR/RED	Multi-engine Ignition
11	PUR/YEL	Multi-engine Ignition
12	PUR/TAN	Multi-engine Ignition
13	YEL/PUR	Starboard one System Link signal
14	WHT/DK BLU	NMEA in (+)
15	WHT	CAN P +
16	TAN	Air temperature signal
17	–	Empty
18	YEL/RED	Starboard two System Link signal
19	YEL/GRN	Port two System Link signal
20 – 21	–	Empty
22	YEL/WHT	Port one System Link signal
23	DK BLU/WHT	NMEA in (–)
24	DK BLU	CAN P -

MerCathode System



a - Controller
b - 20-amp fuse
c - Electrode
d - BLACK wire - with engine harness or separate, model dependant

Fuel System

Section 5A - Component Description

Table of Contents

5A

Introduction

The following text describes proper diagnosis and service of the Cummins MerCruiser Diesel Electronic Control System (ECS) for the diesel fuel injection system with a high-pressure fuel pump and a common fuel rail (sometimes referred to as an accumulator).

All information is based on the latest product information available at the time of publication. We reserve the right to make changes without notice.

This manual and any subsequent publication provides information required to properly maintain the Cummins MerCruiser Diesel engine control system.

Precautions

Follow these instructions to ensure safe and proper service and repair of all Cummins MerCruiser Diesel Electronic Control System (ECS) engines.

-
- Replace parts with those recommended by Cummins MerCruiser Diesel.
- Use only special tools as listed in the document.

IMPORTANT: Using replacement parts, service procedures, or tools not recommended by Cummins MerCruiser Diesel can compromise personal safety or engine operation. Ensure that replacement parts have the same part number as the original or one that is directly superseded from the original.

Observe the following when working on ECS equipped engines:

- Observe all Warnings, Cautions, and Notices.
- Before removing any ECM (engine control module) system component, disconnect the negative (–) battery cable.
- Never start the engine with the terminal ends of the battery cables unsecured.
- Never separate the battery from the on-board electrical system while the engine is operating.
- Never separate the battery feed wire from the charging system while the engine is operating.
- Disconnect the battery when using an secondary battery charger.
- Ensure that all cable harnesses are connected solidly and that battery connections are thoroughly clean.
- Never connect or disconnect the wiring harness or injection harness at the ECM when the key switch is in the on position.
- Before attempting any electric arc welding, disconnect the battery leads and the ECM connector.
- When steam cleaning engines, do not direct the steam cleaning nozzle at the ECM system components, as this may result in corrosion or other damage to electrical components.
- Only use the specified test equipment. Unapproved test equipment may give incorrect results or damage ECS components.
- All voltage measurements using a voltmeter require a digital voltmeter with a rating of 10 megaohms input impedance.

Testing Procedure

1. When a test light is specified, a low-power test light must be used. Do not use a high-wattage test light. While a particular brand of test light is not suggested, a simple test, as shown below, on any test light will ensure it to be safe for system circuit testing:
   a. Connect an accurate ammeter (such as the high-impedance digital multimeter) in series with the test light being tested, and power the test light/ammeter circuit with the battery.
   b. If the ammeter indicates less than 3/10 amp current flow (.3 A or 300 mA), the test light is safe to use.
   c. If the ammeter indicates more than 3/10 amp current flow (.3 A or 300 mA), the test light is not safe to use.

NOTE: Using a test light with 100 mA or less rating may show a faint glow when test actually states no light.

2. When using a DVOM to perform voltage measurements, turn the key switch to the off position when connecting the DVOM to the circuitry to be tested.

General Information

Basic Knowledge and Tools Required

To use the information in this manual most effectively you should be familiar with wiring diagrams; the meaning of volts, ohms and amperes; and the basic theories of electricity and electrical diagnostics. System diagnosis requires specialized equipment. Become acquainted with the tools and their use before attempting to diagnose the system. Any special tools required for ECS service are listed in this manual.

Visual and Physical Inspection

IMPORTANT: A careful visual and physical inspection must be performed as part of any diagnostic procedure and may reveal a solution that eliminates the need for further diagnosis.

Inspect all wiring for proper connections, signs of burning, chafing, and pinched or cut wires.

Electrostatic Discharge Damage

Control system electronics operate at a low voltage and are susceptible to damage caused by electrostatic discharge. Less than 100 volts of static electricity can cause damage to electronic components. By comparison, it takes as much as 4,000 volts for a person to feel a static discharge.

A person can become statically charged in several ways, the most common methods are by friction and by induction. An example of charging by friction is a person sliding across a seat which can build up a charge of as much as 25,000 volts. Charging by induction occurs when a person with well-insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off, leaving the person highly charged with the opposite polarity. Static charges of either type can cause damage. Use caution when handling and testing electronic components.

Diagnostic Information

The diagnostic information and functional checks in **Section 5F** of this manual are designed to locate a faulty circuit or component through the process of elimination. The information assumes that the system functioned correctly at the time of assembly and that there are not multiple failures.

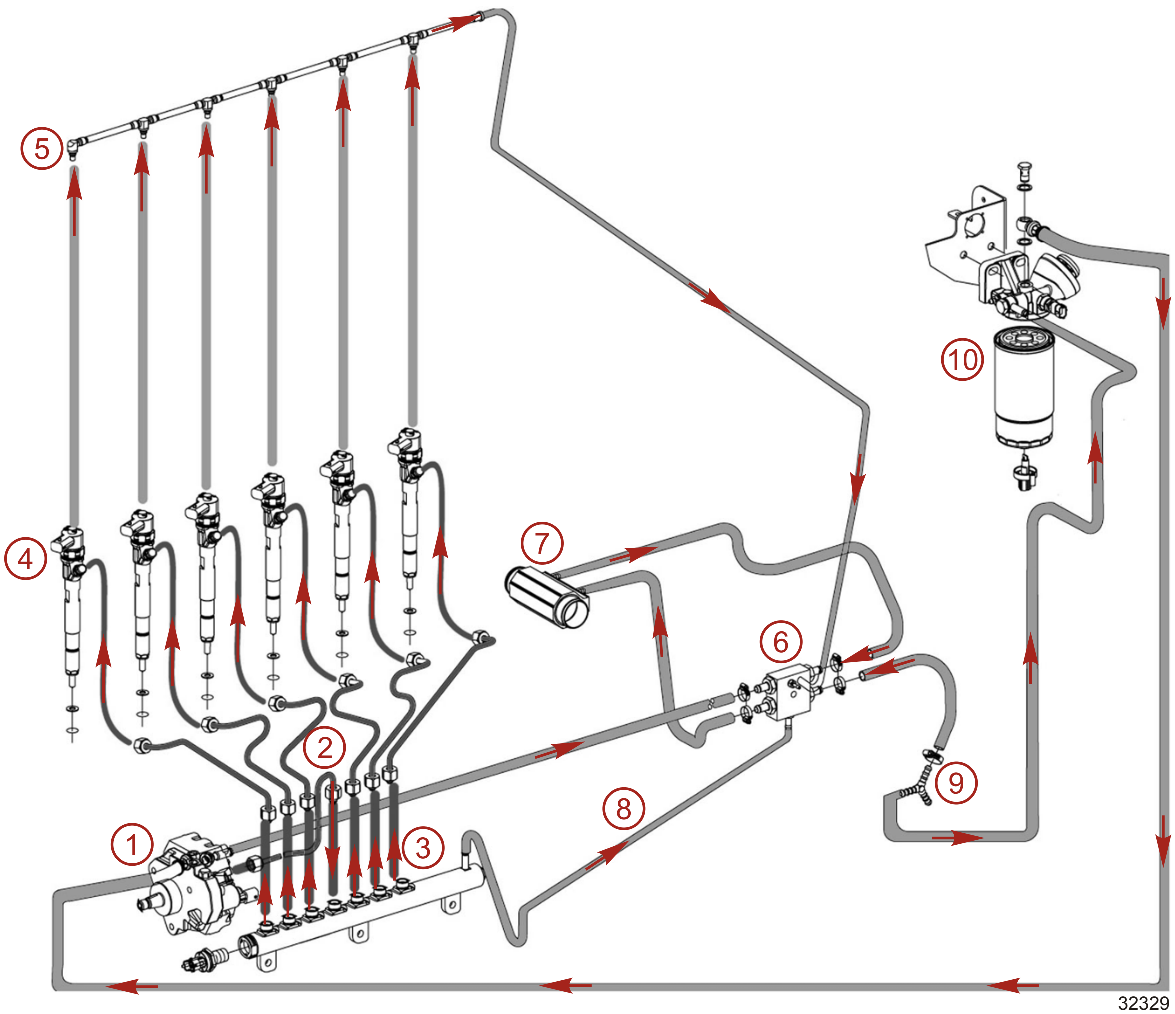
Terminology

Abbreviations

BARO	Barometric Pressure
BAT	Battery Positive Terminal, Battery or System Voltage
B+	Battery Positive
CKT	Circuit
CONN	Connector
CYL	Cylinder
DEG	Degrees
DIAG	Diagnostic
DLC	Data Link Connector
DTC	Diagnostic Trouble Code
DVOM	Digital Volt Ohmmeter
ECM	Engine Control Module
ECT	Engine Coolant Temperature
EEPROM	Electronic Erasable Programmable Read Only Memory
EMI	Electromagnetic Interference
ENG	Engine
GND	Ground
GPH	Gallons Per Hour
IAT	Intake Air Temperature
in.hg	Inches Of Mercury
INJ	Injection
IGN	Ignition
kPa	Kilopascal
KV	Kilovolts
LDF	MAP or Boost Pressure Sensor
LGS	Low Idle Switch
MAP	Manifold Absolute Pressure
MIL	Malfunction Indicator Lamp
msec	Millisecond
mV	Millivolt
N/C	Normally Closed
N/O	Normally Open
PID	Packet of Informational Data
PROM	Programmable Read Only Memory
RAM	Random Access Memory
REF HI	Reference High
REF LO	Reference Low
ROM	Read Only Memory
SRC	Signal Range Check
SW	Switch
TACH	Tachometer
TERM	Terminal

TP	Throttle Position Sensor
V	Volts
VAC	Vacuum
WOT	Wide Open Throttle

Fuel Flow Diagram



1 - High pressure fuel pump
2 - High pressure fuel supply
3 - Common fuel rail
4 - Fuel Injectors
5 - Fuel return lines
6 - Fuel block
7 - Fuel cooler
8 - Fuel rail fuel return
9 - Fuel supply T-fitting
10 - Fuel filter

Electronic Control Module (ECM) and Sensors

General Description

The Cummins MerCruiser Diesel Electronic Control System is equipped with a computer that provides the operator with state-of-the-art control of fuel delivery. Computers use voltage to send and receive information.

Computers and Voltage Signals

Voltage is electrical pressure. Voltage does not flow in circuits. Instead, voltage causes current. Current does the real work in electrical circuits. It is current—the flow of electrically charged particles—that energizes solenoids, closes relays, and lights lamps.

Besides causing currents in circuits, voltage can be used as a signal. Voltage signals can send information by changing levels, changing waveform (shape), or changing the speed at which the signal switches from one level to another. Computers use voltage signals to communicate with one another. The different sections inside computers also use voltage signals to communicate with each other.

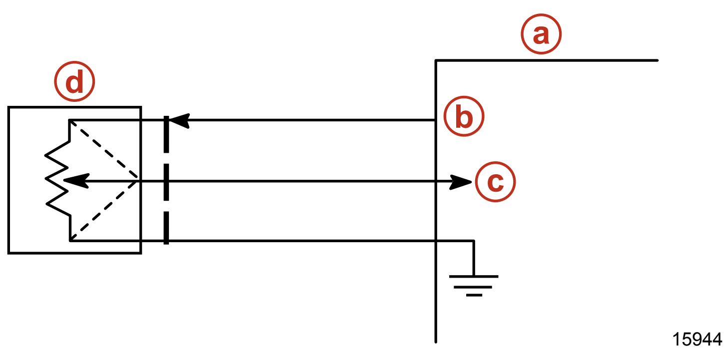
There are two kinds of voltage signals, analog and digital. Both of these are used in computer systems. It's important to understand the difference between them and the different ways they are used.

Analog Signals

An analog signal is continuously variable. This means that the signal can be any voltage within a certain range. An analog signal usually gives information about a condition that changes continuously over a certain range. For example, in a marine engine, information about temperature is usually provided by an analog signal. There are two general types of sensors that produce analog signals: the 3-wire and the 2-wire sensor.

SENSORS WITH MORE THAN TWO-WIRES (MAP / IAT AND TP)

As an example, the following figure shows a schematic representation of a 3-wire sensor. All 3-wire sensors have a reference voltage, a ground, and a variable wiper. The lead coming off of the wiper will be the signal to the ECM. As this wiper position changes, the signal voltage returned to the computer also changes.

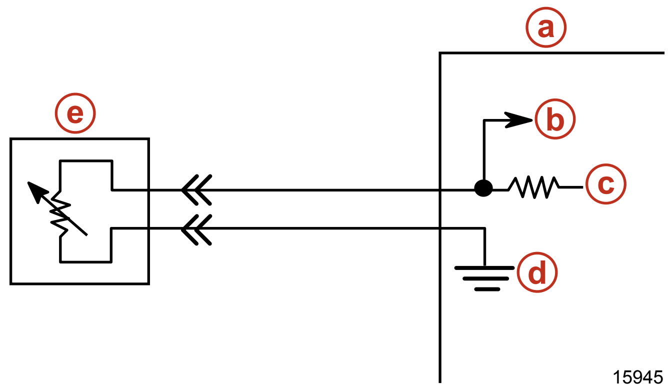


3-Wire sensor

a - ECM	**c -** Signal input
b - Voltage out	**d -** Typical sensor

TWO-WIRE SENSORS (ECT)

The following figure is the schematic of a 2-wire type sensor. This sensor is basically a variable resistor in series with a fixed-known resistor within the computer. By knowing the values of the input voltage and the voltage drop across the known resistor, the value of the variable resistor can be determined. The variable resistors that are commonly used are called thermistors. A thermistor's resistance varies inversely with temperature.



2-Wire sensor

a - ECM
b - Sensor signal
c - 5 Volt
d - Sensor ground
e - Typical sensor

Analog Value Conditioning

The analog value conditioning is subdivided into two parts: sampling the analog signals and scaling and checking the raw values.

The following analog values are made available as messages by the analog value conditioning circuits of the ECM:

- Water temperature
- Air temperature
- Fuel temperature
- Intake manifold pressure (boost pressure)
- Atmospheric pressure
- Throttle position (TP)
- Instrumented Injector Needle movement
- TP current
- Reference voltage
- Battery voltage

Analog value sampling

Sampling saves the results of the periodic analog and digital conversion as raw values. The stored values are evaluated at a later time.

In addition to periodic signal sampling there is also an active speed-synchronous sampling. Upon starts, the speed-synchronous sampling conversion that may be running is stopped. In the next signal sampling period, the discontinued conversion is again started.

Analog Value Evaluation

To process the raw values there are three different loop frames: speed-synchronous (speed interrupt-synchronous up to a maximum of 6 ms), fast time-synchronous (20 ms) and slow time-synchronous (100 ms).

To evaluate the analog signals, the raw values are checked and converted. Checking consists of a signal range check (SRC). If the raw values exceed the valid signal range they are replaced by a stored default value. As an example, an engine coolant temperature (ECT) sensor malfunction would set an internal switch, causing a default value to replace the signal from the defective ECT sensor.

The data set parameter is selected so that the default value is accepted over a ramp (time) function or directly. If the raw value is again in a valid range after a SRC error, the new value is brought to the current value.

The raw data values are scaled along a predetermined curve. There are additional special routines for evaluating the TP sensor and MAP sensor which are scaled through their supply voltage.

In case of TP sensor failure, such as a SRC defect on supply voltage, the ECM substitutes a default fuel quantity value and limits engine speed to 800 RPM.

The ECM is also programmed to respond to variations from other components. For example, if certain preset SRC value thresholds are exceeded the ECM will store the errors and may execute internal diagnostic routines to evaluate the data error.

NOTE: *The ECM will attempt to identify the source of a faulty component or input by comparing current input data to stored historical and default data.*

Digital Signals

GENERAL

The ECM uses digital signals in a code that contains only ones and zeros. The high voltage of the digital signal represents a one (1), and no voltage represents a zero (0). Each zero and each one is called a bit of information, or just a bit. Eight bits together are called a word. A word, therefore, contains some combination of eight binary code bits: eight ones, eight zeros, five ones and three zeros, and so on.

Computers use binary code for internal processing and external communication. By stringing together thousands of bits, computers can communicate and store a variety of information quickly and accurately. To a computer that understands binary, 11001011 might mean that it should reset engine RPM at a lower level.

PROCESSING THE DIGITAL INPUTS

The digital inputs are centrally read, processed, and distributed throughout the system. The first input message indicates the raw electrical conditions and includes an internal message indicating the logical, validity-checked conditions of the inputs.

Digital input signals that are processed:

1. Low-idle switch
2. Terminal 15 (battery voltage, key ON)
3. Terminal 15, not validity-checked
4. Logical conditions, validity-checked
5. Electrical conditions, not validity-checked

Inputs that are not used are masked out. Each input signal is checked for validity. Every input is assigned a logic level and compared to four data set parameters:

1. Maximum
2. Off-Limit
3. On-Limit
4. Minimum

IMPORTANT: Terminal 15 (battery voltage, key ON) input is not validity checked and status is also made available.

SWITCH TYPES

Switched (discreet) inputs to the ECM are either pull-up or pull-down data types.

Pull-up type switches provide a voltage signal to the ECM when the switch is closed. Pull-down type switches trigger an ECM response when the ECM recognizes that the switch is open.

Switched input is also used to provide frequency information to the ECM.

PULSE COUNTERS

The ECM uses the time between switched input voltage pulses to determine pulse counter frequency information.

The Crankshaft Speed Sensor provides a pulse input. The ECM compares Crankshaft Speed Sensor pulse frequency to stored pulse per engine revolution data and calculates engine RPM.

Engine Control Module (ECM)

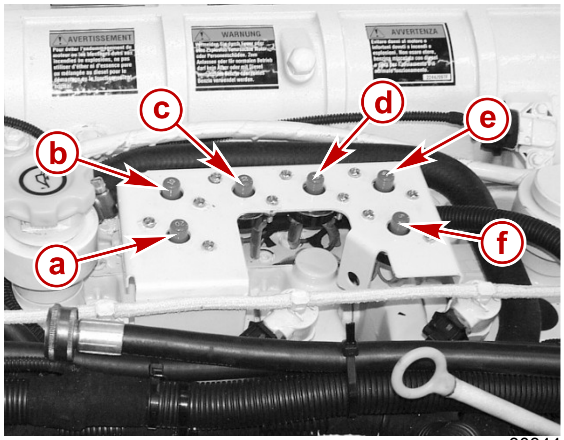
The ECM controls the fuel injection system by monitoring the various sensors and controls systems that affect engine performance.

The ECM also performs a diagnostic function. It can recognize operational problems and store a code or codes, which identify the problem areas and aid the technician in making repairs.

30343

ECM

An ignition key switch controlled 10-ampere circuit breaker located on the circuit breaker panel on top of the engine supplies the ECM with switched power. The engine may crank but will not start If any of the ECM circuit breakers are open. If the ECM does not receive a 12-volt power signal no ECM dependant vessel systems will function properly. SmartCraft instrumentation will display a no communication error message.



30344

Reference	Circuit breaker rating	Protection	Location on fuse panel
a	20-amp	Key unswitched power to helm	Lower left
b	10-amp	Switched power to ECM	Upper left
c	10-amp	Key switch to ECM	Middle left
d	15-amp	Switched power to ECM	Middle right
e	15-amp	ECM switched power to SIM	Upper right
f	5-amp	Power-diagnostic connector	Lower right

The ECM provides 4.9 volts or 12 volts supply voltage to power various sensors and switches. These ECM circuits will not power a standard test light due to the internal ECM circuits' high resistance. Accurate voltage readings require the use of a 10 megaohm input impedance digital voltmeter.

There are three types of memory storage within the ECM.

- Read-only memory (ROM) is a permanent memory that is soldered to the circuit boards of the ECM. The ROM stores the ECM control programs. ROM memory can not be reprogrammed and does not need power to be retained.
- Random-access memory (RAM) is the microprocessor scratch pad. The processor can write into or read from this memory as needed. This memory is erasable and needs a constant supply of voltage to be retained.
- Electronic erasable programmable read-only memory (EEPROM) is the ECM component that contains engine calibration information specific to the engine application.

Speed Density System

The electronic engine control system fuel management function is a speed and air density system. Three sensors establish the engine speed and air density factors used by the ECM's fuel management routines: the Crankshaft Speed sensor, Intake Air Temperature sensor, and the Manifold Absolute Pressure sensor.

SPEED

The Crankshaft Speed sensor signal comes from a three-wire magnetic pickup mounted on the starboard side of the engine block. The ECM uses this information to determine the RPM factor for fuel quantity and injection timing management.

DENSITY

The Intake Air Temperature (IAT) and the Manifold Absolute Pressure (MAP) sensors are combined in one sensor assembly. The data they provide to the ECM determines the air density factor.

The IAT sensor is a temperature dependant variable resistance thermistor. When intake air temperature is low, circuit resistance is high, when the intake temperature is high circuit resistance is low.

The Manifold Absolute Pressure (MAP) sensor monitors changes in intake manifold pressure due to changes in engine load and atmospheric conditions.

The MAP sensor sends this pressure information to the ECM, and the ECM calculates the fuel delivery schedule to achieve a target engine RPM based upon Throttle Position Sensor input. Fuel delivery is modified by changes in the timing and duration of the fuel injection pulse. A decrease in manifold pressure (or vacuum increase) causes a decrease in the amount of fuel delivered to the engine.

ECM Input and Sensor Descriptions

The ECM converts the input signals from various sensors, switches, and other devices to create digital output instructions that control the fuel system. The following is an overview of that input and output process followed by a brief description of the components.

The ECM microprocessors receive input signals from the sensors listed:

- Crankshaft speed sensor
- Camshaft position sensor
- IAT/MAP sensor
- Rail fuel pressure sensor
- ECT (engine coolant temperature) sensor
- Engine oil temperature and pressure sensor
- Engine fuel temperature sensor
- TP sensor (a setpoint generator)

The ECM microprocessors compares the input signals to stored reference maps and process the output signals shown:

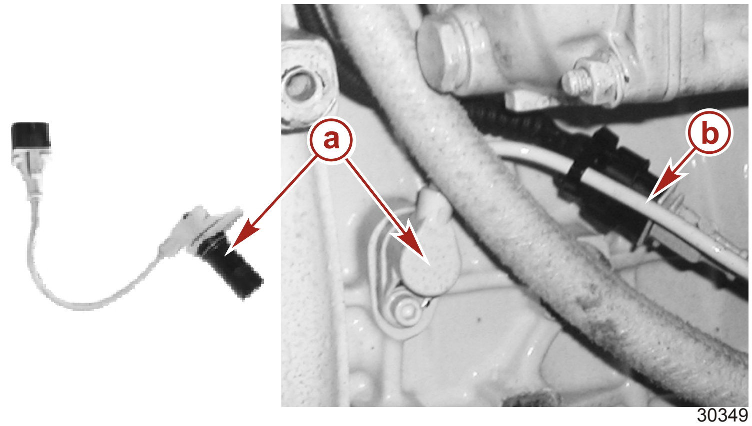
- Starting control
- Start of injection
- Injected fuel quantity
- Engine shut off

The actuators controlled by the ECM output signals include:

- Electronically controlled pressure-control valve (mounted on the high-pressure pump)
- Fuel injectors

Crankshaft Sensor

The crankshaft speed sensor is an induction-type pulse generator that scans for notches on the leading edge of the flywheel to sense the engine speed. The resulting change in magnetic flux induces an AC voltage signal which the ECM evaluates. The ECM processes the signal to establish TDC and the crankshaft position relative to TDC.

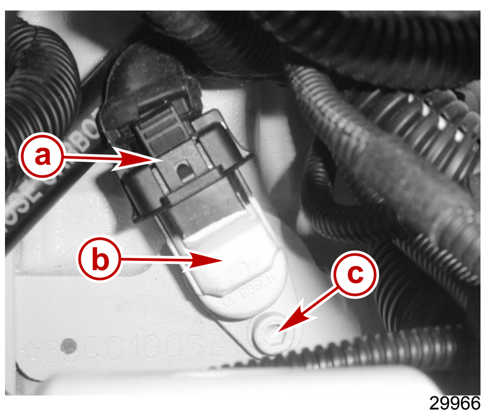


a - Crankshaft speed sensor
b - Harness connector

A failure in the crankshaft speed sensor circuit will set DTC P0335.

Camshaft Position Sensor

The camshaft position sensor uses a Hall effect generated signal to inform the ECM of camshaft position. A magnetic pickup attached to the rotating camshaft passes the camshaft position sensor creating a voltage signal. The ECM processes this short-duration voltage signal to establish when cylinder one is on its compression stroke. This voltage signal indicating the compression stroke on cylinder one is required during the starting sequence and cannot be gathered from the crankshaft-speed sensor.



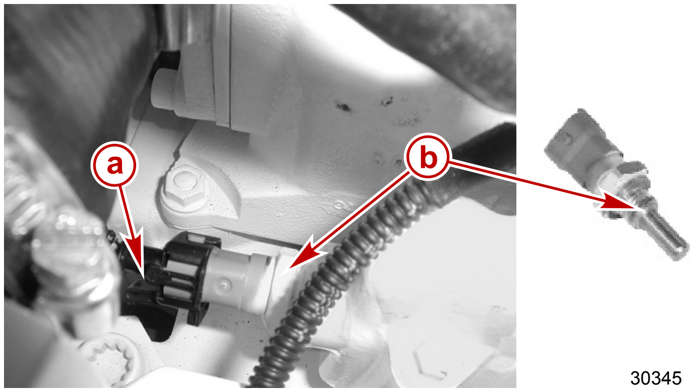
a - Harness connector
b - Camshaft position sensor
c - Screw

A crankshaft-speed signal will allow a running engine will continue to operate after camshaft position sensor failure. The engine will not start without camshaft position sensor information.

A failure in the camshaft position sensor or circuit will set DTCs P0016, P0340, or P0641. Refer to the appropriate DTC diagnostic chart for troubleshooting procedures.

Engine Coolant Temperature (ECT) Sensor

The engine coolant temperature (ECT) sensor is a thermistor immersed in the engine coolant stream. A thermistor is a resistor which changes value based on temperature. Low coolant temperature produces a high resistance, while high temperature causes a low resistance.



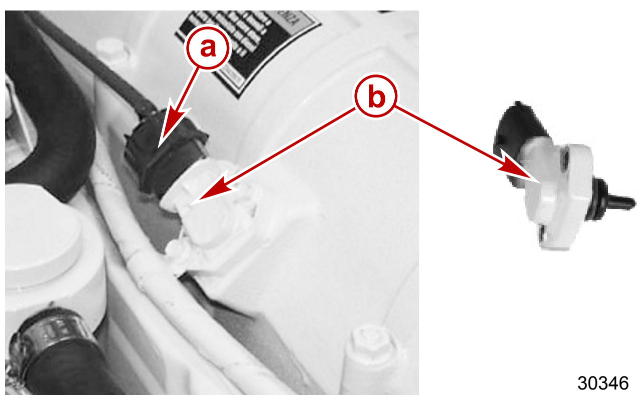
a - Harness connector **b -** ECT sensor

The ECM supplies a fixed current to the ECT through a resistor in the ECM and measures the voltage. The voltage is high when the engine is cold, and low when the engine is hot. By measuring the voltage, the ECM knows the engine coolant temperature. Engine coolant temperature affects most systems the ECM controls.

A failure in the ECT circuit will set DTC P0115. Refer to the appropriate DTC diagnostic chart for troubleshooting procedures. ECT failure generally indicates a sensor failure or wiring short.

Manifold Absolute Pressure Sensor And Intake Air Temperature Assembly

The Manifold Absolute Pressure (MAP) and Intake Air Temperature (IAT) sensor form an assembly.



a - Harness connector **b -** MAP and IAT sensor

INTAKE AIR TEMPERATURE (IAT) SENSOR

The IAT sensor portion of the assembly is a thermistor (a resistor which changes value based on temperature). Low temperature produces a high resistance, while high temperature causes a low resistance.

The ECM supplies a fixed current to the IAT sensor through a resistor in the ECM and measures the voltage. The ECM voltage will be high when the intake manifold air is cold, and low when the intake manifold air is hot.

A failure in the IAT sensor circuit will set DTC P0110. Refer to the appropriate DTC diagnostic chart for troubleshooting procedures.

Manifold Absolute Pressure (MAP) Sensor

The manifold absolute pressure (MAP) sensor is a pressure transducer that measures the changes in the intake manifold pressure. The pressure changes as a result of engine load and speed change, and the MAP sensor converts this to a voltage output.

The ECM sends a 5-volt reference signal to the MAP sensor. As the manifold pressure changes, the electrical resistance of the MAP sensor also changes. By monitoring the sensor output voltage, the ECM knows the manifold pressure. A higher pressure, low vacuum (high voltage) requires more fuel, while a lower pressure, higher vacuum (low voltage) requires less fuel. The ECM uses the MAP sensor to control fuel delivery and injection timing.

A closed throttle position on engine coast-down would produce a relatively low MAP output voltage, while a wide open throttle would produce a high MAP output voltage. This higher output voltage is produced because the pressure inside the manifold is increasing. When manifold pressure is high, vacuum is low.

A failure in the MAP sensor circuit will set DTC P0235. Refer to the appropriate DTC diagnostic chart for troubleshooting procedures.

Engine Fuel Temperature (EFT) Sensor

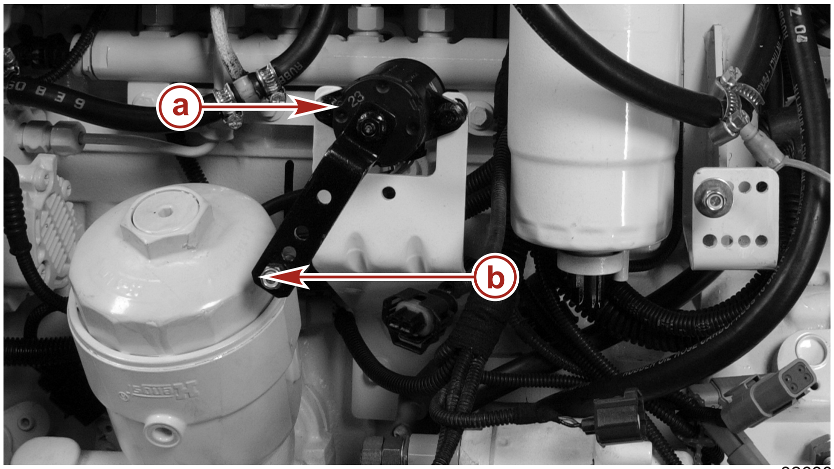
The fuel temperature sensor is a thermistor (a resistor which changes value based on temperature) immersed in the fuel inside the upper chamber of the fuel pump. It is not a serviceable item. Low fuel temperature produces a high resistance, while high fuel temperature causes low resistance.

The ECM supplies a fixed current to the pump through a resistor in the ECM and measures the voltage. The voltage is high when the fuel is cold and low when the fuel is hot. The return voltage is used by the ECM to determine fuel temperature.

A failure in the fuel temperature circuit will set DTC P0180. Refer to the appropriate DTC diagnostic chart for troubleshooting procedures. It is not suggested that the high pressure fuel pump be replaced for this failure unless the customer complains of related performance problems.

Throttle Position (TP) Sensor

The throttle position (TP) sensor is a potentiometer connected to the throttle cable. The TP sensor receives a 5-volt reference signal from the ECM and returns an output voltage based upon throttle position. The three-wire TP sensor connector also includes an ECM ground circuit. At a closed throttle position, the voltage output of the TP is low (approximately 0.4 volt). As the throttle position changes the output increases. At wide open throttle (WOT) the output voltage should be near 4.5 volts. By monitoring the output voltage from the TP sensor, the ECM can determine fuel delivery based on the throttle position (operator demand).



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a - Throttle position sensor
b - Throttle cable bell crank

Potential TP sensor failures:

- TP sensor out of range (SRC high or low).
- Low idle switch defective.
- TP sensor supply voltage incorrect.
- Plausibility (possibility of error) between TP sensor and low idle switch signal to the ECM.

Any TP sensor error or failure will set DTC P1515. Once this DTC is set the ECM will limit engine speed to 800 RPM. Refer to the appropriate DTC diagnostic chart for troubleshooting procedures.

Fuel Management

Modes of Operation

ENGINE STARTING

During engine startup the ECM determines fuel delivery needs based upon the camshaft position signal, crankshaft speed, and engine coolant temperature input information. Throttle position has no influence on the starting procedure. Camshaft position sensor failure will cause a crank-no-start condition.

ENGINE OPERATION

During engine operation the ECM uses data signals from the throttle position and crankshaft speed sensors to determine correct fuel delivery through the electronic fuel injectors. The ECM uses a rail fuel pressure sensor to control the fuel supply from the high-pressure fuel pump. Fuel delivery is also adjusted according to the following information:

- **Fuel temperature**: The ECM uses this information to calculate the correct air-to-fuel ratio. Fuel temperature and volume data is used to determine the density of the injected fuel.
- **Air intake temperature and absolute barometric pressure**: These inputs are used by the ECM to optimize the ideal air-to-fuel ratio for the prevailing engine operating conditions.

The maximum flow rate of the fuel entering the engine is also limited by the ECM according engine speed.

ENGINE SPEED CHANGES

The ECM adjusts the engine operating strategy during acceleration and deceleration in order to provide smooth operation while reducing engine noise and exhaust emissions.

ENGINE SHUT OFF

The principle of auto-ignition as applied to the diesel engine means that the engine can only be switched off by interrupting the supply of fuel.

The engine is switched OFF by the ECM stopping the signal to the fuel injectors resulting in no fuel being supplied to the engine.

Fuel Supply Components

HIGH PRESSURE FUEL PUMP

NOTE: *The high-pressure fuel pump, pressure-control valve, RFP sensor, and injectors are not serviceable. If any need service, consult a Cummins MerCruiser Diesel Authorized Repair Facility or the nearest Bosch Dealer Service Network office.*

The high pressure fuel pump consists of a gear-driven eccentric cam mechanism that drives three separate pistons in calibrated volume cylinders. The fuel is compressed until the pressure reaches or exceeds the fuel pressure in the fuel rail. An outlet valve in each chamber then opens releasing pressurized fuel into the fuel rail which functions as a high pressure fuel accumulator. The high pressure fuel pump supplies fuel in a volume proportional to engine speed.

Excess fuel is returned to the low-pressure side of the fuel supply system by the RFP sensor mounted on the fuel rail.

The high pressure fuel pump is highly efficient and results in less parasitic power loss than a conventional diesel injection pump.

FUEL RAIL (ACCUMULATOR)

The common fuel rail, shared by all injectors, functions as an accumulator to dampen the effects of the high-pressure pump output and minimize fuel pressure fluctuation when the injectors open. The volume of the rail and the RFP sensor ensure that fuel rail pressure remains nearly constant at all times ensuring proper delivery under all engine operating conditions.

RAIL FUEL PRESSURE (RFP) SENSOR

A rail fuel pressure (RFP) sensor measures fuel rail pressure. The ECM processes the RFP signal and as necessary sends a signal to the electronically controlled Pressure-control Valve in the fuel rail to hold or release fuel pressure until the pressure in the fuel rail is correct.

ELECTRONICALLY CONTROLLED PRESSURE-CONTROL VALVE

An electronically controlled pressure-control valve is used to return excess fuel volume and relieve excess fuel pressure in the fuel rail during idle and in less than full-load operating conditions. The pressure control valve can operate as either a straight mechanical device or as an ECM controlled (energized) valve. The ball and seat design employs a spring that maintains fuel pressure in the rail at approximately 100 bar 1450 PSIand an electromagnet that can be energized by the ECM to hold the valve open or closed until the correct fuel pressure is reached.

SENSORS

See **ECM Input and Sensor Descriptions** for a complete listing and brief description of the other sensors involved in fuel management.

Diagnosis and Testing

IMPORTANT: For component specific diagnostic and testing information see SECTION 5F.

ECM Self-Diagnostics

The ECM performs a continual self-diagnosis on certain control functions. This diagnostic capability is complemented by the diagnostic procedures contained in this manual. The ECM's language for communicating the source of a malfunction is a system of diagnostic codes. The codes are four digit numbers preceded by the letter P. The prefix letter "P" is an abbreviation for Power train, an internationally standardized reference. When a malfunction is detected by the ECM, a code is stored in ECM memory.

ECM Reactions During Operation

The ECM performs diagnostic checks of the electronic diesel fuel injection system. When a problem is detected a Diagnostic Trouble Code (DTC), or fault code, will be stored in the ECM's memory. Specific DTC numbers are generated according to the component that is reporting data that falls outside the range of values expected by the ECM.

DTCs can be displayed by the appropriate SmartCraft instrumentation and retrieved and displayed with the Computer Diagnostic System (CDS) tool. The CDS tool is available through Cummins MerCruiser Diesel.

Notes:

Fuel System

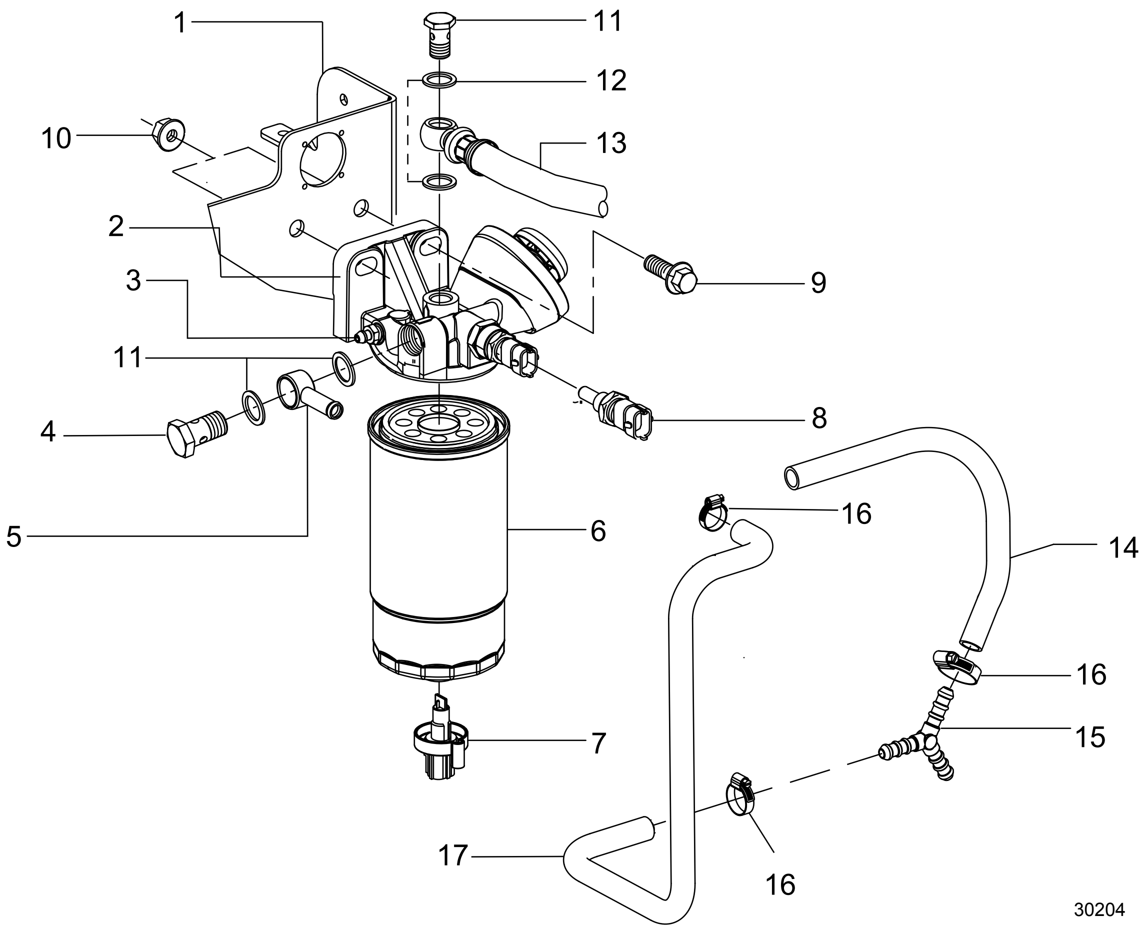
Section 5B - Fuel Filter Assembly

Table of Contents

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Water-separating fuel filter sealing ring	Obtain Locally

Exploded View, Fuel Filter Assembly



Ref. No.	Qty.	Description	Torque		
			Nm	lb–in.	lb–ft
1	1	Fuel filter bracket	–	–	–
2	1	Fuel filter base and primer assembly	–	–	–
3	1	Bleed screw	–	–	–
4	1	Fuel inlet hollow bolt	17	148	–
5	1	Fuel inlet fitting	–	–	–
6	1	Water-separating fuel filter	–	–	–
7	1	Water in fuel (WIF) sensor	2.5	–	22
8	1	Engine fuel temperature (EFT) sensor	18	–	159
9	2	Fuel filter assembly mounting screw	34	–	25
10	2	Fuel filter assembly mounting nut	34	–	25
11	1	Hollow bolt	17	148	–
12	2	Sealing washer	–	–	–
13	1	Fuel line	–	–	–
14	1	Fuel manifold return line	–	–	–
15	1	Y-fitting fuel inlet	–	–	–
16	3	Clamp	4.6	41	–
17	1	Fuel line	–	–	–

Water-Separating Fuel Filter

⚠ WARNING

Fuel is flammable and explosive. Ensure the key switch is off and the lanyard is positioned so that the engine cannot start. Do not smoke or allow sources of spark or open flame in the area while servicing. Keep the work area well ventilated and avoid prolonged exposure to vapors. Always check for leaks before attempting to start the engine and wipe up any spilled fuel immediately.

NOTICE

Water entering the fuel injection system will cause corrosion and rusting of the injectors and other components, disabling the fuel injection system. Check daily for water in the water-separating fuel filter and have the engine inspected immediately if there is evidence of water in the fuel system.

IMPORTANT: Use a suitable container to collect fuel. Clean up any spills immediately and dispose of fuel in a safe manner in accordance with all local, federal, and international regulations.

The engine-mounted water-separating fuel filter is equipped with a water-in-fuel (WIF) sensor that should alert the operator when water is present in the filter. This fuel filter needs to be replaced at specified intervals or whenever water is detected in the fuel, whichever comes first.

The WIF sensor detects water in the fuel, and displays an alert depending upon the boat instrumentation package and if equipped:

- SmartTach
- VesselView

Refer **Instrumentation**.

Drain or replace the remote mounted primary filter at specified intervals, or whenever water is detected in the engine-mounted fuel filter.

Draining

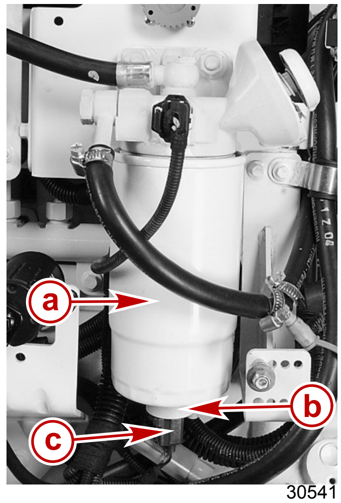
The engine-mounted water-separating fuel filter can be drained of water and small dirt particles by opening the drain cap on the bottom of the filter.

NOTE: *To ensure complete drainage in warm weather, drain the filter before starting daily operations. In cold weather, where there is a possibility that the condensed water will freeze, drain the filter shortly after the end of daily operations.*

NOTE: *Place a suitable container under the fuel filter to catch contaminated fuel or water and dispose of it properly.*

1. Place a container under the drain cap on the filter.

2. Open the drain by turning the drain cap counterclockwise (as viewed from the bottom of the filter) until fuel starts to drain. Do not remove the drain cap.



a - Filter
b - Drain cap
c - WIF sensor wire connection

3. Drain until the fuel is clear in appearance.
4. Close the drain cap by turning it clockwise. Tighten it securely.
5. Fill the fuel filter. See **Filling**.

Replacing

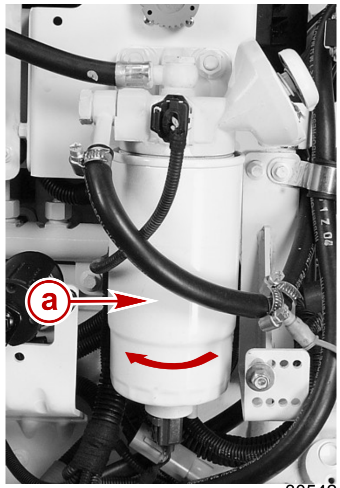
⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

IMPORTANT: The element cannot be cleaned and reused. It must be replaced.

1. Disconnect both battery cables from the battery.
2. Disconnect the Water in Fuel (WIF) sensor wires, if equipped.

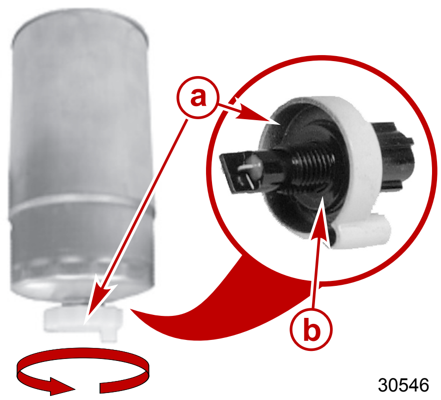
3. Remove the water-separating fuel filter and sealing ring from the mounting bracket. Do not use a filter wrench.



a - Water-separating fuel filter

NOTE: *Retain and reuse the existing WIF sensor (filter drain). Replace the O-ring on the WIF sensor (filter drain).*

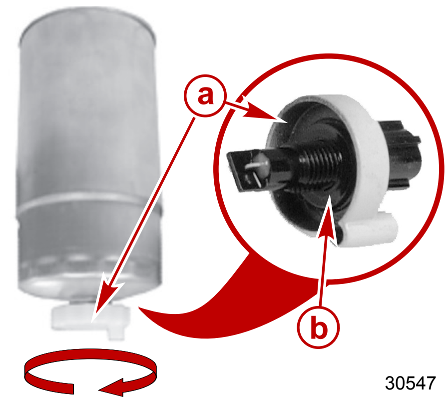
4. Remove the WIF sensor and O-ring seal from the bottom of the existing fuel filter. Note the position of the O-ring seal.



a - WIF sensor
b - O-ring seal

5. Discard the used filter and O-ring seal as defined by local authorities.

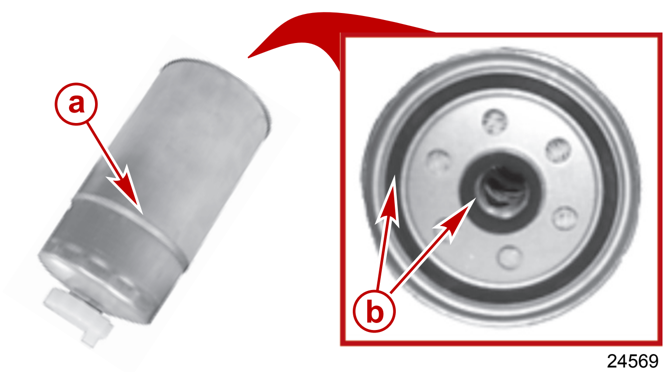
6. Install the WIF sensor with a new O-ring on the new water-separating fuel filter.



a - WIF sensor
b - O-ring seal

Description	Nm	lb–in.	lb–ft
Water in fuel sensor (filter drain)	2.5	–	22

7. Lubricate the fuel filter seals.

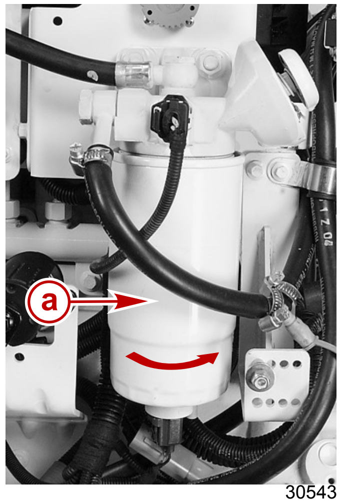


Typical

a - Water-separating fuel filter
b - Seals

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Water-separating fuel filter sealing ring	Obtain Locally

8. Align the filter to the bracket. Tighten the filter by hand in the direction shown to secure the filter to the bracket. Do not use a filter wrench.



a - Water-separating fuel filter

9. Ensure that the drain cap is securely tightened.
10. Connect the WIF sensor wires.
11. Fill the water-separating fuel filter with fuel. See **Filling**.
12. Check the filter and drain cap for fuel leaks.
13. Connect the battery cables.
14. Start and operate the engine. Check the filter connection for fuel leaks. If leaks exist, recheck filter installation. If leaks continue, stop the engine immediately and contact your Cummins MerCruiser Diesel Authorized Repair Facility.

Filling

A type of hand pump and primer plunger is located on the fuel filter bracket. Use it to:

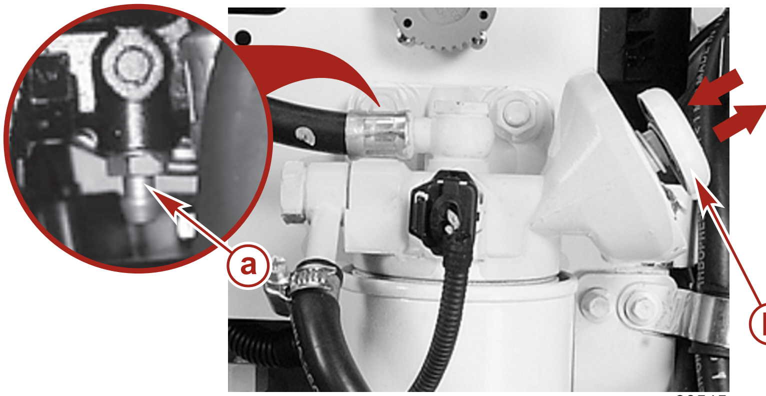
- Refill the fuel filter when draining or changing the filter.
- Refill the fuel system on the engine if the system was run dry.
- Prime the fuel system if the engine has not been run for an extended period.

IMPORTANT: To ensure that unfiltered fuel does not get into the fuel system, use only the hand pump and primer plunger to fill the fuel filter.

NOTE: Follow this procedure after installing a new filter or if the fuel has been drained from the filter while checking for water.

1. Loosen the air vent (bleed) screw on the fuel filter bracket.

2. Move the primer plunger up and down repeatedly. The filter is full when an air-free stream of fuel flows from the air vent screw.



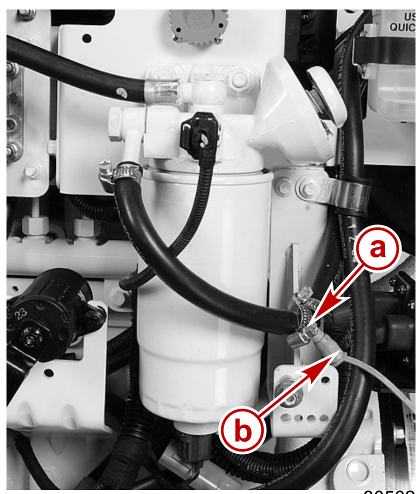
a - Air vent screw
b - Primer plunger

3. Securely tighten the air vent screw.

Fuel Filter Assembly

Removal

1. Disconnect and plug the fuel tank inlet line from the Y-fitting, or close the fuel supply valve, if equipped.



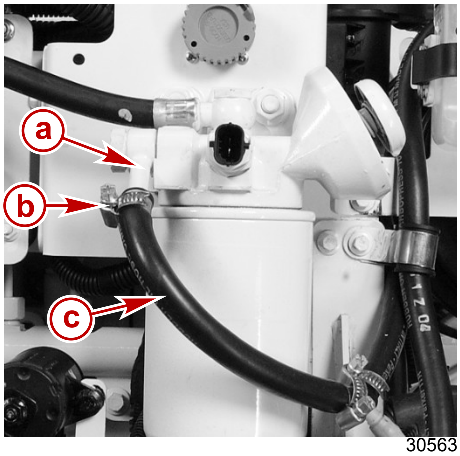
a - Fuel tank inlet line Y-fitting
b - Cap

2. Drain and remove the water-separating fuel filter. Rerer to **Water-Separating Fuel Filter**.

NOTE: If the fuel filter assembly is to be replaced, remove the engine fuel temperature (EFT) sensor. Refer to ***Section 5F–Engine Fuel Temperature (EFT) Sensor****.*

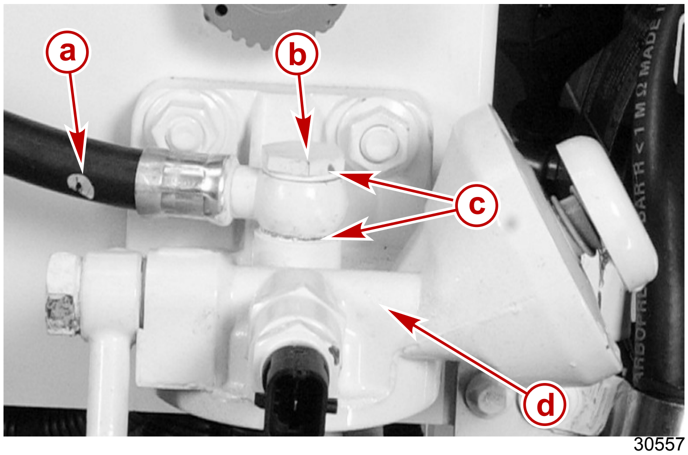
3. Disconnect the engine fuel temperature (EFT) sensor harness connection.

4. Disconnect the fuel inlet line from the fuel inlet adaptor.



a - Fuel inlet adaptor
b - Clamp
c - Fuel inlet line

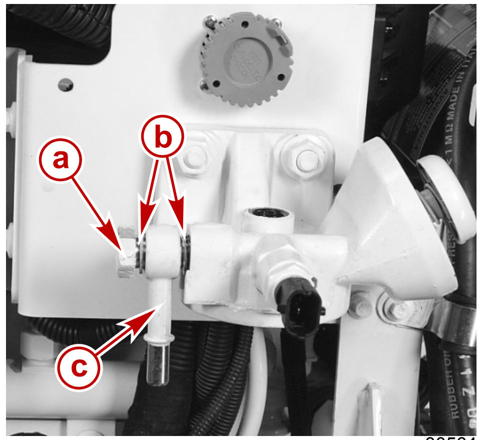
5. Remove the hollow bolt and sealing washers from the fuel pump inlet line. Discard the sealing washers.



a - Fuel pump inlet line
b - Hollow bolt
c - Sealing washers
d - Fuel filter assembly

NOTE: *If the fuel filter assembly is to be replaced, remove the fuel inlet adaptor from the fuel filter assembly.*

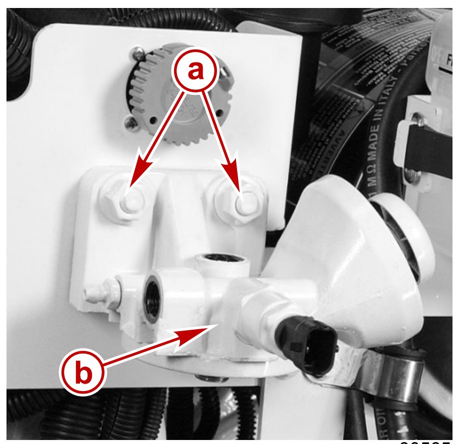
6. If necessary, remove the fuel inlet line adaptor hollow bolt. Discard the sealing washers.



30564

a - Hollow bolt
b - Sealing washers
c - Fuel inlet adaptor

7. Remove the fuel filter base mounting nuts and remove the base from the fuel filter bracket.



30565

a - Fuel filter assembly mounting nut
b - Fuel filter assembly

Cleaning and Inspection

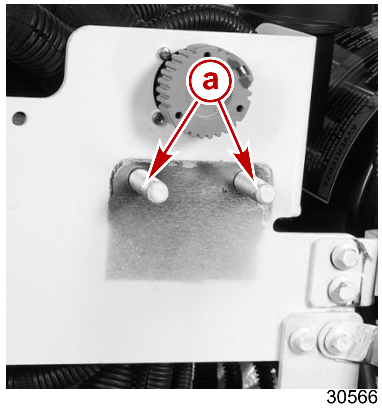
1. Wipe off the filter base assembly with a clean shop towel.

IMPORTANT: Do not allow solvent or any other contaminant to enter the fuel primer.

2. Inspect for and replace any damaged fasteners.

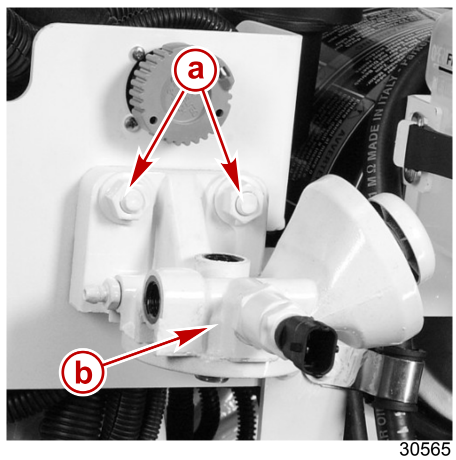
Installation

1. Check that the fuel filter assembly mounting bolts are installed in the bracket.



a - Fuel filter assembly mounting bolts

2. Install the fuel filter base to the bracket using the mounting nuts.

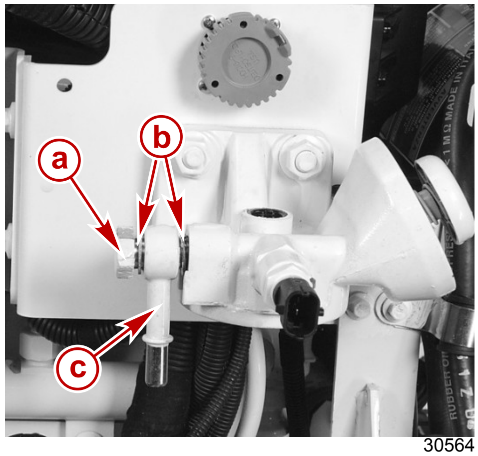


a - Fuel filter assembly mounting nut
b - Fuel filter assembly

3. Counter-hold the fuel filter assembly mounting bolts and tighten the mounting nuts.

Description	Nm	lb–in.	lb–ft
Fuel filter base mounting screw	34	–	25

4. Install new sealing washers on the hollow bolt and install the fuel inlet line adaptor.

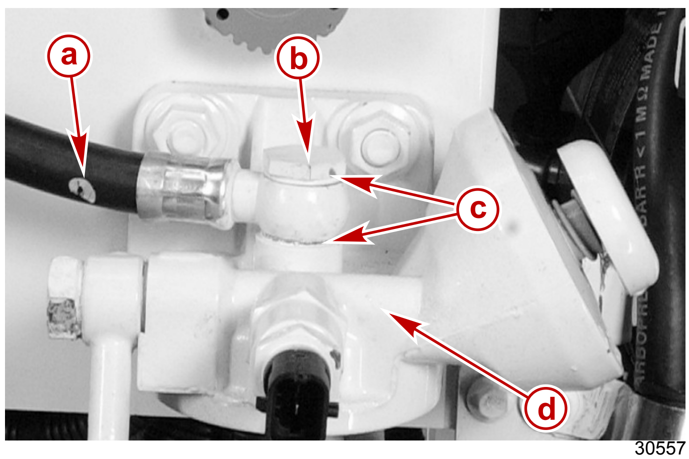


a - Hollow bolt
b - Sealing washers
c - Fuel inlet adaptor

5. Tighten the hollow bolt to specification.

Description	Nm	lb–in.	lb–ft
Fuel inlet line hollow bolt	14	148	–

6. Install new sealing washers on the hollow bolt and install the fuel pump fuel line.

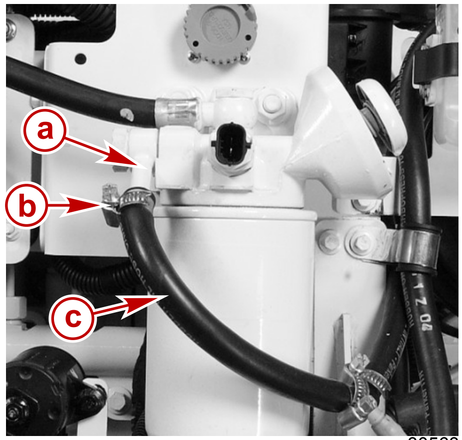


a - Fuel pump inlet line
b - Hollow bolt
c - Sealing washers
d - Fuel filter assembly

7. Tighten the hollow bolt to specification.

Description	Nm	lb–in.	lb–ft
Fuel pump fuel line hollow bolt	17	148	–

8. Install the clamp on the fuel inlet line and connect the line to the fuel inlet adaptor. Tighten the clamp securely.



a - Fuel inlet adaptor
b - Clamp
c - Fuel inlet line

9. Connect the EFT sensor harness connection.
10. Install a new water-separating fuel filter. Refer to **Water-Separating Fuel Filter**.
11. Connect the fuel tank inlet line to the Y-fitting or open the fuel supply valve if equipped.

Purging Air From The Fuel System

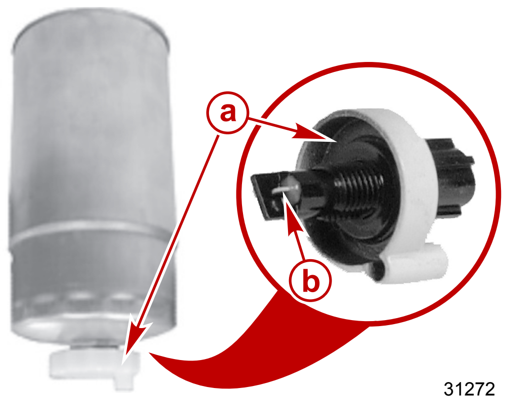
IMPORTANT: The injection pump and fuel injectors have very close tolerances, and require absolute cleanliness during service procedures. Minute particles of dirt or small amounts of water can cause the fuel injection system to malfunction.

The process of draining and replacing the water-separating fuel filter, including purging a new filter of air, is the only process that requires air to be purged from the system. The design of the common rail fuel system prevents any need to purge air from the high pressure fuel pump itself.

Water In Fuel (WIF) Warning System

The audio warning system and system display will warn the operator when the filter is full, indicating the need to drain the water and sediment from the drain cap.

A WIF probe in the fuel filter drain cap activates the warning system when water in the fuel surrounds the probe's electrodes and closes its circuit.



a - Drain cap
b - WIF probe

Notes:

Fuel System

Section 5C - Common Rail and Fuel Lines

Table of Contents

Common Rail Repair and Service

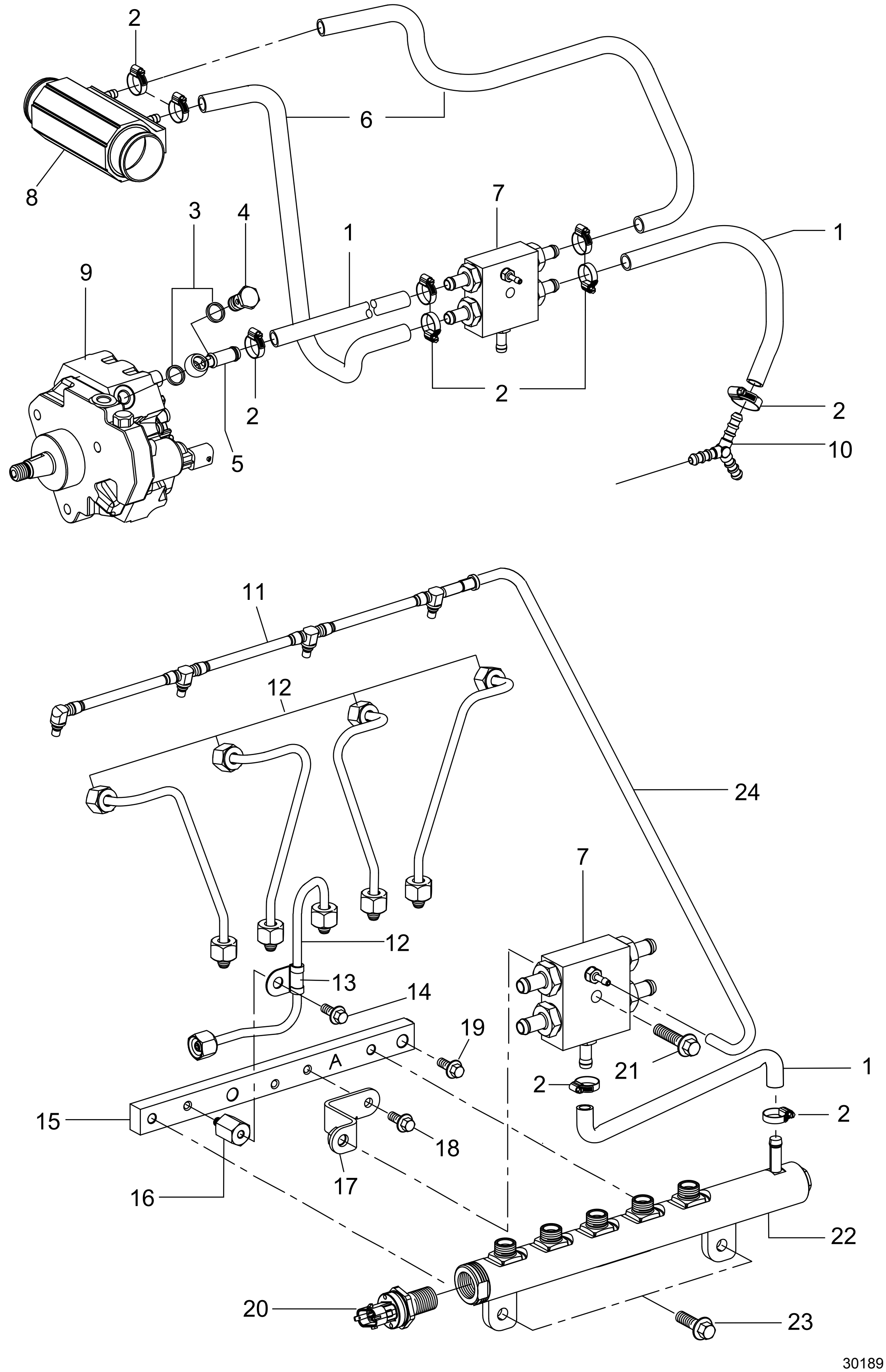
The Robert Bosch Corporation has a worldwide network of authorized Bosch Service Dealers to service their products.

The high pressure fuel pump, common rail, and injectors must be sent to an authorized Bosch Service Center.

When shipping an injection pump to a service center for adjustments or repairs, the fuel return line hollow bolt must accompany the unit. The hollow bolt incorporates a sized orifice for proper pressure that is matched to the pump. The pump cannot be properly adjusted without the matched orifice.

Contact the Bosch distributor nearest you for the location of an authorized Bosch Service Center.

Exploded View—Common Rail, Fuel Manifold, and Fuel Lines



2.8 shown, 4.2 similiar

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	3	Fuel line			
2	9	Clamp	4.6	41	–
3	2	Sealing washer			
4	1	Hollow bolt	27.5	–	20
5	1	Adaptor			
6	2	Fuel cooler fuel lines			
7	1	Fuel manifold			
8	1	Fuel cooler			
9	1	Fuel pump			
10	1	Y-fitting			
11	1	Injector return line			
12	5	High pressure fuel lines	See **High Pressure Fuel Lines** of this section.		
13	1	Clamp			
14	1	Clamp screw	14.7	130	–
15	1	Common rail mounting bracket			
16	1	High pressure fuel line clamp spacer			
17	1	Fuel manifold bracket			
18	1	Fuel manifold bracket mounting screw	24.5	–	18
19	1	Common rail mounting bracket screw	33	–	24
20	1	Rail fuel pressure sensor	35	–	26
21	1	Fuel manifold mounting screw	10.8	96	–
22	1	Common rail			
23	2	Common rail mounting screw	33	–	24
24	1	Fuel line			

High Pressure Fuel Lines

Removal

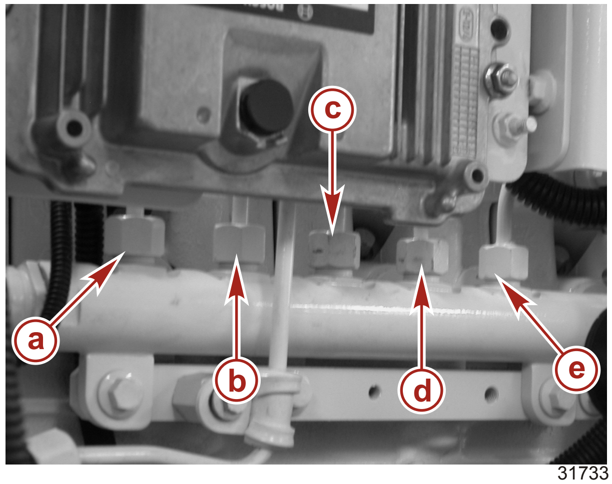
⚠ CAUTION

Failure to release pressure from the fuel system will result in fuel spraying out, which can cause a fire or explosion. Allow the engine to cool completely and release all fuel pressure before servicing any part of the fuel system. Always protect eyes and skin from pressurized fuel and vapors.

IMPORTANT: Only remove the fuel lines as necessary for the repair being performed. The high pressure fuel lines are not reusable and must be replaced if removed.

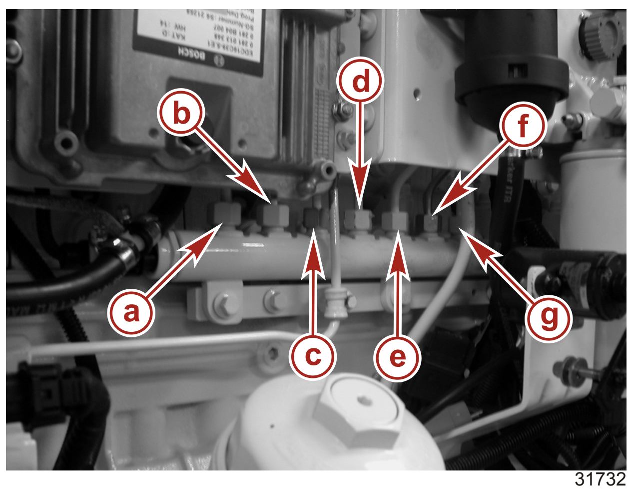
1. Allow the engine to cool to relieve fuel system pressure.
2. Use a clean shop towel to prevent fuel spraying. Clean up any spilled fuel.

3. Loosen the high pressure fuel line sleeve nuts on the common rail.



2.8 common rail

a - Cylinder 1 fuel line
b - Cylinder 2 fuel line
c - Common rail supply line
d - Cylinder 3 fuel line
e - Cylinder 4 fuel line

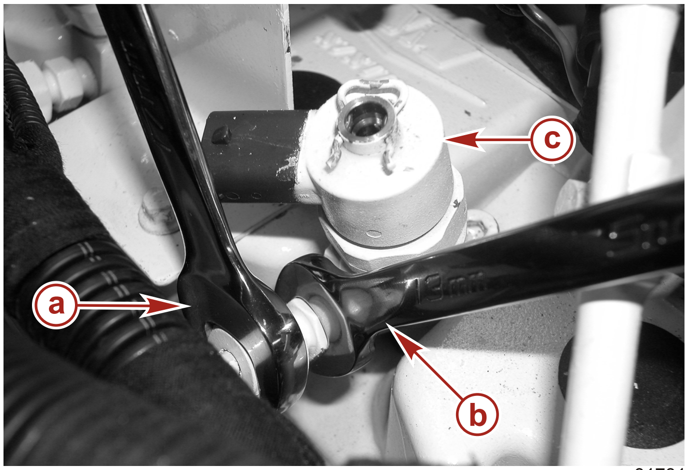


4.2 common rail

a - Cylinder 1 fuel line
b - Cylinder 2 fuel line
c - Cylinder 3 fuel line
d - Common rail supply line
e - Cylinder 4 fuel line
f - Cylinder 5 fuel line
g - Cylinder 6 fuel line

IMPORTANT: Counterhold each injector fuel inlet on the injectors with a second wrench when loosening the high pressure fuel line sleeve nuts.

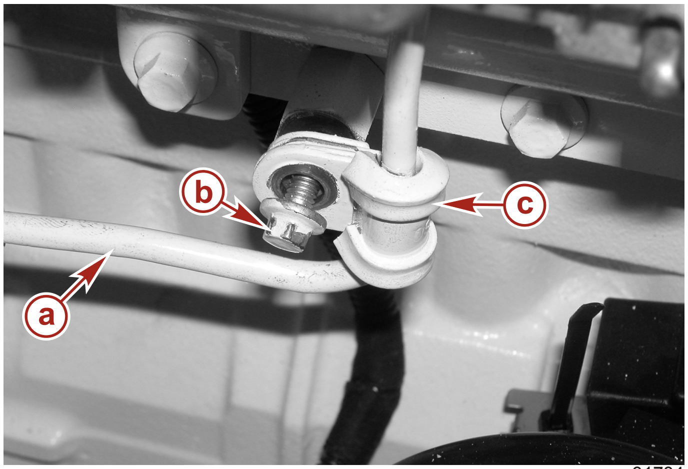
4. Counterhold the injector fuel inlet and loosen the high pressure fuel line sleeve nuts at the fuel injectors.



31731

a - Fuel line fitting
b - Injector fitting
c - Fuel injector

5. Loosen the sleeve nut on the fuel pump high pressure line.
6. Remove the injector high pressure fuel lines.
7. Remove the fuel pump high pressure fuel line clamp screw.
8. Retain the clamp and screw and discard the fuel lines.



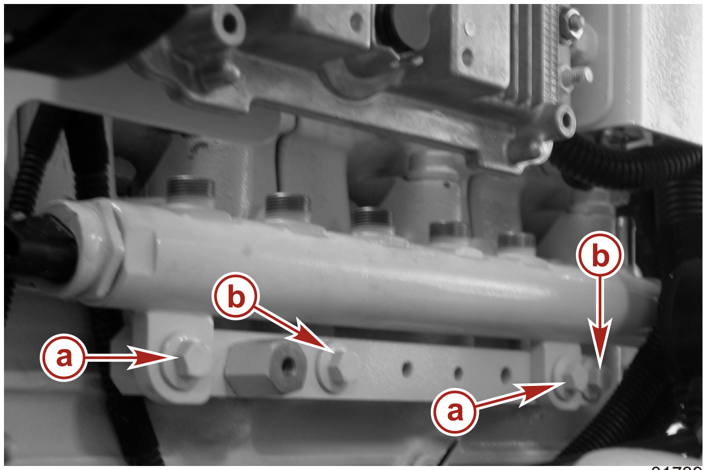
31734

a - Fuel pump high pressure line
b - Screw
c - Clamp

Installation

1. Confirm that the fuel injectors and the high-pressure fuel pump are properly installed and torqued to specification. Refer to **Section 5D–Fuel Injectors** and **Section 5E: Fuel Pump**.

2. f the common rail was previously installed, loosen –but do not remove– the common rail and common rail bracket screws. Refer to Common Rail for detailed information.

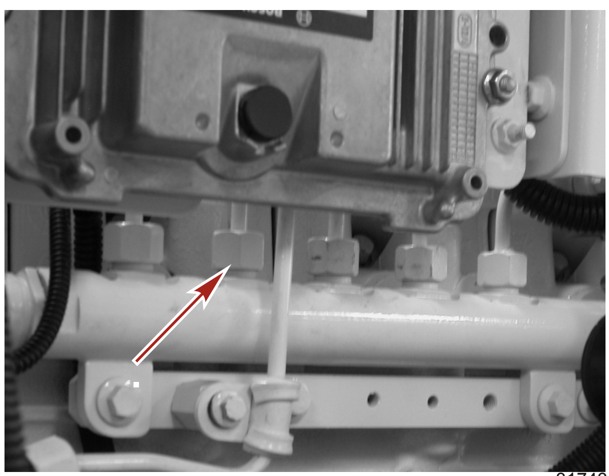


2.8 shown, 4.2 similar

a - **Common rail screws**
b - **Bracket screws**

IMPORTANT: The high pressure fuel lines are not reusable and must be replaced if removed.

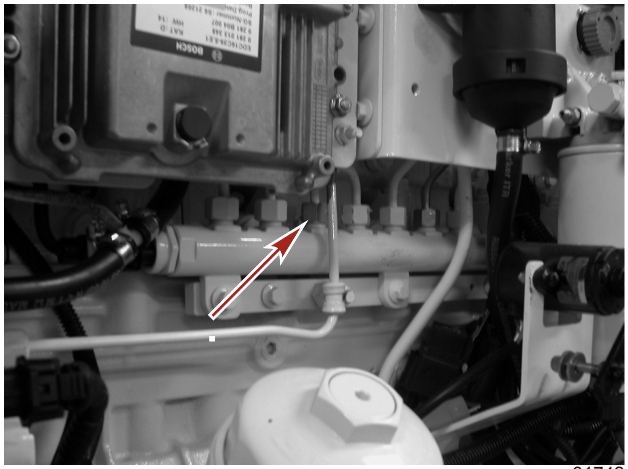
3. Install the injector fuel lines and hand–tighten the sleeve nuts.
4. Install the clamp on the fuel pump high–pressure line.
5. Install the clamp screw and hand–tighten.
6. *On 2.8 models*, tighten injector fuel line number 2 at the common rail.



2.8, Injector line 2

Description	Nm	lb–in.	lb–ft.
Fuel line sleeve nut (common rail)	19	168	–

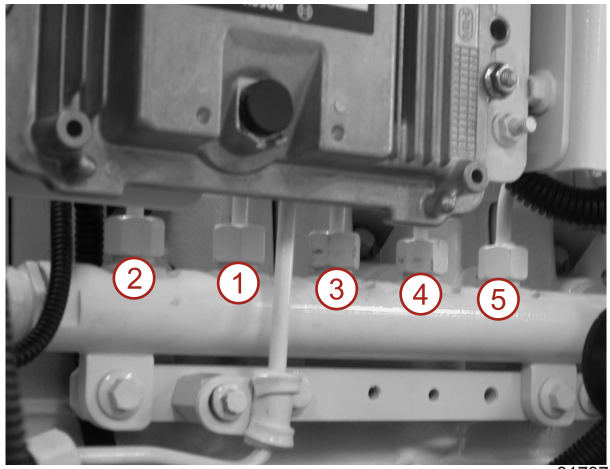
7. On 4.2 models, tighten injector fuel line 3 at the common rail.


31742

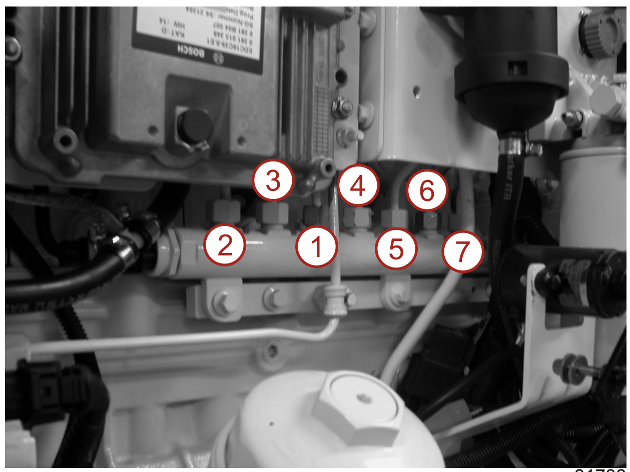
4.2, Injector line 3

Description	Nm	lb–in.	lb–ft.
Fuel line sleeve nut (common rail)	19	168	–

8. Tighten the remaining fuel line sleeve nuts at the common rail in the depicted order.



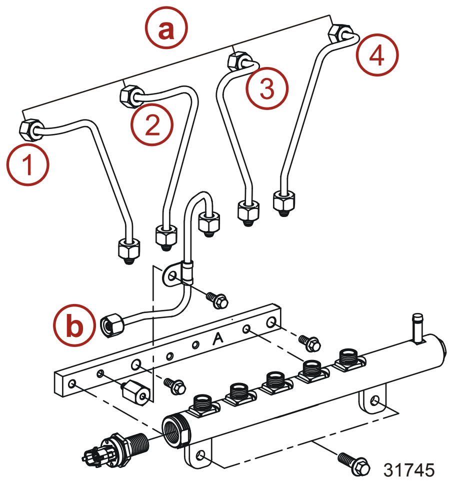
2.8



4.2

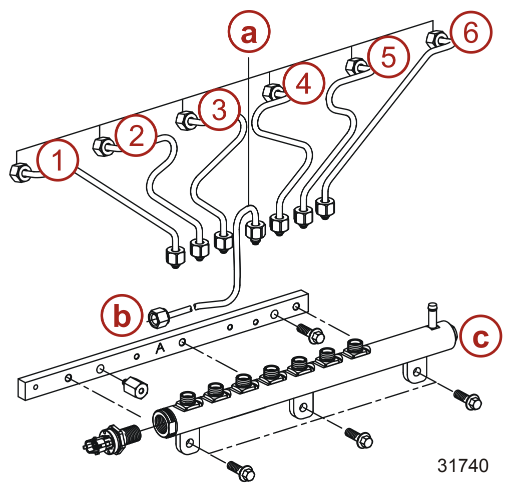
Description	Nm	lb–in.	lb–ft.
Fuel line sleeve nut (common rail)	19	168	–

9. Tighten the injector fuel line sleeve nuts at the injectors in the depicted order.



2.8

a - Fuel injector lines
b - Fuel Pump high pressure supply line

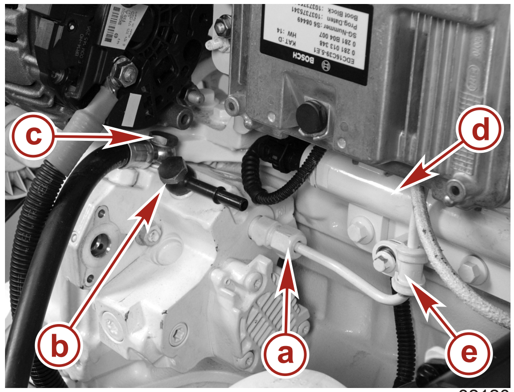


4.2

a - Fuel injector lines
b - Fuel pump high pressure line
c - Common rail

Description	Nm	lb–in.	lb–ft.
Fuel line sleeve nut (injector)	27	–	20

10. Tighten the fuel pump high pressure line sleeve nut at the fuel pump.



32120

Fuel pressue high pressure connections

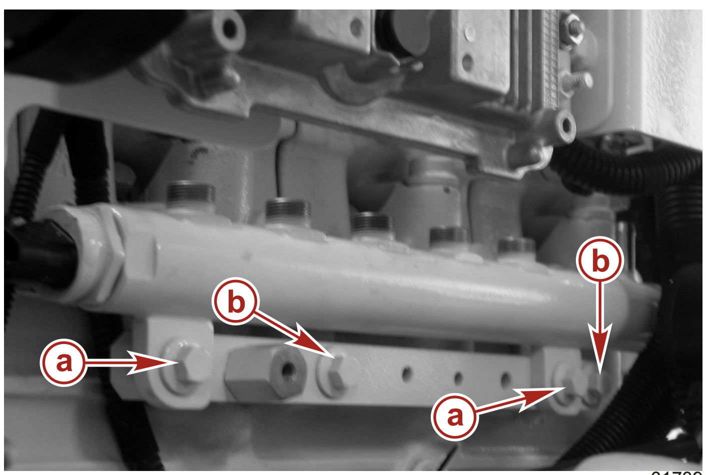
a - High pressure line
b - Fuel return line fitting
c - Fuel supply line
d - Fuel rail
e - High pressure line clamp

Description	Nm	lb–in.	lb–ft
High pressure line sleeve nut (fuel pump)	20	177	–

11. Tighten the fuel pump high pressure line clamp screw.

Description	Nm	lb–in.	lb–ft
Screw, high pressure line clamp	14.7	130	–

12. Tighten the common rail and bracket mounting screws.



31739

2.8 shown, 4.2 similar

a - Common rail screws
b - Bracket screws

Description	Nm	lb–in.	lb–ft
Common rail and bracket mounting screw	33	–	24

Common Rail

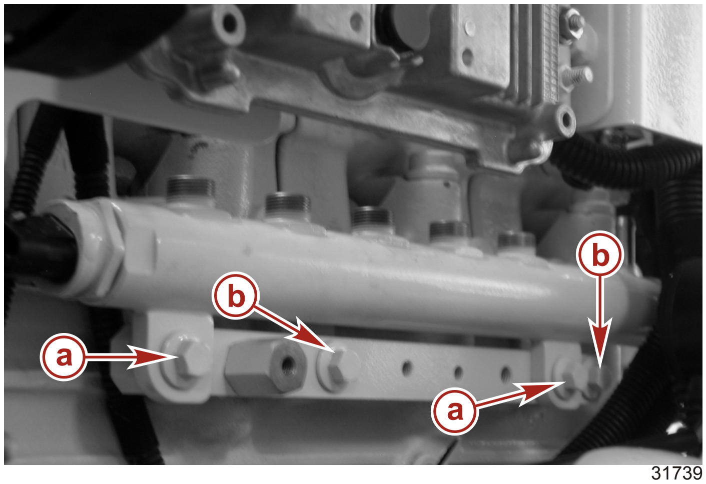
Removal

⚠ CAUTION

Failure to release pressure from the fuel system will result in fuel spraying out, which can cause a fire or explosion. Allow the engine to cool completely and release all fuel pressure before servicing any part of the fuel system. Always protect eyes and skin from pressurized fuel and vapors.

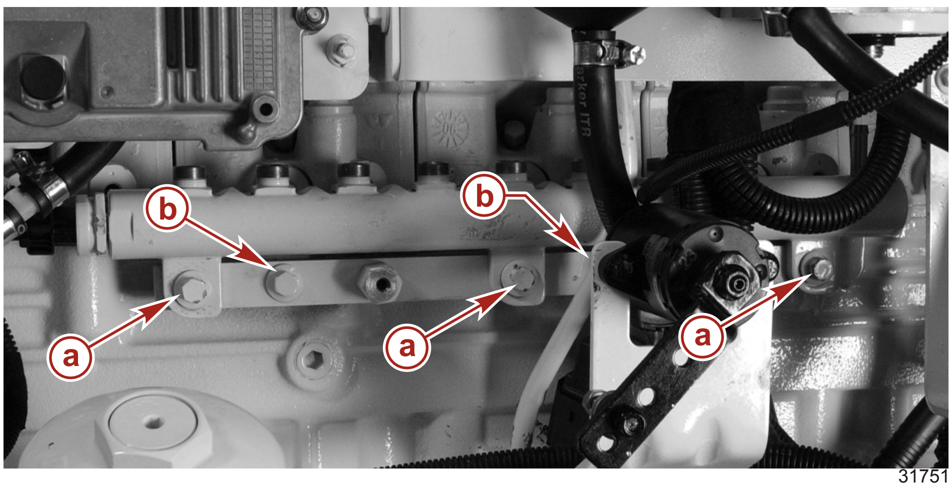
1. Allow the engine to cool to relieve fuel system pressure.
2. Disconnect the fuel rail pressure sensor.
3. Disconnect the common rail overflow fuel line.
4. *On 4.2 models*, remove the water separating fuel filter or TP sensor and bracket to gain access to the fuel lines and fuel rail
5. Remove the fuel manifold. See **Fuel Manifold**.
6. Remove the high pressure fuel lines. See **High Pressure Fuel Lines**.

7. Remove the fuel rail mounting screws and remove the fuel rail from the bracket.



2.8

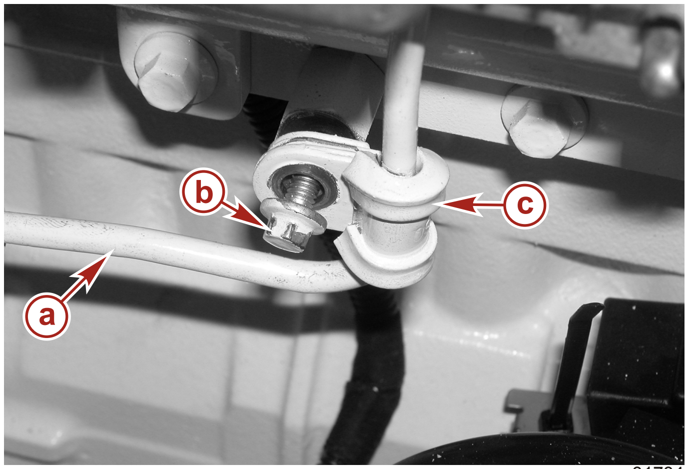
a - Common rail screws
b - Bracket screws



4.2

a - Common rail screws
b - Bracket screws

8. Remove the high pressure fuel line clamp.



a - Fuel pump high pressure line
b - Screw
c - Clamp

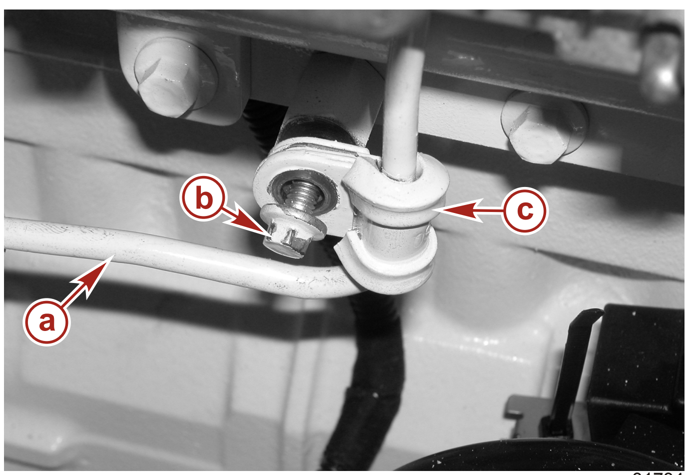
9. Remove the fuel rail bracket screws and remove the bracket from the engine.

Installation

1. Install the common rail bracket using the common rail bracket screws.
2. Tighten the common rail bracket screws to specification.

Description	Nm	lb–in.	lb–ft
Common rail bracket screws	33	–	24

3. Install the high pressure fuel line clamp.



2.8 and 4.2 are similar

a - Fuel pump high pressure line
b - Screw
c - Clamp

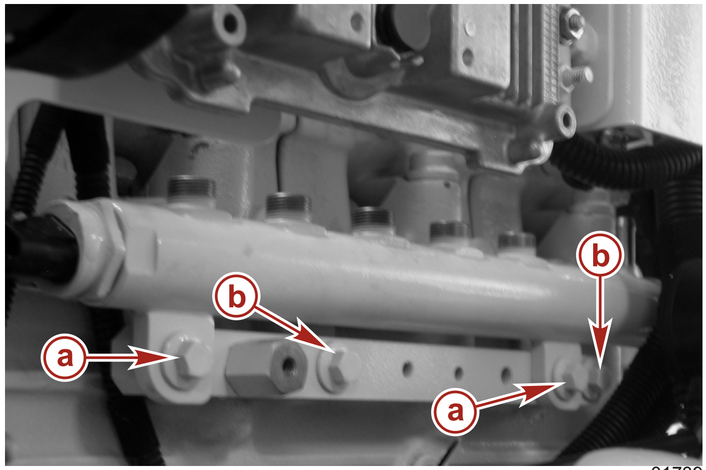
4. Install the high pressure fuel line clamp. Hand tighten only.

IMPORTANT: Do not overtighten the common rail mounting screws. The common rail and high pressure fuel line clamp must be slightly loose to allow the proper installation of the high pressure fuel lines.

5. If it has been removed, install the fuel rail pressure sensor. Torque to specification.

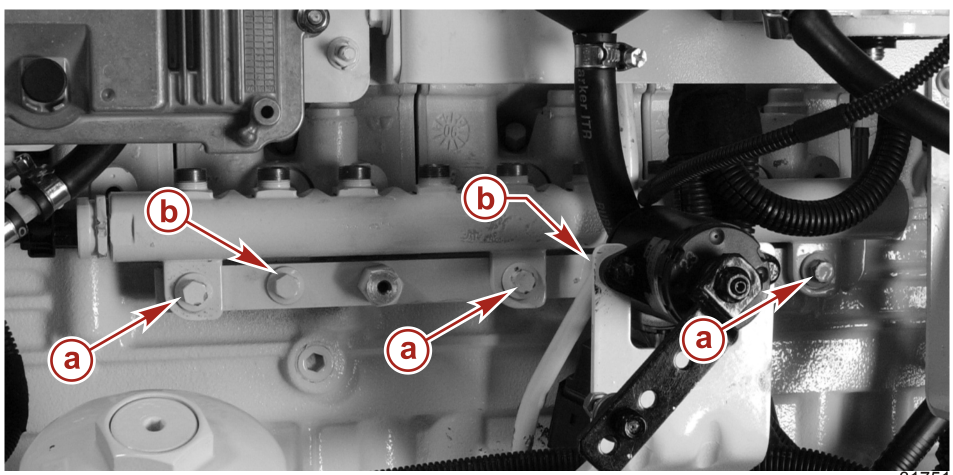
Description	Nm	lb–in.	lb–ft
Fuel rail pressure sensor	35	—	26

6. Install the fuel rail and fuel rail mounting screws. Hand tighten only.



2.8

a - Fuel rail mounting screws
b - Bracket mounting screws



4.2

a - Fuel rail mounting screws
b - Bracket mounting screws

7. Install the high pressure fuel lines. See **High Pressure Fuel Lines**.
8. Torque the common rail and bracket mounting screws.

Description	Nm	lb–in.	lb–ft
Common rail mounting screw	33	—	24

9. Torque the high pressure fuel line clamp.

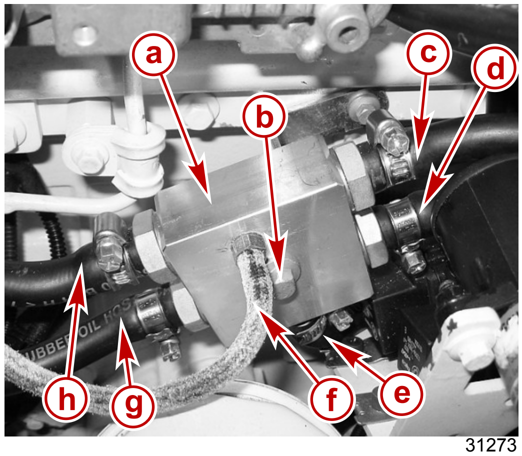
Description	Nm	lb–in.	lb–ft
High pressure fuel line clamp screw	14.7	130	–

10. Install the fuel manifold. See **Fuel Manifold**.

Fuel Manifold

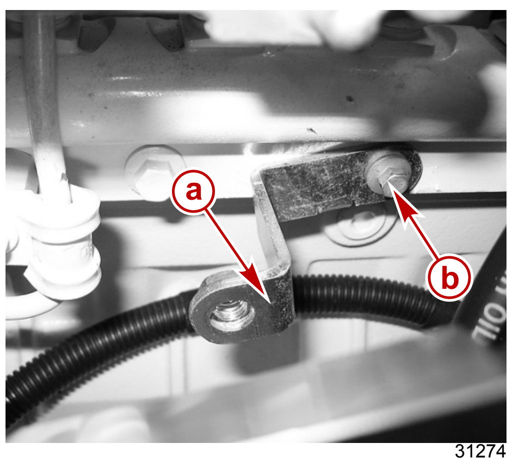
Removal

1. Relieve the fuel system pressure.
2. Disconnect the fuel manifold fuel lines.
3. Remove the fuel manifold retaining screw.



a - Fuel manifold
b - Retaining screw
c - Fuel cooler inlet line
d - Fuel return line to water-separating fuel filter
e - Common rail overflow fuel line
f - Injector overflow fuel line
g - Fuel cooler return line
h - Fuel pump overflow line

4. Remove the fuel manifold bracket screw.
5. Remove the fuel manifold bracket from the common rail bracket.



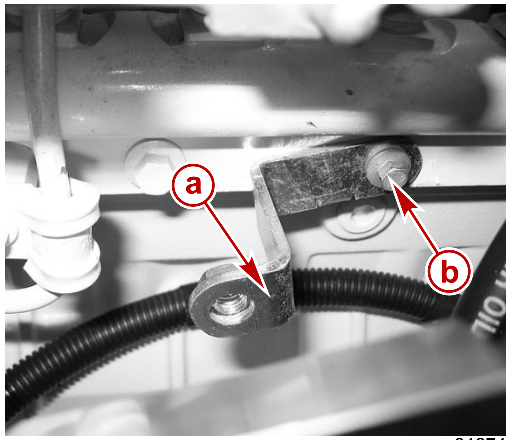
a - Fuel manifold bracket
b - Screw

Cleaning and Inspection

1. Clean the fuel manifold with warm soapy water.
2. Dry the manifold and its orifices with compressed air.
3. Inspect the manifold for any damage. Replace if necessary.

Installation

1. Install the fuel manifold bracket and fuel manifold bracket screw as shown.



31274

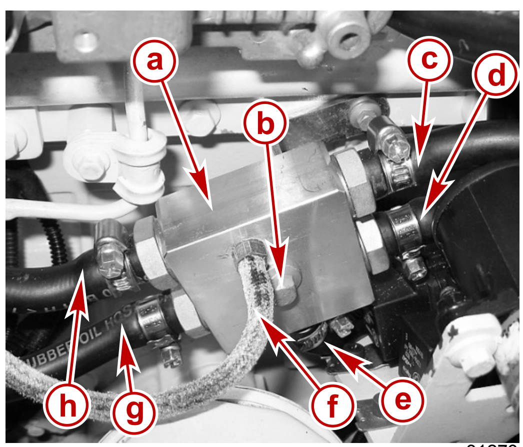
a - Fuel manifold bracket
b - Screw

Description	Nm	lb–in.	lb–ft
Fuel manifold bracket screw	24.5	–	18

2. Attach the fuel manifold to the bracket with the fuel manifold retaining screw.
3. Torque the fuel manifold retaining screw.

Description	Nm	lb–in.	lb–ft
Fuel manifold screw	10.8	96	–

4. Connect the fuel hoses to fuel manifold as shown. Tighten the hose clamps securely.



31273

a - Fuel manifold
b - Retaining screw
c - Fuel cooler inlet line
d - Fuel return line to water-separating fuel filter
e - Common rail overflow fuel line
f - Injector overflow fuel line
g - Fuel cooler return line
h - Fuel pump overflow line

Notes:

Fuel System

Section 5D - Fuel Injectors

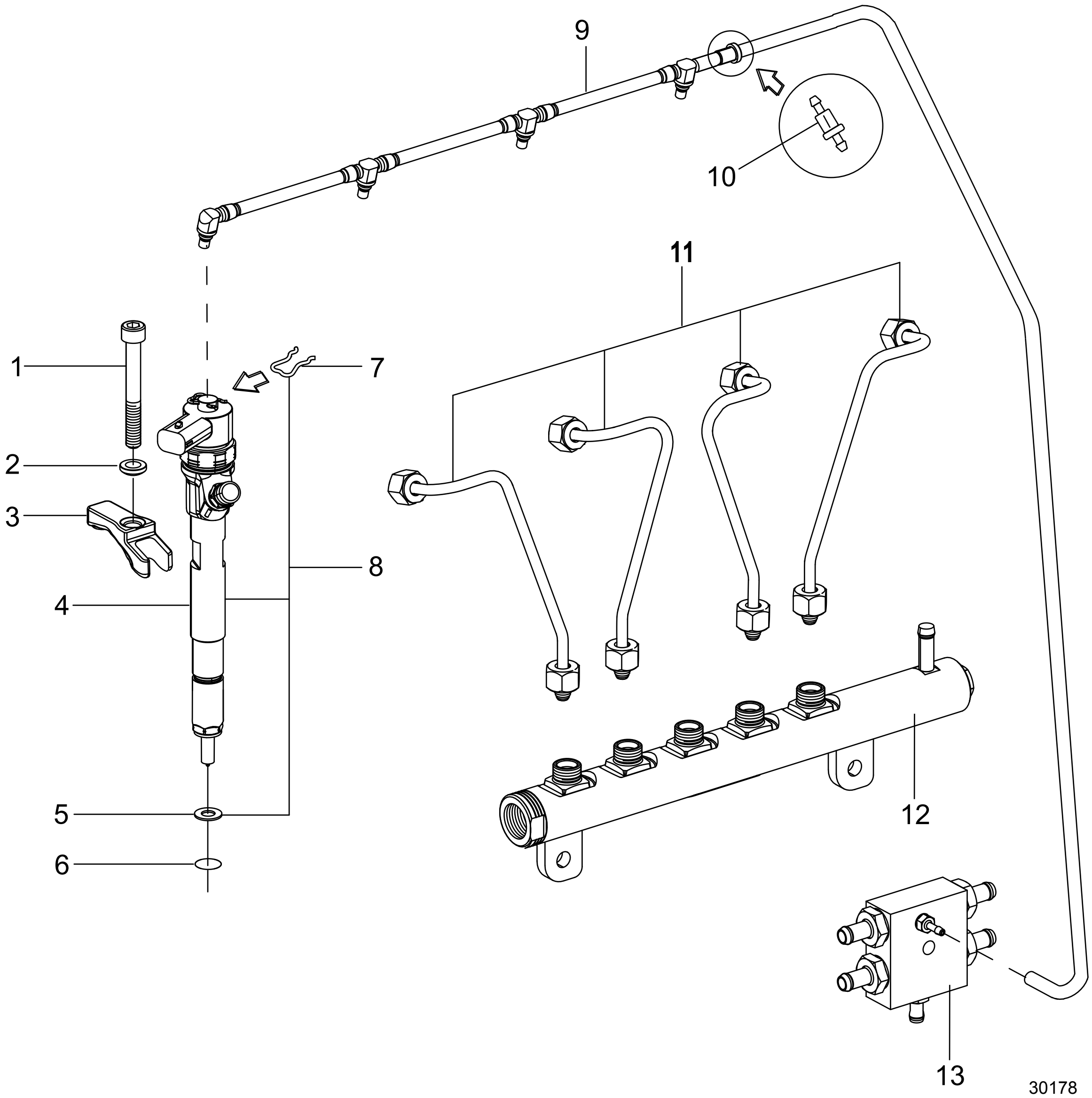
Table of Contents

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Injector O-ring seal	Obtain Locally

Notes:

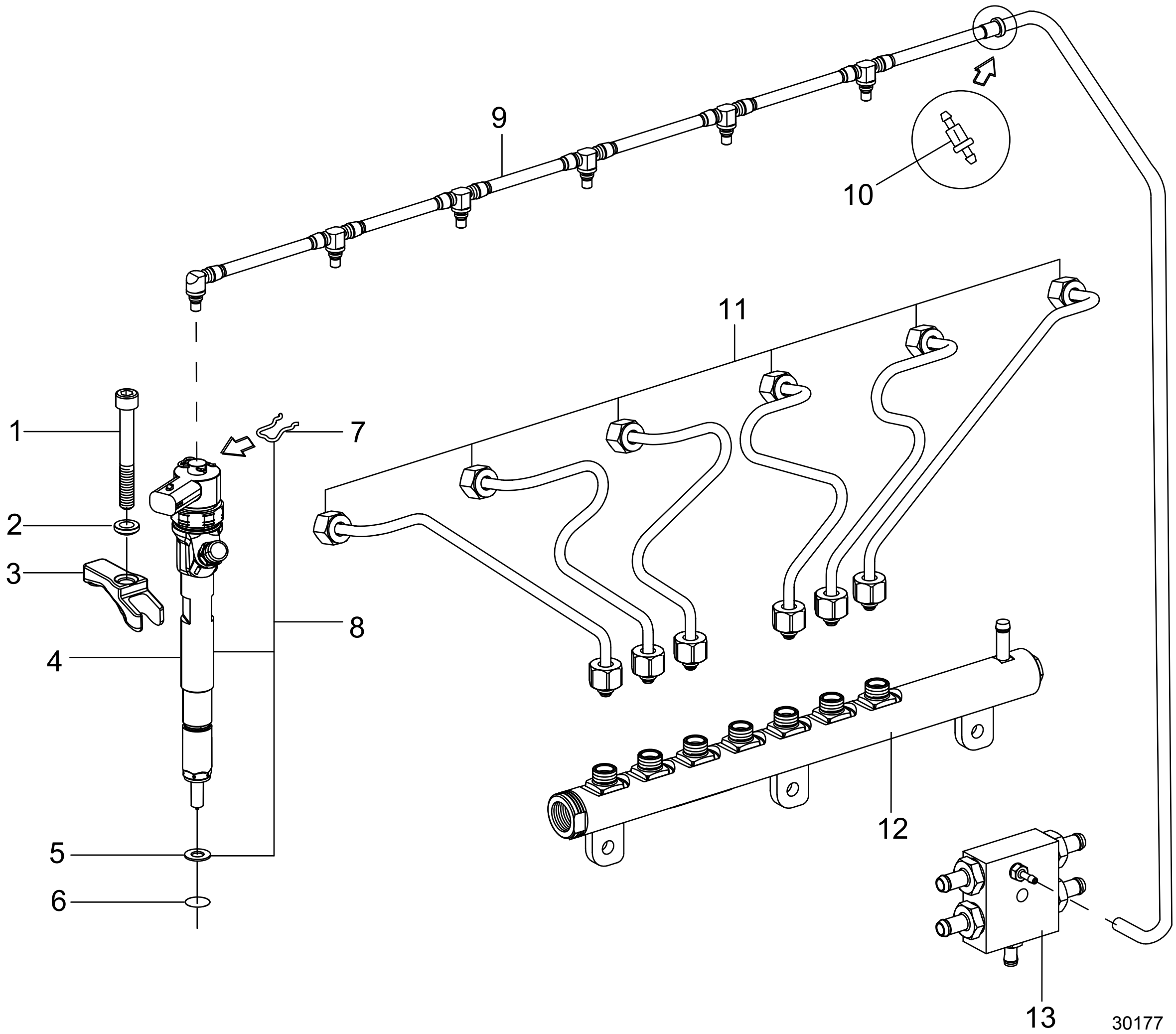
Exploded View—2.8 Fuel Injectors And Related



Exploded View—2.8 Fuel Injectors And Related

Ref. No.	Qty.	Description	Torque		
			Nm	lb–in.	lb–ft
1	4	Injector clamp retaining screw	37.3	–	28
2	4	Washer	–	–	–
3	4	Injector clamp	–	–	–
4	4	Injector	–	–	–
5	4	Nozzle gasket	–	–	–
6	4	O-ring	–	–	–
7	4	Horseshoe clip	–	–	–
8	4	Injector assembly	–	–	–
9	1	Injector fuel return line	–	–	–
10	1	Pressure valve	–	–	–
11	4	High pressure injector lines	Refer to **5C–High Pressure Fuel Lines**.		
12	1	Common rail	–	–	–
13	1	Fuel manifold	–	–	–

Exploded View—4.2 Fuel Injectors And Related



Exploded View—4.2 Fuel Injectors And Related

Ref. No.	Qty.	Description	Torque		
			Nm	lb–in.	lb–ft
1	6	Injector clamp retaining screw	37.3	–	28
2	6	Washer	–	–	–
3	6	Injector clamp	–	–	–
4	6	Injector	–	–	–
5	6	Nozzle gasket	–	–	–
–	6	O-ring	–	–	–
7	6	Horseshoe clip	–	–	–
8	6	Injector assembly	–	–	–
9	1	Injector fuel return line	–	–	–
10	1	Pressure valve	–	–	–
11	6	High pressure injector lines	Refer to **5C–High Pressure Fuel Lines**.		
12	1	Common rail	–	–	–
13	1	Fuel manifold	–	–	–

Fuel Injector Repair and Service

The Robert Bosch Corporation has a worldwide network of authorized Bosch Service Dealers to service their products.

The high pressure fuel pump, common rail, and injectors must be sent to an authorized Bosch Service Center.

When shipping an injection pump to a service center for adjustments or repairs, the fuel return line hollow bolt must accompany the unit. The hollow bolt incorporates a calibrated sized orifice for proper pressure that is matched to the pump. The pump cannot be adjusted properly without the matched orifice.

Contact the Bosch distributor nearest you for the location of an authorized Bosch Service Center.

Fuel Injectors

Description

In the electronic fuel injection system, the injectors (with their nozzles in their nozzle holders) are an important connection between the fuel pump and the engine.

The injectors:

- Meter the injected fuel volume.
- Meter the rate and pulse frequency of fuel discharge.
- Accurately direct the fuel spray in the cylinder.
- Isolate the injection system from the combustion process.

Electronically controlled diesel engines use a calibrated hole type injector nozzle. These injectors are individually calibrated and are cylinder specific according to ECM programming. The injector spray holes are machined at specifically engineered angles in the nozzle body and must be correctly oriented within the combustion chamber.

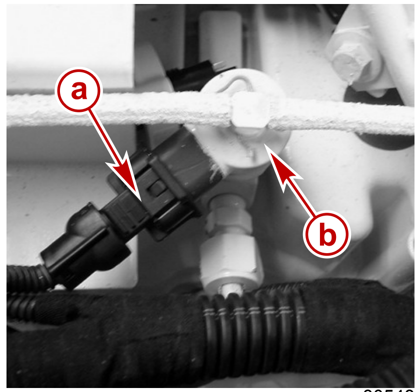
The fuel injectors are controlled electronically through the ECM.

Removal

⚠ CAUTION

Failure to release pressure from the fuel system will result in fuel spraying out, which can cause a fire or explosion. Allow the engine to cool completely and release all fuel pressure before servicing any part of the fuel system. Always protect eyes and skin from pressurized fuel and vapors.

1. Disconnect the injector harness connection.



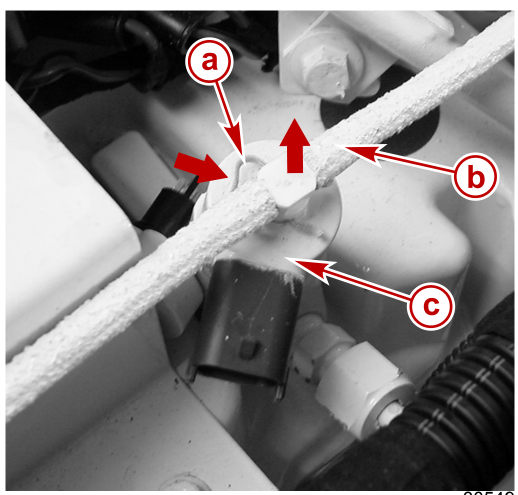
30548

a - Harness connector
b - Injector

IMPORTANT: If replacing the injector, remove and retain the horseshoe clip for installation.

NOTE: The horseshoe retaining clips for the fuel injector return line cannot be replaced as an individual part. If a clip is lost or damaged the entire return line assembly must be replaced to obtain a new clip.

2. Push in the horseshoe clips and pull up on the fuel injector return line.

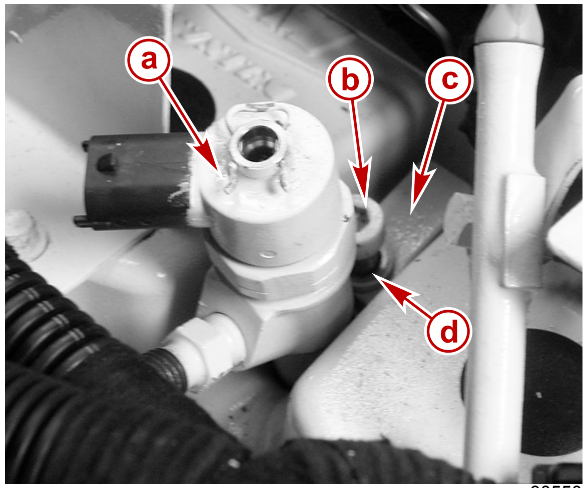


30549

a - Horseshoe clip
b - Injector return line
c - Injector

3. Clean around the fuel injectors, fittings, and pipes.
4. Remove the components necessary to gain access to the high pressure fuel lines. See the appropriate sections for procedures.

5. Remove the high pressure fuel lines. Refer to **Section 5C–Common Rail and Fuel Lines** for removal procedures.
6. Remove the injector–clamp screw and washer.
7. Remove the injector–clamp. Retain all components.



30550

a - Injector
b - Injector clamp screw
c - Washer
d - Clamp

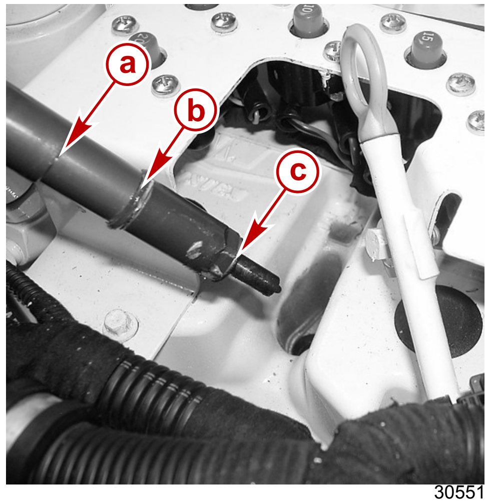
IMPORTANT: To protect the injector nozzle from rust, wet all parts with diesel fuel before handling.

NOTE: *To assist in removal, rotate the injector slightly clockwise and counterclockwise to break any seal formed by paint or corrosion.*

IMPORTANT: Note the location of each injector for installation. Each injector is specifically calibrated to its cylinder.

8. Withdraw the fuel injector from the bore together with mounting hardware. Note its location for installation.

9. Discard the copper sealing washer and O-ring.



a - Fuel injector
b - O-ring
c - Copper sealing washer

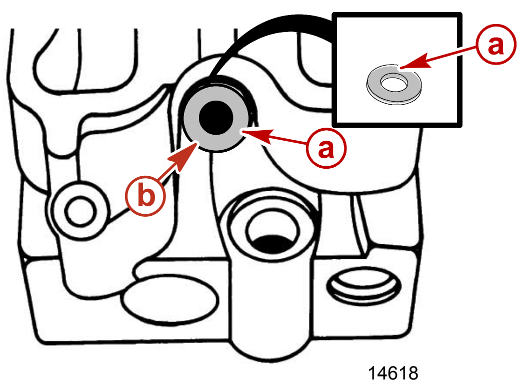
Inspection

1. Remove any injector seal that may have stayed in the head. Do not gouge or nick the injector seat.
2. Ensure that cylinder head injector bores are clean.

Installation

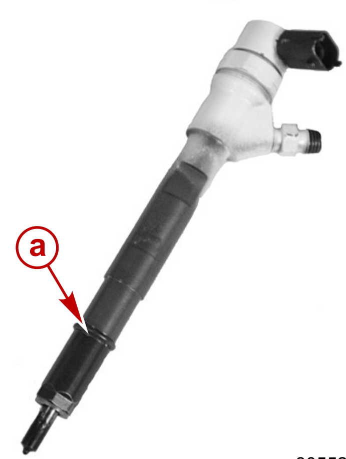
IMPORTANT: Ensure that the copper sealing washer is centered in the injector bore and fully seated on the cylinder head.

1. Place a new copper sealing washer in the injector bore on the injector seat as shown.



a - Copper sealing washer
b - Injector bore

2. Install a new O-ring seal in the groove on the injector. Lubricate the seal.



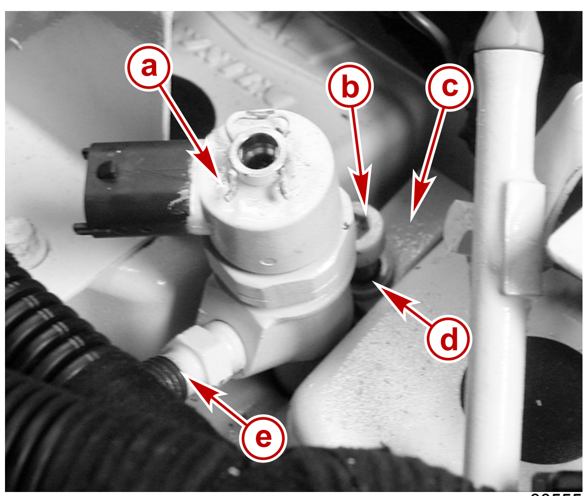
30552

a - O-ring

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Injector O-ring seal	Obtain Locally

IMPORTANT: Each injector is specifically calibrated to its cylinder. Install the injector in the same cylinder from which it was removed.

3. Point the fuel inlet adapter away from the valve cover and install the injector. Check that the injector O-ring seal is not damaged during installation.
4. Install the injector clamp, washer, and clamp screw.



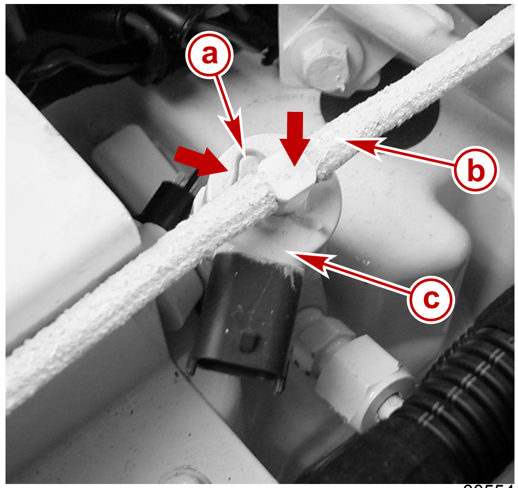
30555

a - Fuel injector
b - Injector clamp screw
c - Injector clamp
d - Washer
e - Fuel inlet adapter

5. Tighten the injector clamp screw to specification.

Description	Nm	lb–in.	lb–ft
Injector clamp screw	21.6	191	–

6. Install the high pressure fuel lines. Refer to **Section 5C–Common Rail and Fuel Lines** for installation procedures.
7. Check that the horseshoe clamp is installed on the injector.
8. Push in on the horseshoe clamp and install the fuel injector return line.



30554

a - Horseshoe clip
b - Injector return line
c - Injector

9. Connect the injector harness connector.
10. If any of the injectors were replaced, use the CDS tool to calibrate the ECM to the new injector. See **ECM Injector Calibration**.

NOTICE
Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

⚠ WARNING
The fuel injection pump generates pressure in excess of 13790 kPa (2000 psi), which is high enough to penetrate or cut the skin. Do not use your fingers to feel for fuel leaks and wear personal protective equipment when servicing the fuel system.

11. Start the engine.

NOTE: It is sometimes helpful to use compressed air to dry the area near fittings when checking for fuel leaks. Wear eye protection when using compressed air.

12. Check for fuel leaks while waiting for the engine to reach normal operating temperature. Immediately stop the engine if leaks existand repair as needed.

ECM Injector Calibration

IMPORTANT: Each injector is specifically calibrated to a specific cylinder. If the injector is not calibrated using the injector metering adjustment (IMA) code, the ECM will not recognize it, and the engine will not operate correctly.

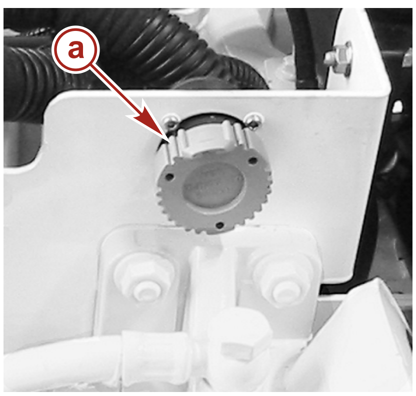
Injectors that are supplied with the engine have the IMA code painted over during the assembly process. The codes are placed on a label and affixed to the back of the ECM for reference.

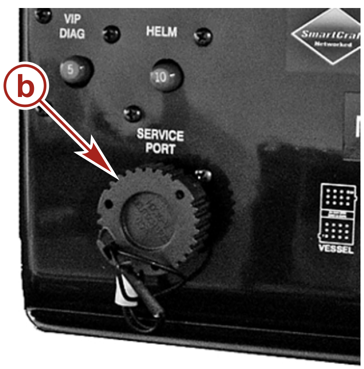
31688

ECM injector IMA label

New injectors come with a new label to update the IMA codes. Write down the IMA numbers for injectors that will not be replaced on the new label. Affix the new label to the back of the ECM for future reference.

1. Check that each injector is properly installed and connected to the wiring harness.
2. Connect the CDS tool to the engine diagnostic connection port.





29971

Engine Diagnostic Connector

a - Engine diagnostic port

VIP Diagnostic Connector

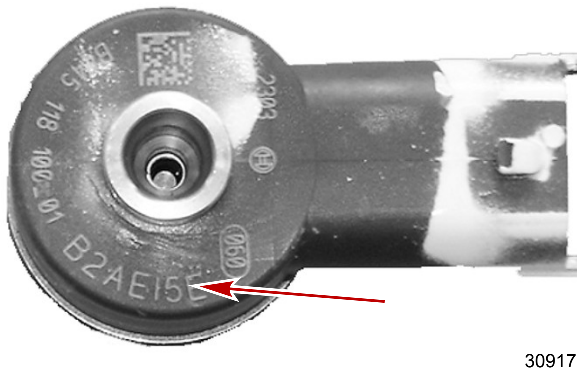
b - VIP diagnostic port

3. Turn the key switch to "ON" but do not start the engine.

IMPORTANT: The injector metering adjustment (IMA) code for new injectors is located on top of each injector.

NOTE: *Injector IMA codes for injectors that come with the engine are located on the back of the ECM.*

4. Follow the on screen instructions to calibrate each injector using the injector metering adjustment (IMA) code.



New injector IMA code

Notes:

Fuel System

Section 5E - High Pressure Fuel Pump

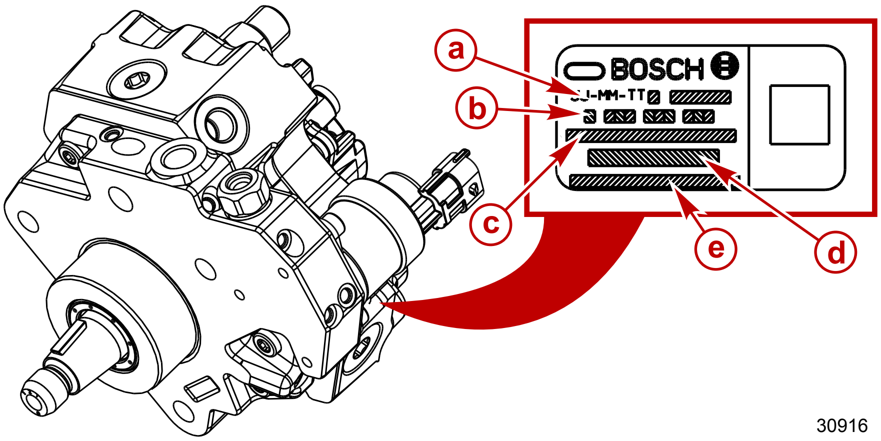
Table of Contents

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Fuel pump gasket	92-34227 1

High Pressure Fuel Pump Identification

The identification tag is located on the fuel pump housing below the fuel pump actuator.



a - Manufacturing date
b - Bosch part number
c - Pump type
d - Customer order number
e - Country of origin

Specifications

Description	
Manufacturer	Robert Bosch Corporation
Type of injection pump	Single plunger Type UI
Manufacturer's identification number	A 413 020 415
Fuel system pressure	1350 bar (19580 PSI)
Delivery begins	Electronically controlled
Governor type	Electronically controlled

Fuel Pump Repair and Service

The Robert Bosch Corporation has a worldwide network of authorized Bosch Service Dealers to service their products.

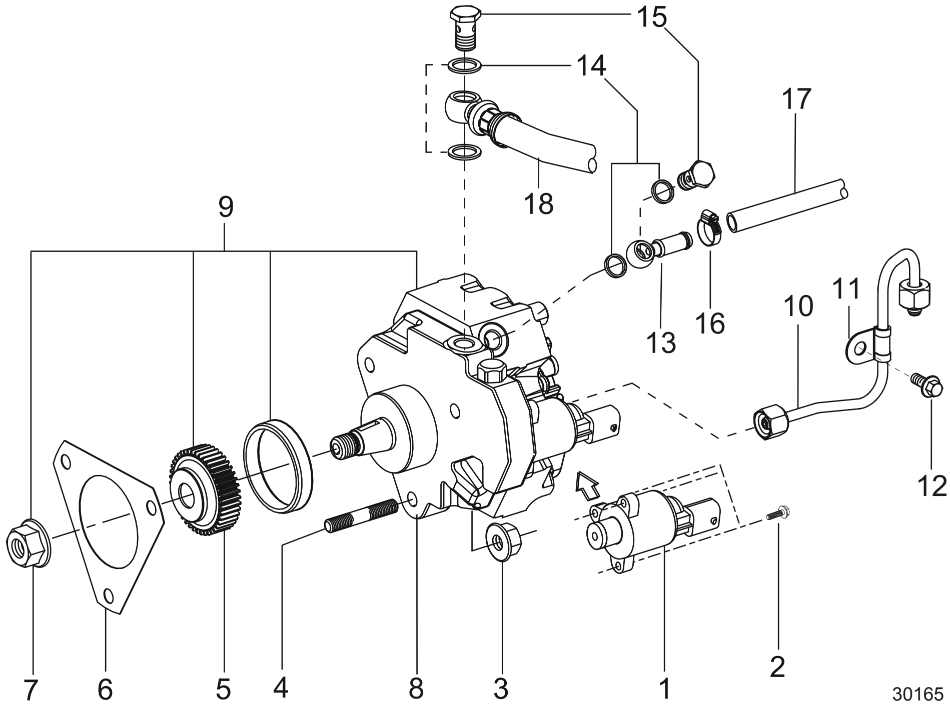
The high pressure fuel pump, common rail, and injectors must be sent to an authorized Bosch Service Center.

When shipping an injection pump to a service center for adjustments or repairs, the fuel return line hollow bolt must accompany the unit. The hollow bolt incorporates a calibrated sized orifice that is matche to the pump for proper pressure which is matched to the pump. The pump cannot be adjusted properly without the matched orifice.

Contact the Bosch distributor nearest you for the location of an authorized Bosch Service Center.

Notes:

Exploded View—High Pressure Fuel Pump



Exploded View—High Pressure Fuel Pump

Ref. No.	Qty.	Description	Torque		
			Nm	lb–in.	lb–ft
1	1	Fuel pump actuator	–	–	–
2	3	Screw	10	88.5	–
3	3	Flange nut	27.5	–	20
4	3	Stud	–	–	–
5	1	Fuel pump gear	–	–	–
6	1	Gasket	–	–	–
7	1	Fuel pump gear nut	86.3	–	64
8	1	High pressure fuel pump	–	–	–
9	1	Fuel pump assembly	–	–	–
10	1	Common rail fuel supply line	20.5	181	–
11	1	Clamp	–	–	–
12	1	Common rail fuel line screw	14.7	130	–
13	1	Overflow adaptor	–	–	–
14	4	Sealing washer	–	–	–
15	2	Hollow bolt	27.5	–	20
16	1	Clamp	1.5	13	–
17	1	Overflow fuel line	–	–	–
18	1	Fuel inlet line	–	–	–

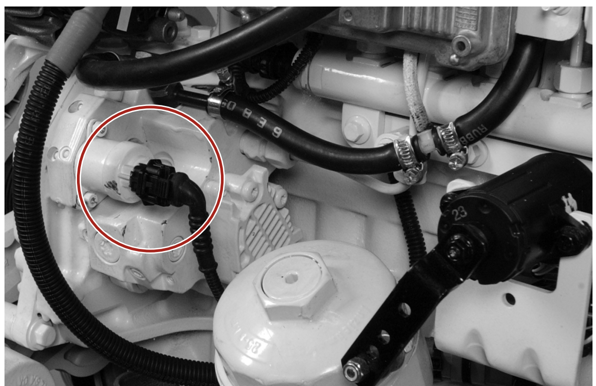
High Pressure Fuel Pump

Removal

⚠ CAUTION

Failure to release pressure from the fuel system will result in fuel spraying out, which can cause a fire or explosion. Allow the engine to cool completely and release all fuel pressure before servicing any part of the fuel system. Always protect eyes and skin from pressurized fuel and vapors.

1. Disconnect the battery cables.
2. Drain the seawater section of the cooling system. Refer to **Section 6A–Draining the Seawater System**.
3. Remove the seawater hoses between the seawater pump, oil cooler, and fuel cooler. Refer to **Section 6A** for procedures.
4. Disconnect the fuel–pump actuator electrical connector from the fuel pump.

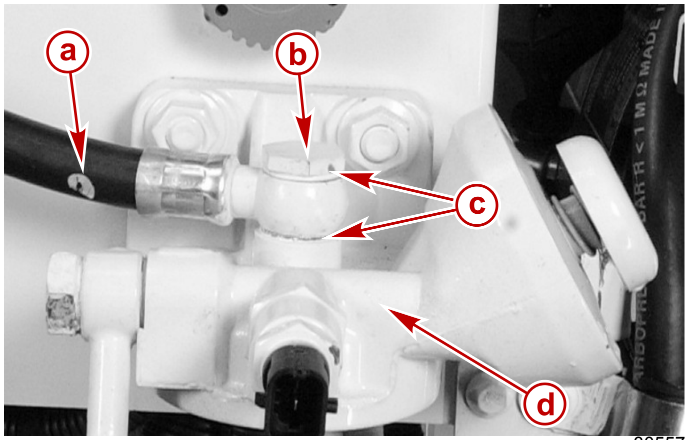


32124

Fuel pump actuator electrical connector

IMPORTANT: The hollow bolts are calibrated and must remain with the pump in their original location.

5. Remove the hollow bolt from the fuel pump inlet line at the fuel filter assembly. Discard the sealing washers.

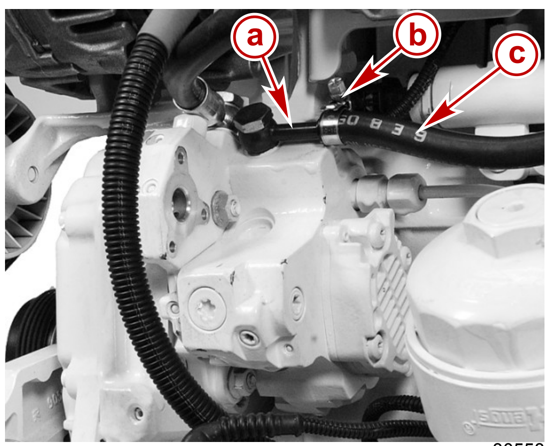


30557

a - Fuel pump inlet line
b - Hollow bolt
c - Sealing washers
d - Fuel filter assembly

NOTE: *If the fuel pump return line adaptor is removed, remove the hollow bolt and discard the sealing washers.*

6. Disconnect the fuel pump return line from the adaptor.



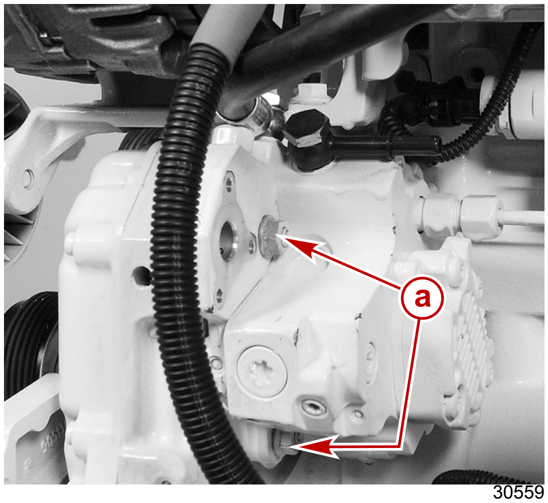
30558

a - Adaptor
b - Clamp
c - Fuel pump return line

IMPORTANT: High pressure fuel lines must be replaced if they are removed.

7. Remove the high pressure common rail fuel line. Refer to **Section 5C–Common Rail and Fuel Lines** for removal procedures.

8. Remove the three injection pump flange nuts.

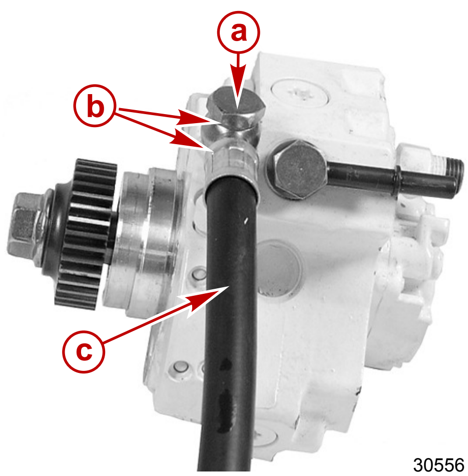


a - Fuel pump flange nuts

9. Carefully remove the pump and set it aside.
10. Remove the fuel pump gasket.

IMPORTANT: The hollow bolts are calibrated and must remain with the pump in their original location.

11. Remove the hollow bolt from the fuel pump inlet line. Discard the sealing washers.



a - Hollow bolt
b - Sealing washers
c - Fuel pump inlet line

IMPORTANT: Leave the battery cables disconnected and attach a notice to the ignition switch to alert others that the engine should not be disturbed.

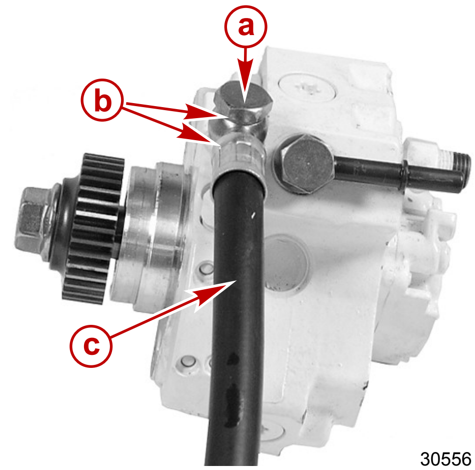
Cleaning and Inspection

1. Clean any gasket remenants off of the fuel pump and timing cover mating surfaces.
2. Inspect the condition of the fuel pump drive gear for any damage. Replace if necessary.

Installation

IMPORTANT: Hollow bolts are calibrated and must remain with the pump in their original location.

1. Using new sealing washers on the hollow bolt, install the fuel pump inlet line.



30556

a - Hollow bolt
b - Sealing washers
c - Fuel pump inlet line

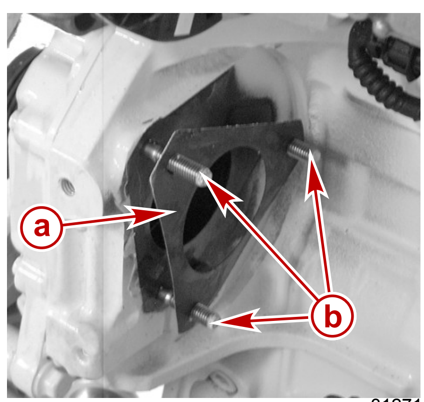
2. Torque the hollow bolt.

Description	Nm	lb–in.	lb–ft
Fuel pump inlet line hollow bolt	16.7	147	—

3. Remove any injection pump backlash by rotating the shaft **counterclockwise** (when facing the pump) until you feel resistance.
4. Apply sealant to the new injection pump gasket.

Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Fuel pump gasket	92-34227 1

5. Install the new fuel pump gasket on the three fuel pump mounting studs.

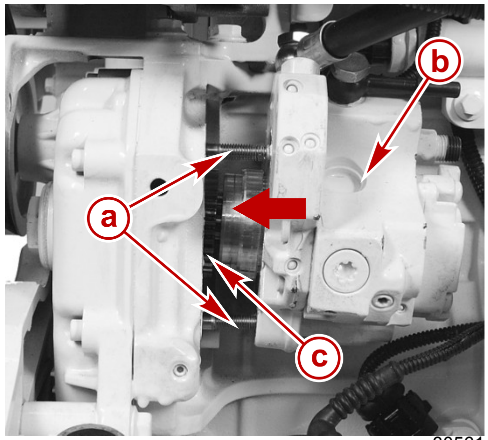


31271

a - Fuel pump gasket
b - Fuel pump mounting studs

6. Install the fuel pump onto the fuel pump mounting studs.

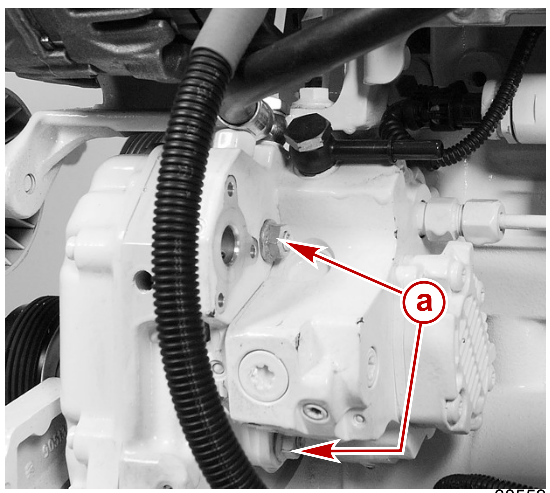
7. Align the fuel pump gear with the gear inside the timing cover and slide the fuel pump into position.



30561

a - Fuel pump mounting studs
b - Fuel pump
c - Fuel pump gear

8. Install the fuel pump flange nuts.



30559

a - Fuel pump flange nuts

9. Torque the fuel pump flange nuts.

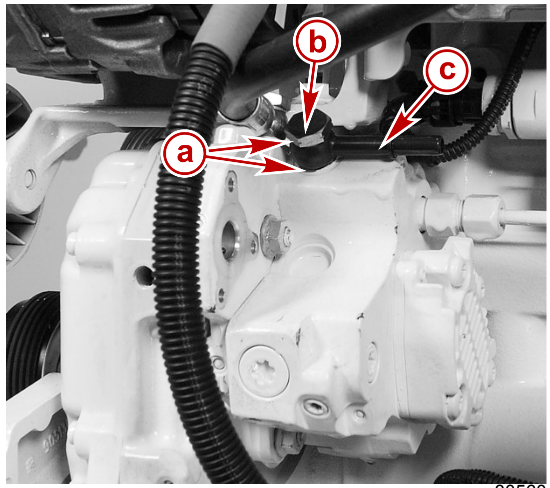
Description	Nm	lb–in.	lb–ft
Fuel pump flange nut	27.5	—	20

IMPORTANT: Do not bend fuel injector pipes. Bending can release metal flakes inside the pipes, causing injectors or fuel pump to malfunction.

10. Install the high pressure common rail fuel line. Refer to **Section 5C–Common Rail and Fuel Lines** for installation procedures..

IMPORTANT: Hollow bolts are calibrated and must remain with the pump in their original location.

11. If necessary, install the fuel pump retun line adaptor using new sealing washers on the hollow bolt.

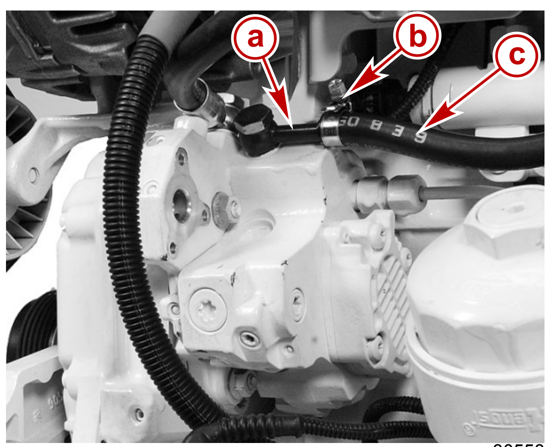


a - Sealing washers
b - Hollow bolt
c - Fuel pump return line adapter

12. Tighten the fuel pump inlet line hollow bolt to specification.

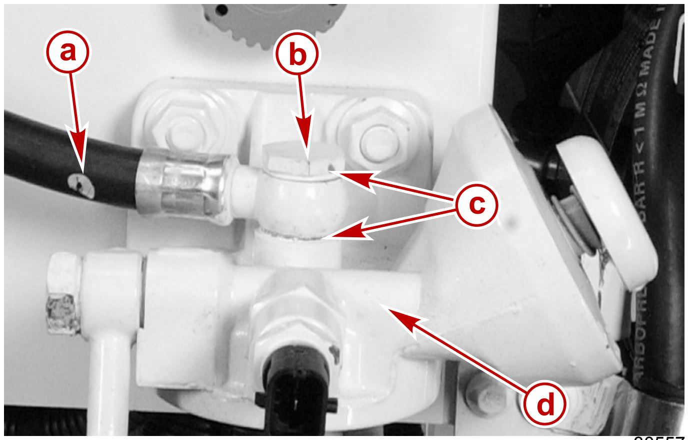
Description	Nm	lb–in.	lb–ft
Fuel pump return line hollow bolt	16.7	147	–

13. Install the fuel pump return line and tighten the clamp securly.



a - Adaptor
b - Clamp
c - Fuel pump return line

14. Using new sealing washers on the hollow bolt, install the fuel pump inlet line at the fuel filter assembly.



30557

- **a -** Fuel pump inlet line
- **b -** Hollow bolt
- **c -** Sealing washers
- **d -** Fuel filter assembly

15. Tighten the fuel pump inlet line hollow bolt to specification.

Description	Nm	lb–in.	lb–ft
Fuel pump inlet line hollow bolt	16.7	147	—

16. Install the fuel pump actuator and connect the wiring harness. Refer to **Section 5F–Fuel Pump Actuator**.
17. Install the seawater hoses between the seawater pump, the oil cooler, and the fuel cooler. Refer to **Section 6A** for procedures.
18. Connect the battery cables.

Fuel System

Section 5F - ECS Diagnostics

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Service Precautions

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⚠ WARNING

Failure to comply with regulations can result in injury from fire or explosion. Electrical system components on this engine are not rated as external ignition–protected (EIP). Do not store or use gasoline on boats equipped with these engines, unless provisions have been made to exclude gasoline vapors from the engine compartment (REF: 33 CFR).

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

⚠ WARNING

Fuel leakage is a fire or explosion hazard, which can cause serious injury or death. Periodically inspect all fuel system components for leaks, softening, hardening, swelling, or corrosion, particularly after storage. Any sign of leakage or deterioration requires replacement before further engine operation.

⚠ WARNING

Fuel is flammable and explosive. Ensure the key switch is off and the lanyard is positioned so that the engine cannot start. Do not smoke or allow sources of spark or open flame in the area while servicing. Keep the work area well ventilated and avoid prolonged exposure to vapors. Always check for leaks before attempting to start the engine and wipe up any spilled fuel immediately.

⚠ WARNING

Fuel vapors trapped in the engine compartment may be an irritant, cause difficulty breathing, or may ignite resulting in a fire or explosion. Always ventilate the engine compartment before servicing the power package.

⚠ CAUTION

Failure to release pressure from the fuel system will result in fuel spraying out, which can cause a fire or explosion. Allow the engine to cool completely and release all fuel pressure before servicing any part of the fuel system. Always protect eyes and skin from pressurized fuel and vapors.

NOTICE

Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

IMPORTANT: Adhere to the following information when working on the fuel system:

- **Always keep a dry chemical fire extinguisher at the work area.**
- **Do NOT replace fuel pipe with fuel hose.**
- **Do NOT attempt any repair to the fuel system until instructions and illustrations relating to the repair are thoroughly understood.**
- **Observe all precautions and notes.**

Replacement Parts Warning

⚠ WARNING
Avoid fire or explosion hazard. Electrical, ignition, and fuel system components on Mercury Marine products comply with federal and international standards to minimize risk of fire or explosion. Do not use replacement electrical or fuel system components that do not comply with these standards. When servicing the electrical and fuel systems, properly install and tighten all components.

General Information

Follow these instructions to ensure safe and proper service and repair of all Cummins MerCruiser Diesel Electronic Control System (ECS) engines.

- Observe all Warnings, Cautions, and Notices within this manual.
- Replace parts with those recommended by Cummins MerCruiser Diesel. Ensure that the replacement has an identical part number as the original.
- Use only special tools as listed in the document.

IMPORTANT: Using replacement parts, service procedures, or tools not recommended by Cummins MerCruiser Diesel can compromise personal safety or engine operation.

Introduction

The following text describes proper diagnosis and service of the Cummins MerCruiser Diesel Electronic Control System (ECS) for the diesel fuel injection system with a high-pressure fuel pump and a common fuel rail (sometimes referred to as an accumulator).

All information is based on the latest product information available at the time of publication. We reserve the right to make changes without notice.

This manual and any subsequent publication provides information required to properly maintain the Cummins MerCruiser Diesel engine control system.

Service Precautions

Observe the following when working on ECS equipped engines:

- Before removing any ECM system component, disconnect the negative battery cable.
- Never start the engine without the battery cable terminal ends being solidly connected.
- Never separate the battery from the on-board electrical system while the engine is operating.
- Never separate the battery feed wire from the charging system while the engine is operating.
- When charging the battery, disconnect it from the boat's electrical system.
- Ensure that all cable harnesses are connected solidly and that battery connections are thoroughly clean.
- Never connect or disconnect the wiring harness at the ECM when the ignition is switched on.

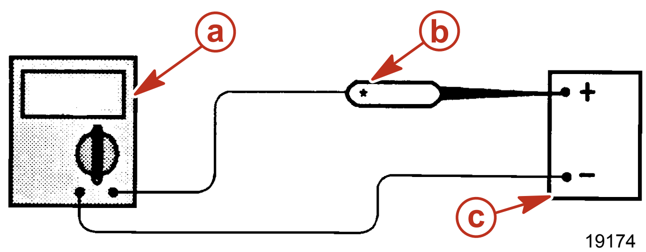
- Before attempting any electric arc welding, disconnect the battery leads, the ECM connectors, and any bonding connections between the engine and the boat.
- When steam cleaning engines, do not direct the steam cleaning nozzle at ECM system components. If this happens, corrosion of the terminals or damage of components can take place.
- Use only the test equipment specified in the diagnostic charts; other test equipment may either give incorrect results or damage good components.
- All voltage measurements using a voltmeter require a digital voltmeter with a rating of 10 mega-ohms input impedance.

ECS and Test Light Compatibility

IMPORTANT: Perform the following test to ensure that a test light is safe for use with this ECS.

When a test light is specified, a low-power test light must be used. Do not use a high-wattage test light. While a particular brand of test light is not suggested, a simple test on any test light, as shown below, will ensure it to be safe for system circuit testing.

1. Connect an accurate ammeter (such as the high impedance digital multimeter) in series with the test light and power the test light-ammeter circuit with the battery.
2. If the ammeter indicates less than 0.3 A (300 mA) current flow, the test light is safe to use.
3. If the ammeter indicates more than 0.3 A (300 mA) current flow, the test light is not safe to use.



a - Ammeter
b - Test light
c - 12 volt battery

NOTE: Using a test light with 100 mA or less rating may show a faint glow when test indicates no light.

Turn the ignition off each time a DVOM is connected to a circuit to perform voltage measurements or is disconnected.

Basic Knowledge and Tools Required

To use the information in this manual most effectively you should be familiar with wiring diagrams; the meaning of volts, ohms and amperes; and the basic theories of electricity and electrical diagnostics. System diagnosis requires specialized equipment. Become acquainted with the tools and their use before attempting to diagnose the system. Any special tools required for ECS service are listed in this manual.

Visual and Physical Inspection

IMPORTANT: A careful visual and physical inspection must be performed as part of any diagnostic procedure and may reveal a solution that eliminates the need for further diagnosis.

Inspect all wiring for proper connections, signs of burning, chafing, and pinched or cut wires.

Electrostatic Discharge Damage

Control system electronics operate at a low voltage and are susceptible to damage caused by electrostatic discharge. Less than 100 volts of static electricity can cause damage to electronic components. By comparison, it takes as much as 4,000 volts for a person to feel a static discharge.

A person can become statically charged in several ways, the most common methods are by friction and by induction. An example of charging by friction is a person sliding across a seat which can build up a charge of as much as 25,000 volts. Charging by induction occurs when a person with well-insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off, leaving the person highly charged with the opposite polarity. Static charges of either type can cause damage. Use caution when handling and testing electronic components.

Diagnostic Information

The diagnostic information and functional checks in **Section 5F** of this manual are designed to locate a faulty circuit or component through the process of elimination. The information assumes that the system functioned correctly at the time of assembly and that there are not multiple failures.

Abbreviations

BARO	Barometric Pressure
BAT	Battery Positive Terminal, Battery or System Voltage
B+	Battery Positive
CKT	Circuit
CONN	Connector
CYL	Cylinder
DEG	Degrees
DIAG	Diagnostic
DLC	Data Link Connector
DTC	Diagnostic Trouble Code
DVOM	Digital Volt Ohmmeter
ECM	Engine Control Module
ECT	Engine Coolant Temperature
EEPROM	Electronic Erasable Programmable Read Only Memory
EMI	Electromagnetic Interference
ENG	Engine
GND	Ground
GPH	Gallons Per Hour
IAT	Intake Air Temperature
in.hg	Inches Of Mercury
INJ	Injection
IGN	Ignition
kPa	Kilopascal
KV	Kilovolts
LDF	MAP or Boost Pressure Sensor
LGS	Low Idle Switch
MAP	Manifold Absolute Pressure

MIL	Malfunction Indicator Lamp
msec	Millisecond
mV	Millivolt
N/C	Normally Closed
N/O	Normally Open
PID	Packet of Informational Data
PROM	Programmable Read Only Memory
RAM	Random Access Memory
REF HI	Reference High
REF LO	Reference Low
ROM	Read Only Memory
SRC	Signal Range Check
SW	Switch
TACH	Tachometer
TERM	Terminal
TP	Throttle Position Sensor
V	Volts
VAC	Vacuum
WOT	Wide Open Throttle

Diagnostic Information

The diagnostic information and functional checks in this manual are designed to locate a faulty circuit or component through logic based on the process of elimination. The information was prepared with the requirement that the system functioned correctly at the time of assembly and that there are no multiple failures.

Abbreviations

ADF	Atmospheric Pressure Sensor
BARO	Barometric Pressure
BAT	Battery positive terminal, battery or system voltage
B+	Battery Positive
CKT	Circuit
CONN	Connector
CYL	Cylinder
DEG	Degrees
DIAG	Diagnostic
DLC	Data Link Connector
DTC	Diagnostic Trouble Code
DVOM	Digital Volt/Ohmmeter
ECM	Engine Control Module
ECT	Engine Coolant Temperature
EEPROM	Electronic Erasable Programmable Read Only Memory
EMI	Electromagnetic Interference
ENG	Engine
GND	Ground

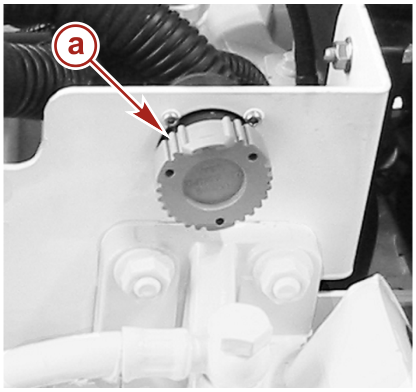
GPH	Gallons per hour
IAT	Intake Air Temperature
in. Hg.	Inches of Mercury
INJ	Injection
IGN	Ignition
kPa	Kilopascal
KV	Kilovolts
LDF	Boost Pressure Sensor (See MAP)
LGS	Low Idle Switch
MAP	Manifold Absolute Pressure
MIL	Malfunction Indicator Lamp
msec	Millisecond
NBF	Instrumented Injector
N/C	Normally Closed
N/O	Normally Open
PID	Packet of Information Data
PROM	Programmable Read Only Memory
PWG	Throttle Position Sensor
RAM	Random Access Memory
REF HI	Reference High
REF LO	Reference Low
ROM	Read Only Memory
SRC	Signal Range Check
SW	Switch
TACH	Tachometer
TERM	Terminal
TPS	Throttle Position Sensor
V	Volts
VAC	Vacuum
WOT	Wide Open Throttle

ECM Self-Diagnostics

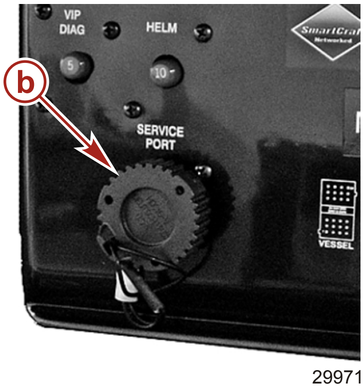
The ECM performs a continual self-diagnosis on certain control functions. This diagnostic capability is complemented by the diagnostic procedures contained in this manual. The ECM's language for communicating the source of a malfunction is a system of fault codes which can be read using the Computer Diagnostic System (CDS) tool.

Reading the Codes

Two 9-pin engine diagnostic connectors allow diagnostic equipment to communicate with the ECM. One connector is attached to a mounting plate on the ECM-side of the engine and is part of the ECS engine interface wiring harness. The second diagnostic connector is located on the front of the Vessel Interface Module (VIP).



Engine Diagnostic Connector



VIP Diagnostic Connector

a - Engine diagnostic port
b - VIP diagnostic port

Computer Diagnostic System (CDS) Tool

IMPORTANT: If using a scan tool other than CDS, follow the manufacturers instructions.

The information displayed by the CDS tool provides access to data that can not be accessed, or is difficult to obtain with other equipment. The CDS tool can isolate the location of a problem in a particular circuit speeding the diagnostic process, frequently eliminating the need to consult diagnostic flow charts and limiting the likelihood of unnecessarily replacing parts.

The CDS tool can be used to:

- Find intermittently shorted or open circuits by monitoring CDS tool data while manipulating wiring harnesses or other components with the engine off
- Check circuits and monitor data streams under operating conditions
- Observe and record various circuits over time
- Compare the operating parameters of a poorly performing engine with those of a know good engine

Clearing Codes with the CDS Tool

NOTE: Refer to the CDS manual for in-depth information concerning CDS tool usage.

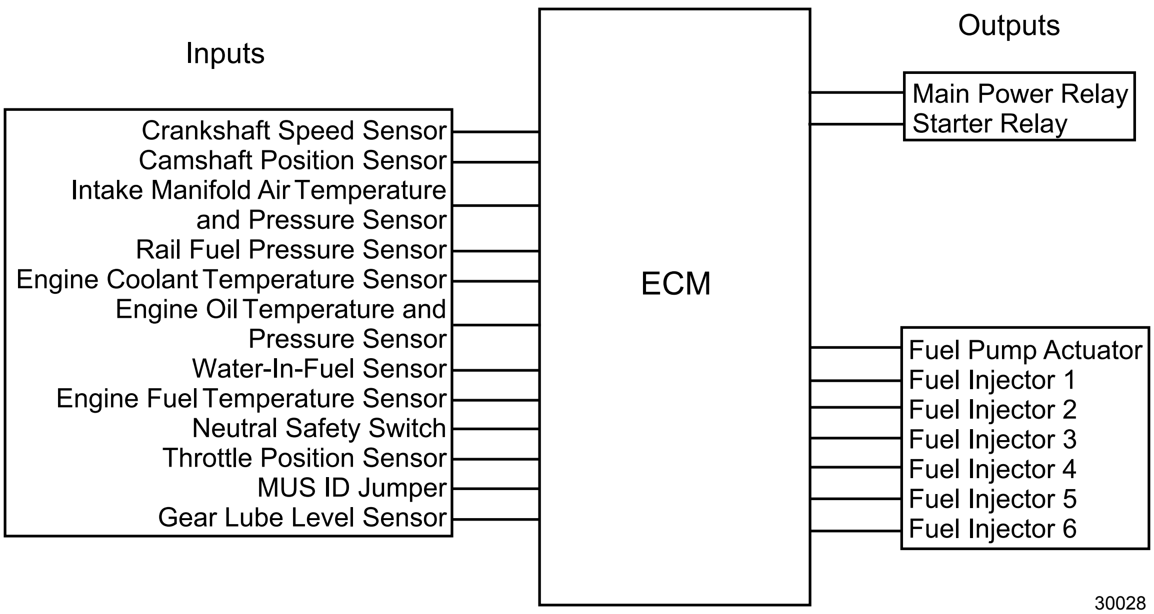
1. Turn the key on.
2. Connect to the ECM using the CDS tool.
3. Click on the **Toolbox** icon.
4. Click on the **Fault Status** icon.
5. Click on the **Freeze Frame** tab.
6. Click on the **Clear Faults** button.
7. If codes are still present, a real system fault exists. Refer to the appropriate troubleshooting and diagnostics section.

Diagnosis of Performance Concerns

If a performance concern still exists after following the troubleshooting and diagnostic circuit checks, an out-of-range sensor may be at fault. The ECM has default fail-safe sensor values to replace an out of range sensed value in the case of a sensor malfunction or a sensor wiring issue. This allows limited engine performance until the vessel is repaired. A basic understanding of sensor operation is necessary to diagnose an out-of-range sensor.

ECM Input and Sensor Diagram

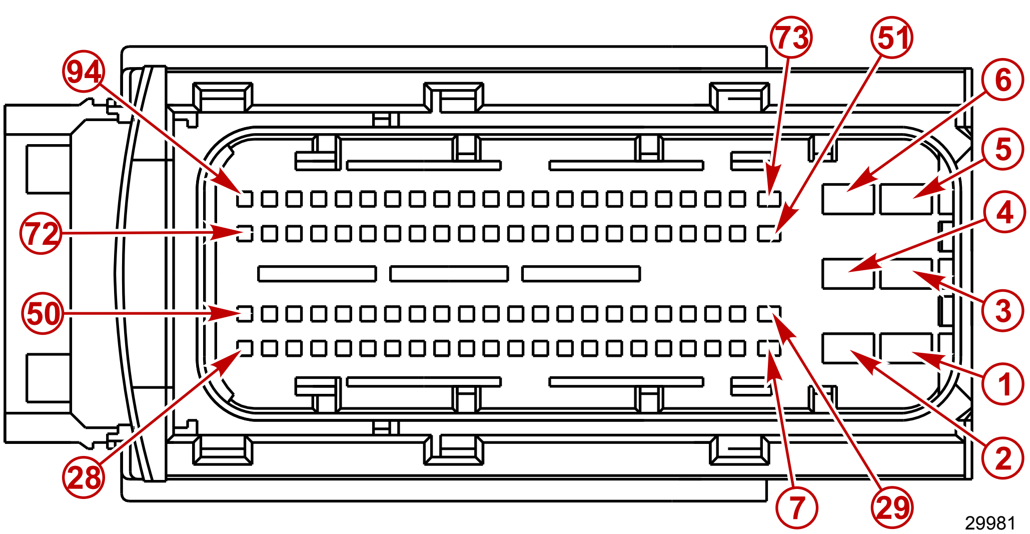
The following shows the sensors, switches, and other inputs and outputs used by the ECM to control its various systems.



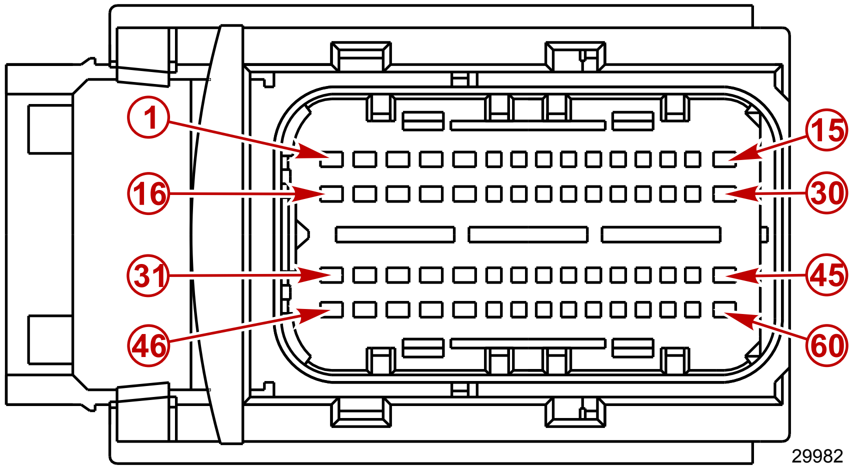
ECM input and sensor diagram

ECM Connector Pin Layout

All related wiring attaches to the ECM with one 60 pin-wiring harness connector (ECM Connector A) and one 94-pin wiring harness connector (ECM Connector K). These connectors are represented by the following diagram. The numbering orientation of the connectors is as shown. For a circuit designation, see **Connector Chart**.



ECM engine interface harness 94-pin connector K



ECM injection harness 60-pin connector A

Connector Chart

The following charts will aid in identification and diagnosis of wiring circuits that are attached to the ECM through the 60-pin connector "A" and 94-pin connector "K".

IMPORTANT: Improper probing of wires and connectors may result in damage to the electrical system. Use caution when installing or servicing electrical system components.

NOTE: Clear each code after disconnecting and reconnecting each sensor. Failure to do so may result in an incorrect diagnosis of the problem.

Injection Harness Connector A (60-Pin)

IMPORTANT: Injector reference numbers indicate the six cylinder engine injector number followed by the four cylinder engine injector number.

Position	Circuit Designation	Wire Color Abbreviation
1	Injector cylinder number 5/3 driver (6 cylinder / 4 cylinder)	LT BLU/GRY
2	Injector cylinder number 6/2 driver (6 cylinder / 4 cylinder)	ORN/BLK
3	Injector cylinder number 4/4 driver (6 cylinder / 4 cylinder)	RED/GRN
7	Crankshaft speed sensor shield	SHIELD
8	Rail fuel pressure return	BLK/PUR
11	Camshaft position sensor +5V Supply	YEL/RED
12	Crankshaft speed (–) Signal	WHT
13	Intake manifold air pressure sensor +5V Supply	WHT/ORN
16	Injector cylinder number 1/1 driver (6 cylinder / 4 cylinder)	BLU/RED
17	Injector cylinder number 3/4 driver (6 cylinder / 4 cylinder)	BRN/WHT
18	Injector cylinder number 2/2 driver (6 cylinder / 4 cylinder)	GRY/RED
19	Fuel pump actuator signal 1	BLK/PNK
20	Camshaft position sensor return	PUR
22	Engine oil temperature and pressure sensor return	BRN
23	Intake manifold air temperature and pressure sensor return	BRN/RED
25	Engine oil pressure sensor +5V supply	ORN
27	Crankshaft speed (+) signal	BRN
28	Rail fuel pressure sensor +5V supply	LT BLU
31	Injector cylinder number 6/2 return (6 cylinder / 4 cylinder)	ORN/BLU
32	Injector cylinder number 4/4 return (6 cylinder / 4 cylinder)	RED/BLK

Position	Circuit Designation	Wire Color Abbreviation
33	Injector cylinder number 3/4 return (6 cylinder / 4 cylinder)	BRN/BLK
40	Intake manifold air pressure signal	WHT/RED
41	Engine coolant temperature sensor return	GRY/GRN
43	Rail fuel pressure signal	YEL
46	Injector cylinder number 5/3 return (6 cylinder / 4 cylinder)	LT BLU/ORN
47	Injector cylinder number 1/1 return (6 cylinder / 4 cylinder)	BLU/BLK
48	Injector cylinder number 2/2 return (6 cylinder / 4 cylinder)	GRY/BLK
49	Fuel pump actuator signal 2	ORN/GRN
50	Camshaft position signal	GRY/WHT
52	Engine oil temperature signal	WHT/BLK
53	Intake manifold air temperature signal	WHT/GRN
56	Engine oil pressure signal	GRN/BLK
58	Engine coolant temperature signal	PNK

Engine Interface Harness Connector K (94-Pin)

Position	Circuit Designation	Wire Color Abbreviation
1	ECM battery (+) from main relay	RED/BRN
2	ECM battery (–)	BLK
4	ECM battery (–)	BLK
5	ECM battery (+) from main relay	RED/BLU
6	ECM battery (–)	BLK
8	Throttle position 2 return	GRN
9	Throttle position 1 signal	WHT
10	Fuel temperature sensor return	GRY/WHT
11	Fuel temperature signal	GRY/BLK
25	KWP2000 engine datalink	PUR/BLK
28	Key switch Input signal	PUR/YEL
30	Throttle position 1 return	BRN
31	Throttle position 2 signal	YEL
38	MUS ID number 1 signal	BRN/WHT
40	Neutral safety signal	PUR/WHT
45	Throttle position 1 +5V supply	PNK
46	Throttle position 2 +5V supply	GRY
55	Starter relay Hi signal	PNK/BLU
56	MUS ID number 2 signal	BRN/BLK
57	Water in fuel signal	GRY/BLU
58	Crank signal	YEL/RED
61	J1939 CAN L	GRN
62	J1939 CAN H	WHT
72	main relay enable signal	WHT/BLK
73	Starter relay Lo signal	PNK/BLK
78	MUS ID number 3 signal	BRN/GRN
83	J1939 CAN L	GRN

Position	Circuit Designation	Wire Color Abbreviation
84	J1939 CAN H	WHT
93	Not used - glow plug signal	BLU/BLK

Troubleshooting ECS System

Diagnostic Trouble Code (DTC) Readouts

The following chart will provide cross-reference information to correlate between DTCs and the associated CDS tool fault code text description.

DTC	CDS Tool Fault Code Text	See
P0016	Crankshaft / Camshaft sensor correlation	**Crankshaft Speed Sensor** or **Camshaft Speed Sensor**
P0087	Fuel rail pressure low warning	**Rail Fuel Pressure Sensor**
P0088	Fuel rail pressure higher than commanded	
P0090	Fuel rail pressure high warning	
P0091	Fuel rail pressure lower than commanded	
P0092	Fuel rail pressure data invalid	
P0110	Intake air temperature sensor voltage out of range	**Intake Air Temperature (IAT) Sensor**
P0113	Intake air temperature high warning	
P0115	Coolant temperature sensor Voltage out of range	**Engine Coolant Temperature (ECT) Sensor**
P0118	Coolant temperature high warning	
P0120	Throttle position sensor 1 voltage out of range	**Throttle Position (TP) Sensor**
P0180	Fuel temperature sensor voltage out of range	**Engine Fuel Temperature (EFT) Sensor**
P0190	Fuel rail pressure sensor voltage out of range	**Rail Fuel Pressure Sensor**
P0195	Oil temperature sensor voltage out of range	**Engine Oil Temperature (EOT) Sensor**
P0198	Oil temperature high warning	
P0201	Cylinder 1 - injector open circuit	**Injector Fault**
P0202	Cylinder 2 - injector open circuit	
P0203	Cylinder 3 - injector open circuit	
P0204	Cylinder 4 - injector open circuit	
P0205	Cylinder 5 - injector open circuit	
P0206	Cylinder 6 - injector open circuit	
P0220	Throttle position sensor 2 voltage out of range	**Throttle Position (TP) Sensor**
P0221	Throttle position sensor voltage out of sync	
P0235	Boost pressure sensor voltage out of range	**Manifold Air Pressure (MAP) Sensor**
P0238	Boost pressure high warning	
P0252	Fuel pressure solenoid open circuit	**Fuel Pressure Solenoid**
P0253	Fuel pressure solenoid shorted low	
P0254	Fuel pressure solenoid shorted high	

DTC	CDS Tool Fault Code Text	See
P0262	Cylinder 1 - injector circuit shorted	**Injector Fault**
P0265	Cylinder 2 - injector circuit shorted	
P0268	Cylinder 3 - injector circuit shorted	
P0271	Cylinder 4 - injector circuit shorted	
P0274	Cylinder 5 - injector circuit shorted	
P0277	Cylinder 6 - injector circuit shorted	
P0335	Crankshaft speed sensor data error	**Crankshaft Speed Sensor**
P0338	Engine overspeed warning	
P0340	Camshaft position sensor data error	**Camshaft Position Sensor**
P0520	Oil pressure sensor voltage out of range	**Engine Oil Pressure (EOP) Sensor**
P0522	Oil pressure critical low warning	
P0524	Oil pressure low warning	
P0560	ECM battery voltage out of range	**Battery and Main Relay**
P0606	ECM internal malfunction	**ECM Internal Error**
P0616	Starter relay low-side shorted	**Starter Circuit**
P0617	Starter relay high-side shorted	
P0641	Sensor supply 1 voltage out of range	**Camshaft Position Sensor** or **Throttle Position (TP) Sensor**
P0651	Sensor supply 2 voltage out of range	**Manifold Air Pressure (MAP) Sensor**, **Rail Fuel Pressure Sensor**, or **Throttle Position (TP) Sensor**
P0685	Main relay control timing error	**Battery and Main Relay**
P0697	Sensor supply 3 voltage out of range	**Engine Oil Pressure (EOP) Sensor**
P1605	Keyswitch signal circuit error	**Keyswitch Circuit**
P1606	Crank signal circuit error	**Starter Circuit**
P1628	ECM dataset variant coding error	**ECM Dataset Variant Coding Error**
P2148	Injector bank 1 circuit error	**Injector Fault**
P2151	Injector bank 2 circuit error	
P2226	Atmospheric pressure sensor voltage out of range	**Atmospheric Pressure (BARO) Sensor**
P2269	Water in fuel detected warning	**Water In Fuel (WIF) Sensor**
P2293	Fuel rail pressure relief valve error	**Rail Fuel Pressure Sensor** or **Fuel Rail Pressure Relief Valve**
U0101	CAN communication error	**CAN Communication Error**
U1001	No DTS CAN message or throttle lever signal present	**DTS CAN Communication Error**
U1002	DTS CAN message error (if DTS installed)	

SmartCraft Display Fault Readouts

The following chart will provide cross-reference information to correlate between SmartCraft display device reported faults and the equivalent diagnostic trouble codes they represent.

Smartcraft Display Text	DTC	CDS Tool Fault Code Text
122 Sensor Boost High	P0235	Boost pressure sensor voltage out of range
123 Sensor Boost Low		
2973 Snsr Boost InRange Error		

Smartcraft Display Text	DTC	CDS Tool Fault Code Text
124 Boost Press High	P0238	Boost pressure high warning
131 Sensor Throt High	P0120	Throttle position sensor 1 voltage out of range
132 Sensor Throt Low		
131 Sensor Throt High	P0220	Throttle position sensor 2 voltage out of range
132 Sensor Throt Low		
135 Sensor Oil Press High	P0520	Oil pressure sensor voltage out of range
141 Sensor Oil Press Low		
143 Oil Press Low	P0524	Oil pressure low warning
144 Sensor Cool T High	P0115	Coolant temperature sensor voltage out of range
145 Sensor Cool T Low		
151 Cool T High	P0118	Coolant temperature high warning
153 Sensor IMT High	P0110	Intake air temperature sensor voltage out of range
154 Sensor IMT Low		
155 IMT High	P0113	Intake air temperature high warning
212 Sensor Oil T High	P0195	Oil temperature sensor voltage out of range
213 Sensor Oil T Low		
214 Oil Temperature High	P0198	Oil temperature high warning
221 Snsr Amb Air Press High	P2226	Atmospheric pressure sensor voltage out of range
222 Snsr Amb Air Press Low		
2249 Low Fuel Press2	P0087	Fuel rail pressure low warning
234 Engine Overspeed	P0338	Engine overspeed warning
271 IMV Shorted Low	P0253	Fuel pressure solenoid shorted low
272 IMV Shorted High	P0254	Fuel pressure solenoid shorted high
322 Injector 1 Error	P0201	Cylinder 1 - injector open circuit
	P0262	Cylinder 1 - injector circuit shorted
323 Injector 5 Error	P0205	Cylinder 5 - injector open circuit
	P0274	Cylinder 5 - injector circuit shorted
324 Injector 3 Error	P0203	Cylinder 3 - injector open circuit
	P0268	Cylinder 3 - injector circuit shorted
325 Injector 6 Error	P0206	Cylinder 6 - injector open circuit
	P0277	Cylinder 6 - injector circuit shorted
331 Injector 2 Error	P0202	Cylinder 2 - injector open circuit
	P0265	Cylinder 2 - injector circuit shorted
332 Injector 4 Error	P0204	Cylinder 4 - injector open circuit
	P0271	Cylinder 4 - injector circuit shorted
415 Oil Pressure Low	P0522	Oil pressure critical low warning
418 Water In Fuel	P2269	Water in fuel detected warning
449 Fuel Press Very High	P0090	Fuel rail pressure high warning
451 Sensor Fuel P High	P0190	Fuel rail pressure sensor voltage out of range
452 Sensor Fuel P Low		
553 High Fuel Pressure	P0088	Fuel rail pressure higher than commanded
554 Fuel Pressure InRange Error	P0092	Fuel rail pressure data Invalid
559 Low Fuel Pressure	P0091	Fuel rail pressure lower than commanded

Smartcraft Display Text	DTC	CDS Tool Fault Code Text
115 Main EPS Error	P0335	Crankshaft speed sensor data error
689 Main/Crank EPS Error		
121 Bkup/Cam EPS Error	P0340	Camshaft position sensor data error
778 Bkup/Cam EPS Error		
ECM Hi Battery Volts	P0560	ECM battery voltage out of range
ECM Lo Battery Volts		

Preliminary Checks

Before using the troubleshooting charts:

- Ensure that the ECM is operating properly.
- Verify that there are no diagnostic trouble codes stored.

Visual and Physical Check

Several of the symptom or condition lists call for careful visual and physical checks. These checks are importance can and save valuable time. Check that:

- All electrical terminals and connectors are clean, tight, free from corrosion, and in the proper location
- All fuel lines and hoses are properly connected and inspect for leaks and restriction
- There are no intake manifold leaks
- The engine is in good mechanical condition

Intermittent Problems

An intermittent problem is a problem that occurs randomly. An intermittent problem may, or may not, store a diagnostic trouble code (DTC). Do not use the diagnostic trouble code charts for intermittent problems unless instructed to do so. Incorrect diagnosis may result in the replacement of good parts.

Most intermittent problems are caused by faulty electrical connections or wiring. Carefully check the suspected circuits for the following problems:

- Poor mating of the connector halves or terminals that are not fully seated in the connector body.
- Improperly formed or damaged terminals and or connectors. All connector terminals and connectors in problem circuit should be carefully reformed or replaced to insure proper contact tension.
- Poor terminal to wire connection (crimping).

The following conditions may also cause an intermittent problem:

- Electrical system interference caused by a sharp electrical surge. Normally, the problem will occur when the faulty component is operated.
- Improper installation of electrical options, such as lights, ship to shore radios, sonar, and so on.
- Improperly routed wires. Wires should be routed away from charging system components.
- An electrical arc at part of internal circuitry shorted to ground such as in starters, relays and alternators.

If visual and physical checks do not find the cause of the problem, test the ECS system with a voltmeter or a scan tool while observing the suspected circuit. An abnormal reading when the problem occurs indicates the problem may be in that circuit.

Symptoms

When troubleshooting a customer complaint based on a symptom or condition, do the following:

- Verify the customer complaint.
- Locate the correct symptom under the condition column in the **Troubleshooting Charts**.
- Check the list of possible causes and corrections under that symptom or condition.

Troubleshooting Charts

Engine Will Not Crank or Cranks Slowly

IMPORTANT: **Check for active fault codes at the beginning of any diagnostic process.**

Condition	Possible Causes	Correction
Engine will not crank or cranks slowly	Starter motor operating, but not cranking the engine	Remove the starter motor. Check for broken flywheel teeth or broken starter motor spring.
	Crankshaft rotation restricted	Rotate the engine to check for rotational resistance.
	Starting circuit connections loose or corroded	Clean and tighten connections. Reapply liquid neoprene, when required.
	Neutral safety switch or starter relay inoperative	Check starter relay supply voltage and proper operation of the neutral safety switch (if equipped). Replace defective parts.
	Battery charge low	Check battery voltage. Replace battery if a charge cannot be held.
	No voltage to starter solenoid	Check voltage to the solenoid. If necessary, replace the solenoid.
	Solenoid or starter motor inoperative	Replace starter motor.

Engine Cranks but Will Not Start

IMPORTANT: **Check for active fault codes at the beginning of any diagnostic process.**

NOTE: The SmartStart feature ends the start cycle after three seconds if no crankshaft speed is reported to the ECM or if engine RPM does not exceed 500 RPM within five seconds of the initiation of a start cycle.

Condition	Possible Causes	Correction
Engine cranks but will not start. No smoke.	No fuel in supply tank	Add fuel.
	Air intake or exhaust plugged	Remove the obstruction.
	Fuel filter plugged	Drain fuel and water separator and replace fuel filter.
	Excessive fuel inlet restriction	Check fuel inlet restriction. Correct cause.
	High pressure fuel pump not getting fuel or fuel is aerated	Check fuel flow and flow and bleed fuel system.
	One or more injectors worn or not operating properly	Check and replace bad or improperly operating injectors.
	Worn or inoperative injection pump	Visually check delivery with externally connected injector to one of the pump outlets. Repair or replace as needed after testing, if fuel is not being delivered.
	Incorrect camshaft timing	Check and correct gear train timing alignment.
	Open lanyard or E-stop circuit	Correct switch position or short in circuit.
	Fuel pump fuel pressure solenoid not responding	Correct wiring defect or replace solenoid as needed.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Engine Hard to Start or Will Not Start

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Engine hard to start or will not start. Smoke from exhaust.	Incorrect starting procedure	The fuel shut-off solenoid control must be in the run position. Ensure that the proper procedure is being used.
	Cranking speed too slow	Verify that the drive or transmission is not engaged.
		Check the battery and starter motor and look for loose or corroded wiring connections.
	Insufficient intake air	Inspect or replace the filter and check for any obstruction to the air supply.
	Air in the fuel system or the fuel supply is inadequate	Check the flow through the filter and bleed the system. Locate and eliminate the air source.
	TP sensor, throttle cable, or both, are loose or damaged	Scan and visually inspect the TP sensor, throttle cable and mounting. Adjust or replace, if necessary.
	Contaminated fuel	Verify by operating the engine with clean fuel from a temporary tank. Check for presence of gasoline. Drain and flush supply tank. Replace the water-separating fuel filter.
	Fuel screen plugged	Check fuel screen.
	One or more injectors plugged or not operating properly	Check and replace improperly operating injectors.
	Malfunctioning, worn, or inoperative injection pump	Scan, repair, or replace components as needed.
	Fuel injectors out of time	Check injector feedback data and wiring.
	Engine compression low	Check compression to identify the problem.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Rough Idle (Irregularly Firing or Engine Shaking)

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Rough idle (irregularly firing or engine shaking)	Idle speed, fuel quantity, or both, too low for the accessories	Adjust the idle speed.
	Engine mounts damaged or loose	Repair or replace the mounts.
	High pressure fuel leaks	Correct leaks in the high-pressure lines, fittings, or delivery valves.
	Air in the fuel system	Bleed the fuel system and eliminate the source of the air.
	Sticking needle valve in an injector	Check and replace the injector with the sticking needle valve.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Engine Operates Rough

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Engine operates rough	Fuel injection lines leaking	Correct leaks in the high-pressure lines, fittings, injector sealing washers or delivery valves.
	Air in the fuel or fuel supply is inadequate	Check the flow through the fuel filter and bleed the system. Locate and eliminate the air source.
	Contaminated fuel	Verify by operating the engine with clean fuel from a temporary tank. Check for presence of gasoline. Drain and flush supply tank. Replace the water separating fuel filter.
	Incorrect valve operation	Check for a bent push-rod or damaged roller lifter. Replace parts if necessary.
	Improperly operating injectors	Replace defective injectors.
	Defective high pressure fuel pump (fuel quantity or solenoid valve)	Scan, repair, or replace injection pump.
	Camshaft out of time	Check and correct gear train timing alignment.
	Damaged camshaft or tappets	Inspect camshaft valve lift. Replace camshaft and tappets.
	Automatic timing advance not operating	Check injection pump and instrumented injector at number 1 cylinder.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Engine Starts, But Will Not Keep Operating.

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Engine starts, but will not keep operating.	Low fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.
	Idle speed or fuel quantity too low for accessories	Adjust the idle speed.
	Intake air or exhaust system restricted	Visually check for exhaust restriction and inspect the air intake. Repair or replace the defective parts.
	Air in the fuel or fuel supply is inadequate	Check the flow through the fuel filter and bleed the system. Locate and eliminate the air source.
	Fuel waxing due to extremely cold weather	Verify by inspecting the fuel filter. Clean the system and use the proper seasonal blend of fuel. Replace water-separating fuel filter. Check fuel filter for proper operation, if equipped.
	Contaminated fuel	Verify by operating the engine with clean fuel from a temporary tank. Check for presence of gasoline. Drain and flush supply tank. Replace water-separating fuel filter.

Surging (Speed Change)

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Surging (speed change)	If the condition occurs at idle, the idle speed is set too low for accessories	Adjust the idle speed.
	High-pressure fuel leak	Inspect and correct leaks in the high-pressure lines, fittings, and delivery valve sealing washers.
	One or more injectors worn or not operating properly	Check and replace the inoperative injector.
	Improperly operating injection pump	Replace the injection pump.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Engine RPM Will Not Reach Rated Speed.

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Engine RPM will not reach rated speed.	Engine overload	Verify high idle speed without load. Investigate operation to ensure correct gear and propeller are being used.
	Improperly operating tachometer	Verify engine speed with a hand tachometer. Correct as required.
	Throttle linkage worn or incorrectly adjusted	Adjust linkage for stop to stop fuel lever travel. Replace linkage if necessary.
	Inadequate fuel supply	Check the fuel flow through the system to locate the reason for inadequate fuel supply. Correct as required.
	Air and fuel controls leak	Check and repair leak. Check AFC tubing for obstruction.
	Improperly operating high pressure fuel pump	Repair or replace injection pump.
	Incorrect ECM part number	Ensure ECM part number is correct for your model; some de-rated ECMs are for dual installations in emission regulated countries.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Low Power

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Low power	Throttle cable not moving to full throttle	Check and correct for stop-to-stop travel.
	High oil level	Check and correct oil level.
	Engine overloaded	Check for added loading from accessories or driven units, brakes dragging, and other changes in vehicle loading. Repair or replace as needed.
	Slow throttle response caused by leaking or obstructed air control tube or improperly operating injection pump	Check for leaks and obstructions. Tighten the fittings. Repair or replace the pump if scan or check determines the pump is not functioning.
	Inadequate intake air flow	Inspect or replace air cleaner element. Look for other restrictions.
	Inadequate fuel supply. Air in the fuel.	Check the flow through the filter to locate the source of the restriction. Check fuel pressure and inlet restriction.
	Excessive exhaust restriction	Check and correct the restriction in the exhaust system.
	High fuel temperature	Verify that the fuel heater, if equipped, is off when the engine is warm. Check for restricted fuel return lines. Repair or replace as needed.
	Poor quality fuel or fuel contaminated with gasoline	Verify by operating with a temporary tank with good fuel. Check for presence of gasoline. Replace water separating fuel filter.
	Air leak between the turbocharger and aftercooler	Check and correct leaks in hoses, gaskets, aftercooler, and around mounting cap screws or through holes in the cooler and end caps.
	Exhaust leak at the manifold and turbocharger	Check and correct leaks in the manifold or turbocharger gaskets. If the manifold is cracked, replace the manifold.
	Improperly operating turbocharger	Inspect or replace turbocharger.
	Wastegate operation	Check wastegate operation.
	Valve not operating	Check for bent push-rod or faulty hydraulic lifter. Replace if necessary.
	Worn or improperly operating injectors	Check or replace injectors.
	Improperly operating high pressure fuel pump	Repair or replace injection pump.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Excessive Exhaust Smoke

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Excessive exhaust smoke	Engine operating too cold (white smoke)	Refer to troubleshooting for coolant temperature below normal (See Cooling System). Inspect glow plugs for proper operation.
	Improper starting procedure (white smoke)	Use proper starting procedures.
	Fuel supply inadequate	Check fuel supply pressure and inlet restriction.
	Injection pump timing	Scan or check pump timing.
	Inadequate air intake	Inspect or change air filter. Look for other restriction. Check charge air cooler for obstructions.
	Air leak between turbocharger and intake manifold	Check and correct air leaks in the air crossover tube, hoses, gaskets, mounting cap screws or through holes in the manifold cover.
	Exhaust leak at the manifold or turbocharger	Check and correct leaks in the manifold or turbocharger gaskets. Replace component if a crack is found.
	Improperly operating turbocharger	Inspect or replace turbocharger.
	Improperly operating injectors	Check and replace any defective injectors.
	Improperly operating or over fueled injector pump	Repair or replace injection pump.
	Piston rings not sealing (blue smoke)	Perform compression and blow-by check. Correct as required.
	Incorrect fuel rail fuel pressure	Check fuel rail pressure sensor and relief valve operation.

Engine Will Not Shut Off

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Engine will not shut off	Engine operating on fumes drawn into the air intake	Check the air intake ducts for the source of the fumes.
	Fuel injection pump or fuel shut-off valve malfunction	Repair or replace the fuel injection pump.

Coolant Temperature Above Normal

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Coolant temperature above normal	Low coolant level	Check coolant level. Add coolant, if necessary. Locate and correct the source of the coolant loss. (See **Closed Cooling System**).
	Incorrect or improperly operating pressure cap	Replace the cap with the correct rating for the system.
	Loose drive belt on the water pump	Check or replace belt or belt tensioner .
	Improperly operating temperature sensor or gauge	Verify that the the gauge and temperature sensor are accurate. Replace the gauge or sensor if either is defective.
	Obstructed or restricted seawater pump inlet	Remove the obstruction or restriction.
	Improperly operating thermostat. Incorrect or no thermostat	Check and replace thermostat.
	Air in the cooling system	Ensure that the fill rate is not being exceeded and that the correct vented thermostat is installed.
		Check for loose hose clamps. Tighten if loose.
		If aeration continues, check for a compression leak through the head gasket.
	Inoperative water pump	Check and replace the water pump.
	Incorrect injection pump timing	Verify that the pump timing marks are aligned. Check and, if necessary, time the injection pump. See **Fuel System**.
	Over-fueled injection pump	Repair or replace the injection pump.
	Plugged cooling passages in the coolers, heat exchanger, cylinder head, head gasket, or engine block	Flush the cooling system and refill with clean coolant.
	Engine overloaded	Verify that the engine load rating is not being exceeded.

Coolant Temperature Below Normal

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Coolant temperature below normal	Incorrect thermostat or contamination in the thermostat	Check and replace the thermostat.
	Temperature sensor or gauge inoperative	Verify that the gauge and sensor are accurate. If not, replace the gauge or sensor.
	Coolant not flowing by the temperature sensor	Check and clean the coolant passages.

Lubricating Oil Pressure Low

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Lubricating oil pressure low	Low oil level	Check and fill with clean engine oil.
		Check for a severe external oil leak that could reduce pressure.
	Oil viscosity thin, diluted, or incorrect specification	Verify that the correct oil is being used. Check for oil dilution. See Engine Mechanical).
	Improperly operating pressure switch or gauge	Verify that the pressure switch is functioning properly. Replace the gauge or pressure switch as required.
	Relief valve stuck open	Check or replace the valve.
	Plugged oil filter	Change the oil filter. Oil filter change interval may need to be revised.
	If cooler was replaced, shipping plugs remain in the cooler	Check and remove the shipping plugs.
	Worn oil pump	Check and replace the oil pump.
	Suction tube loose or tube seal leaking	Check and replace the seal.
	Loose main bearing cap	Check and install new main bearing and tighten main bearing cap to specification.
	Worn bearings or incorrect bearings installed	Inspect and replace main bearings or connecting rod bearings. Check and replace the piston cooling nozzles.
	Oil jet under the piston is a bad fit into the main carrier	Check oil jet position.

Lubricating Oil Pressure Too High

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Lubricating oil pressure too high	Pressure switch or gauge not operating properly	Verify that the pressure switch is functioning properly. If not, replace the switch or gauge, or both.
	Engine operating too cold	See "Coolant Temperature Below Normal" troubleshooting chart.
	Oil viscosity too thick	Make sure that the correct oil is being used. See **Maintenance**.
	Oil pressure relief valve stuck closed or binding	Check and replace the relief valve.

Lubricating Oil Loss

Condition	Possible Causes	Correction
Lubricating oil loss	External leaks	Visually inspect for oil leaks. Repair as required.
	Crankcase overfilled	Verify that the correct dipstick and/or the correctly marked dipstick is being used.
	Incorrect oil specification or viscosity	Ensure that the correct oil is being used.
		Look for reduced viscosity resulting from dilution by fuel.
		Review and reduce the interval between oil changes.
	Oil cooler leak	Check and replace the oil cooler.
	High blow-by forcing oil out through the breather	Check the breather tube area for signs of oil loss. Repair as required.
	Turbocharger leaking oil into the air intake	Inspect aftercooler for evidence of oil transfer. Repair as required.
	Piston rings not sealing; Oil being consumed by the engine	Perform compression check. Repair as required.

Compression Knocks

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Compression knocks	Air in the fuel system	Bleed the fuel system.
	Poor quality fuel or contaminated fuel (water or gasoline in fuel)	Verify by operating from a temporary tank with good fuel. Clean and flush the fuel supply tanks. Replace the water separating fuel filter.
	Engine overloaded	Verify that the engine load rating is not being exceeded.
	Incorrect injection pump timing	Scan and check the injection pump timing.
	Improperly operating injectors	Check and replace the inoperative injectors.

Excessive Vibration

Condition	Possible Causes	Correction
Excessive vibration	Loose or broken engine mounts	Replace engine mounts.
	Damaged or improperly operating accessories	Check and repair or replace the vibrating accessory.
	Improperly operating vibration damper	Inspect and replace the vibration damper.
	Worn or damaged alternator bearing	Check and, if necessary, replace the alternator.
	Flywheel housing misaligned	Check and correct the flywheel housing alignment.
	Loose or broken power component	Inspect the crankshaft and connecting rods for damage that causes an imbalance. Repair or replace as required.
	Worn or unbalanced drive line components	Check and repair drive line components.

Excessive Engine Noise

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Excessive engine noise	Drive belt squeal from insufficient tension or abnormally high loading	Inspect the drive belt and check the drive belt tension.
	Intake air or exhaust leaks	See **Excessive Exhaust Smoke** (Engine Diagnosis-Performance).
	Excessive valve lash	Ensure that the push rods are not bent and that the rocker levers are not severely worn. Replace as necessary.
	Turbocharger noise	Check turbocharger impeller and turbine wheel for housing contact. Repair or replace as required.
	Gear train noise	Visually inspect and measure the gear backlash. Replace gears as required.
	Power function knock	Check and replace, if necessary, main and connecting rod bearings.

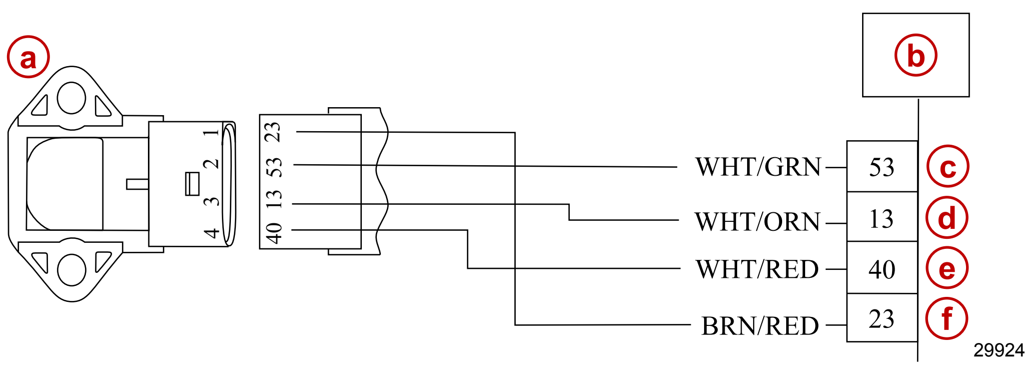
Alternator Not Charging or Insufficient Charging

IMPORTANT: Check for active fault codes at the beginning of any diagnostic process.

Condition	Possible Causes	Correction
Alternator not charging or insufficient charging	Loose or corroded battery terminals	Clean and tighten battery cable connections.
	Alternator belt slipping	Check and replace and/or adjust the alternator belt.
	Alternator pulley loose on the shaft	Tighten the alternator pulley.
	Improperly operating alternator	Check and, if necessary, replace alternator.

Manifold Air Pressure Sensor

Manifold Air Pressure (MAP) Sensor



a - MAP and IAT sensor assembly
b - ECM 60-pin connector "A"
c - IAT signal
d - 5-volt reference signal
e - MAP signal
f - Sensor ground

Circuit Description

The MAP sensor and Intake Air Temperature (IAT) sensor form an assembly. The MAP sensor portion of this assembly is a pressure transducer that measures changes in the intake manifold pressure. The pressure changes as a result of engine load and speed change, and the MAP sensor converts this to a voltage output signal.

NOTE: *This component may be referred to as a boost pressure sensor due to the presence of a turbocharger.*

The ECM sends a 5 volt reference signal to the MAP sensor. As the manifold pressure changes, the electrical resistance of the MAP sensor also changes. By monitoring the sensor output voltage, the ECM knows the manifold pressure. A higher pressure, low vacuum (high voltage) requires more fuel, while a lower pressure, higher vacuum (low voltage) requires less fuel. The ECM uses the MAP sensor to control fuel delivery and injection.

A faulty MAP sensor circuit can generate the following diagnostic trouble codes.

<table>
<tr><th>DTC</th><th>Reason</th><th>Effect</th><th colspan="2">Condition</th></tr>
<tr><td>P0235</td><td>Boost pressure sensor voltage out of range. The MAP sensor output voltage is above the upper limit or below the lower limit or there is an implausibility with the barometric pressure sensor.</td><td>No effect on the engine.</td><td colspan="2">>4848.48 mV
<337.2 mV
difference between atmospheric sensor >150 hPa</td></tr>
<tr><td rowspan="3">P0238</td><td rowspan="3">High boost pressure warning. Intake manifold pressure signal indicates the intake manifold pressure has exceeded the maximum limit for the given engine rating.</td><td rowspan="3">The engine torque limitation will limit the engine speed to 3600 RPM.</td><td>MR504</td><td rowspan="2">>3300 hPa</td></tr>
<tr><td>MR704</td></tr>
<tr><td>MR706</td><td>>3400 hPa</td></tr>
<tr><td>P0651</td><td>Sensor supply 2 voltage out of range. The sensor supply 2 circuit output voltage is above the upper limit or below the lower limit. This circuit supplies power to the throttle position 2 sensor, the fuel rail pressure sensor, and the boost pressure sensor.</td><td>The engine fuel quantity limitation will limit the engine speed to 3000 RPM.</td><td colspan="2">>5.2 V
<4.8 V</td></tr>
</table>

ECM 60-Pin Connector "A" CKT pin	Name
40	MAP signal
13	5-volt reference signal
23	Sensor ground (–)

Test Description

Verify continuity between the following pins:

ECM 60-Pin Connector "A"	4-terminal connector at MAP
40	4
13	3
23	1

Verify the sensor voltage on pin 40 of the ECM 60-pin connector "A" or on pin 4 of the MAP sensor as a function of pressure.

Pressure (mm Hg)	Pressure (Hg)	Pressure (PSI)	Voltage (VDC)
0	0	0	0.09–0.10
381	15	7	0.83–0.91
635	25	12	1.31–1.45
1549	61	30	3.07–3.39
2057	81	40	4.04–4.47

Diagnostic Help

Check for the following:

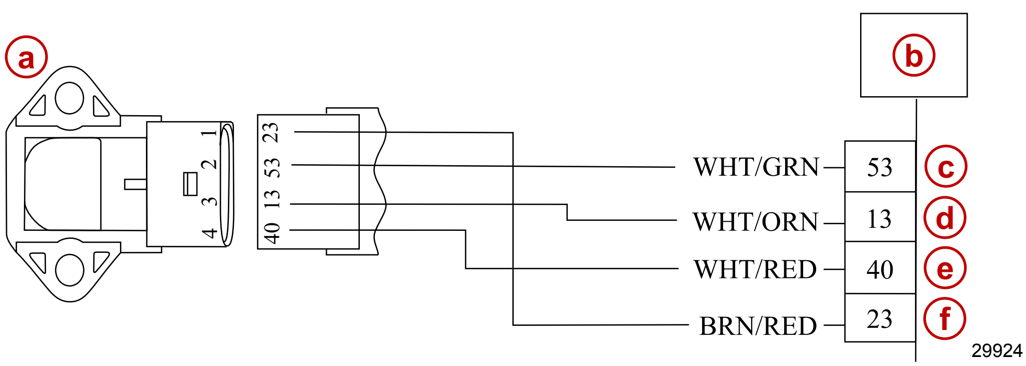
- Open or shorted circuits in pins 40, 13, or 23 (causes a low amount of smoke)
- Loose sensor assembly or a damaged O-ring seal (causes a high amount of smoke)
- A terminal or pin at the MAP connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals a cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective MAP sensor
- A defective ECM

IMPORTANT: Replace the O-ring seal whenever removing the MAP and IAT sensor. Tighten the sensor to specification.

Description	Nm	lb. in.	lb. ft.
Intake manifold pressure sensor screw	3.3	29	–

Intake Air Temperature Sensor

IAT (Intake Air Temperature) Sensor



a - MAP and IAT sensor assembly
b - ECM 60-pin connector "A"
c - IAT signal
d - 5-volt reference signal
e - MAP signal
f - Sensor ground

Circuit Description

The IAT sensor and MAP sensor form an assembly. The IAT portion of the assembly is a thermistor (a resistor that changes value based on temperature). Low temperature produces a high resistance, while high temperature causes a low resistance. The ECM supplies a 5-volt signal to the sensor through a resistor in the ECM and measures the voltage divider output. The ECM monitors the voltage on the signal pin and converts this to a temperature value. The ECM voltage will be high when the intake air is cold and low when the intake manifold air is hot.

A faulty IAT sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0110	Intake air temperature sensor voltage out of range. The intake manifold air temperature sensor output voltage is above the upper limit or below the lower limit.	No effect on the engine.	>4941.35 mV <166.18 mV
P0113	High intake air temperature warning. Intake air temperature signal indicates the intake manifold air temperature is above the engine protection critical limit.		>95° C

ECM 60-Pin Connector "A" CKT pin	Name
23	Sensor ground
53	IAT signal

Test Description

Verify continuity between the following pins:

ECM 60-Pin Connector "A"	4-terminal connector at IAT
23	1
53	2

Verify the sensor resistance between the two IAT sensor terminals as a function of temperature:

NOTE: *Stabilization time before each measurement in the test medium is a minimum of 10 minutes.*

Temperature °C (°F)	Resistance (kOhm)
–10 (14)	8.95–9.90
0 (32)	5.61–6.17
20 (68)	2.40–2.62
40 (104)	1.15–1.25
70 (158)	0.431–0.462

Diagnostic Help

Check for the following:

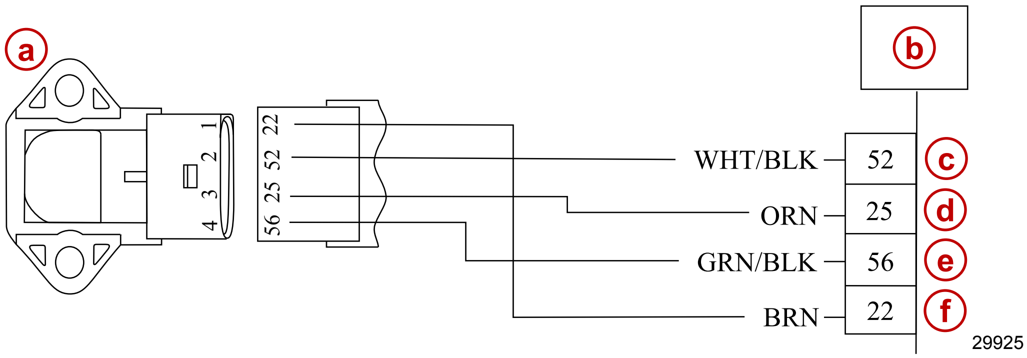
- An open circuit or a short circuit in CKT pins 23 or 53
- A terminal or pin at the IAT connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins

- A defective IAT sensor
- A defective ECM

IMPORTANT: Replace the O-ring seal whenever removing the IAT and MAP sensor. Tighten the sensor to specification.

Description	Nm	lb. in.	lb. ft.
Intake manifold air temperature sensor screw	3.3	29	–

Engine Oil Pressure Sensor



a - EOP and EOT sensor assembly
b - ECM 60-pin connector "A"
c - EOT signal
d - 5-volt reference signal
e - EOP signal
f - Sensor ground

Circuit Description

The Engine Oil Pressure sensor (EOP) and the Engine Oil Temperature (EOT) sensor form an assembly. The EOP sensor portion of this assembly is a pressure transducer that measures the changes in the engine oil pressure. The pressure changes as a result of engine load and speed change, and the EOP sensor converts this to a voltage output signal.

The ECM sends a 5 volt reference signal to the EOP sensor. Changes in the engine oil pressure change the resistance of the EOP sensor. By monitoring the sensor output voltage, the ECM knows the engine oil pressure. A higher pressure results in a higher voltage while a lower pressure results in a lower voltage. The ECM uses the EOP sensor to monitor engine protection limits.

A faulty EOP sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0520	Oil pressure sensor voltage out of range. The engine oil pressure sensor output voltage is above the upper limit or below the lower limit.	No effect on the engine.	>4838.7 mV <254.1 mV
P0522	Critical low oil pressure warning. Engine oil pressure signal indicates engine oil pressure is well below engine protection limit.	The engine torque limitation will limit the engine speed to 3600 RPM.	<180 kPa
P0524	Low oil pressure warning. Engine oil pressure signal indicates engine oil pressure is below engine protection limit.		<210 kPa
P0697	Sensor supply 3 voltage out of range. The sensor supply 3 circuit output voltage is above the upper limit or below the lower limit. This circuit supplies power to the oil pressure sensor.		>5.2 V <4.8 V

ECM 60-Pin Connector "A" CKT pin	Name
56	EOP signal
25	5-volt reference signal
22	Sensor ground (–)

Test Description

Verify continuity between the following pins:

ECM 60-Pin Connector "A"	4-terminal connector at EOP
56	4
25	3
22	1

Verify the sensor supply voltage between terminals 1 and 3 of the sensor connector on the engine harness with the sensor disconnected and the keyswitch on:

Voltage (V)	Measurement
5	4.75–5.25

Verify the sensor voltage on pin 56 of the ECM 60-pin connector "A" or on pin 4 of the MAP sensor as a function of pressure.

Pressure kPa (PSI)	Voltage (VDC)
101 (15)	0.68–0.75
274 (40)	1.37–1.52
446 (65)	2.06–2.28
584 (85)	2.61–2.89
722 (105)	3.16–3.50
860 (125)	3.71–4.11
1000 (145)	4.27–4.73

Diagnostic Help

Check for the following:

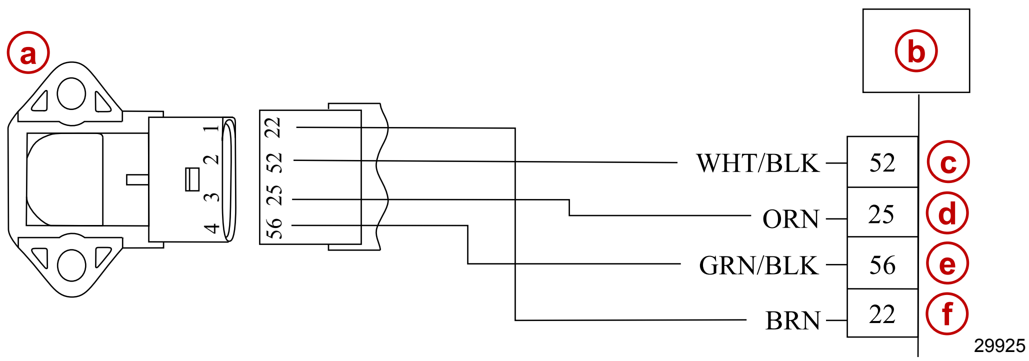
- An open circuit or a short circuit in CKT pins 56, 25, or 52

- A loose assembly on the oil pressure mounting location on the block or a damaged O-ring seal will cause an improper signal
- A terminal or pin at the MAP connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective EOP sensor
- A defective ECM

IMPORTANT: Replace the O-ring seal whenever removing the EOP and EOT sensor. Torque the sensor to specification when replacing.

Description	Nm	lb. in.	lb. ft.
Engine oil pressure sensor screw	11.5	102	–

Engine Oil Temperature Sensor



a - EOP and EOT sensor assembly
b - ECM 60-pin connector "A"
c - EOT signal
d - 5-volt reference signal
e - EOP signal
f - Sensor ground

Circuit Description

The Engine Oil Temperature (EOT) sensor and the Engine Oil Pressure (EOP) sensor form an assembly. The EOT portion of the assembly is a thermistor (a resistor that changes value based on temperature). Low temperature produces a high resistance, while high temperature causes a low resistance. The ECM supplies a 5 volt signal to the sensor through a resistor in the ECM and measures the voltage divider output.

The ECM monitors the voltage on the signal pin and converts this to a temperature value. The ECM voltage will be high when the engine oil is cold and low when the engine oil is hot. A faulty EOT sensor circuit can generate the following diagnostic trouble codes:

DTC	Reason	Effect	Condition
P0195	Oil temperature sensor voltage out of range. The engine oil temperature signal output voltage is above the upper limit, below the lower limit, or there is an implausibility with the coolant temperature sensor.	No effect on the engine.	>4799.609 mV <141.74 mV
P0198	High oil temperature warning. Engine oil temperature signal indicates the engine oil temperature is above the engine protection critical limit.	The engine torque limitation will limit the engine speed to 3600 RPM.	>120° C

ECM 60-Pin Connector "A" CKT pin	Name
22	Sensor ground
52	EOT signal

Test Description

Verify continuity between the following pins:

ECM 60-Pin Connector "A"	4-terminal connector at EOT
22	1
52	2

Verify the sensor resistance between the two EOT sensor terminals as a function of temperature:

NOTE: *Stabilization time before each measurement in the test medium is a minimum of 10 minutes.*

Temperature °C (°F)	Resistance (kOhm)
0 (32)	5.670–6.120
25 (77)	1.990–2.120
50 (122)	0.811–0.857
75 (167)	0.365–0.383
100 (212)	0.183–0.190

Diagnostic Help

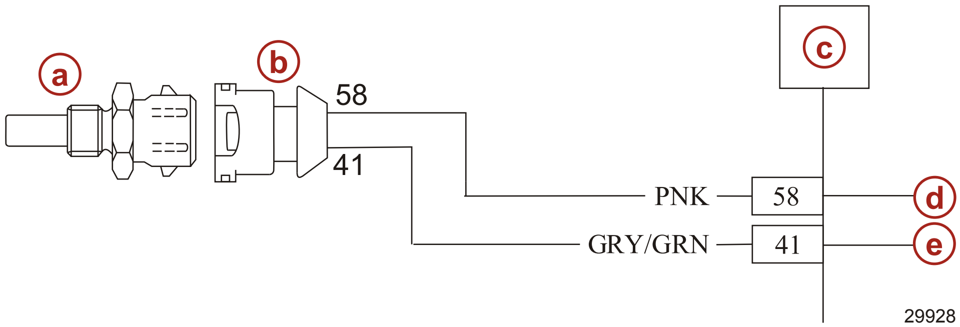
Check for the following:

- An open circuit or a short circuit in CKT pins 22 or 52
- A terminal or pin at the EOT connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective EOT sensor
- A defective ECM

IMPORTANT: Replace the O-ring seal whenever removing the EOP and EOT sensor. Torque the sensor to specification when replacing.

Description	Nm	lb. in.	lb. ft.
Engine oil temperature sensor screw	11.5	102	–

Engine Coolant Temperature Sensor



a - ECT sensor
b - ECT connector
c - ECM 60-pin connector "A"
d - 5-volt reference signal
e - Sensor return signal

Circuit Description

The engine coolant temperature (ECT) sensor is a thermistor (a resistor that changes value based on temperature) immersed in the engine coolant stream. Low coolant temperature produces a high resistance, while high temperature causes low resistance. The ECM supplies a 5 volt signal to the ECT through a resistor in the ECM and measures the voltage divider output. The voltage is high when the engine is cold and low when the engine is hot. The ECM monitors the voltage on the signal pin and converts this to a temperature value. The engine coolant temperature value is used by the ECM for the engine protection system and engine emissions control.

A faulty ECT sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0115	Coolant temperature sensor voltage out of range. The engine coolant temperature sensor output voltage is above the upper limit, below the lower limit, or there is an implausibility with the oil temperature sensor.	The setting of this DTC has no effect on engine operation.	>4960.89 mV <205.279 mV
P0118	High coolant temperature warning. The engine coolant temperature signal indicates the engine coolant temperature is above the engine protection critical limit.	The engine torque limitation will limit the engine speed to 3600 RPM.	>105° C

ECM 60-Pin Connector "A" CKT pin	Name
58	Engine Coolant Temperature Sensor (ECT) signal
41	Sensor ground (–)

Test Description

Verify continuity between the following pins:

ECM 60-Pin Connector "A"	2-terminal connector at ECT
58	1
41	2

Verify the sensor resistance between the ECT signal and ground terminals as a function of temperature. Check the sensor resistance falls within the range shown in the following table.

NOTE: Stabilization time before each measurement in the test medium is a minimum of 10 minutes.

Temperature °C (°F)	Resistance (kOhm)
0 (32)	5.470–6.330
25 (77)	1.940–2.170
60 (140)	0.573–0.618
80 (176)	0.313–0.332
100 (212)	0.182–0.191

Diagnostic Help

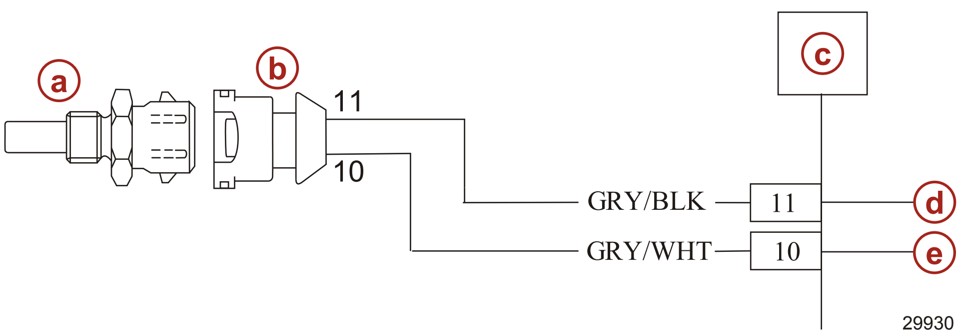
Check for the following:

- An open circuit or a short circuit in CKT pins 58 or 41
- A terminal or pin at the ECT connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective ECT sensor
- A defective ECM

IMPORTANT: Torque the ECT sensor to specification when replacing.

Description	Nm	lb. in.	lb. ft.
Coolant temperature sensor	22	195	–

Engine Fuel Temperature Sensor



a - EFT sensor
b - EFT connector
c - ECM 94-pin connector "K"
d - 5-volt reference signal
e - Sensor return signal

Circuit Description

The engine fuel temperature (EFT) sensor is a thermistor (a resistor that changes value based on temperature). Low temperature produces a high resistance, while high temperature causes a low resistance. The ECM supplies a 5 volt signal to the sensor through a resistor in the ECM and measures the voltage divider output. The ECM monitors the voltage on the signal pin and converts this to a temperature value. The ECM voltage will be high when the fuel temperature is cold and low when the fuel temperature is hot. The ECM uses the EFT sensor to monitor engine protection limits.

A faulty EFT sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0180	Fuel temperature sensor voltage out of range. The fuel temperature signal output voltage is above the upper limit or below the lower limit.	No effect on the engine.	>4936.5 mV <132 mV

ECM 94-Pin Connector "K" CKT pin	Name
11	Engine fuel temperature sensor (EFT) signal
10	Sensor ground (–)

Test Description

Verify continuity between the following pins:

ECM 94-Pin Connector "K"	2-terminal connector at EFT
11	1
10	2

Verify the sensor resistance between the EFT signal and ground terminals as a function of temperatures. Check the sensor resistance falls within the range in the following table.

NOTE: Stabilization time before each measurement in the test medium is a minimum of 10 minutes.

Temperature °C (°F)	Resistance (kOhm)
–30 (–22)	23.5–28.7
0 (32)	5.47–6.33
25 (77)	1.94–2.17
60 (140)	0.57–0.62
100 (212)	0.18–0.19
110 (230)	0.14–0.15

Diagnostic Help

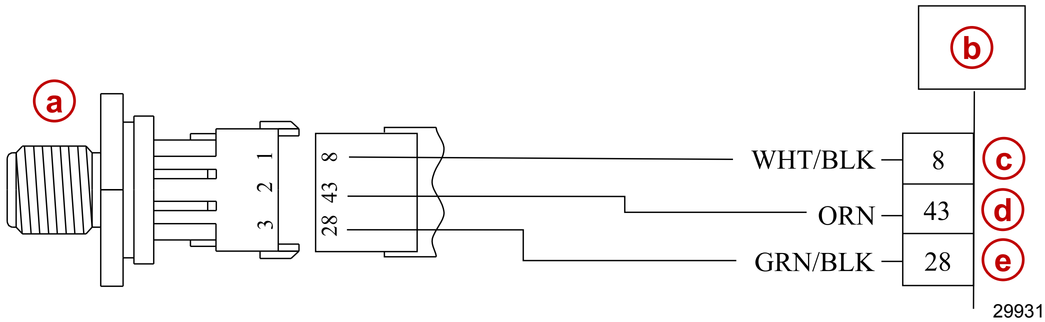
Check for the following:

- An open circuit or a short circuit in CKT pins 11 or 10
- A terminal or pin at the EFT connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective EFT sensor
- A defective ECM

IMPORTANT: Torque the EFT sensor to specification when replacing.

Description	Nm	lb. in.	lb. ft.
Fuel temperature sensor	35	–	26

Rail Fuel Pressure Sensor



a - RFP sensor
b - ECM 60-pin connector "A"
c - Sensor ground
d - RFP signal
e - 5-volt reference signal

Circuit Description

The rail fuel pressure (RFP) sensor is a pressure transducer that measures the changes in the fuel rail pressure. The pressure changes as a result of engine load and speed change, and the RFP sensor converts this to a voltage output signal to the ECM.

The ECM sends a 5 volt reference signal to the RFP sensor. As the fuel rail pressure changes, the electrical signal of the RFP sensor also changes. The ECM monitors the sensor output voltage signal and converts this to a pressure value. A higher pressure results in a higher voltage while a lower pressure results in a lower voltage. The ECM uses the RFP sensor to monitor fuel delivery to the common rail fuel system.

A faulty RFP sensor circuit can generate the following diagnostic trouble codes.

<table>
<tr><th>DTC</th><th>Reason</th><th>Effect</th><th colspan="3">Condition</th></tr>
<tr><td rowspan="3">P0087</td><td rowspan="3">Fuel rail pressure low warning. Fuel rail pressure signal indicates that fuel pressure is below the minimum limit for the given engine rating.</td><td rowspan="3">No effect on the engine.</td><td colspan="2">400–800 RPM</td><td>120 bar (1740 PSI)</td></tr>
<tr><td colspan="2">1000–2800 RPM</td><td>150 bar (2175 PSI)</td></tr>
<tr><td colspan="2">3200–4500 RPM</td><td>200 bar (2900 PSI)</td></tr>
<tr><td rowspan="10">P0088</td><td rowspan="10">Fuel rail pressure higher than commanded. The ECM detects the fuel rail pressure is higher than the commanded pressure.</td><td rowspan="10">The engine fuel quantity limitation will limit the engine speed to 3000 RPM.</td><td rowspan="6">MR504 and MR704</td><td>400 RPM</td><td>500 bar (7251 PSI)</td></tr>
<tr><td>500 RPM</td><td>350 bar (5076 PSI)</td></tr>
<tr><td>630 RPM</td><td>300 bar (4351 PSI)</td></tr>
<tr><td>800–1800 RPM</td><td>200 bar (2900 PSI)</td></tr>
<tr><td>2000–3400 RPM</td><td>180 bar (2610 PSI)</td></tr>
<tr><td>3800–4000 RPM</td><td>170 bar (2465 PSI)</td></tr>
<tr><td rowspan="4">MR706</td><td>400 RPM</td><td>500 bar (7251 PSI)</td></tr>
<tr><td>500 RPM</td><td>350 bar (5076 PSI)</td></tr>
<tr><td>630 RPM</td><td>300 bar (4351 PSI)</td></tr>
<tr><td>800–4000 RPM</td><td>200 bar (2900 PSI)</td></tr>
<tr><td>P0090</td><td>Fuel rail pressure high warning. Fuel rail pressure signal indicates that fuel pressure has exceeded the maximum limit for the given engine rating.</td><td>No effect on the engine.</td><td colspan="3">1750 bar (25381 PSI)</td></tr>
</table>

<table>
<tr><th>DTC</th><th>Reason</th><th>Effect</th><th colspan="3">Condition</th></tr>
<tr><td rowspan="5">P0091</td><td rowspan="5">Fuel rail pressure lower than commanded. The ECM detects the the fuel rail pressure is lower than commanded pressure.</td><td rowspan="5">The engine fuel quantity limitation will limit the engine speed to 3000 RPM.</td><td rowspan="3">MR504 and MR704</td><td>400–1000 RPM</td><td>–300 bar (–4351 PSI)</td></tr>
<tr><td>1200–2400 RPM</td><td>–250 bar (–3625 PSI)</td></tr>
<tr><td>3200–4000 RPM</td><td>–200 bar (–2900 PSI)</td></tr>
<tr><td rowspan="2">MR706</td><td>400–2000 RPM</td><td>–350 bar (–5076 PSI)</td></tr>
<tr><td>2300–4000 RPM</td><td>–300 bar (–4351 PSI)</td></tr>
<tr><td>P0092</td><td>Fuel rail pressure data invalid. The ECM detects the rail fuel pressure is not changing with fuel flow correctly.</td><td>No effect on the engine.</td><td colspan="3">No condition exists.</td></tr>
<tr><td>P0190</td><td>Fuel rail pressure sensor voltage out of range. The fuel pressure signal output voltage is above the upper limit or below the lower limit.</td><td>The engine fuel quantity limitation will limit the engine speed to 3000 RPM.</td><td colspan="3">>4750.7 mV
<254 mV</td></tr>
<tr><td>P0651</td><td>Sensor supply 2 voltage out of range. The sensor supply 2 circuit output voltage is above the upper limit or below the lower limit. This circuit supplies power to the throttle position 2 sensor, the fuel rail pressure sensor, and the boost pressure sensor.</td><td></td><td colspan="3"></td></tr>
<tr><td>P2293</td><td>Fuel rail pressure relief valve error. The ECM detects the fuel rail pressure relief valve is not responding correctly.</td><td>No effect on the engine.</td><td colspan="3">No condition exists.</td></tr>
</table>

ECM 60-Pin Connector "A" CKT pin	Name
43	RFP signal
28	5-volt reference signal
8	Sensor ground (–)

Test Description

Verify continuity between the following pins:

ECM 60-Pin Connector "A"	3-terminal connector at RFP
43	2
28	3
8	1

Verify the sensor supply voltage between terminals 1 and 3 of the sensor connector on the engine harness with the sensor disconnected and the keyswitch on:

Voltage (V)	Measurement
5	4.75–5.25

Verify the sensor voltage on pin 43 of the ECM 60-pin connector "A" or on pin 2 of the RFP sensor as a function of pressure.

Pressure	Voltage (VDC)
0 bar (0 PSI)	0.50
400 bar (2801 PSI)	1.39
700 bar (10153 PSI)	2.06

Pressure	Voltage (VDC)
1000 bar (14504 PSI)	2.72
1400 bar (20305 PSI)	3.61
1800 bar (26107 PSI)	4.50

Diagnostic Help

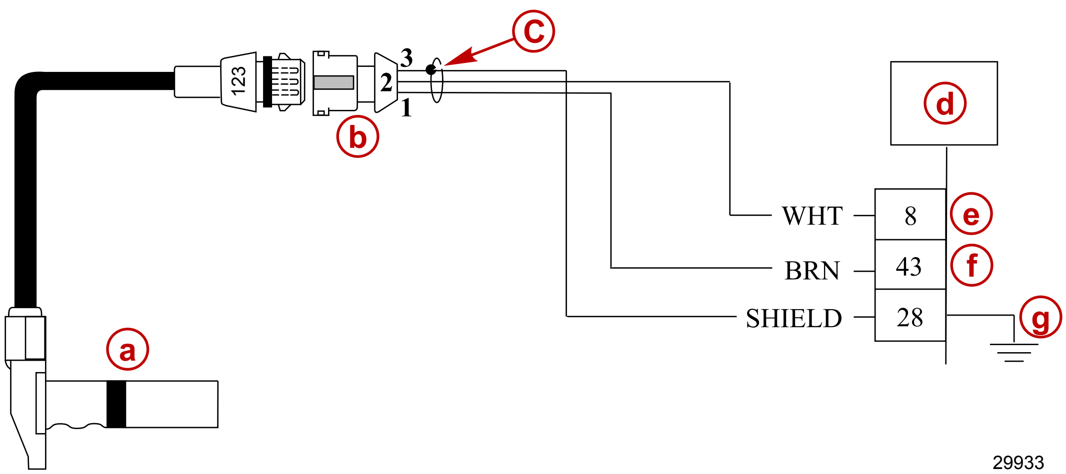
Check for the following:

- An open or short circuit in CKT pins 43, 28, or 8 (causes a loss of engine power)
- A loose assembly on the fuel rail or a damaged O-ring seal (causes an improper signal and a possible loss in fuel rail pressure)
- A terminal or pin at the RFP connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective RFP sensor
- A defective ECM

IMPORTANT: Replace the O-ring seal and torque the sensor to specification when installing.

Description	Nm	lb. in.	lb. ft.
Rail Fuel Pressure Sensor	70	–	51.6

Crankshaft Speed Sensor



a - Crankshaft speed sensor
b - Harness connector
c - Symbol for shielded twisted pair
d - ECM 60-pin connector "A"
e - Sensor ground (–)
f - Sensor ECM input signal
g - Shield ground

Circuit Description

The Crankshaft Speed sensor is an induction-type pulse generator that mounts close the leading edge of the flywheel. Four notches (drilling) serve to sense the engine speed. The resulting change in magnetic flux induces an AC voltage signal that the ECM evaluates. The ECM processes the signal to establish TDC and the crankshaft position relative to TDC. This sensor is commonly referred to as the RPM engine speed sensor.

A faulty engine speed sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition	
P0016	Crankshaft and camshaft sensor correlation. The ECM detects the engine speed sensor data is inconsistent.	No effect on the engine.	MR504	OFFSET > 24°
			MR704	OFFSET > 30°
			MR706	
P0335	Crankshaft speed sensor data error. The crankshaft speed sensor data is lost, erratic, intermittent, or incorrect.	The engine will shut off.	No condition exists.	
P0338	Engine overspeed warning. The engine speed signal indicates engine speed above engine protection limit.	The engine torque limitation will limit the engine speed to 3600 RPM.	>4300 RPM	

ECM 60-Pin Connector "A" CKT Pin	Name
27	ECM input signal from crankshaft speed sensor
12	Sensor ground (Digital –)
7	Shield ground

Test Description

Verify continuity between the following:

ECM 60-Pin Connector "A"	3-Terminal Connector
27	1
12	2
7	3 (shield wire)

Verify the resistance between terminals 1 and 2 of the sensor:

Resistance (Ohm)	Maximum Measurement
1000	1000 ohm

Diagnostic Help

Check for the following:

- An open circuit or a short circuit in CKT pins 22 or 52
- A terminal or pin at the crankshaft speed sensor connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective crankshaft speed sensor sensor
- A defective ECM

FAULT CODE 115

Attempting to start the engine while there is an open circuit in the crankshaft speed sensor circuit will trigger fault code 115. Correct the fault by repairing the open circuit and then use the following procedure to clear the fault code.

IMPORTANT: The timing in this procedure is extremely important.

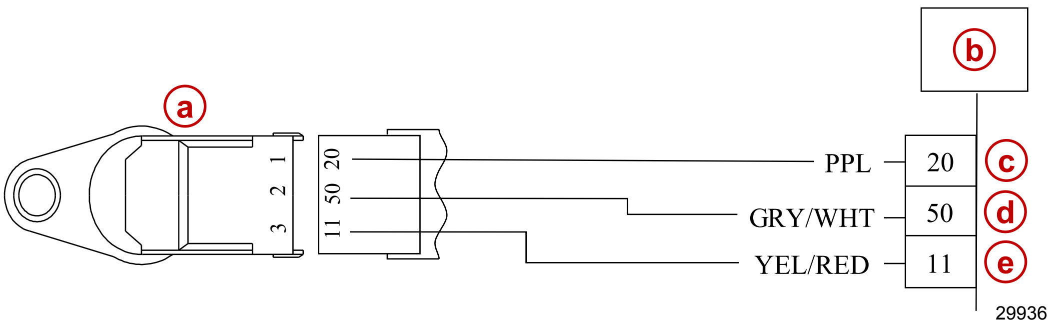
1. Shut the engine down and wait 10 seconds.

NOTE: Fault code 115 is present on the SmartTach as long as the key switch is on, or the engine is running.

2. Restart the engine.
3. Shut the engine down, turn the key switch to "OFF" for 10 seconds.
4. Turn the key switch to "ON."
5. Wait 3–5 seconds, when the 'OKAY' screens appear on the tachometer, start the engine.

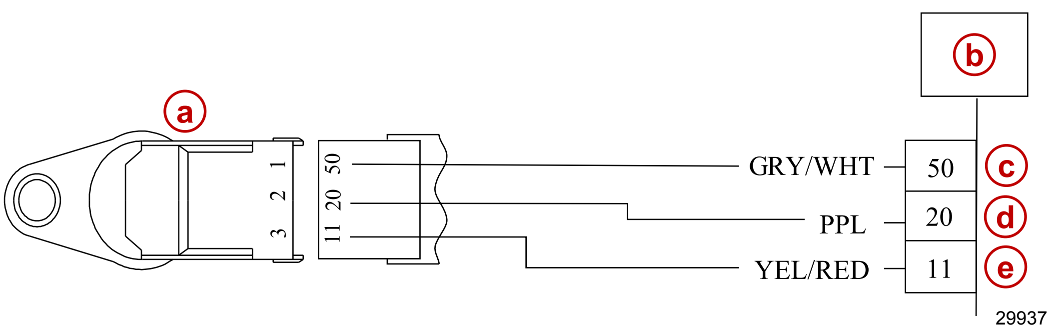
Camshaft Position Sensor

QSD 2.8 and 4.2 Camshaft Position Sensor



a - Camshaft position sensor
b - ECM 60-pin connector "A"
c - Sensor ground
d - Camshaft position signal
e - 5-volt reference signal

QSD 2.0 Camshaft Position Sensor



a - Camshaft position sensor
b - ECM 60-pin connector "A"
c - Camshaft position signal
d - Sensor ground
e - 5-volt reference signal

Circuit Description

The camshaft position sensor is a hall-effect sensor and is used as a reference to time the sequential fuel injection. As the engine rotates the sensor will signal to the ECM the engine is approaching number 1 and the timing of the injection pulse is determined.

A faulty camshaft position sensor circuit can generate the following diagnostic trouble codes.

<table>
<tr><th>DTC</th><th>Reason</th><th>Effect</th><th colspan="2">Condition</th></tr>
<tr><td rowspan="3">P0016</td><td rowspan="3">Crankshaft and camshaft sensor correlation. The ECM detects the engine speed sensor data is inconsistent.</td><td rowspan="3">No effect on the engine.</td><td>MR504</td><td>Offset > 24°</td></tr>
<tr><td>MR704</td><td rowspan="2">Offset > 30°</td></tr>
<tr><td>MR706</td></tr>
<tr><td>P0340</td><td>Camshaft position sensor data error. The camshaft position sensor data is lost, erratic, intermittent, or incorrect.</td><td>No effect on the engine.</td><td colspan="2">No condition exists.</td></tr>
<tr><td>P0641</td><td>Sensor supply 1 voltage out of range. The sensor supply 1 circuit output voltage is above the upper limit or below the lower limit. This circuit supplies power to the throttle position 1 sensor and the camshaft position sensor.</td><td>The engine torque limitation will limit the engine speed to 3600 RPM.</td><td colspan="2">>5.2 V
<4.8 V</td></tr>
</table>

ECM 60-Pin Connector "A" CKT Pin	Name
50	ECM input signal from Camshaft Position sensor
11	5-volt reference signal
20	Sensor ground

Test Description

Verify continuity between the following:

QSD 2.8 AND 4.2

ECM 60-Pin Connector "A"	3-Terminal Connector
50	2
11	3
20	1

QSD 2.0

ECM 60-Pin Connector "A"	3-Terminal Connector
50	1
11	3
20	2

Verify the sensor supply voltage between terminals 1 and 3 (2.8 and 4.2) or 2 and 3 (2.0) of the sensor connector on the engine harness with the sensor disconnected and the keyswitch on:

Voltage (V)	Minimum and Maximum Measurement
5	4.75 V–5.25 V

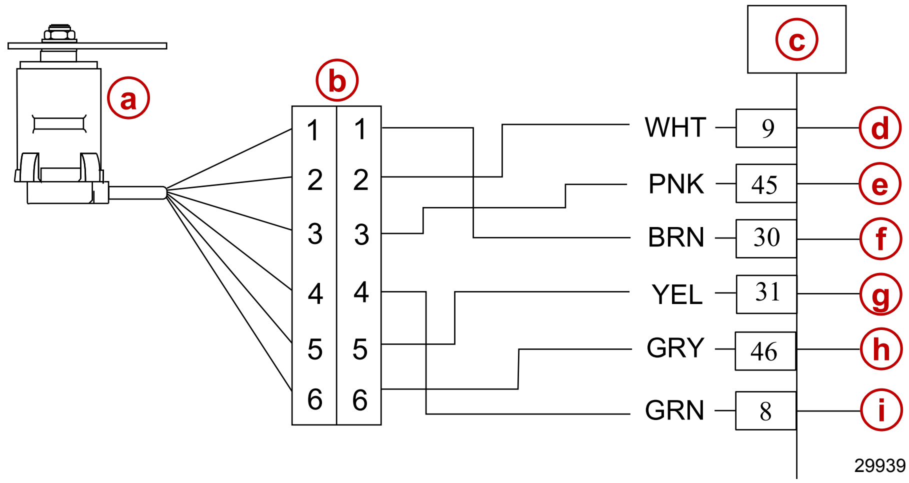
Diagnostic Help

Check for the following:

- An open circuit or a short circuit in CKT pins 50, 11, or 20
- A terminal or pin at the camshaft position sensor connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector

- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- Sensor mounting is improper
- A defective camshaft position sensor
- A defective ECM

Throttle Position Sensor



a - TP sensor
b - Harness connector
c - ECM 94-pin connector "K"
d - TP sensor TP1 signal
e - 5-volt TP1 reference signal
f - TP1 sensor ground (–)
g - TP sensor TP2 signal
h - 5-volt TP1 reference signal
i - TP1 sensor ground (–)

Circuit Description

The throttle position (TP) sensor translates throttle position into a set of voltage signals the ECM interprets. The TP sensor is a pair of linear potentiometers, TP1 and TP2. These potentiometers are supplied as a pair to offer redundancy for the throttle signal. The ECM supplies 5 volts to the sensor and processes the returning voltage signals to calculate throttle percentage. The TP output voltages varies from idle–WOT. As the throttle position changes the output increases, so that at WOT, the output voltage is near 3.65 V for TP1 and 1.6 V for TP2. By monitoring the TP sensor output voltages, the ECM determines fuel delivery based on the throttle position (operator demand).

A faulty TP sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0120	Throttle position sensor 1 voltage out of range. The throttle position 1 sensor output voltage is above the upper limit or below the lower limit.	No effect on the engine.	>4800 mV <200 mV
P0220	Throttle position sensor 2 voltage out of range. The throttle position 2 sensor output voltage is above the upper limit or below the lower limit.		>2424.242 mV <97.752 mV
P0221	Throttle position sensor voltage out of sync. The throttle position sensor output voltages are not consistent with each other.		DEVIATION > 190.616 mV

DTC	Reason	Effect	Condition
P0641	Sensor supply 1 voltage out of Range. The sensor supply 1 circuit output voltage is above the upper limit or below the lower limit. This circuit supplies power to the throttle position 1 sensor and the camshaft position sensor.	The engine torque limitation will limit the engine speed to 3600 RPM.	>5.2 V <4.8 V
P0651	Sensor supply 2 voltage out of range. The sensor supply 2 circuit output voltage is above the upper limit or below the lower limit. This circuit supplies power to the throttle position 2 sensor, the fuel rail pressure sensor, and the boost pressure sensor.	The engine fuel quantity limitation will limit the engine speed to 3000 RPM.	>5.2 V <4.8 V

ECM 94-Pin Connector "K" CKT Pin	Name
9	TP 1 sensor signal
31	TP 2 sensor signal
45	5-volt TP 1 reference signal
46	5-volt TP 2 reference signal
30	Sensor TP 1 ground (–)
8	Sensor TP 2 ground (–)

Test Description

***NOTE:** Observe constant voltage at the very first part and the very last part of the TP's rotation.*

Verify continuity between the following:

ECM 94-Pin Connector "K"	6-terminal connector
9	2
31	5
45	3
46	6
30	1
8	4

Verify supply voltage to the TP sensor with the 6-terminal connector unplugged and the keyswitch on. Measure between terminals 1 and 3 as well as 4 and 6 of the TP sensor connector on the engine harness:

Volts (V)	Minimum and Maximum Measurement
5	4.75–5.25 V

With the key off and the 6-terminal connector unplugged, verify that the TP sensor potentiometer resistance between terminals 1 and 3 for U1 and 4 and 6 for U2 of the sensor connector:

Condition	Resistance (Ohm)	Minimum and Maximum Measurement
TP U1 at idle position	1050	± 100
TP U1 at WOT position	1650	
TP U2 at idle position	1400	
TP U2 at WOT position	2000	

Verify the signal voltage on pin 9 (TP1 output signal) or pin 31 (TP2 output signal) of the ECM 94-pin connector "K" of the Throttle Position Sensor as a function of percent throttle.

Throttle (%)	TP1 Vout Voltage (VDC)	TP2 Vout Voltage (VDC)
0 (Idle)	0.88	0.56
10	1.16	0.67
20	1.43	0.77
30	1.71	0.87
40	1.98	0.98
50	2.25	1.08
60	2.53	1.19
70	2.8	1.29
80	3.07	1.39
90	3.35	1.5
100 (WOT)	3.62	1.6

Diagnostic Help

Check for the following:

- An open circuit or a short circuit in CKT pins 2, 5, 3, 6, 4, or 1
- A terminal or pin at the TP connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective TP sensor
- A defective ECM

IMPORTANT: Torque the TP sensor to specification when replacing.

Description	Nm	lb. in.	lb. ft.
Throttle position sensor screw	10.8	95	–

Atmospheric Pressure Sensor

29940

ECM

Circuit Description

The atmospheric pressure (BARO) sensor is located inside the ECM. It is not serviceable or replaceable individually. Replace the ECM to repair a faulty BARO sensor.

A faulty BARO sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P2226	Atmospheric pressure sensor voltage out of range. The barometric pressure sensor output voltage is above the upper limit, below the lower limit, or there is an implausibility with the boost pressure sensor.	No effect on the engine.	>4750.7 mV <2170.1 mV

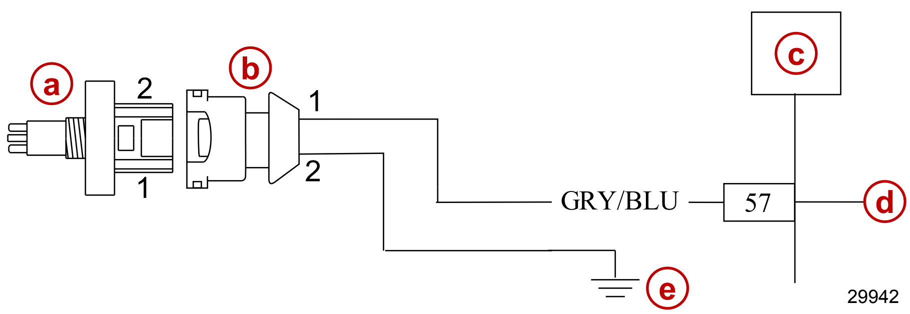
Test Description

Verify failure using either the CDS tool or a SmartCraft display device. There are no individual circuits to be tested. All BARO sensor circuits are located inside the ECM and are not serviceable.

Diagnostic Help

The BARO sensor is integrated in, and serviced with the ECM.

Water In Fuel Sensor



29942

- **a -** WIF sensor
- **b -** WIF sensor connector
- **c -** ECM 94-pin connector "K"
- **d -** WIF signal
- **e -** Sensor ground (–)

Circuit Description

The water in fuel (WIF) sensor acts as a switch depending on the medium it is immersed in. The WIF sensor provides a closed circuit to ground when water is detected in the fuel filter assembly.

A faulty WIF sensor circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P2269	Water in fuel detected warning. Water is detected in the fuel filter.	The engine torque limitation will limit the engine speed to 3600 RPM.	No conditions exist.

ECM 94-Pin Connector "K" CKT Pin	Name
57	WIF sensor signal
2	Sensor ground (–)
4	
6	

Test Description

Verify continuity between the following:

ECM 94-Pin Connector "K"	2-terminal connector
57	2
2	1
4	
6	

If there is no water in the fuel-water separator bowl verify the circuit state across the WIF sensor connector terminals 1 and 2 with the harness unplugged.

Condition	Circuit State
No Water Detected	Open
Water detected	Close

Diagnostic Help

NOTE: If there is debris on the WIF sensor probes themselves, clean the probes. If corrosion has occurred to the WIF sensor tips replace the WIF sensor.

Check for the following:

- An open circuit or a short circuit in CKT pins 1 or 2
- A debris build up or corrosion on the WIF sensor probes
- A terminal or pin at the WIF connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective WIF sensor
- A defective ECM

Fuel Injector Faults

30013

Fuel injector

Circuit Description

The injector solenoid valves control fueling quantity and injection timing. The ECM energizes the solenoid by closing a high-side and a low-side switch. On a 6-cylinder engine the injectors for cylinders 1, 2, and 3 (front bank) share a single high-side switch that connects the injector circuit to the source of high voltage inside the ECM. Likewise, the injectors for cylinders 4, 5, and 6 (rear bank) also share a single high-side switch. On a 4-cylinder engine the injectors for cylinders 1 and 4 (front bank) share a single high-side switch that connects the injector circuit to the source of high voltage inside the ECM. Likewise, the injectors for cylinders 2 and 3 (rear bank) also share a single high-side switch. Each injector circuit has a dedicated low-side switch that completes the circuit path to ground inside the ECM. The ECM senses current as each injector is actuated. If multiple injector fault codes occur in the same bank a short circuit exists. The ECM can also detect when unintended fuel injection occurs by monitoring fuel rail pressure and engine speed.

A faulty injector circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect			Condition
P0201	Injector open circuit. High resistance detected in the specified injector circuit or no current detected at the specified injector driver or return pin when voltage supplied.	Injector	1	The ECU fuel quantity limitation is lower than the mechanical limit due to the loss of injector.	Injector open circuit.
P0202			2		
P0203			3		
P0204			4		
P0205			5	The engine will shut off.	
P0206			6		

<table>
<tr><th>DTC</th><th>Reason</th><th colspan="3">Effect</th><th>Condition</th></tr>
<tr><td>P0262</td><td rowspan="6">Injector circuit shorted. The ECM detects a short circuit on low-side to battery, a general short circuit, or a short circuit from low-side to high-side on the injector solenoid driver in the specified cylinder circuit.</td><td rowspan="6">Cylinder</td><td>1</td><td rowspan="6">The engine will shut off.</td><td rowspan="9">No conditions exist.</td></tr>
<tr><td>P0265</td><td>2</td></tr>
<tr><td>P0268</td><td>3</td></tr>
<tr><td>P0271</td><td>4</td></tr>
<tr><td>P0274</td><td>5</td></tr>
<tr><td>P0277</td><td>6</td></tr>
<tr><td>P0611</td><td>Injector energizing time error. The ECM detects the injector did not energize within the specified window of time.</td><td colspan="3">Not applied.</td></tr>
<tr><td>P2148</td><td rowspan="2">Injector bank circuit error. The ECM detects a short circuit on low-side to ground or a general short circuit on the specified injector bank circuit.</td><td colspan="2">Injector Bank 1</td><td rowspan="2">The engine will shut off.</td></tr>
<tr><td>P2151</td><td colspan="2">Injector Bank 2</td></tr>
</table>

MR706

<table>
<tr><th>ECM 60-Pin Connector "A" CKT Pin</th><th colspan="4">Name</th></tr>
<tr><td>16</td><td rowspan="12">Injector</td><td>1</td><td rowspan="3">Bank 1</td><td rowspan="6">Power</td></tr>
<tr><td>18</td><td>2</td></tr>
<tr><td>17</td><td>3</td></tr>
<tr><td>3</td><td>4</td><td rowspan="3">Bank 2</td></tr>
<tr><td>1</td><td>5</td></tr>
<tr><td>2</td><td>6</td></tr>
<tr><td>47</td><td>1</td><td rowspan="6" colspan="2">Return</td></tr>
<tr><td>48</td><td>2</td></tr>
<tr><td>33</td><td>3</td></tr>
<tr><td>32</td><td>4</td></tr>
<tr><td>46</td><td>5</td></tr>
<tr><td>31</td><td>6</td></tr>
</table>

MR504 AND MR704

<table>
<tr><th>ECM 60-Pin Connector "A" CKT Pin</th><th colspan="4">Name</th></tr>
<tr><td>16</td><td rowspan="8">Injector</td><td>1</td><td rowspan="2">Bank 1</td><td rowspan="4">Power</td></tr>
<tr><td>17</td><td>4</td></tr>
<tr><td>1</td><td>3</td><td rowspan="2">Bank 2</td></tr>
<tr><td>2</td><td>2</td></tr>
<tr><td>47</td><td>1</td><td rowspan="4" colspan="2">Return</td></tr>
<tr><td>46</td><td>4</td></tr>
<tr><td>33</td><td>3</td></tr>
<tr><td>31</td><td>2</td></tr>
</table>

Test Description

Verify continuity between the following:

ECM 60-Pin Connector "A"	2-terminal connector - name 6 cyl/4 cyl
16	1 - Injector 1/1 connector

ECM 60-Pin Connector "A"	2-terminal connector - name 6 cyl/4 cyl
47	2 - Injector 1/1 connector
18	1 - Injector 2/- connector
48	2 - Injector 2/- connector
17	1 - Injector 3/4 connector
33	2 - Injector 3/4 connector
3	1 - Injector 4/- connector
32	2 - Injector 4/- connector
1	1 - Injector 5/3 connector
46	2 - Injector 5/3 connector
2	1 - Injector 6/2 connector
31	2 - Injector 6/2 connector

With the key off and the 2-terminal harness connector unplugged from the injector in question, verify that the injector solenoid resistance between terminals 1 and 2 is the following:

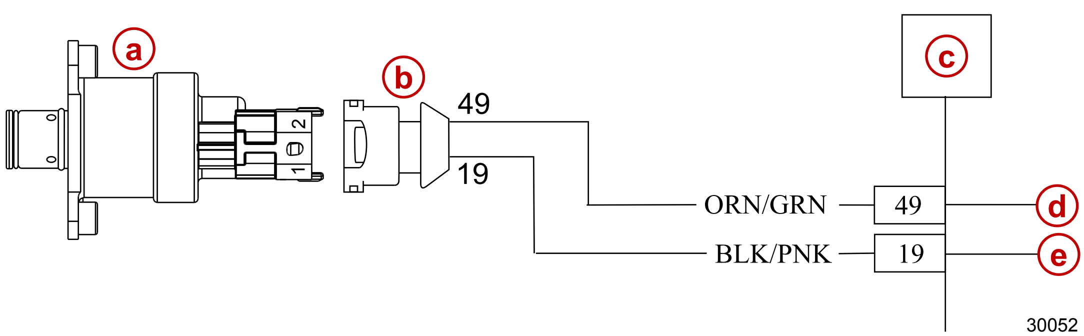
Condition Resistance (Ohm)	Minimum and Maximum measurement
0.255	0.215–0.295

Diagnostic Help

Check for the following:

- An open circuit or a short circuit in CKT 60-pin ECM connector A harness or pins 1 or 2.
- A terminal or pin at the injector connection or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed.
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector.
- Wire insulation damage.
- Dirt, debris, or moisture in or on the connector pins
- A defective injector.
- A defective ECM.

Fuel Pressure Solenoid



a - Fuel pressure solenoid
b - Harness connector
c - ECM 60-pin connector "A"
d - Fuel pressure solenoid 2
e - Fuel pressure solenoid 1

Circuit Description

The fuel pressure solenoid circuit is enabled by a pulse width modulation driver from the ECM. The ECM varies the PWM signal to this solenoid in order to set the fuel flow by the fuel pump actuator based on engine operating conditions. PWM duty cycle to the fuel pressure solenoid depends on the difference between desired rail pressure and sensed rail pressure.

A faulty Fuel Pressure Solenoid circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0252	Fuel Pressure Solenoid Open Circuit. The ECM has detected no load, excess temperature, or open circuit on the fuel pressure solenoid circuit.	The engine fuel quantity limitation will limit the engine speed to 3000 RPM.	No conditions exist.
P0253	Fuel Pressure Solenoid Shorted Low. The fuel pressure solenoid output voltage is below normal or shorted to a low source.	The engine will shut off.	
P0254	Fuel Pressure Solenoid Shorted High. The fuel pressure solenoid output voltage is above normal or shorted to a high source.	The engine fuel quantity limitation will limit the engine speed to 3000 RPM.	

ECM 60-Pin Connector "A" CKT Pin	Name
19	Fuel Pressure Solenoid 1
49	Fuel Pressure Solenoid 2

Test Description

Verify continuity between the following:

ECM 60-Pin Connector "A"	2-terminal connector
19	1
49	2

Verify the actuator's resistance between terminals 1 and 2 of the Fuel Pump Actuator.

Resistance (Ohm)	Minimum and Maximum (Ohm)
2.88	2.6–3.15

Verify the supply voltage to the fuel pump actuator with the 2-terminal engine harness connector unplugged and the keyswitch on. Measure the voltage between terminals 1 and 2 of the fuel control actuator connector on the engine harness.

Volts	Minimum and Maximum
12	Battery voltage

Diagnostic Help

Verify the following:

1. Open or short on CKT pin 1 or CKT pin 2
2. Bent, corroded, broken, expanded, poorly crimped or recessed terminal or pin at the fuel pump actuator connection or ECM
3. Missing or damaged connector seals, loose connector, cracked or broken connector shell, wire insulation damage, or dirt, debris or moisture in or on the connector pins
4. Defective fuel pump actuator

5. Defective ECM

Fuel Rail Pressure Relief Valve

Circuit Description

The fuel rail pressure relief valve is a mechanical relief valve which is normally closed. In the event of critical high rail pressure this valve opens in order to relieve fuel pressure and dump fuel back to tank. The ECM monitors this valve closely using the rail pressure sensor and will flag a fault if it sees a condition which indicates a malfunctioning valve. These conditions include a valve that did not open at the required pressure, a valve that has opened too many times, or a valve that was open longer than the specification allows.

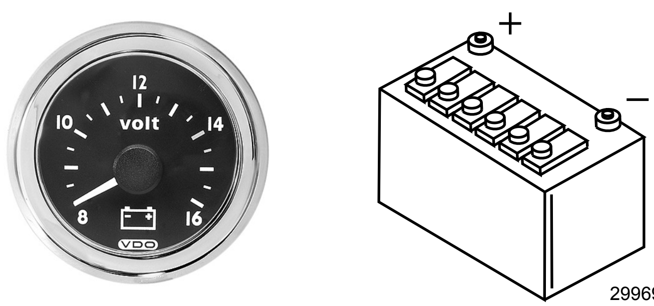
A faulty fuel rail pressure relief valve can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P2293	Fuel Rail Pressure Relief Valve Error. The ECM has detected that the fuel rail pressure relief valve is not responding correctly.	No effect on the engine.	No conditions exist.

Diagnostic Help

The fuel pressure relief valve is not serviceable and must be replaced if defective.

Battery and Main Relay



29969

Circuit Description

The electronic control module (ECM) receives a constant voltage supply through the unswitched power harness which is connected directly to the battery. The ECM receives switched battery input when the key switch is turned to "RUN." If the ECM battery voltage drops below 9 V an ECM fault is triggered by the low battery voltage condition. If the battery voltage drops from 6–9 V the fuel pump actuator begins to work improperly. The ECM stops working when the battery voltage drops below 6 V. The ECM also flags a fault in a high battery voltage condition where the voltage exceeds 20 VDC. The ECM also monitors the condition of the main relay and verifies if it is responding correctly.

ECM battery voltage or main relay circuits can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0560	ECM battery voltage out of range. The ECM supply voltage is above the maximum limit or below the minimum limit.	No effect on the engine.	>18 V <7.5 V
P0685	Main relay control timing error. The ECM detects that the main relay did not energize within the specified window of time.		No conditions exist.

ECM 94-Pin Connector "K" CKT Pin	Name
1	Battery (+) to ECM from 10 Amp CB
5	Battery (+) to ECM from 15 Amp CB
2	Battery (-) to ECM from 4-pos power connector
4	
6	
72	Main Relay Enable

Test Description

Verify continuity between the following:

ECM 94-Pin Connector "K"	Main Relay Connector
1	87
5	
72	85

Main Relay	4-terminal power connector
30 and 86	3 and 4

Battery	4-terminal power connector
Battery (–)	1
	2
Battery (+)	3
	4

ECM 94-Pin Connector "K"	4-terminal power connector
2,4, and 6	1 and 2

Diagnostic Help

Check for the following:

- A terminal or pin at the Battery, circuit breakers, 4-pos engine power connector, main relay, or ECM 94-pin connector "K" that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- Battery voltage that does not fall below threshold even when cranking
- Incorrect serpentine belt tension
- An energizing time fault in the main relay
- Unswitched Battery supply to engine power connector blown fuses
- Open circuit in the battery supply (+) or ground (–) circuits
- The voltage, using a multimeter, at CKT pins 1 and 5 is battery voltage
- Unswitched battery was not disconnected for 30 seconds after key off
- Intermittent short circuit or open circuit on the battery supply to the ECM 94-pin connector "K" in CKT pin 1, 5, or 72 to main relay
- 10 and 15 amp battery (+) to ECM CB's tripped

- A defective alternator
- A defective main relay or circuit breaker
- A defective ECM

Keyswitch Circuit

Circuit Description

The keyswitch signal is supplied to the ECM through a single circuit. When turned to "RUN," the keyswitch provides an input voltage to the ECM which turns the control system on or off. The ECM does this by energizing the main relay by pulling the relay coil to ground when a valid keyswitch signal is registered.

A faulty keyswitch circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P1605	Keyswitch signal circuit error. The ECM detects an error in the keyswitch circuit signal.	No effect on the engine.	No conditions exist.

ECM 94-Pin Connector "K" CKT Pin	Name
28	Keyswitch input signal

Test Description

Verify continuity between the following:

ECM 94-Pin Connector "K"	12-pos Engine Connector
28	4

Verify the keyswitch supply voltage to the ECM with the ECM 94-Pin Connector "K" disconnected and the keyswitch on. Measure the voltage between terminals 28 and 2, 4, or 6 of the ECM 94-Pin Connector "K."

Volts	Minimum and Maximum
12	Battery voltage

Diagnostic Help

Check for the following:

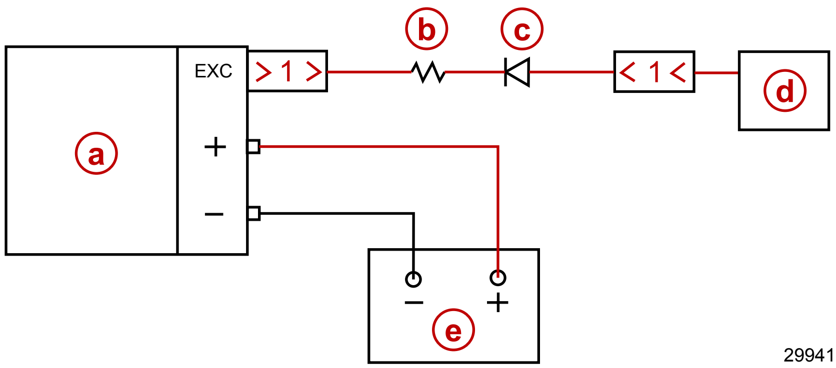
- An open circuit in CKT pin 28 from the ignition switch or keyswitch (10-Amp CB tripped)
- A terminal or pin at the 12-pos engine connection, keyswitch CB, or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective ignition switch or circuit breaker
- An internal ECM system failure. A defective ECM

Alternator Excitation Circuit

Circuit Description

The alternator excitation circuit is powered directly by the key switch circuit, which is diode protected from the alternator. The diode is contained in a jumper harness that connects the alternator to the key switch circuit. **If the alternator excitation jumper is modified to route around the diode, the key switch circuit connects directly to unswitched battery power. The control system can not be shut down with the key switch if this occurs.**

Circuit Diagram



a - Alternator
b - 82-Ohm resistor
c - 3-Amp, 200-volt diode
d - Keyswitch
e - Battery

Starter Circuit

Circuit Description

The starter circuit incorporates smart start capability. If a crank signal is registered by the system integration module (SIM) the engine will crank over for 3 seconds if no engine RPM is seen and 5 seconds if engine RPM is present. This feature allows greater longevity from engine and starter components. If a crank signal command is sent to the SIM when the engine is already running, the engine will shut down. Upon receiving a valid crank signal from the SIM, the ECM provides both a Hi and Lo signal to the starter relay coil to initiate cranking.

A faulty starter circuit can generate the following diagnostic trouble codes.

DTC	Reason	Effect	Condition
P0616	Starter relay low-side shorted. No load or short circuit to ground or battery detected at low-side starter relay circuit.	The engine will not start "mechanically."	No conditions exist.
P0617	Starter relay high-side shorted. Short circuit to ground or battery detected at high-side starter relay circuit.		
P1606	Crank signal circuit error. The ECM detects the crank signal is always active.	No effect on the engine.	

ECM 94-Pin Connector "K" CKT Pin	Name
58	Crank input signal

ECM 94-Pin Connector "K" CKT Pin	Name
55	Starter relay enable Hi signal
73	Starter relay enable Lo signal

Test Description

Verify continuity between the following:

ECM 94-Pin Connector "K"	12-pos Engine Connector
58	5

ECM 94-Pin Connector "K"	4-pos Starter Relay Connector
55	86
73	85

When troubleshooting a no-crank issue, verify the control handles are in neutral, the lanyard switch is correctly installed and not in the off position.

Verify the crank signal to the ECM by first checking terminal 5 of the 12-pin engine connector. The crank signal is approximately +12V and is only active when the keyswitch is held in the crank position or the start/stop button is pressed.

If a crank signal is continually present with or without the keyswitch in "START" or the start/stop button engaged, there is a short circuit to the battery on the crank signal circuit or a defective SIM.

Verify the SIM is transmitting a crank signal by checking the voltage of pin 58 on the ECM 94-pin connector "K." If a crank signal is present, the voltage will be +12V.

Check that the ECM is controlling the starter relay correctly by verifying there is a +12V signal on the 4-pos starter relay connector pin 86. Verify there is a ground (–) supply on the 4-pos starter relay connector pin 85.

If the starter enable signals are correct, verify the starter relay is a +12V output on relay pin 87, which is connected to the starter solenoid. A +12V signal present on the starter solenoid connection point, can damage the starter.

Diagnostic Help

Check for the following:

- A short circuit on the SIM crank signal output
- Starter Relay enable circuits shorted high, low or to each other
- A terminal or pin at the keyswitch, 12-pos engine connector, starter relay connector, or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- A defective starter solenoid or starter motor
- A defective ECM
- A defective SIM

ECM Internal Error

29940

ECM

Circuit Description

The ECM is capable of determining if failures have occurred to circuits within the ECM through self-diagnosis. If the ECM detects an error regarding internal circuitry or components it will set the following diagnostic trouble code.

DTC	Reason	Effect	Condition
P0606	ECM internal malfunction. ECM internal error related to memory hardware failures, internal voltage supply, or communication circuits.	No effect on the engine.	Internal condition.

Diagnostic Help

The ECM is not serviceable and must be replaced when defective.

CAN Communication Error

Circuit Description

The ECM monitors activity over the CAN communication bus. CAN bus errors arise due to CAN message time-outs, a bus wiring short or open, and communication issues.

A CAN communication error generates the following diagnostic trouble code.

DTC	Reason	Effect	Condition
U0101	CAN communication error. SAE J1939 ECM network communication data erratic, intermittent, or incorrect.	No effect on the engine.	No condition exists.

Diagnostic Help

Check for the following:

- Continuity on all CAN bus circuits across CAN Hi (+) and CAN Low (–)
- No intermittent shorts to ground, battery, or from CAN Hi (+) to CAN Low (–)
- A terminal or pin at the 12-pos engine connector, VIP, or ECM that is bent, corroded, broken, expanded, poorly crimped, or recessed
- Missing or damaged connector seals, cracked or broken connector shell, or a loose connector
- Wire insulation damage
- Dirt, debris, or moisture in or on the connector pins
- Termination resistors are placed correctly on the network

- A defective ECM if there is no communication possible

DTS CAN Communication Error

Circuit Description

The ECM can use a digital throttle and shift (DTS) system in place of the mechanical cable throttle and shift. It uses a CAN message for throttle commands rather than the throttle position sensor. The ECM will monitor these messages and display a fault code if an error exists.

DTS CAN communication errors may generate the following diagnostic trouble codes.

IMPORTANT: DTC U1002 may be set in non-DTS applications. Ignore the code if this is the case.

DTC	Reason	Effect	Condition
U1001	No DTS CAN message or throttle lever signal present. The ECM is not receiving throttle information.	No effect on the engine.	No conditions exist.
U1002	DTS CAN message error (if DTS is installed). The output command from the multiplexed throttle is incorrect or the ECM did not receive the digital throttle commands in time.		

Diagnostic Help

Check for the following:

- There is a system DTS throttle source signal
- The control head is powered on and there is communication present
- Replace the ECM

ECM Dataset Variant Coding Error

29940

ECM

Circuit Description

The ECM dataset variant coding error appears as a result of an ECM calibration failure. The EEPROM reads and interprets the defect memory at startup. If an error or implausibility exists the ECM registers the following fault.

DTC	Reason	Effect	Condition
P1628	ECM dataset variant coding error. The dataset variant coding is invalid or not set.	No effect on the engine.	No conditions exist.

Diagnostic Help

The ECM is not serviceable and must be replaced when defective.

Fuel System

Section 5G - ECS Repair

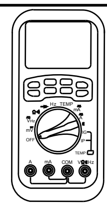
Table of Contents

5
G

Lubricants, Sealants, Adhesives

Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	ECT sensor threads EFT sensor threads Switch threads	92-809822
25	Liquid Neoprene	Electrical connections	92- 25711 3
87	High Performance Gear Lubricant	Gear lube monitor	92-858064K01
121	15W40 4-cycle Diesel Engine Oil	Fuel pump actuator O-ring	92-858042K01

Special Tools

DMT 2004 Digital Multimeter	91-892647A01
 4516	Measures RPM on spark ignition (SI) engines, ohms, amperes, AC and DC voltages; records maximums and minimums simultaneously, and accurately reads in high RFI environments.

Special Service Procedures

High Pressure Fuel Pump Repair

The Robert Bosch Corporation has a network of authorized Bosch Service Dealers throughout the world to service their products. Sent pump and injectors to an authorized Bosch Service Center. When shipping a high pressure fuel pump to a service center for adjustments or repairs, the fuel return line hollow bolt must accompany the unit. The hollow bolt incorporates a sized orifice (is calibrated) and is matched to the pump. The pump cannot be properly adjusted without this matched orifice. Contact the Bosch distributor nearest you for the location of an authorized Bosch Service Center.

Wiring Harness Service

General Information

Marine engine control circuits contain many special design features not found in standard land vehicle wiring. Environmental protection is used extensively to protect electrical contacts. Proper splicing methods must be used when making repairs. The proper operation of low amperage input/output circuits depends upon good continuity between circuit connectors. It is important before component replacement and/or during normal troubleshooting procedures that a visual inspection of any questionable mating connector is performed. Mating surfaces should be properly formed, clean and likely to make proper contact. Some typical causes of connector problems include:

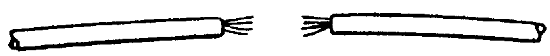
- Improperly formed contacts and/or connector housing
- Damaged contacts or housing due to improper engagement
- Corrosion, sealer or other contaminants on the contact mating surfaces
- Incomplete mating of the connector halves during assembly or during subsequent troubleshooting procedures
- Connectors have come apart due to vibration and/or temperature cycling
- Terminals not fully seated in the connector body

- Inadequate terminal crimps to the wire

Replace wire harnesses with proper part number harnesses. When signal wires are spliced into a harness, use the same gauge wire with high temperature insulation only. With the low current and voltage levels found in the system, it is important that the best possible bond be made at all wire splices by soldering the splices, as shown in Wire Repair. Use care when probing a connector or replacing connector terminals. It is possible to short between opposite terminals. If this happens, certain components can be damaged. Always use jumper wires with the corresponding mating terminals between connectors for circuit checking. Never probe through connector seals, wire insulation, boots, nipples or covers. Microscopic damage or holes may result in eventual water intrusion, corrosion and/or component or circuit failure.

Wire Repair

1. Locate damaged wire.
2. Remove the insulation as required.



19192

3. Splice two wires together using a splice clip. Solder with rosin core solder.

19201

4. Cover the splice with a heat-shrink sleeve to insulate from other wires.

Connector Service

Most connectors in the engine compartment are protected against moisture and dirt that could create oxidation and deposits on the terminals. This protection is important because of the very low voltage and current levels found in the electronic system. The connectors have a lock which secures the male and female terminals together. A secondary lock holds the seal and terminal into the connector. When diagnosing connectors open circuits are often difficult to locate by sight because oxidation or terminal misalignments are hidden by the connectors. Merely wiggling a connector on a sensor or in the wiring harness may locate the open circuit condition. This should always be considered when an open circuit or failed sensor is indicated. Intermittent problems may also be caused by oxidized or loose connections. Before making a connector repair, be certain of the type of connector. Some connectors look similar but are serviced differently. Replacement connectors and terminals are listed in the Parts Catalog.

NOTE: *Replacement connectors for Cummins MerCruiser ECS engines may come with the wires already attached to the connector.*

Main and Starter Relays

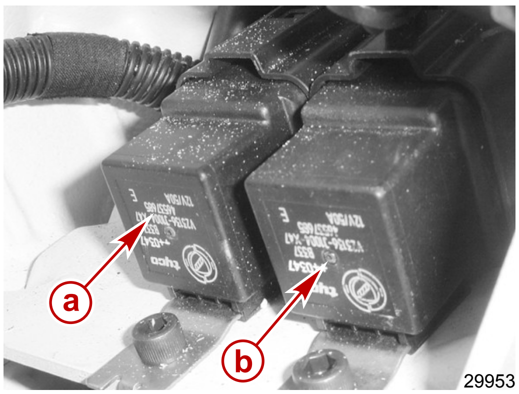
Relay, Module, and Sensor Servicing (On Board Service)

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

Removal

1. Remove the relay anchoring screws.
2. Detach the main and starter relays from the receptacle mounted on the electrical bracket.



a - Main relay
b - Starter relay

Cleaning

IMPORTANT: The main relay is an electrical component. Do not soak in any liquid cleaner or solvent: damage may result.

1. Clean the exterior with a dry cloth.
2. Clean the terminals with a suitable cleaner.

Inspection

1. Look for any evidence of physical damage to the base or connector surfaces of the relay.
2. Inspect the electrical pins of the relay for straightness and corrosion.
3. Inspect the connectors on the wiring harness for corrosion and for terminals that may have backed out of the harness.

Testing

NOTE: The relay numbers can be found on the bottom of the relay.

The following information applies to operation and tests of the relays:

1. Both relays:
   a. Terminal 30 is battery voltage.
   b. Terminal 85 is grounded by the ECM.

2. Main relay only:
   a. Terminal 87 is connected (a circuit is formed) to terminal 30 in the energized (on) position. Terminal 87 then supplies battery voltage to two ECM pins.
   b. Terminal 86 is connected to terminal 30.
3. Starter relay only:
   a. Terminal 87 is connected (a circuit is formed) to terminal 30 in the energized (on) position. Terminal 87 then supplies battery voltage to enable the starter motor.
   b. Terminal 86 is powered by the ECM to energize the relay.

Installation

1. Insert the main and starter relays into the receptacle on the electrical bracket.
2. Secure with anchoring screw.

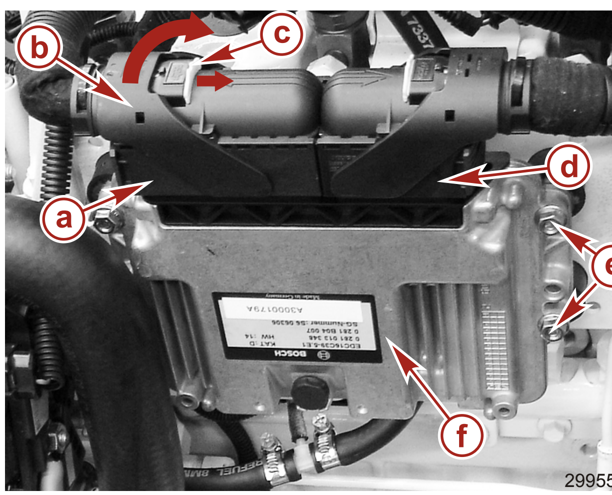
Electronic Control Module (ECM)

IMPORTANT: See Service Precautions at the beginning of this section before proceeding.

IMPORTANT: The ECM is a sensitive electrical device, subject to electrostatic damage. Take care not to touch connector pins when removing, cleaning, or installing the ECM.

Removal

1. Slide the lock in the direction shown.
2. Rotate the connector handle in the direction shown and lift to disconnect the 94-pin electrical connector K from the ECM.
3. Repeat steps 1 and 2 and disconnect the 60-pin electrical connector A from the ECM.
4. Remove the ECM mounting nuts. Retain the hardware.
5. Remove the ECM from the electrical bracket.



a - 94-pin ECM connector K
b - Connector Handle
c - Sliding lock
d - 60-pin ECM connector A
e - Mounting nuts (two not shown)
f - ECM

Cleaning

1. Clean the exterior of the ECM with a dry cloth. Be careful to avoid contact with the connector pins.
2. Clean the ECM mounting bracket to assure a good ground (–) contact.

Inspection

NOTE: The ECM is a sealed electrical component. If a scan check has shown it to be defective, replace the unit with another ECM having the same part number and service number as the original.

1. Inspect outer surfaces for any obvious damage.
2. Inspect the electrical pins of the ECM for straightness and corrosion.
3. Inspect the connectors on the wiring harness for corrosion and terminals that may have backed out of the harness.

Installation

1. Mount the new ECM to the electrical bracket using the retained hardware.
2. Torque mounting nuts.

Description	Nm	lb. in.	lb. ft.
ECM mounting nut	10.8	95	–

3. Connect and lock the 60-pin electrical connector to the ECM.
4. Connect and lock the 94-pin electrical connector to the ECM.

Testing

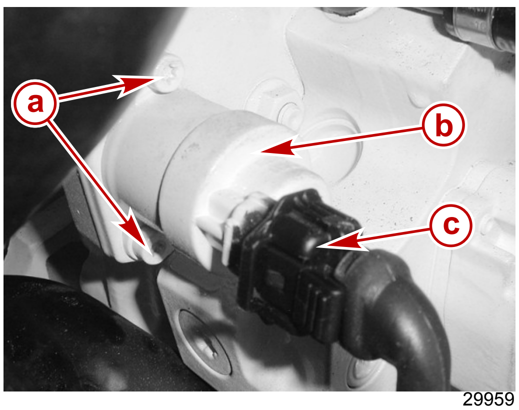
See Diagnostic Circuit Checks for information and procedures.

Fuel Pump Actuator

IMPORTANT: See Service Precautions at the beginning of this section before proceeding.

Removal

1. Disconnect the fuel pump actuator harness connector.
2. Remove the fuel pump actuator screws.
3. Remove the fuel pump actuator.



a - Screws
b - Fuel pump actuator
c - Harness connector

Cleaning

1. Clean the sensor with a dry cloth.
2. Remove the sealing washer and clean the seating area.
3. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the base or the connector surfaces.
2. Visually inspect the sensor electrical pins for straightness and corrosion.
3. Visually inspect the wiring harness connectors for corrosion or terminals that may have backed out of the harness.

Installation

1. Install a new O-ring on the fuel pump actuator.
2. Lubricate the O-ring with clean oil.

Tube Ref No.	Description	Where Used	Part No.
121	15W40 4-cycle Diesel Engine Oil	Fuel pump actuator O-ring	92-858042K01

3. Turn the fuel pump actuator clockwise while pressing it into the bore. Verify the fuel pump actuator flange is flush with the mounting surface.
4. Tighten the fuel pump actuator screws to specification.

Description	Nm	lb. in.	lb. ft.
Fuel pump actuator screw	6	50	–

5. Connect and lock the fuel pump actuator harness connector.

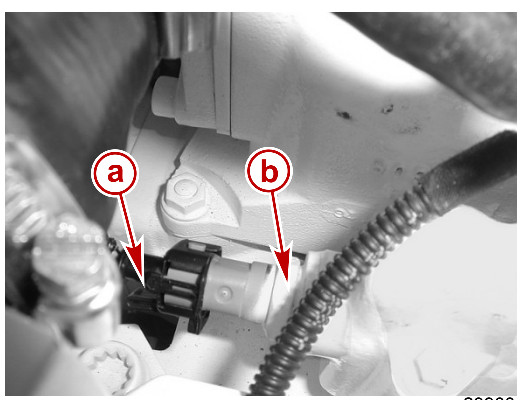
Engine Coolant Temperature Sensor

Removal

IMPORTANT: See Service Precautions at the beginning of this section before proceeding.

NOTE: Handle the engine coolant temperature (ECT) sensor carefully as any damage to it will affect operation of the ECS (Electronic Control System).

1. Refer to **Section 6B** for coolant draining procedures.
2. Disconnect the engine coolant temperature (ECT) sensor harness connector.
3. Counterhold the reducer fitting, if equipped, with a separate tool.
4. Remove the ECT sensor.



29960

a - Harness connector
b - ECT sensor

Cleaning

1. Clean the sensor with a dry cloth.
2. Remove the sealing washer and clean the seating area.

3. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the base or the connector surfaces.
2. Visually inspect the sensor electrical pins for straightness and corrosion.
3. Visually inspect the wiring harness connectors for corrosion or terminals that may have backed out of the harness.

Installation

1. Apply sealant to the ECT sensor threads.

Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	ECT sensor threads	92-809822

2. Install the ECT sensor.
3. Tighten the ECT sensor to specification.

Description	Nm	lb. in.	lb. ft.
ECT sensor screw	19.6	173	–

4. Connect the ECT sensor harness connector.
5. Refer to **Section 6B: Closed-cooling System** and fill the engine with the specified coolant.

Testing

See **Diagnostic Circuit Checks** for information and procedures.

Engine Fuel Temperature Sensor

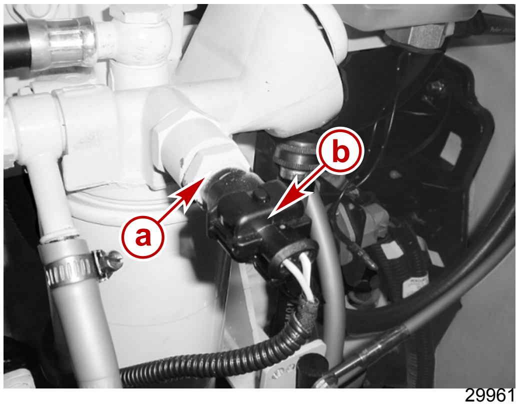
Important Information

IMPORTANT: See Service Precautions at the beginning of this section before proceeding.

Removal

1. Disconnect the electrical connectors from the engine fuel temperature sensor (EFT) sensor.
2. Counterhold the reducer fitting, if equipped, with a separate tool.
3. Gradually loosen the EFT sensor to relieve the fuel pressure. Properly contain any fuel that drains from the fuel system.

4. Remove the EFT sensor.



a - EFT sensor
b - Harness connector

Cleaning

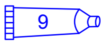
1. Clean the sensor with a dry cloth.
2. Remove the sealing washer and clean the seating area.
3. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the base or the connector surfaces.
2. Visually inspect the sensor electrical pins for straightness and corrosion.
3. Visually inspect the wiring harness connectors for corrosion or terminals that may have backed out of the harness.

Installation

1. Apply sealant to the EFT sensor threads.

Tube Ref No.	Description	Where Used	Part No.
 9	Loctite 567 PST Pipe Sealant	EFT sensor threads	92-809822

2. Install the EFT sensor.
3. Tighten the EFT sensor to specification.

Description	Nm	lb. in.	lb. ft.
Engine fuel temperature sensor screw	18	159	–

4. Connect and lock the EFT sensor electrical connector.

Testing

See **Diagnostic Circuit Checks** for information and procedures.

Manifold Absolute Pressure and Intake Air Temperature Sensor

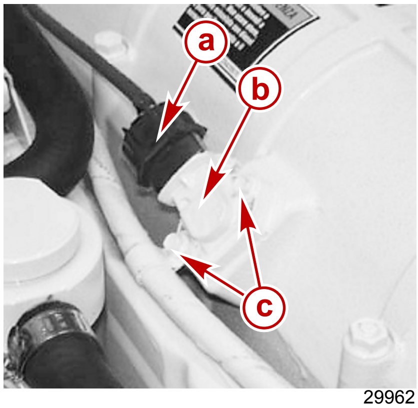
Removal

NOTE: See Service Precautions in Repair Procedures before continuing.

NOTE: The manifold absolute pressure (MAP) and intake air temperature (IAT) sensors are included in one assembly.

1. Disconnect the manifold absolute pressure (MAP) and intake air temperature (IAT) sensor harness connector.

2. Remove the MAP and IAT sensor screws.
3. Remove the sensor from the aftercooler housing.



a - Harness connector
b - MAP and IAT sensor
c - Screws

Cleaning

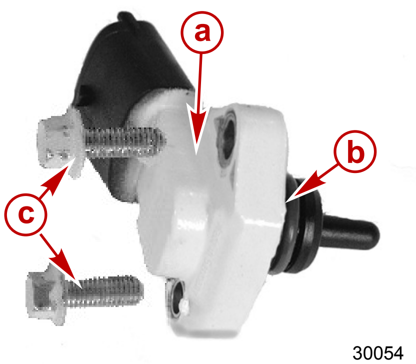
1. Clean the sensor with a dry cloth.
2. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the sensor base or connector surfaces.
2. Visually inspect the sensor electrical pins for straightness and corrosion.
3. Visually inspect the wiring harness connectors for corrosion and terminals backed out of the harness.
4. Inspect the O-ring for damage.

Installation

1. Install a new MAP and IAT sensor O-ring.
2. Install the EOP and EOT sensor to the plenum using the screws with washers.



a - MAP and IAT sensor
b - O-ring
c - Screws

3. Torque the screws.

Description	Nm	lb. in.	lb. ft.
MAP and IAT sensor screw	11	97	–

4. Connect and lock the EOP and EOT sensor harness connector.

Testing

See **Diagnostic Circuit Checks** for information and procedures.

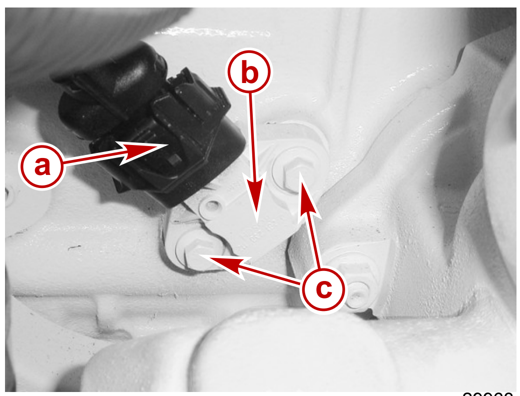
Engine Oil Pressure and Engine Oil Temperature Sensor

Removal

NOTE: See Service Precautions in Repair Procedures before continuing.

NOTE: The engine oil pressure (EOP) and engine oil temperature (EOT) sensors are in a single assembly.

1. Disconnect the EOP and EOT sensor harness connector.
2. Remove the EOP and EOT sensor screws.
3. Remove the sensor from its mounting location.



a - Harness connector
b - EOP and EOT sensor
c - Screws

Cleaning

1. Clean the sensor with a dry cloth.
2. Clean the harness connector.

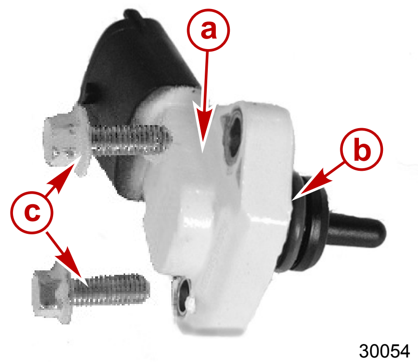
Inspection

1. Look for evidence of any physical damage to the sensor base or connector surfaces.
2. Visually inspect the sensor electrical pins for straightness and corrosion.
3. Visually inspect the wiring harness connectors for corrosion and terminals backed out of the harness.
4. Inspect the O-ring for damage.

Installation

1. Install a new O-ring on the EOP and EOT sensor.

2. Install the EOP and EOT sensor to the plenum using the screws with washers.



a - EOP and EOT sensor
b - O-ring
c - Screws

3. Torque the screws.

Description	Nm	lb. in.	lb. ft.
EOP and EOT sensor screw	11	97	–

4. Connect and lock the EOP and EOT sensor harness connector.

Testing

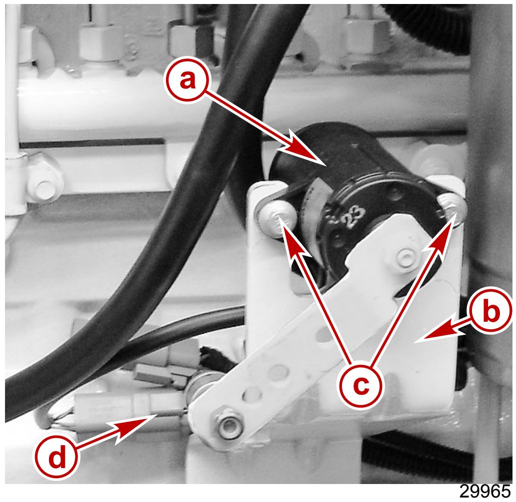
See **Diagnostic Circuit Checks** for information and procedures.

Throttle Position Sensor

Removal

1. Disconnect the throttle cable.
2. Disconnect the throttle position (TP) sensor harness connector.
3. Remove the TP sensor screws.

4. Remove the sensor from the electrical bracket.



29965

a - TP sensor
b - Electrical bracket
c - Bolt and flange nut
d - Harness connector

Cleaning

1. Clean the sensor with a dry cloth.
2. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the base or the connector surfaces.
2. Visually inspect the sensor electrical pins for straightness and corrosion.
3. Visually inspect the wiring harness connectors for corrosion or terminals that may have backed out of the harness.

Installation

1. Install the TP sensor onto the electrical bracket using the bolts with flanged nuts.
2. Torque the flange nuts.

Description	Nm	lb. in.	lb. ft.
TP sensor flange nut	10.8	95	–

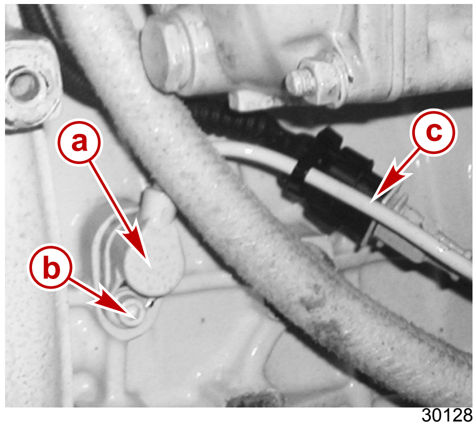
3. Connect the TP sensor harness connector.
4. Install the throttle cable. Refer to **Section 2**.
5. Check the TP sensor output voltage and verify the full throttle range. See **Testing Diagnostic Circuit Check**.

Crankshaft Speed Sensor

Removal

1. Disconnect the crankshaft speed sensor from the engine harness.
2. Remove the sensor Allen-head screw.

3. Withdraw the crankshaft speed sensor from the starboard side of the engine.



a - crankshaft speed sensor
b - Allen-head screw
c - Harness connection

Cleaning

1. Clean the sensor and connector with a dry cloth.
2. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the sensor surfaces and the tip of the sensor.
2. Visually inspect the connectors for corrosion and terminals that may have backed out of the harness.
3. Inspect the O-ring seal for damage.

Installation

1. Install a new crankshaft speed sensor O-ring.
2. Insert the crankshaft speed sensor into the flywheel housing.
3. Install the sensor Allen-head screw with washer.
4. Torque the Allen-head screw.

Description	Nm	lb. in.	lb. ft.
Crankshaft speed sensor Allen-head screw	8	71	–

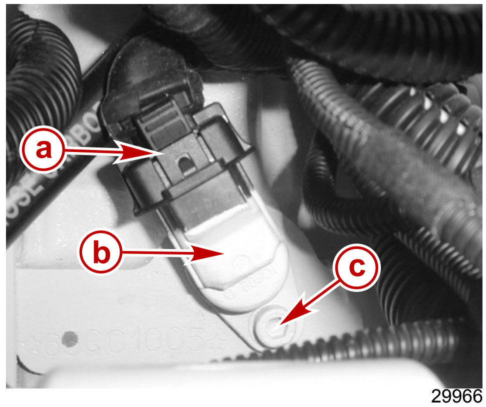
5. Connect the crankshaft speed sensor to the engine harness.

Camshaft Position Sensor

Removal

1. Disconnect the camshaft position sensor from the injection harness.
2. Remove the screw.

3. Withdraw the camshaft position sensor.



a - Harness connector
b - Camshaft position sensor
c - Screw

Cleaning

1. Clean the sensor and connector with a dry cloth.
2. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the sensor surfaces and the tip of the sensor.
2. Visually inspect the connectors for corrosion and terminals that may have backed out of the harness.
3. Inspect the O-ring seal for damage.

Installation

1. Install a new camshaft position sensor O-ring.
2. Insert the camshaft position sensor and screw.
3. Torque the screw.

Description	Nm	lb. in.	lb. ft.
Camshaft position sensor screw	8	71	–

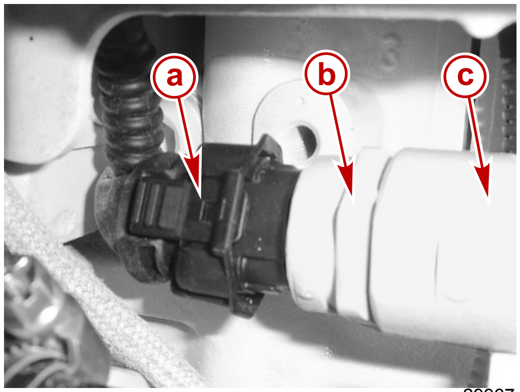
4. Connect and lock the camshaft position sensor harness connector.

Rail Fuel Pressure Sensor

Removal

1. Disconnect the rail fuel pressure sensor harness connector.

2. Remove the rail fuel pressure sensor from the common rail.



a - Harness connector
b - Rail fuel pressure sensor
c - Common rail

Cleaning

1. Clean the sensor and connector with a dry cloth.
2. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the sensor surfaces and the tip of the sensor.
2. Visually inspect the connectors for corrosion and terminals that may have backed out of the harness.
3. Inspect the O-ring seal and sensor threads for damage.

Installation

1. Install a new rail fuel pressure sensor O-ring.
2. Insert the rail fuel pressure sensor into the fuel rail.
3. Screw the rail fuel pressure sensor into the fuel rail.
4. Torque the sensor.

Description	Nm	lb. in.	lb. ft.
Rail fuel pressure sensor	70	–	51.6

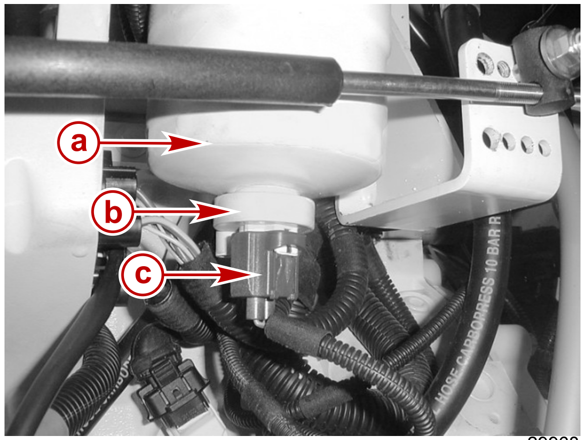
5. Connect and lock the rail fuel pressure sensor harness connector.

Water In Fuel Sensor

Removal

1. Disconnect the water in fuel (WIF) sensor harness connector.

2. Remove the WIF sensor from the fuel filter housing assembly. Refer to **Section 1B**.



a - Fuel filter housing
b - WIF sensor
c - Harness connector

Cleaning

1. Clean the sensor and connector with a dry cloth.
2. Clean the harness connector.

Inspection

1. Look for evidence of any physical damage to the sensor surfaces and the tip of the sensor.
2. Visually inspect the connectors for corrosion and terminals that may have backed out of the harness.
3. Inspect the O-ring seal and sensor threads for damage.

Installation

1. Install a new WIF sensor O-ring.
2. Screw the WIF sensor into the fuel filter housing assembly.
3. Torque the WIF sensor.

Description	Nm	lb. in.	lb. ft.
WIF sensor	1.2	10.6	–

4. Connect and lock the electrical connector to the WIF sensor.

Gear Lube Monitor Switch

Removal

The gear lube monitor switch is serviced with the gear lube monitor assembly.

1. Disconnect the engine harness wiring from the gear lube monitor switch.
2. Remove the gear lube monitor from its bracket.
3. Empty the gear lube monitor into a suitable container.
4. Disconnect the gear lube monitor hose from its fitting.

Installation

1. Connect and securely clamp the gear lube monitor hose to the fitting on the gear lube monitor.

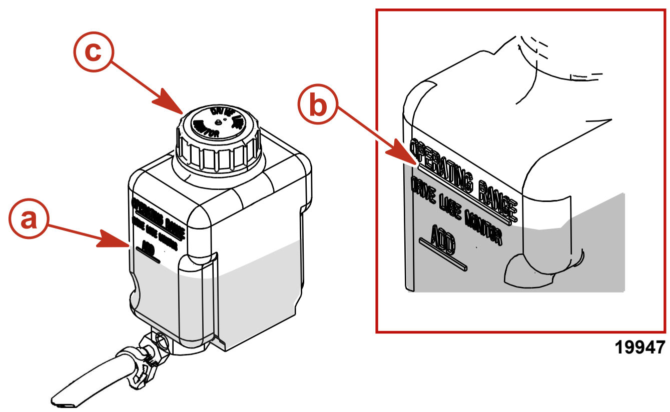
2. Secure the gear lube monitor in its bracket.
3. Connect the orange engine harness wire to the tan/blue gear lube monitor sensor wire.
4. Connect the black engine harness wire to the black gear lube sensor wire.
5. Fill the gear lube monitor to the "operating range" (full) mark with lubricant.

Tube Ref No.	Description	Where Used	Part No.
87	High Performance Gear Lubricant	Gear lube monitor	92-858064K01

Testing

The gear lube monitor switch is normally open when the fluid level is correct. If the gear lube is low the switch will close.

1. Ensure that the gear lube monitor bottle is filled to the "OPERATING RANGE" (full) mark.



Gear lube monitor

a - Gear lube level at the "ADD" mark
b - Gear lube level at the "OPERATING RANGE" mark
c - Gear lube monitor cap

2. Disconnect the engine harness wiring from the two gear lube monitor switch wires.
3. Connect a continuity meter between the two switch wires.

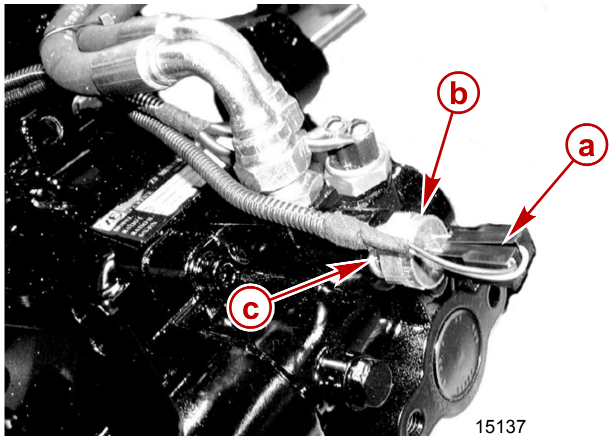
DMT 2004 Digital Multimeter	91-892647A01

4. With the gear lube monitor bottle filled to the "OPERATING RANGE" (full) mark there should be no continuity in the switch
5. If continuity exists, replace the gear lube monitor.
6. An empty gear lube monitor bottle, or one with the float fully depressed for diagnostic purposes, will result in measured continuity.
7. If no continuity exists, replace the gear lube monitor.
8. If continuity testing indicates an operational gear lube monitor switch, inspect the connectors and engine wiring for corrosion and wiring shorts.

Transmission Fluid Temperature Switch

Removal

1. Remove the engine harness wiring from the transmission fluid temperature switch.



Typical

a - Harness wiring
b - Transmission fluid temperature switch
c - Sealing washer

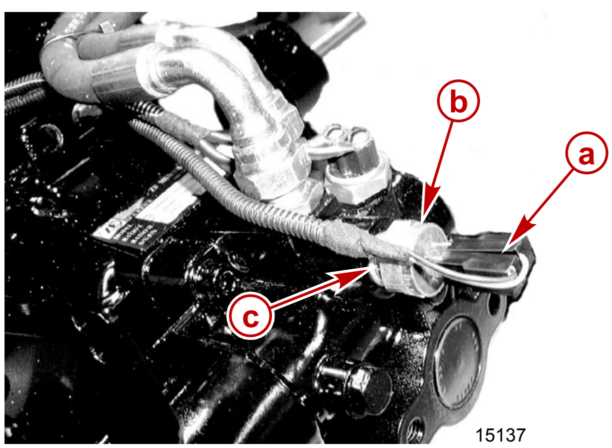
2. Prepare to contain spilled fluid.
3. Remove the transmission fluid temperature switch.
4. Inspect the transmission fluid temperature switch sealing washer. Replace if distorted or damaged.

Installation

1. Apply thread sealant to the threads of the transmission fluid temperature switch.

Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	Switch threads	92-809822

2. Install the switch and sealing washer into the transmission and tighten securely.



Typical

a - Harness wiring
b - Transmission fluid temperature switch
c - Sealing washer

3. Reconnect the harness wires and coat connection with sealant.

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Electrical connections	92- 25711 3

4. Check transmission fluid level.

Testing

The switch is located on the transmission of MIE engines. The switch is normally open and will close at a predetermined temperature that is dependant application and switch part number.

Description	Opens	Closes
Switch (PN 48952)	66° to 77° C (150° to 170° F)	88° to 93° C (190° to 200° F)
Switch (PN 87-86080)	79° to 91° C (175° to 195° F)	102° to 107° C (215° to 225° F)
Switch (PN 87-88031)	82° to 93° C (160° to 200° F)	104° to 116° C (220° to 240° F)

1. Disconnect the wiring and remove the transmission fluid temperature switch from the transmission.
2. Connect the leads of a DMT or ohmmeter to the switch's electrical terminals.
3. At ambient temperature the switch should have no continuity. A defective switch must be replaced.
4. Heat the switch with a suitable controlled heat source (such as a sand bath) and observe switch continuity (open or closed) at the specified temperature ranges. A defective switch must be replaced.

Description	Opens	Closes
Switch (PN 48952)	66° to 77° C (150° to 170° F)	88° to 93° C (190° to 200° F)
Switch (PN 87-86080)	79° to 91° C (175° to 195° F)	102° to 107° C (215° to 225° F)
Switch (PN 87-88031)	82° to 93° C (160° to 200° F)	104° to 116° C (220° to 240° F)

5. Allow the switch to cool before handling and installation.

Cooling System

Section 6A - Closed-Cooling System

Table of Contents

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
	Fleetguard Compleat with DCA4, Fleetguard Part Number: CC2825, Container size: 3-3/4 liters, 1 U.S. gallon	Closed cooling system	
	Marine Caulking	Seawater inlet mounting surfaces	Obtain Locally
		Closed cooling system	
7	Loctite 271 Threadlocker	Seawater inlet nut	92-809819
9	Loctite 567 PST Pipe Sealant	Fuel cooler fittings	92-809822
12	Loctite Master Gasket Kit	Backside of seawater pump cam and screw threads	92-12564 2
		Water circulating pump gasket	
19	Perfect Seal	Drain plug or fitting threads	92-34227 1
80	SAE Engine Oil 30W	Seawater pump shaft	Obtain Locally
		O-ring seals	
		Heat exchanger to thermostat housing O-ring seal	
123	Marine Engine Coolant	Closed cooling system (This coolant only available in Europe.)	92-813054A2
		Closed cooling system	

Closed Cooling System Specifications

Capacity

Closed Cooling System	Models	
	QSD 2.8	QSD 4.2
Capacity	12 L (3 1/4 U.S. gal.)	17.25 liters (4 1/2 U.S. gallons)

Thermostat

Thermostat		Models	
		QSD 2.8	QSD 4.2
Operating temperature	Start opening	80° C (176° F)	
	End opening	95° C (203° F)	

Pressure Cap

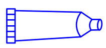
Pressure Cap	Models	
	QSD 2.8	QSD 4.2
Operating pressure	100 kPa (14.5 psi)	

Coolant (Antifreeze)

IMPORTANT: The coolant (antifreeze) used must be a solution of low silicate ethylene glycol containing special additives and deionized, purified water. Using other types of engine coolant may cause fouling of the heat exchangers and overheating of the engine. Do not combine different types of coolants without knowing that they are compatible. Refer to the coolant manufacturer's instructions.

NOTE: We recommend using a 50/50 solution of coolant (antifreeze) and deionized, purified water. When operating where seawater temperatures are greater than 32 °C (90 °F), you can use a 25/75 solution of coolant (antifreeze) and deionized, purified water for improved cooling performance.

These specified, premixed formulas require no mixing with water or other additives. They prevents silicate gelling which can restrict engine cooling passages and provide freeze protection to –38° C (–33° F).

Tube Ref No.	Description	Where Used	Part No.
	Marine Engine Coolant	Closed cooling system (This coolant only available in Europe.)	92-813054A2
	Fleetguard Compleat with DCA4, Fleetguard Part Number: CC2825, Container size: 3-3/4 liters, 1 U.S. gallon	Closed cooling system	

Precautions

⚠ CAUTION

A sudden loss of pressure can cause hot coolant to boil and discharge violently resulting in serious injury from burns. Allow the engine to cool down before removing the coolant pressure cap.

NOTICE

Water trapped in the seawater section of the cooling system can cause corrosion or freeze damage. Drain the seawater section of the cooling system immediately after operation or before any length of storage in cold weather. If the boat is in the water, keep the seacock closed until restarting the engine to prevent water from flowing back into the cooling system. If the boat is not fitted with a seacock, leave the water inlet hose disconnected and plugged.

NOTE: As a precautionary measure, attach a tag to the key switch or steering wheel of the boat reminding the operator to open the seacock or unplug and reconnect the water inlet hose before starting the engine.

NOTICE

Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

NOTICE

Water trapped in the passages of the heat exchanger can cause corrosion or freeze damage. Drain all sections of the heat exchanger immediately after operation or before any length of storage in cold weather.

IMPORTANT: The closed cooling section must be kept full year-round with the specified coolant.

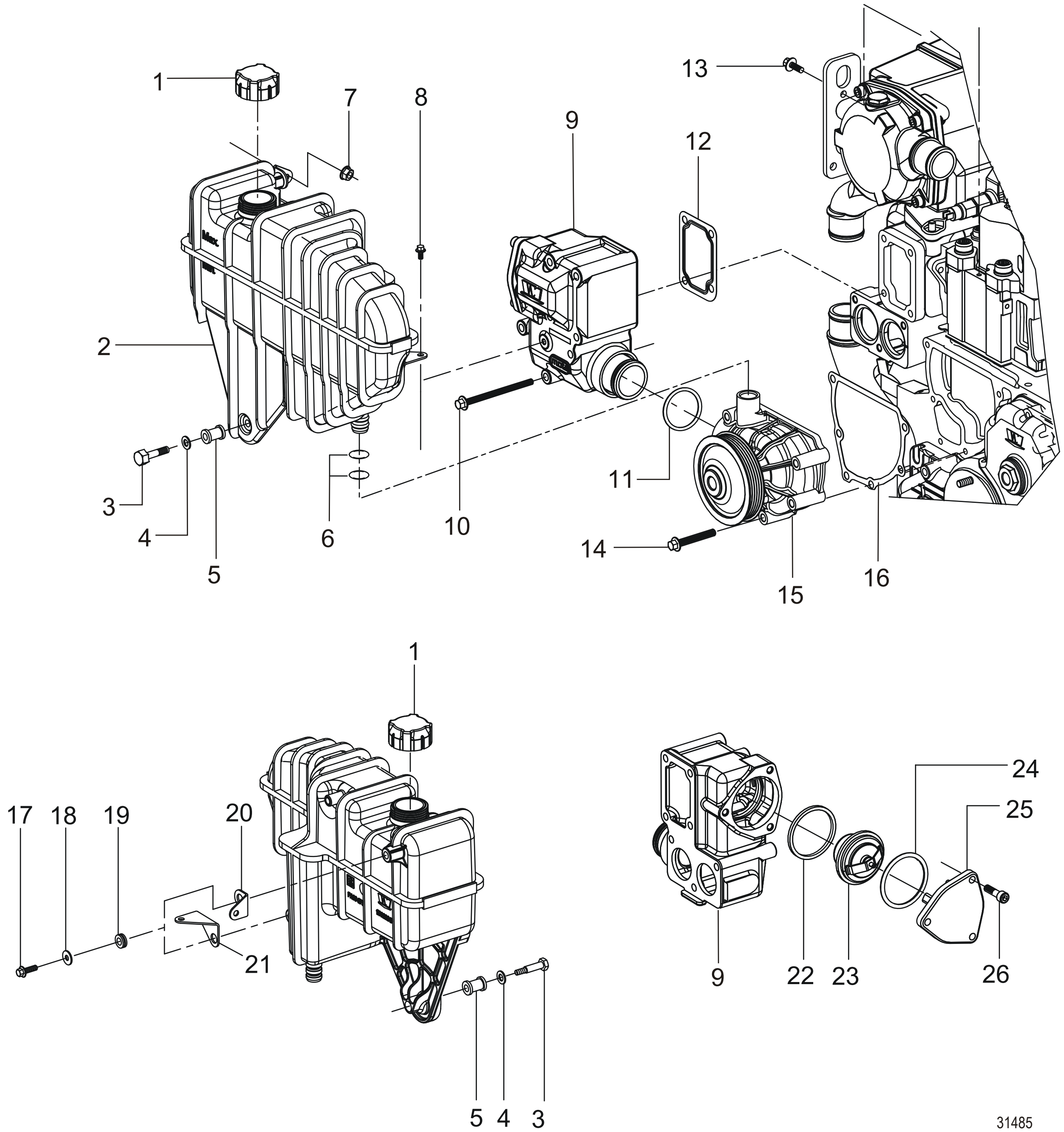
IMPORTANT: Do not use Propylene Glycol anti-freeze in the closed cooling system of the engine.

NOTICE
For instructions on flushing the seawater cooling system or finding the interval for changing the coolant, see Section 1B—Maintenance.

Notes:

Exploded Views

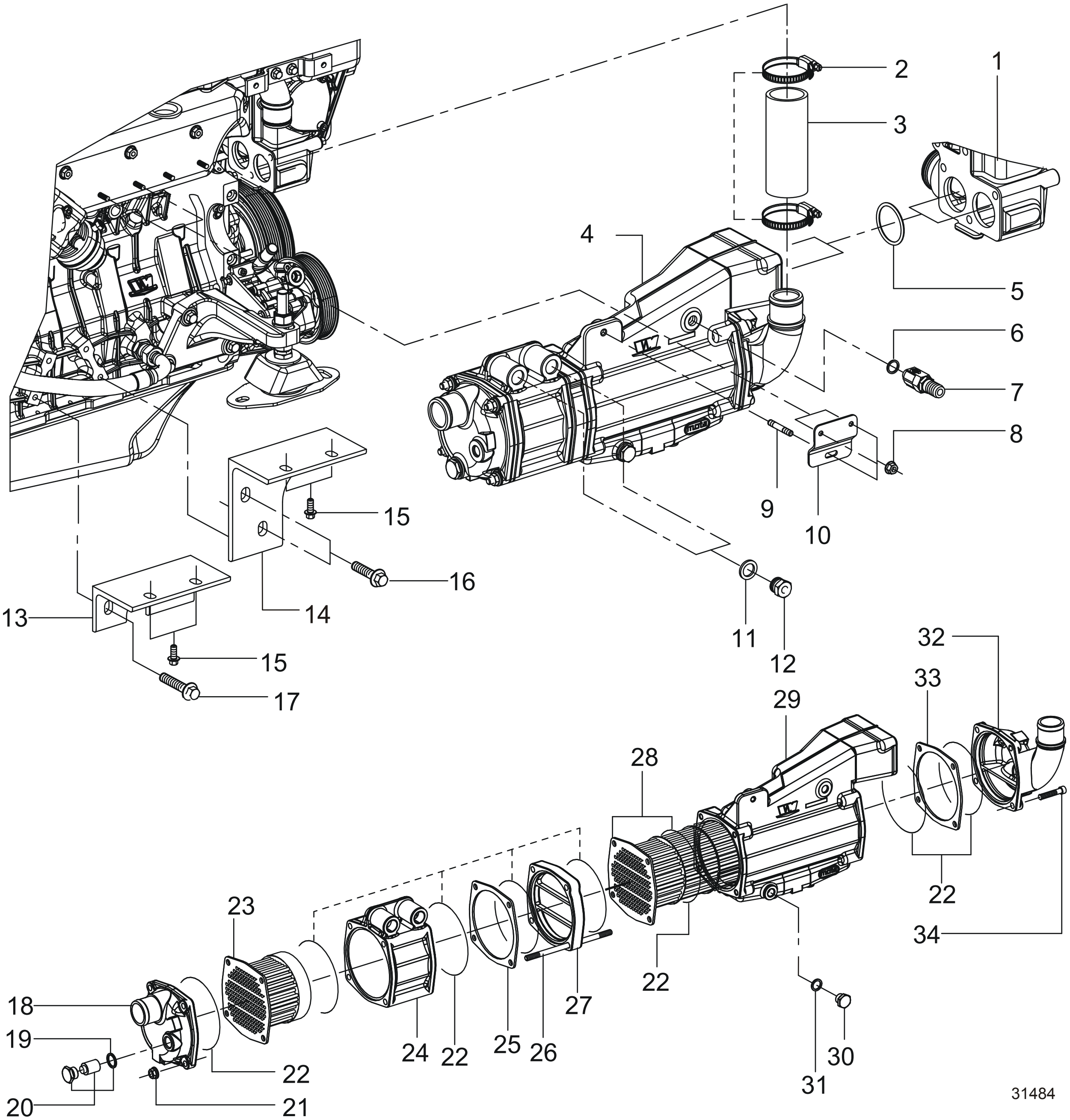
Exploded View—Cooling System Components



Exploded View—Cooling System Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. In.	lb. ft.
1	1	Cap			
2	1	Coolant expansion tank and reservoir			
3	1	Screw	10.8	95	–
4	1	Washer			
5	1	Isolator			
6	2	O-ring			
7	1	Nut	10.8	95	–
8	1	Screw	5.4	47	–
9	1	Thermostat housing			
10	1	Screw	24.5	–	18
11	1	O-ring			
12	1	Gasket			
13	1	Screw			
14	6	Screw	32.4	–	23
15	1	Water pump assembly			
16	1	Gasket			
17	1	Screw			
18	2	Washer			
19	1	Nut	24.5	–	18
20	1	Bracket			
21	1	Bracket			
22	1	O-ring			
23	1	Thermostat			
24	1	O-ring			
25	1	Cover plate			
26	3	Screw	24.5	–	18

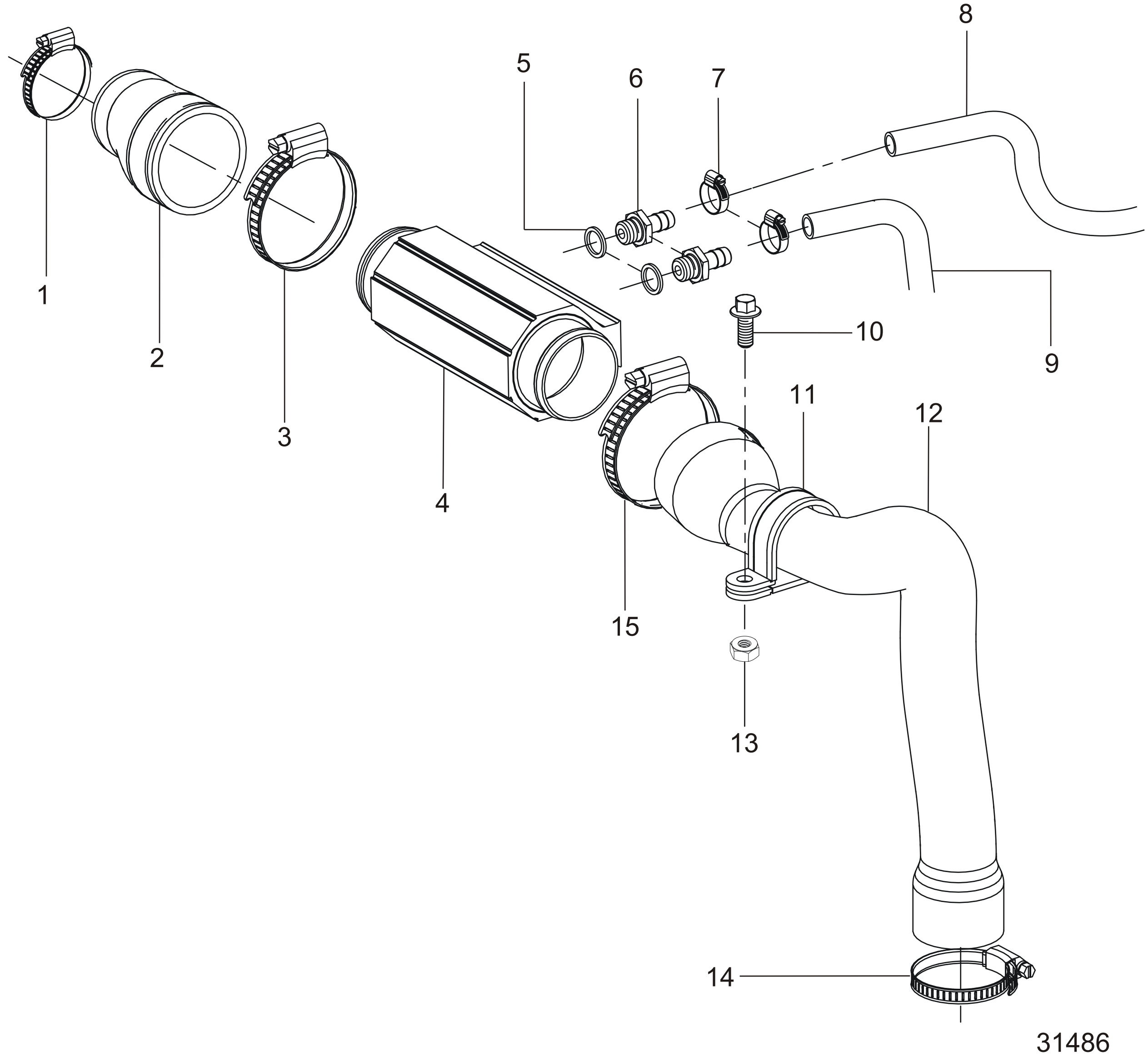
Exploded View—Heat Exchanger and Related Components



Exploded View—Heat Exchanger and Related Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. In.	lb. ft.
1	1	Lower thermostat housing			
2	2	Hose clamp			
3	1	Hose			
4	1	Heat exchanger			
5	2	O-ring			
6	1	O-ring			
7	1	Hot water valve	24.5	–	18
8	1	Nut	24.5	–	18
9	1	Stud			
10	1	Bracket			
11	1	Sealing washer			
12	1	Plug			
13	1	Bracket (4.2)			
14	1	Bracket (2.8)			
15	2	Screw	19.6	173	–
16	2	Screw (2.8)	19.6	173	–
17	2	Screw (4.2)	19.6	173	–
18	1	Cover			
19	1	Sealing washer			
20	1	Anode assembly			
21	4	Nut	24.5	–	18
22	8	O-ring			
23	1	Core insert			
24	1	Cooler			
25	1	Plate			
26	4	Stud			
27	1	Spacer			
28	1	Core Insert			
29	1	Exchanger body			
30	1	Plug			
31	1	Sealing washer			
32	1	Cover			
33	1	Plate			
34	4	Screw	24.5	–	18

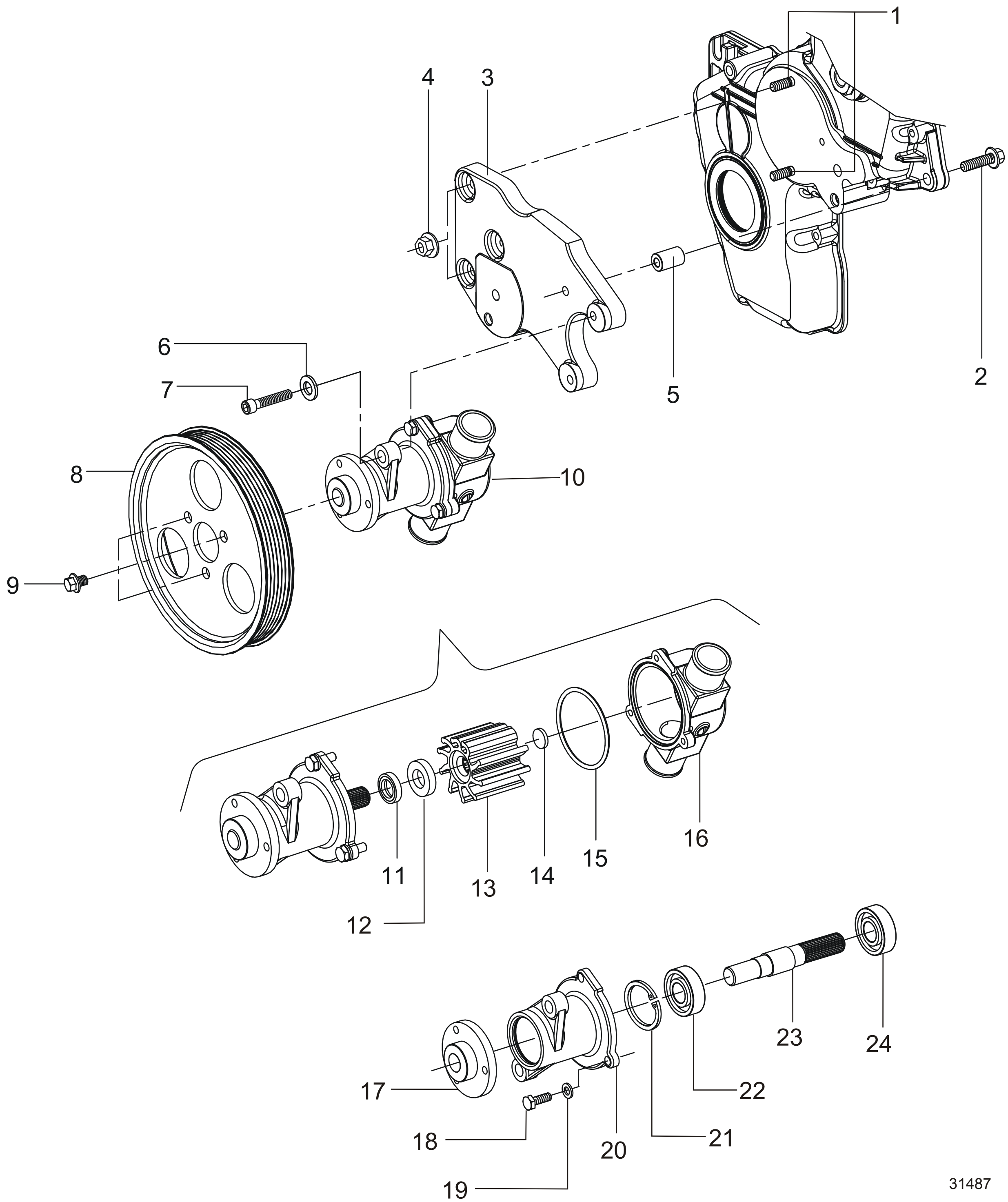
Exploded View—Fuel Cooler and Related Components



Exploded View—Fuel Cooler and Related Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. In.	lb. ft.
1	1	Hose clamp	4.6	40	–
2	1	Fuel cooler seawater outlet hose			
3	1	Hose clamp	4.6	40	–
4	1	Fuel cooler			
5	2	Sealing washers			
6	2	Barb fitting	10.8	95	–
7	2	Hose clamp	4.6	40	–
8	1	Upper fuel hose (to the fuel tank return fuel line)			
9	1	Lower fuel hose (from the injection pump)			
10	1	Bolt			
11	1	J-clip			
12	1	Fuel cooler seawater inlet hose			
13	1	Nut	24.5	–	18
14	1	Hose clamp	4.6	40	–

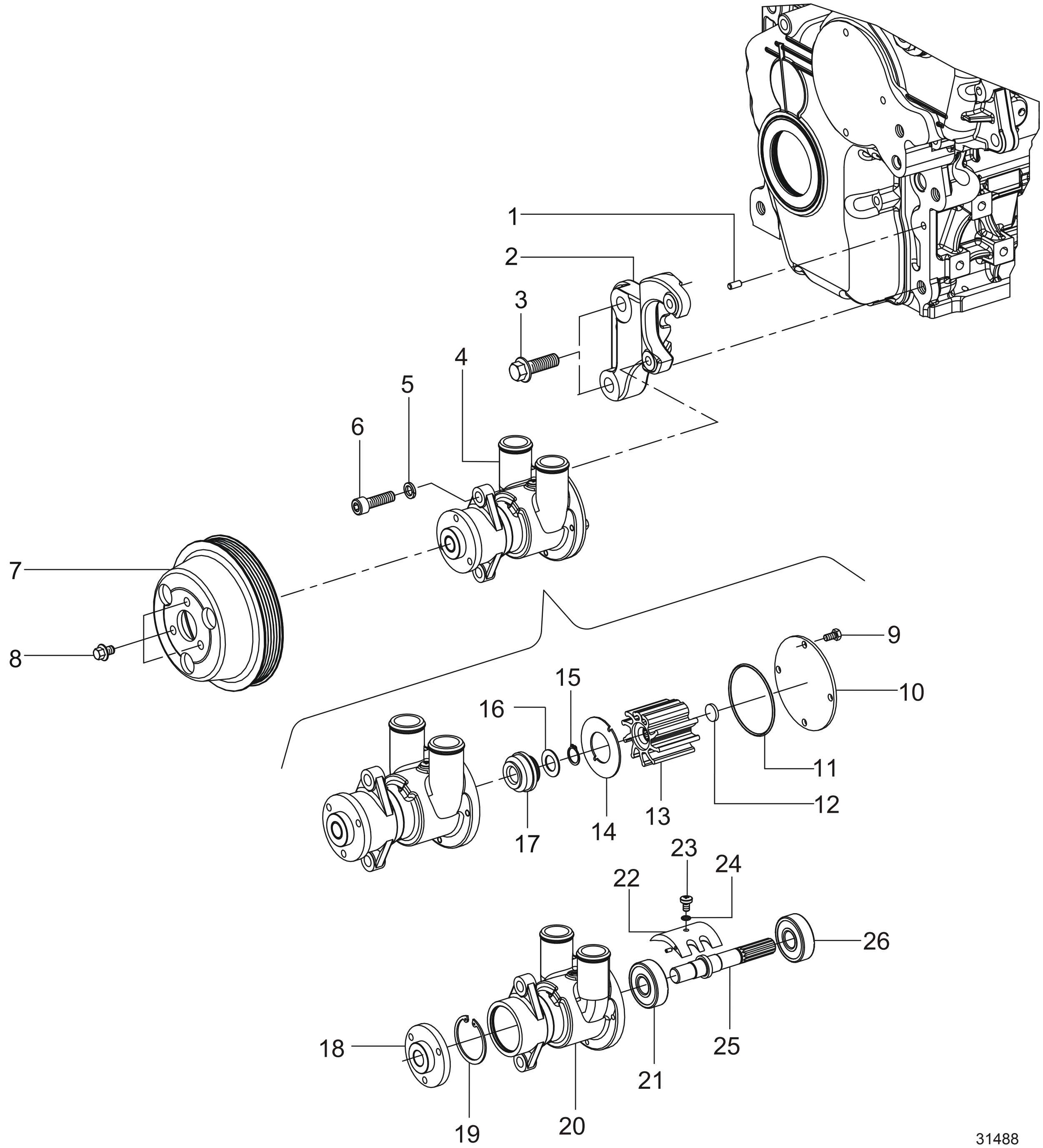
Exploded View— 2.8 Seawater Pump and Related Components



Exploded View— 2.8 Seawater Pump and Related Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. In.	lb. ft.
1	2	Stud			
2	1	Screw			
3	1	Bracket			
4	2	Nut			
5	1	Spacer			
6	1	Washer	47.1	–	34
7	2	Screw			
8	1	Pulley			
9	3	Screw	24.5	–	18
10	1	Seawater pump assembly			
11	1	Seal			
12	1	Washer			
13	1	Impeller			
14	1	Seal			
15	1	O-ring			
16	1	Water pump housing (rear)			
17	1	Hub			
18	3	Screw			
19	3	Lock washer			
20	1	Water pump housing (front)			
21	1	Snap ring			
22	1	Bearing			
23	1	Shaft			
24	1	Bearing			

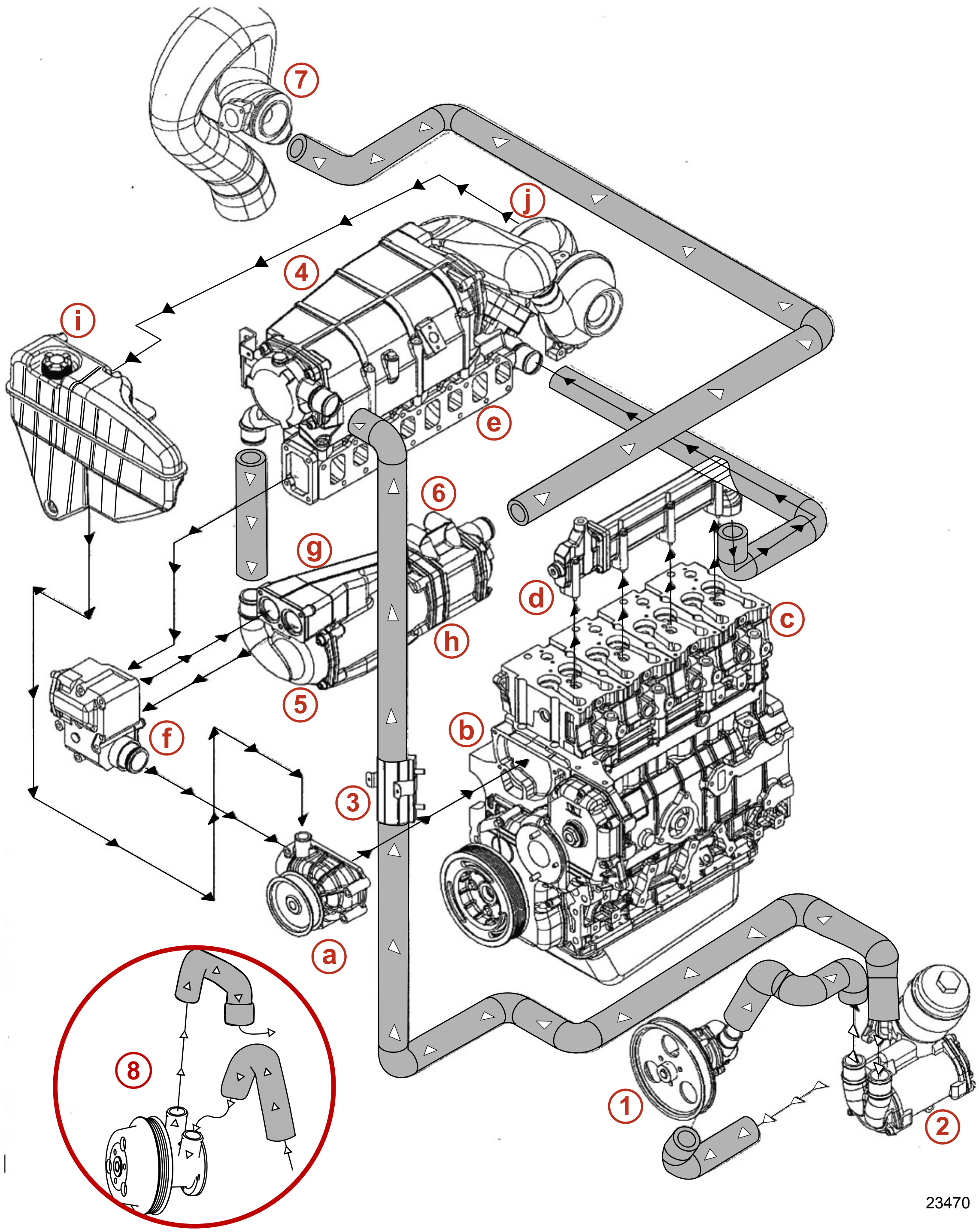
Exploded View— 4.2 Seawater Pump and Related Components



Exploded View— 4.2 Seawater Pump and Related Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. In.	lb. ft.
1	1	Dowel pin			
2	1	Bracket			
3	2	Screw	47.1	–	34
4	1	Seawater pump assembly			
5	2	Washer			
6	2	Screw	47.1	–	34
7	1	Pulley			
8	3	Screw	24.5	–	18
9	4	Screw			
10	1	Cover plate			
11	1	O-ring			
12	1	Seal			
13	1	Impeller			
14	1	Washer			
15	1	Snap ring			
16	1	Washer			
17	1	Mechanical seal			
18	1	Hub			
19	1	Snap ring			
20	1	Water pump housing			
21	1	Bearing			
22	1	Cam			
23	1	Screw			
24	1	Sealing washer			
25	1	Shaft			
26	1	Bearing			

Cooling System Flow Diagram—Typical



2.8 shown, 4.2 similar

Closed cooling system

a - Engine water circulating pump

b - Engine block

c - Cylinder heads

d - Coolant manifold

e - Intake and exhaust manifold assembly

f - Thermostat housing

g - Heat exchanger

h - Fluid cooler

i - Expansion tank

j - Turbocharger

Seawater system

1 - 2.8 seawater pump (seawater inlet)

2 - Engine oil cooler

3 - Fuel cooler

4 - Aftercooler

5 - Heat exchanger

6 - Fluid cooler

7 - Sterndrive model exhaust riser or inboard model exhaust elbow (seawater overboard)

8 - 4.2 seawater pump (seawater inlet)

Seawater Section Components

Seawater Pickup Connection

Water pickup connections must be large enough to permit sufficient water flow to the engine seawater pump for adequate engine cooling.

IMPORTANT: Do not install the water pickup directly in line with the propeller, as the pickup may create turbulence and allow air to flow into the propeller slipstream. This air flow causes propeller ventilation and adversely affects boat performance.

The water pickup must supply a positive head of seawater while underway. The water pickup should be located as close to the seawater pump inlet as possible and in an area where an uninterrupted, solid stream of water will flow past when the boat is underway.

Use only wire-reinforced seawater hose with adequate wall thickness to prevent collapse during maximum levels of seawater pump suction. Secure the hose connections with double hose clamps. Follow manufacturer instructions for installing the seawater pickup and seawater strainer.

Seawater pickup connections	
Through-hull or through-transom pickup flow requirement	150 liters (40 U.S. gal.) minimum per minute
Seawater hose diameter (wire-reinforced)	38 mm (1-1/2 in.)

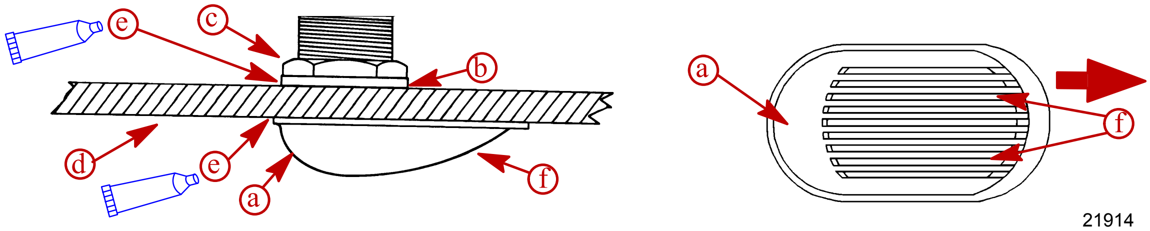
INSTALLATION

NOTE: If using a seawater pickup other than the QuickSilver model referenced below, follow the installation instructions supplied by the manufacturer.

1. Install the Quicksilver through-hull seawater pickup:
   a. Drill a 50 mm (2 in.) hole through the hull in an appropriate location. See **Installation Requirements**.
   b. Apply marine caulking (sealer) to mounting surface on the seawater pickup where hull contact will occur when the pickup is installed.

Description	Where Used	Part Number
Marine Caulking	Seawater inlet mounting surfaces	Obtain locally

   c. Ensure that the slots in the water pickup are facing forward (toward the bow of the boat), and install the water pickup through the hull.
   d. Apply marine caulking as needed inside the boat.
   e. Position the washer on the fitting and install the large nut.
   f. Apply sealant to the threads of the nut and install on the pickup on the inside of the boat. Torque the nut.



a - Seawater pickup (through-hull fitting)
b - Washer
c - Large nut
d - Hull of boat
e - Marine caulking
f - Slots facing forward

Tube Ref No.	Description	Where Used	Part No.
	Marine Caulking	Seawater inlet mounting surfaces	Obtain Locally

Tube Ref No.	Description	Where Used	Part No.
7	Loctite 271 Threadlocker	Seawater inlet nut	92-809819

Description	Nm	lb. in.	lb. ft.
Seawater inlet nut	42		35

NOTE: If the pickup being installed does not have mounting screws on the underside where mounted to the hull, ensure that the slots are still facing forward after the nut is torqued.

Seacock

If a seacock (water inlet valve) is being used, it must be installed between the seawater pickup and the seawater pickup pump (or seawater strainer, if equipped), to allow the operator to shut off the seawater in case of a leak or when the boat is not in use. This will also allow the operator to flush or drain the engine, or clean the sea strainer while the boat is in the water. Install the seacock in an area where it will be easily accessible and supported adequately to prevent hose fatigue.

The seacock, if equipped, must have an internal cross-sectional area equal to or greater than the sewater hose to prevent restricting the seawater flow.

Seacock (water inlet valve)	
Size (internal cross sectional area)	38 mm (1-1/2 in.) minimum

Seawater Strainer

The seawater strainer, if equipped, must be of sufficient size to ensure that an adequate supply of seawater will be maintained for cooling the engine. A minimum flow rate is required.

Seawater strainer	
Flow requirement	150 liters (40 U.S. gal.) minimum per minute

Draining the Seawater System

⚠ CAUTION

Water can enter the bilge when the drain system is open, damaging the engine or causing the boat to sink. Remove the boat from the water or close the seacock, disconnect and plug the seawater inlet hose, and ensure the bilge pump is operational before draining. Do not operate the engine with the drain system open.

IMPORTANT: The engine must be as level as possible to ensure complete draining of the cooling system.

Drain the seawater system of the power package before cold weather (freezing temperature), seasonal storage, or extended storage.

IMPORTANT: The boat must not be operating during this procedure.

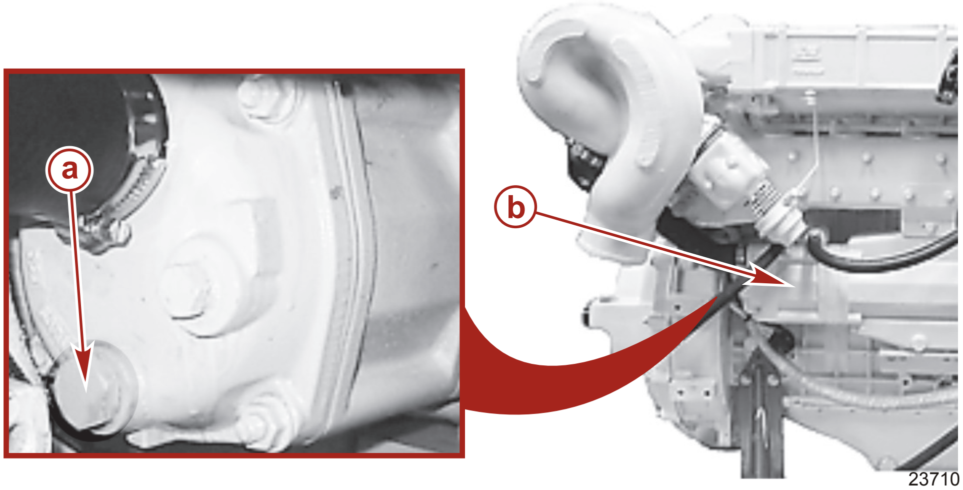
⚠ CAUTION

Water can enter the bilge when the drain system is open, damaging the engine or causing the boat to sink. Remove the boat from the water or close the seacock, disconnect and plug the seawater inlet hose, and ensure the bilge pump is operational before draining. Do not operate the engine with the drain system open.

1. Remove the boat from the water if possible.
2. **If the boat is to remain in the water**, turn on the bilge pump, close the seacock (if equipped), or disconnect and plug the seawater inlet hose.
3. Make the engine as level as possible to ensure complete draining of the seawater system.

NOTE: *The anode assembly on the back of the fluid cooler can be used as a drain plug.*

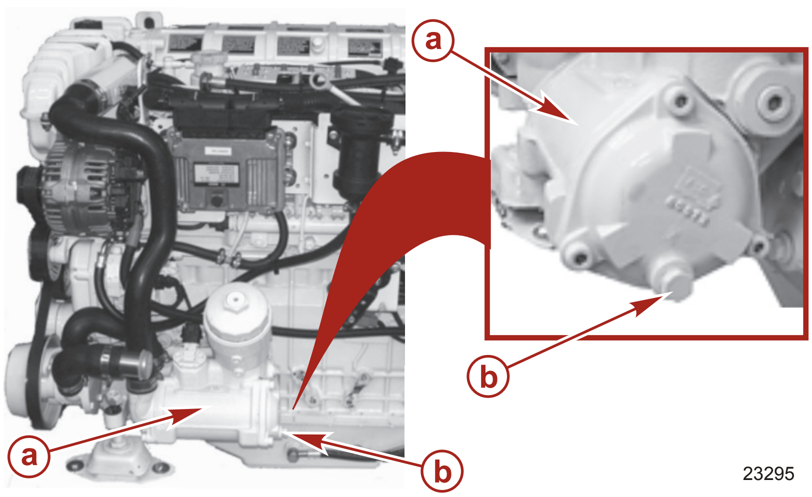
4. Remove the drain plug from the aft end cover of the fluid cooler.



Typical engine

a - Anode assembly drain plug **b -** Fluid cooler

5. Remove the drain plug, or fitting (if equipped), from the aft end cover of the engine oil cooler.

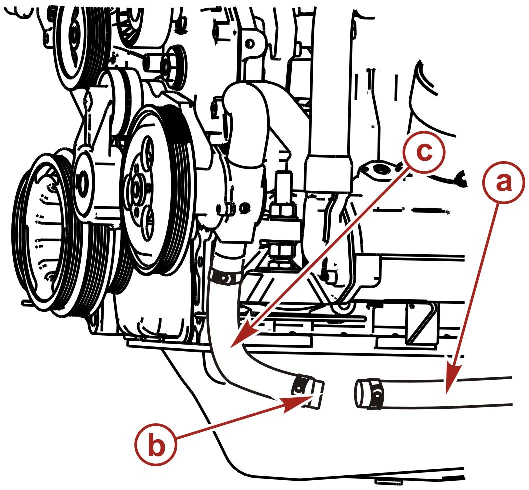


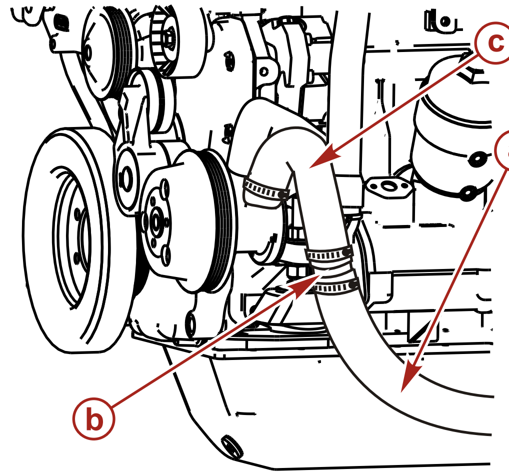
Typical engine

a - Engine oil cooler **b -** Drain plug, or fitting if equipped

NOTE: *In the following steps, the hoses may require lowering or bending to allow seawater to drain completely.*

6. Disconnect the seawater inlet hose from the connector on the seawater pump hose and drain.

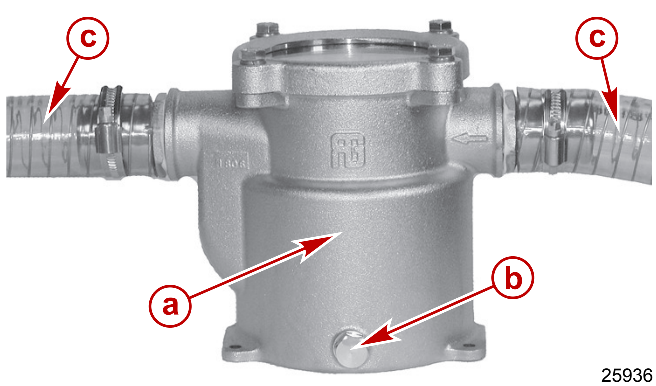




2.8 4.2

a - Seawater inlet hose
b - Connector
c - Seawater pump hose

7. Repeatedly clean out the drain holes using a stiff piece of wire until the seawater section is completely drained.
8. **On models equipped with a seawater strainer**, remove the hose at the seawater strainer and drain the hose completely. Drain and empty the seawater strainer. Reconnect the hose and tighten the hose clamps securely. Install the sealing washer and drain plug.



a - Seawater strainer
b - Sealing washer and drain plug
c - Hose

9. After the seawater has completely drained, apply sealant to the threads of the drain plugs or fittings (if equipped). Install and tighten the drain plugs or fittings securely.

Tube Ref No.	Description	Where Used	Part No.
19	Perfect Seal	Drain plug or fitting threads	92-34227 1

10. Reconnect the hoses. Tighten the hose clamps securely.

Cleaning the Seawater Strainer, if Equipped

NOTICE

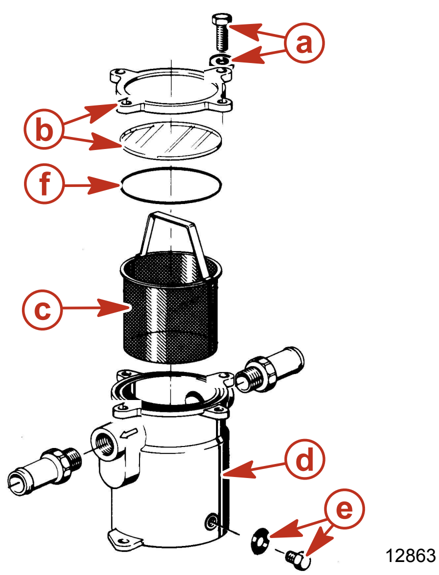
An open seawater strainer or seacock during some service or maintenance procedures can introduce water into the boat, causing damage or sinking the boat. Always close the water supply from the seawater pump, water inlet, or seacock when performing service or maintenance on the cooling system.

1. With the engine off, close the seacock, if equipped, or remove and plug the seawater inlet hose.
2. Remove the screws, washers, and cover.
3. Remove the strainer, drain plug, and sealing washer.
4. Clean all the debris from the strainer housing. Flush both the strainer and housing with clean water.
5. Check the cover gasket and replace when damaged or if it leaks.
6. Reinstall the strainer, drain plug, and sealing washer.

⚠ CAUTION

Seawater leaking from the seawater strainer could cause excess water in the bilge, damaging the engine or causing the boat to sink. Do not overtighten the cover screws, or the cover may warp and introduce seawater into the bilge.

7. Install the seal and cover using the screws and washers. Do not overtighten the cover screws.



a - Screws and washers
b - Cover with glass
c - Strainer
d - Housing
e - Drain plug and sealing washer
f - Seal

8. Open the seacock, if equipped, or remove the plug and reconnect the seawater inlet hose.
9. Upon first starting the engine, check for leaks or air in the system that would indicate an external leak.

Seawater Pump—2.8

Removal

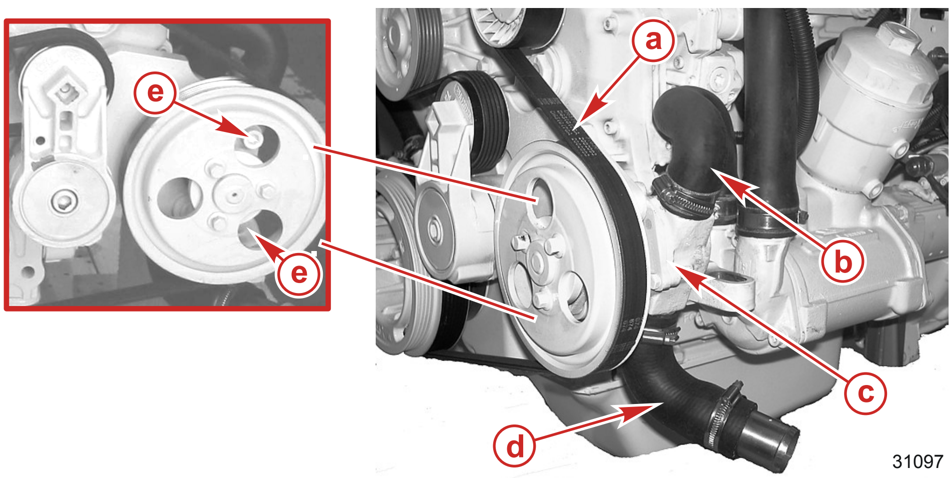
NOTICE

If the boat is at rest in the water with the engine off, an open seacock or water inlet hose could introduce water into the engine's cooling system or the boat. Keep the seacock or water inlet hose plugged until ready to start the engine. Attach a tag to the ignition switch or steering wheel to inform others of the water inlet connection.

1. Close the seacock if equipped, or disconnect and plug the seawater inlet hose if the boat is to remain in the water.
2. Drain the seawater from the cooling system. See **Section 1B: Seawater System**.
3. Remove the serpentine belt.
4. Remove the seawater pump inlet and outlet hose. Drain the seawater into a suitable container.

NOTE: Some engines may have spacers on the mounting screws, between the seawater pump mounting flanges and the engine front bracket. Retain any spacers for use during assembly.

5. Remove the two seawater pump mounting screws.
6. Remove the seawater pump.

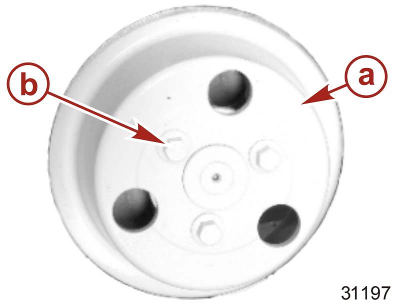


a - Serpentine belt
b - Outlet hose
c - Seawater pump
d - Inlet hose
e - Seawater pump mounting screw

Disassembly

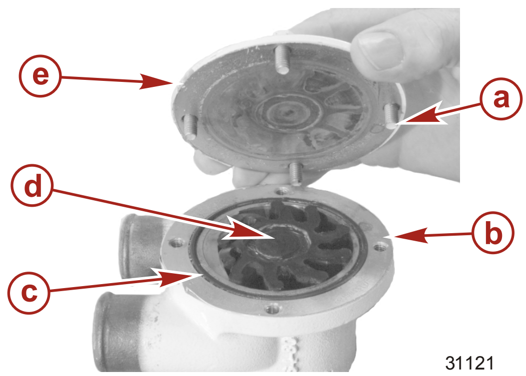
1. Clamp the seawater pump in a soft-jawed vise.

2. Loosen the three flange screws on the seawater pump pulley and remove the pulley.



a - Pulley
b - Flange screws

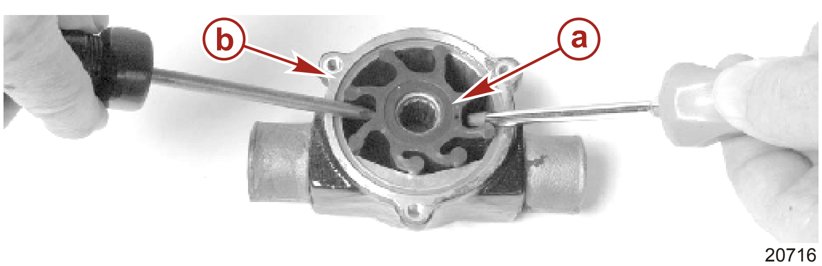
3. Loosen the four screws on the cover of the impeller and bearing housing.
4. Remove the cover.
5. Remove the rubber seal from the center of the impeller.
6. Remove and discard the pump cover O-ring seal from the groove.



a - Screw
b - Impeller and bearing housing
c - Pump cover O-ring seal
d - Rubber seal
e - Cover

IMPORTANT: Be careful not to damage the impeller or impeller housing during removal.

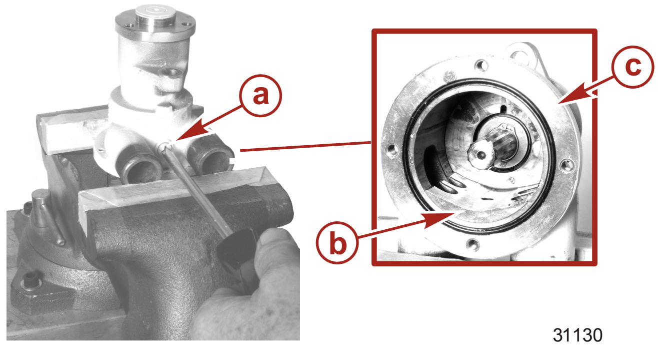
7. Note the direction of the impeller vane rotation and suitably mark the outer surface of the impeller for proper orientation during assembly.



Typical impeller removal using two screwdrivers

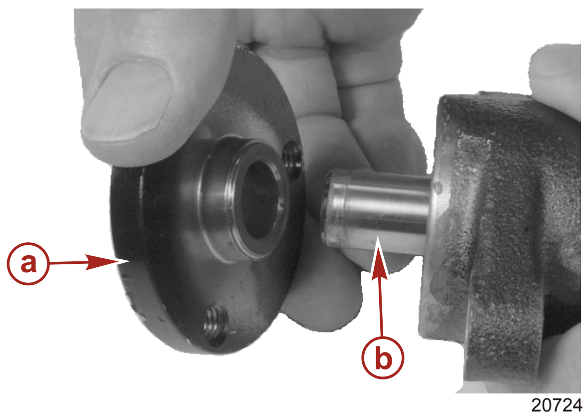
a - Impeller
b - Impeller housing

8. Remove the impeller from the impeller housing using a pair of pliers to grasp the hub of the impeller (preferred method) or two screwdrivers to pry the impeller out of the impeller housing. Ensure that the impeller or impeller housing is not damaged.
9. Remove the cam screw and O-ring and remove the cam from the impeller housing.



a - Cam screw and O-ring
b - Cam
c - Impeller housing

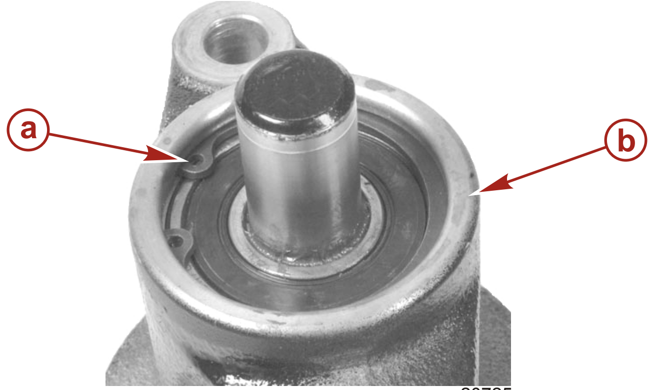
10. Using an arbor press and suitable hardware, press the seawater pump pulley flange off of the pump shaft.



Typical pulley flange, all similar

a - Pulley flange
b - Pump shaft

11. Remove the internal snap ring from the bearing housing.

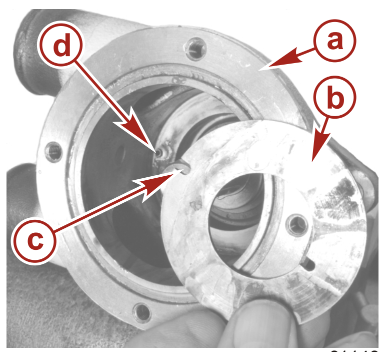


20725

a - Internal snap ring
b - Bearing housing

IMPORTANT: To avoid interference with the ball bearings during disassembly, do not damage the spline end of the pump shaft.

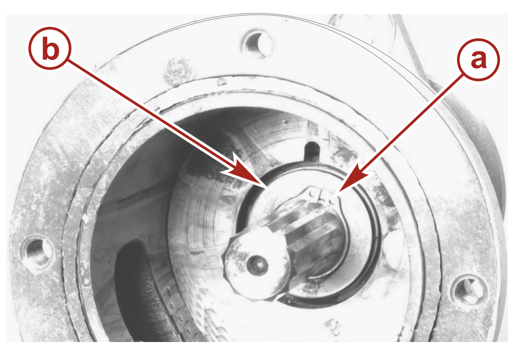
12. Remove the wear plate (thrust washer) from inside the pump housing. Note that the wear plate has a notch that aligns with a pin in the housing.



31143

a - Pump housing
b - Wear plate
c - Notch
d - Pin

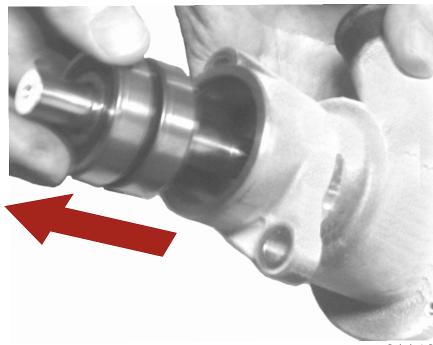
13. Remove the external retaining ring from the pump shaft.
14. Remove the spacer-washer from the shaft.



31144

a - External retaining ring
b - Spacer-washer

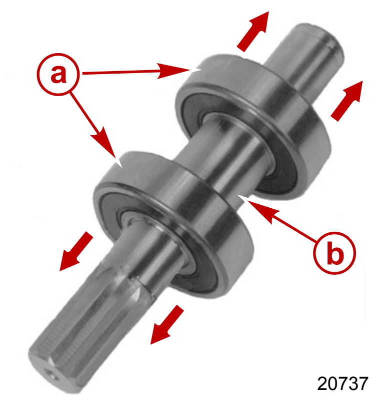
15. Press—or lightly tap using a plastic or brass hammer—the spline end of the pump shaft in the direction indicated by the arrow to remove the pump shaft from the bearing housing.



Pump shaft removal

IMPORTANT: Take note of the factory markings on the bearings, or suitably mark each bearing to ensure installation in their original position if reused.

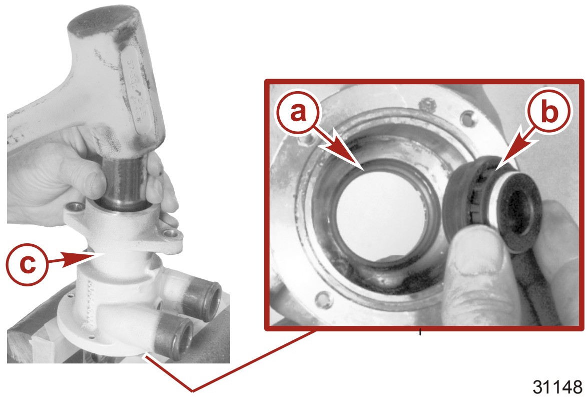
16. Using an arbor press and suitable hardware, remove one bearing at a time from the pump shaft. The bearings press off of the shaft in opposite directions. Press only on the inner race of the bearings.



Typical

a - Bearing
b - Pump shaft

17. Using a suitable device and hardware, press or drive the pump shaft mechanical seal from the seat in the bearing housing.



a - Seat
b - Mechanical seal
c - Bearing housing

Cleaning

1. Put on safely glasses.
2. Clean the metal parts in solvent and dry the parts with compressed air.
3. After cleaning, apply engine oil to the shaft and bearings to prevent rusting.

Inspection

1. Inspect the bearing housing. Examine the surfaces where the bearings contact housing for evidence of bearing outer races turning in the housing.
2. Inspect the bearings for a worn or defective condition. Examine sealed bearings for evidence of loss of factory grease or evidence of internal contamination.
3. Inspect the two-part seal from the bearing housing.
4. Inspect the seawater pump shaft for grooves in the surface where the seals contact the shaft.
5. Inspect where the bearings contact the shaft for evidence of the inner races turning on the shaft.
6. Inspect the impeller housing.
7. Inspect the cam for scratches or gouging.
8. Inspect the impeller splines and shaft splines.
9. Inspect the seawater pump impeller for wear on the sides and the tips of the blades.
10. Inspect the blades for cracks in the area where the blades must flex.
11. Replace the impeller if the blades remain in a curved position.

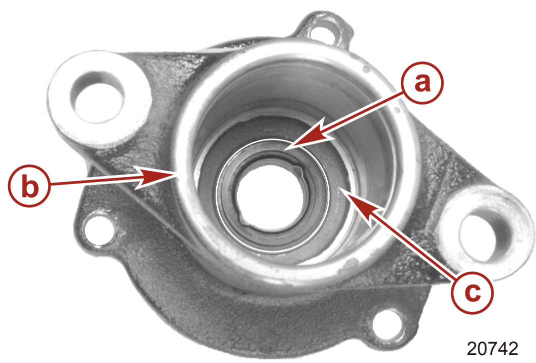
Assembly

1. Lightly lubricate the seawater pump shaft.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Seawater pump shaft	Obtain Locally

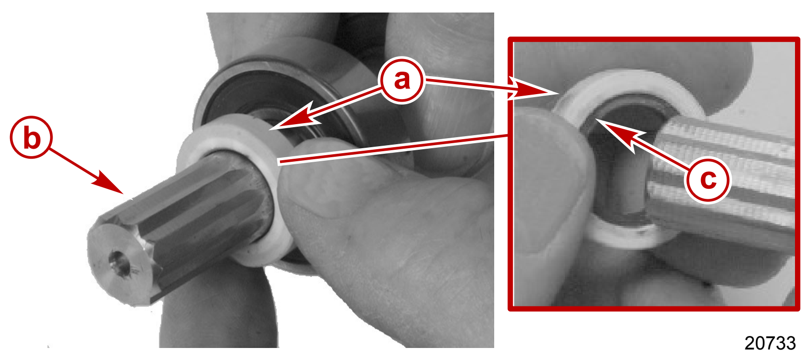
IMPORTANT: If the bearings are reused, ensure they are installed in their original positions.

2. Press the bearings on the pump shaft using an arbor press and suitable hardware. Press only on the inner race of the bearings.
3. Using a suitable device and hardware, press the brass and carbon part of the seal into the bearing housing. The brass side of the seal will face toward the impeller. Press on the seal until the carbon side of the seal is flush with the bottom (inside) of the bearing housing.



a - Brass and carbon part—carbon side
b - Bearing housing
c - Bottom (inside)

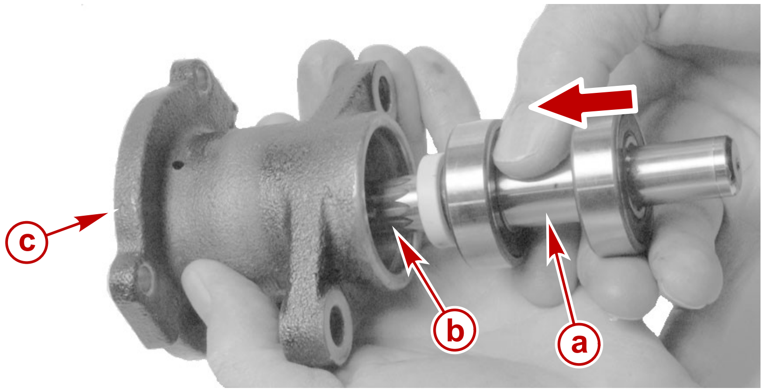
4. Slide the white ceramic part of the seal on the spline end of the shaft. Ensure the smooth side of the seal faces the spline end of the shaft and the side with the quad-ring rubber seal faces the bearing.



a - White ceramic part of the seal—smooth side
b - Spline end
c - Quad-ring rubber seal

IMPORTANT: To avoid interference with the pulley assembly, do not damage the end of the pump shaft during bearing installation. Do not damage either part of the seal.

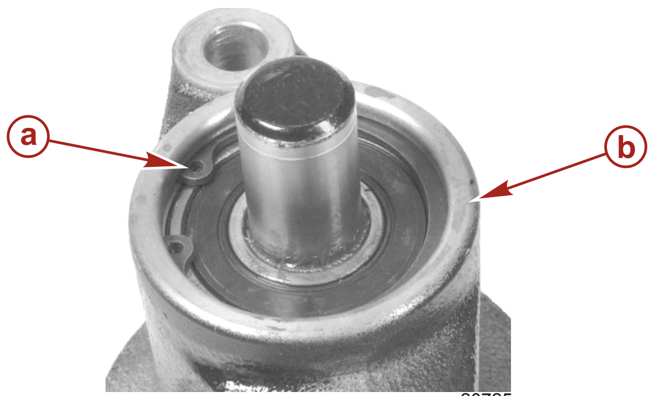
5. Insert the spline end into the bearing housing. Lightly tap, using a plastic or brass hammer, or press the pulley end of the pump shaft into the bearing housing until the bearings seat in the housing.



20746

a - Pump shaft
b - Spline end
c - Bearing housing

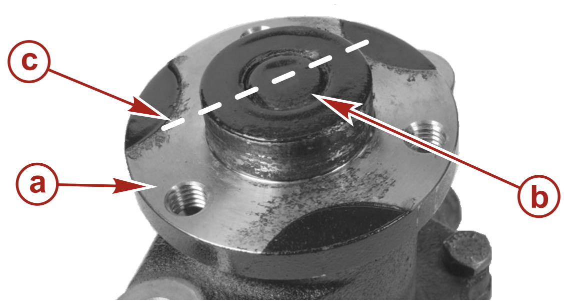
6. Install the internal snap ring into the bearing housing.



20725

a - Internal snap ring
b - Bearing housing

7. Using an arbor press and suitable hardware, press the seawater pump pulley flange onto the pump shaft. The outer edge of the pulley flange will be parallel to the end of the pump shaft when correctly installed.



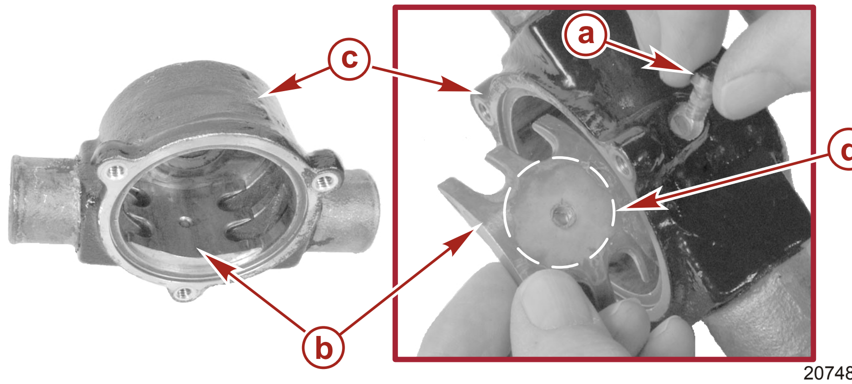
20747

a - Pulley flange
b - Pump shaft
c - Parallel

8. Apply sealant to the seawater pump cam screw and to the area on the backside of the cam as indicated.

Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Backside of seawater pump cam and screw threads	92-12564 2

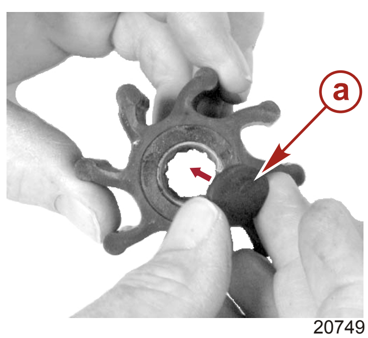
9. Install the cam into the impeller housing.
10. Install and securely tighten the cam screw.



a - Cam screw
b - Cam
c - Impeller housing
d - Sealant area

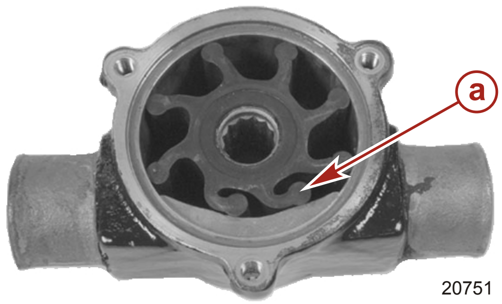
IMPORTANT: If the outer surface of the impeller was not marked during removal and the original direction of rotation cannot be determined, replace the impeller.

11. Push the rubber seal into the end of the impeller that will enter the impeller housing first during installation.



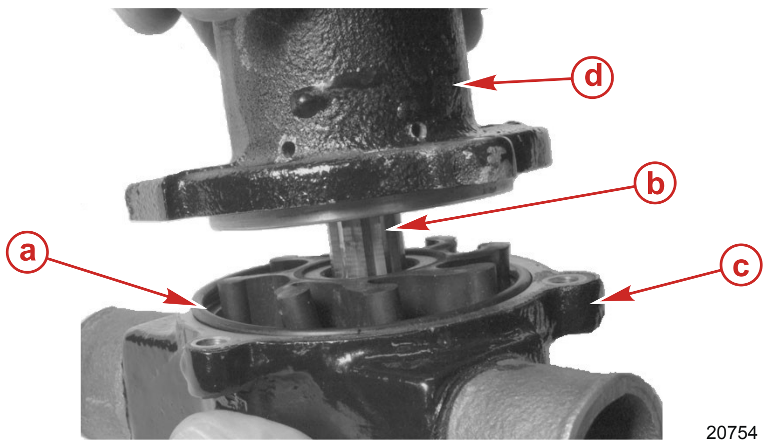
a - Rubber seal

12. Install the impeller and rubber seal into the impeller housing by turning the impeller clockwise while simultaneously pushing inward. After installation, the blades should be flexed in the direction shown.



a - Direction of blade flex

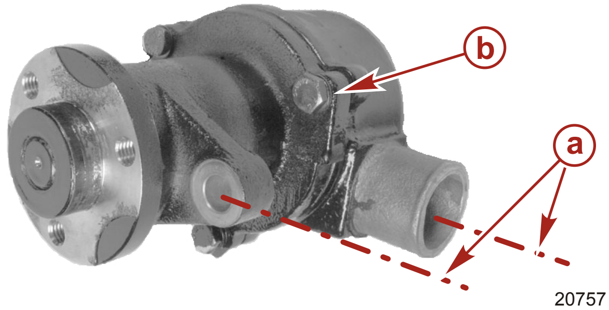
13. Install the O-ring into the groove of the impeller housing.
14. Insert the spline end of the pump shaft into the impeller. Slide the bearing housing assembly over the impeller and onto the impeller housing using a twisting motion, if necessary, in the direction of engine rotation.



a - O-ring
b - Pump shaft spline end
c - Impeller housing
d - Bearing housing assembly

15. Turn the assembly to align the mounting flanges in-line with the pump outlet and inlet fittings as shown.

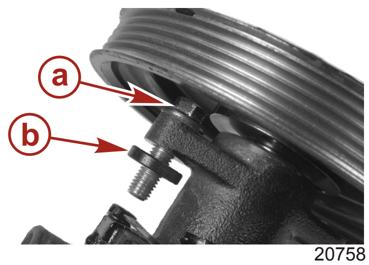
16. Install and securely tighten the three screws with lockwashers.



a - Alignment reference marks
b - Screw and lockwasher

Installation

1. Position the seawater pump on the engine front bracket.
2. Ensure that the spacers, if equipped, are present on the two seawater pump mounting screws prior to installation.



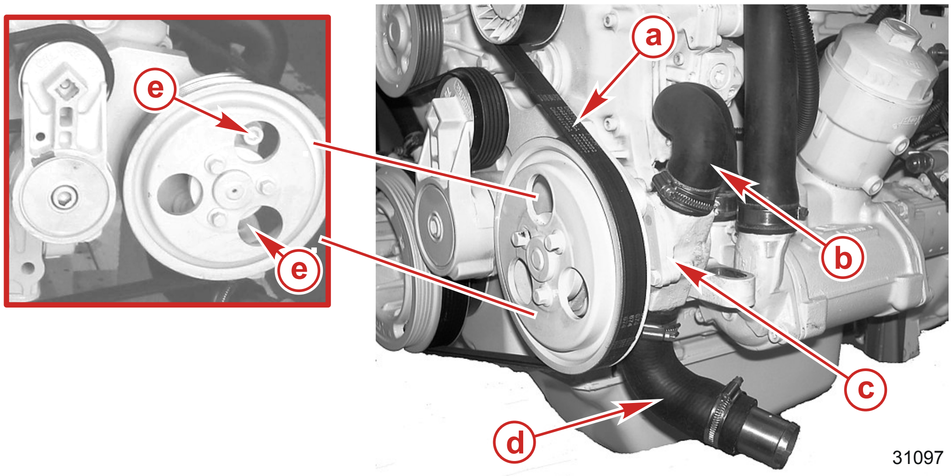
a - Mounting screw
b - Spacer, if equipped

3. Install and torque the two seawater pump mounting screws.

Description	Nm	lb. in.	lb. ft.
Seawater pump mounting screw	47.1	–	34

4. Install the serpentine drive belt. Ensure that the seawater pump pulley is properly aligned with the serpentine belt.
5. Install the seawater pump inlet and outlet hose. Tighten the hose clamps securely.
6. Open the seacock if equipped, or unplug and connect the seawater inlet hose.

7. Check for leaks when you first start the engine.



a - Serpentine belt
b - Outlet hose
c - Seawater pump
d - Inlet hose
e - Seawater pump mounting screw

Seawater Pump—4.2

Removal

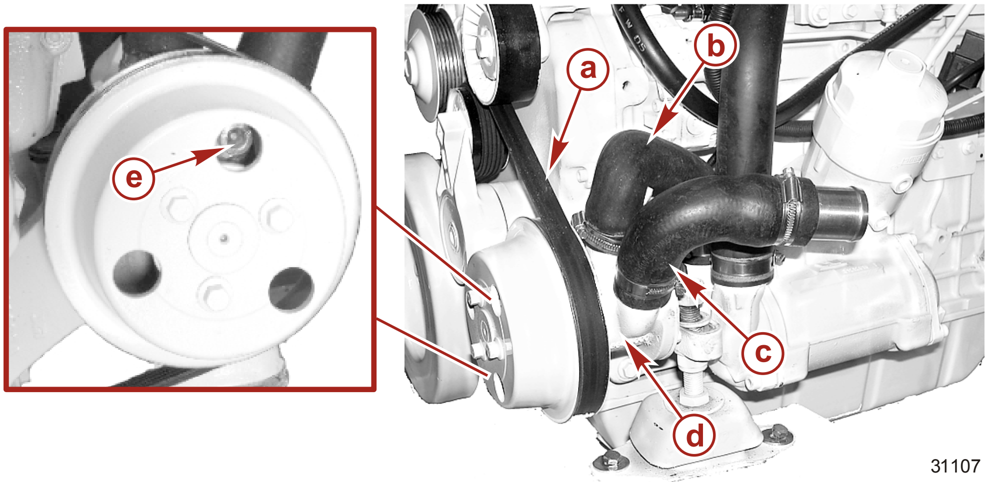
NOTICE
If the boat is at rest in the water with the engine off, an open seacock or water inlet hose could introduce water into the engine's cooling system or the boat. Keep the seacock or water inlet hose plugged until ready to start the engine. Attach a tag to the ignition switch or steering wheel to inform others of the water inlet connection.

1. Close the seacock if equipped, or disconnect and plug the seawater inlet hose if the boat is to remain in the water.
2. Drain the seawater from the cooling system. Refer to **Section 1B: Seawater System**.
3. Remove the serpentine belt.
4. Remove the seawater pump inlet and outlet hose. Drain the seawater into a suitable container.

NOTE: Some engines may have spacers on the mounting screws, between the seawater pump mounting flanges and the engine front bracket. Retain any spacers for use during assembly.

5. Remove the two seawater pump mounting screws.

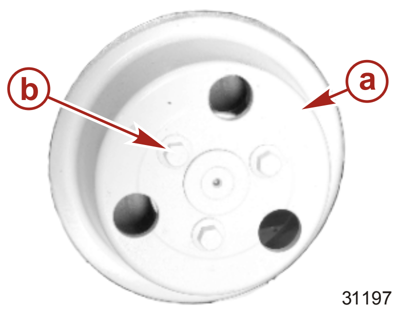
6. Remove the seawater pump.



a - Serpentine belt
b - Outlet hose
c - Inlet hose
d - Seawater pump
e - Seawater pump mounting screw (one not visible in this view)

Disassembly

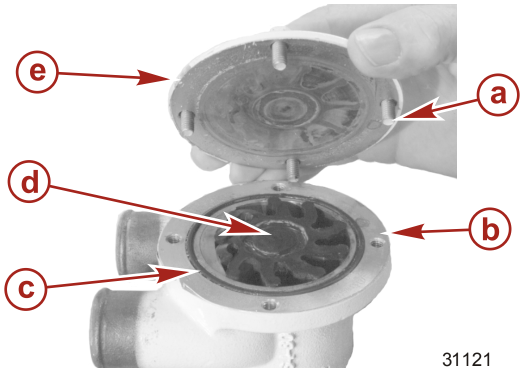
1. Clamp the seawater pump in a soft-jawed vise.
2. Loosen the three flange screws on the seawater pump pulley and remove the pulley.



a - Pulley
b - Flange screws

3. Loosen the four screws on the cover of the impeller and bearing housing.
4. Remove the cover.
5. Remove the rubber seal from the center of the impeller.

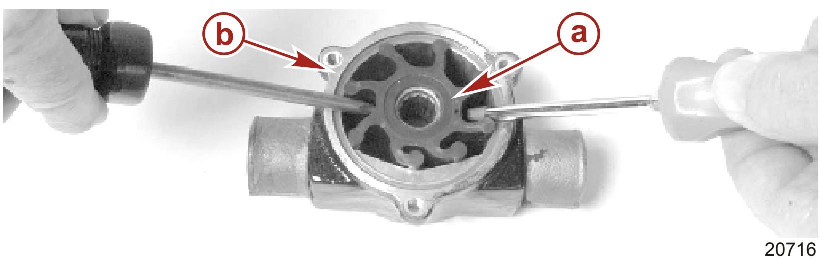
6. Remove and discard the pump cover O-ring seal from the groove.



a - Screw
b - Impeller and bearing housing
c - Pump cover O-ring seal
d - Rubber seal
e - Cover

IMPORTANT: Be careful not to damage the impeller or impeller housing during removal.

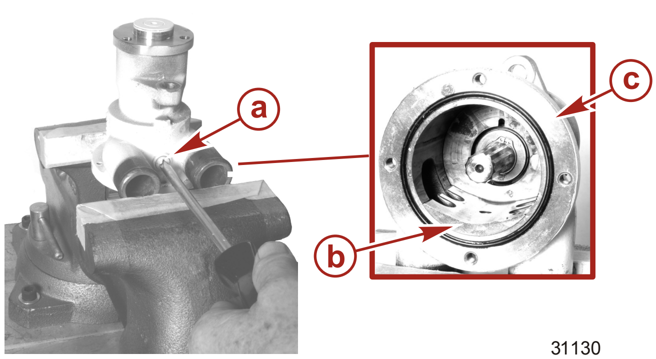
7. Note the direction of the impeller vane rotation and suitably mark the outer surface of the impeller for proper orientation during assembly.



Typical impeller removal using two screwdrivers

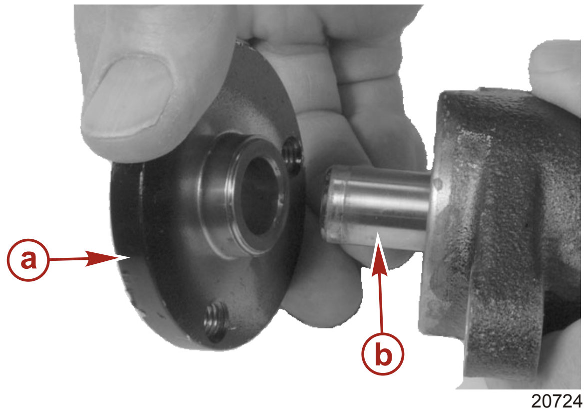
a - Impeller
b - Impeller housing

8. Remove the impeller from the impeller housing using a pair of pliers to grasp the hub of the impeller (preferred method) or two screwdrivers to pry the impeller out of the impeller housing. Ensure that the impeller or impeller housing is not damaged.
9. Remove the cam screw and O-ring and remove the cam from the impeller housing.



a - Cam screw and O-ring
b - Cam
c - Impeller housing

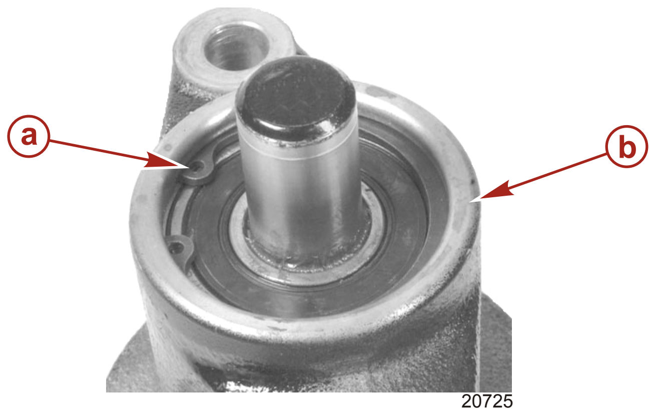
10. Using an arbor press and suitable hardware, press the seawater pump pulley flange off of the pump shaft.



Typical pulley flange, all similar

a - Pulley flange
b - Pump shaft

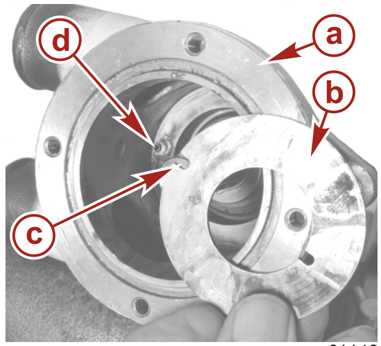
11. Remove the internal snap ring from the bearing housing.



a - Internal snap ring
b - Bearing housing

IMPORTANT: To avoid interference with the ball bearings during disassembly, do not damage the spline end of the pump shaft.

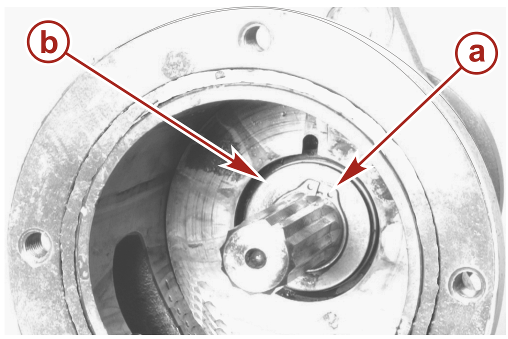
12. Remove the wear plate (thrust washer) from inside the pump housing. Note that the wear plate has a notch that aligns with a pin in the housing.



31143

a - Pump housing
b - Wear plate
c - Notch
d - Pin

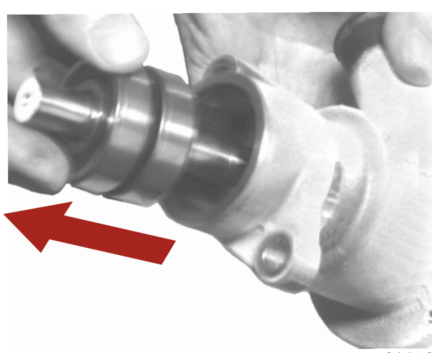
13. Remove the external retaining ring from the pump shaft.
14. Remove the spacer-washer from the shaft.



31144

a - External retaining ring
b - Spacer-washer

15. Press—or lightly tap using a plastic or brass hammer—the spline end of the pump shaft in the direction indicated by the arrow to remove the pump shaft from the bearing housing.

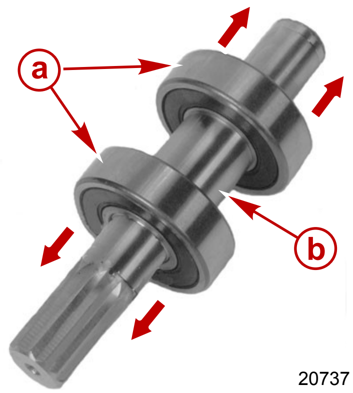


31146

Pump shaft removal

IMPORTANT: Take note of the factory markings on the bearings, or suitably mark each bearing to ensure installation in their original position if reused.

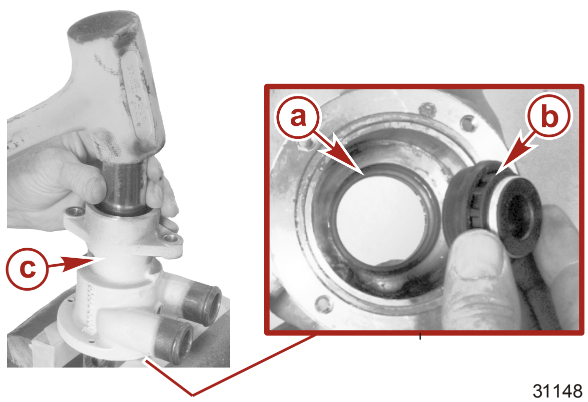
16. Using an arbor press and suitable hardware, remove one bearing at a time from the pump shaft. The bearings press off of the shaft in opposite directions. Press only on the inner race of the bearings.



Typical

a - Bearing
b - Pump shaft

17. Using a suitable device and hardware, press or drive the pump shaft mechanical seal from the seat in the bearing housing.



a - Seat
b - Mechanical seal
c - Bearing housing

Cleaning

1. Put on safely glasses.
2. Clean the metal parts in solvent and dry the parts with compressed air.
3. After cleaning, apply engine oil to the shaft and bearings to prevent rusting.

Inspection

1. Inspect the bearing housing. Examine the surfaces where the bearings contact housing for evidence of bearing outer races turning in the housing.
2. Inspect the bearings for a worn or defective condition. Examine sealed bearings for evidence of loss of factory grease or evidence of internal contamination.
3. Inspect the two-part seal from the bearing housing.
4. Inspect the seawater pump shaft for grooves in the surface where the seals contact the shaft.

5. Inspect where the bearings contact the shaft for evidence of the inner races turning on the shaft.
6. Inspect the impeller housing.
7. Inspect the cam for scratches or gouging.
8. Inspect the impeller splines and shaft splines.
9. Inspect the seawater pump impeller for wear on the sides and the tips of the blades.
10. Inspect the blades for cracks in the area where the blades must flex.
11. Replace the impeller if the blades remain in a curved position.

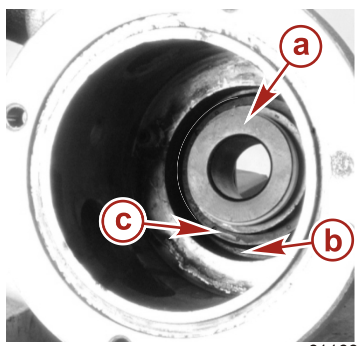
Assembly

1. Lightly lubricate the seawater pump shaft.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Seawater pump shaft	Obtain Locally

IMPORTANT: Ensure the bearings are installed in their original positions if being reused.

2. Press the bearings on the pump shaft using an arbor press and suitable hardware. Press only on the inner race of the bearings.
3. Using a suitable device and hardware, press the mechanical seal into the bearing housing as shown. Press on the outer edge of the seal until it is seated in the bearing housing.

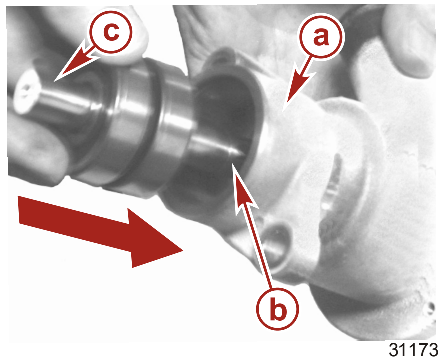


31163

a - Mechanical seal
b - Seat
c - Outer edge

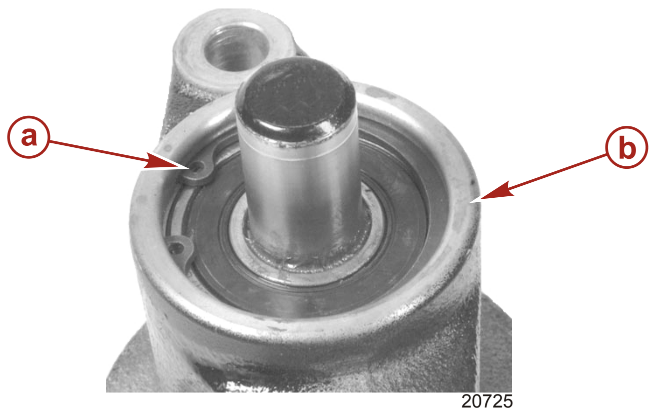
IMPORTANT: To avoid interference with the pulley assembly, do not damage the end of the pump shaft during bearing installation. Do not damage either part of the seal.

4. Insert the spline end of the pump shaft into the bearing housing. Lightly tap, using a plastic or brass hammer, or press on the pulley end of the pump shaft until the bearings seat in the housing.



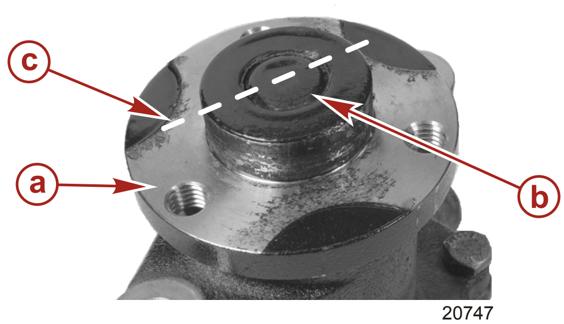
a - Bearing housing
b - Spline end
c - Pump shaft

5. Install the internal snap ring into the bearing housing.



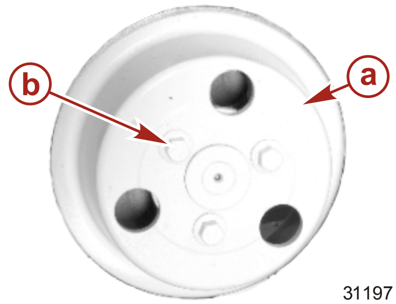
a - Internal snap ring
b - Bearing housing

6. Using an arbor press and suitable hardware, press the seawater pump pulley flange onto the pump shaft. The outer edge of the pulley flange will be flush with the end of the pump shaft when correctly installed.



a - Pulley flange
b - Pump shaft
c - Shaft and flange flush

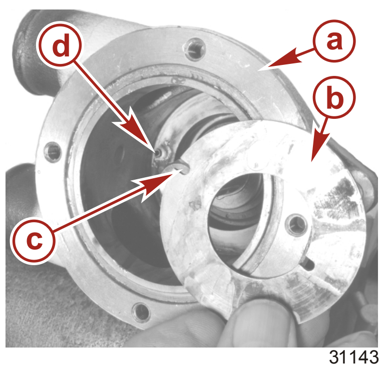
7. Install the seawater pump pulley. Torque the three flange screws.



a - Pulley
b - Flange screw

Description	Nm	lb. in.	lb. ft.
Seawater pump pulley flange screw	24.5	–	18

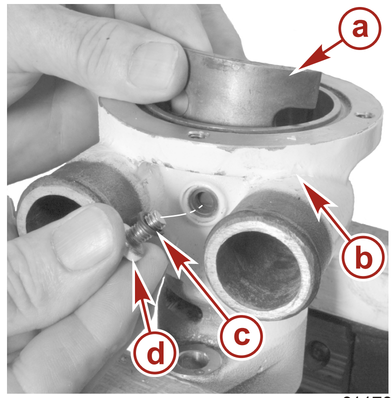
8. Install the wear plate (thrust washer) into the pump housing. Align the notch on the wear plate with the pin in the housing.



a - Pump housing
b - Wear plate
c - Notch
d - Pin

9. Install the cam into the impeller housing.
10. Install the O-ring on the cam screw.

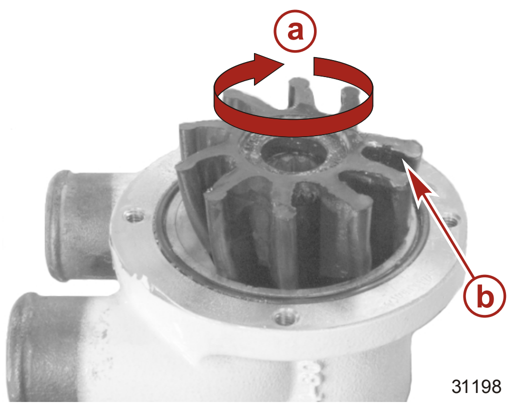
11. Install and securely tighten the cam screw.



a - Cam
b - Impeller housing
c - O-ring
d - Cam screw

IMPORTANT: Replace the impeller if the original direction of impeller rotation cannot be determined.

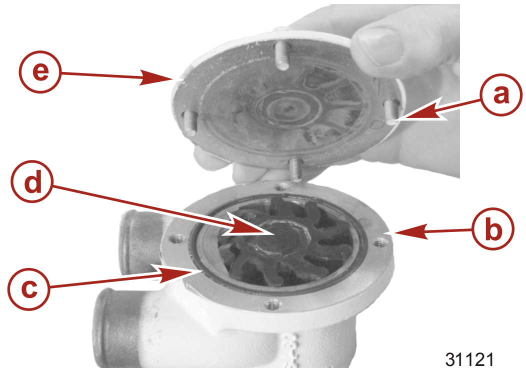
12. Install the impeller into the impeller housing by turning the impeller clockwise while simultaneously pushing inward. After installation, the blades should be flexed opposite the direction of rotation.



a - Turn clockwise
b - Direction of blade flex

13. Push the rubber seal into the center of the impeller.
14. Install the pump cover O-ring seal into the groove of the impeller housing.

15. Install the cover and securely tighten the four screws in a crisscross pattern.



a - Screw
b - Impeller and bearing housing
c - Pump cover O-ring seal
d - Plug
e - Cover

Installation

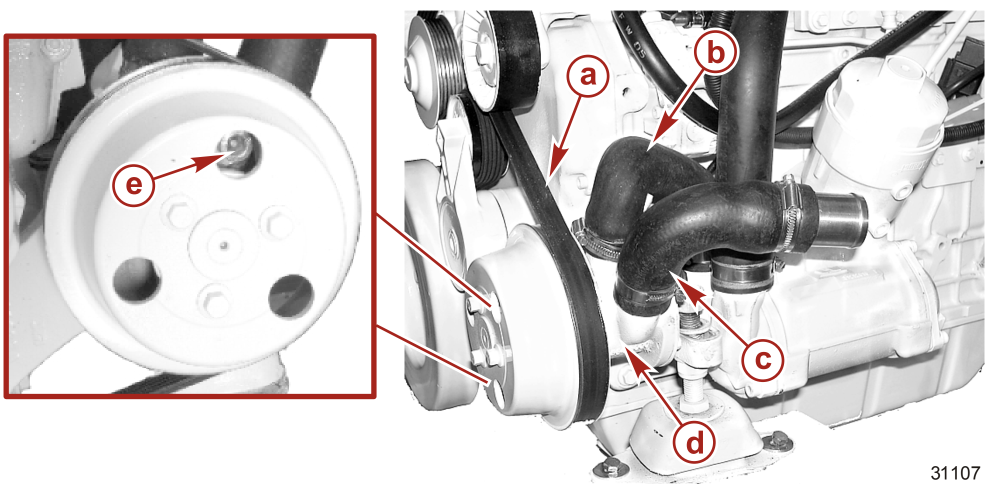
1. Position the seawater pump on the engine front bracket.

NOTE: Some engines may have spacers on the mounting screws, between the seawater pump mounting flanges and the engine front bracket.

2. Install and torque the two seawater pump mounting screws.

Description	Nm	lb. in.	lb. ft.
Seawater pump mounting screw	47.1	–	34

3. Install the serpentine drive belt. Ensure that the seawater pump pulley is properly aligned with the serpentine belt.
4. Install the seawater pump inlet and outlet hose. Tighten the hose clamps securely.



a - Serpentine belt
b - Outlet hose
c - Inlet hose
d - Seawater pump
e - Seawater pump mounting screw (one not visible in this view)

5. Open the seacock if equipped, or unplug and connect the seawater inlet hose.

6. Start the engine and inspect for leaks.

Testing the Closed-Cooling System

Testing the Closed Cooling System

⚠ CAUTION

A sudden loss of pressure can cause hot coolant to boil and discharge violently resulting in serious injury from burns. Allow the engine to cool down before removing the coolant pressure cap.

Testing for Alkalinity

The coolant in the closed cooling (fresh water) section of the cooling system should be changed at specified intervals. See the **Maintenance Schedules**. Checked for alkalinity at least once between change intervals.

To check coolant for alkalinity, proceed as follows:

1. Obtain pink litmus paper from a local supplier.
2. Allow the engine to cool.
3. Remove the pressure cap from the coolant reservoir and insert one end of the litmus paper into the coolant.
4. **If pink litmus paper turns blue**, the coolant is alkaline and need not be replaced.
5. If pink litmus paper remains pink, coolant is not alkaline and must be replaced. See Changing The Coolant.

Pressure Testing

If the closed cooled system is suspected of leaking or not holding sufficient pressure and no visible signs of leakage can be found, perform the following test:

1. Allow the engine to cool.
2. Remove the pressure cap from the expansion tank and coolant reservoir.
3. Clean and inspect the pressure cap to ensure that the pressure cap is maintaining proper pressure in system. See **Testing The Pressure Cap**.
4. Clean the inside of the filler neck to remove any deposits or debris.
5. Examine the expansion tank and coolant reservoir sealing surface for nicks or other damage. The surface must be perfectly smooth to achieve a good seal between it and the rubber seal on the pressure cap.
6. Adjust the coolant level in closed cooling (fresh water) section to 25 mm (1 in.) below filler neck.
7. Attach an automotive-type cooling system pressure tester to filler neck. Pressurize the closed cooling system to amount specified in the following chart, based on pressure cap rating for your engine.

Pressure Cap	
Operating pressure	1 bar (14.5 PSI)

8. Observe the pressure tester gauge reading for approximately two minutes; pressure should not drop during this time. If pressure drops, proceed with the following steps until leakage is found.

9. While maintaining the specified pressure on the closed cooling system, visually inspect the external portion of the cooling system (hoses, gaskets, drain plugs, core plugs, circulating pump seal, and so on) for leakage. Also listen closely for bubbling or hissing, as they indicate a leak.
10. See **Testing The Heat Exchanger** in this section and test as outlined.
11. If no leakage could be found in the above steps, the engine is leaking internally, probably due to one or more of the following:
    - Loose cylinder head bolts or damaged gasket
    - Loose turbocharger bolts or damaged gasket
    - Loose exhaust elbow or damaged gasket
    - Cracked or porous cylinder head or block
    - Cracked or porous exhaust manifold
12. Proceed as follows until the location of the internal leak is found:
    a. Start the engine. Pressurize the closed cooling system to the previously specified amount and observe the pressure gauge on the tester. If the needle in the gauge vibrates, compression or combustion is leaking into the closed cooled section from a leak in a combustion chamber. Stop the engine.
    b. Remove the plugs in the glow plug holes (one at a time) from the cylinders and examine for the presence of coolant. A plug that is perfectly clean or milky appearing indicates a leak.
    c. Drain the oil from the engine and examine for the presence of coolant. Oil usually will be milky or discolored, if coolant is present.
    d. If coolant is present, remove the engine from the boat and remove the oil pan. With the engine in the upright position, pressurize the closed cooled section to the previously specified amount and examine the internal surfaces of the engine to locate the leak.
    e. If no leaks can be found in the above steps, the entire engine must be disassembled and inspected for leaks.

Cylinder Head Gasket Leak Testing

A leaking head gasket will cause combustion gas to be forced into the cooling system. The mixture of coolant and tiny air bubbles is a poor heat conductor and will overheat an engine quickly. Compression tests or cooling system pressure checks normally will not detect the leak because the test pressure is far below the combustion pressures that cause the leak.

An effective test follows.

IMPORTANT: Operate the boat in open water for this test. It is best to operate the engine at or above cruising speed during this test. Usually a failed head gasket will not cause the engine to overheat below cruising speed.

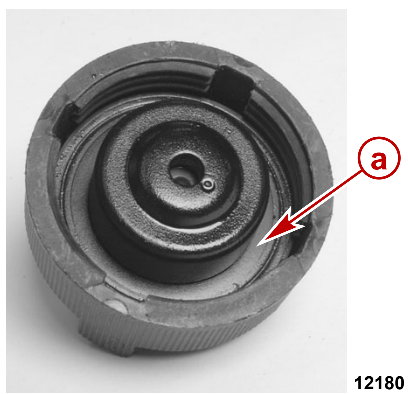
1. **During idle and warm-up:** some coolant or air or both will leave the expansion tank and reservoir.
2. **During cruising speed (2800 – 3200 RPM):** coolant or air, or both, leaving the expansion tank and coolant reservoir should stop after approximately five minutes of operation at a steady RPM. A leaking head gasket will produce air bubbling. The frequency and size of the bubbles will depend on the size of the leak.
3. **At higher speeds (3200 – 3600 RPM):** Normal operation is the same as described in step 2 above. A failed head gasket will cause the bubbles to come faster and may be accompanied by violent, intermittent bursts of coolant.

It is important not to confuse normal warm-up expansion with a failed head gasket. Normal warm-up produces an intermittent flow of coolant which will stop within approximately five minutes at a steady RPM. A head gasket leak will not stop because a failed head gasket allows the continued passage of air. This may be accompanied by violent, intermittent bursts of coolant leaving the expansion tank or reservoir. If coolant continues to flow but not in violent, intermittent bursts from the expansion tank or reservoir at cruising speed, something other than the head gasket is causing the engine to overheat.

Pressure Cap Testing

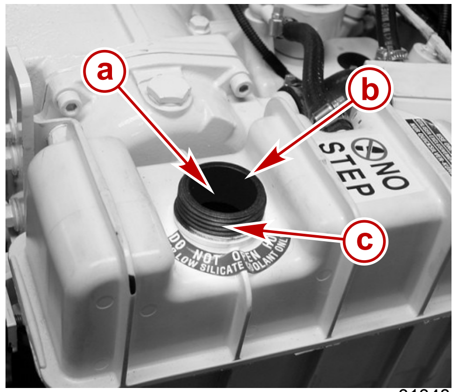
The pressure cap is designed to maintain a pressure of approximately its rated capacity on the closed cooling system once the engine has attained operating temperature. Refer to **Section 6A: Closed Cooling System Specifications**. The pressure cap should be cleaned, inspected, and pressure-tested at regular intervals or whenever the pressure cap is suspected of not maintaining proper pressure.

1. Allow the engine to cool.
2. Carefully remove the pressure cap from the expansion tank and coolant reservoir.
3. Wash the cap with clean water to remove any deposits or debris from sealing surfaces.
4. Inspect the gasket on the pressure cap for tears, cuts, cracks, or other signs of deterioration.
5. Replace the pressure cap if the gasket is damaged.



a - Gasket

6. Examine the sealing surface of the expansion tank and coolant reservoir filler neck to ensure that it is perfectly smooth and free of debris. Also, inspect the threads of the filler neck to ensure that they are not damaged.



a - Expansion tank and coolant reservoir filler neck
b - Sealing surface
c - Threads

7. Using a suitable cooling system pressure tester, test the pressure cap to ensure that it releases at the specified pressure and does not leak. Refer to the pressure tester instructions for the correct test procedure.

Pressure Cap	
Operating pressure	1.0 ± 0.1 bar (14.5 ± 1.4 psi

8. Replace the pressure cap if measured values are less than specified.

Draining the Closed Cooling System

NOTICE

Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

NOTE: For instructions on draining the seawater section, see ***Draining the Seawater System*** *in this section.*

IMPORTANT: Observe the following points.

- Ensure that the engine is as level as possible to promote complete draining of the cooling system.
- The closed cooling section must be filled year-round with the required coolant. If the engine will be exposed to freezing temperatures, ensure that the closed cooling section is filled with a solution of ethylene glycol antifreeze and water properly mixed to protect the engine to the lowest temperature to which it will be exposed.
- Do not use propylene glycol antifreeze in the closed-cooling section of the engine.

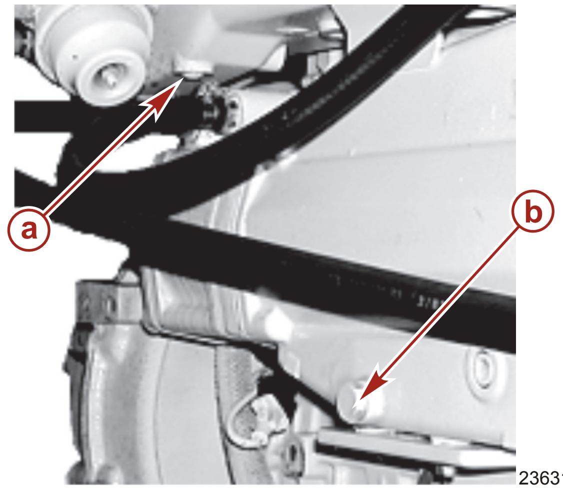
⚠ CAUTION

A sudden loss of pressure can cause hot coolant to boil and discharge violently resulting in serious injury from burns. Allow the engine to cool down before removing the coolant pressure cap.

1. Allow the engine to cool.
2. Remove the pressure cap from the expansion tank and coolant reservoir.

NOTE: Drain coolant into a suitable container. Dispose of old coolant properly.

3. Remove the intake and exhaust manifold drain plug.
4. Remove the heat exchanger drain plug.



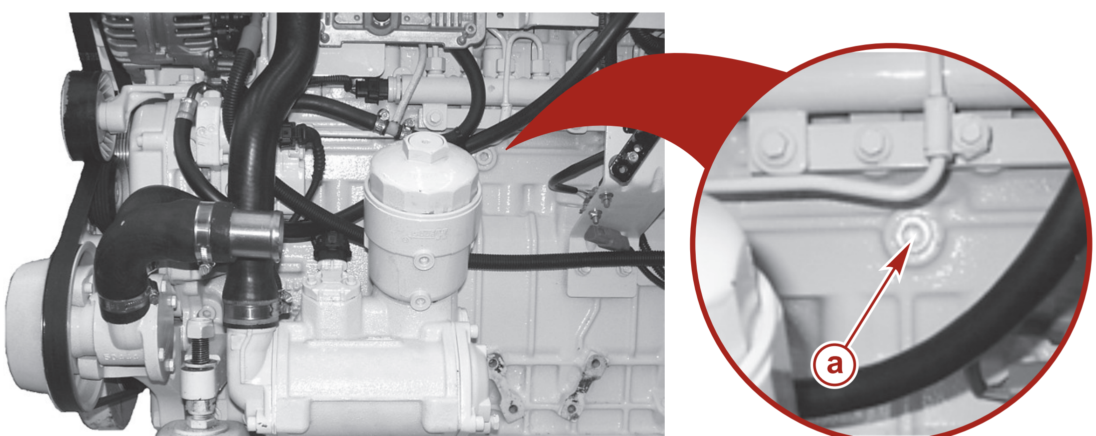
23631

4.2 shown, 2.8 similar

a - Intake and exhaust manifold drain plug

b - Fluid cooler drain plug

5. Open the engine block drain plug.



24552

4.2 shown, 2.8 similar

a - Engine block drain plug

6. After the coolant has drained completely, install the intake and exhaust manifold drain plug, the heat exchanger drain plug, and the engine block drain plug. Tighten all drain plugs securely.

7. If required, clean the closed cooling system. See your local Cummins MerCruiser Diesel Authorized Repair Facility.
8. Fill the system with the specified coolant. See **Filling the Closed Cooling System**.

Cleaning the Closed Cooling System

The closed cooling section of the cooling system should be cleaned at least once every two years or whenever decreased cooling efficiency is experienced.

Use a high-grade automotive cooling system cleaner to remove closed cooling system deposits. Follow the manufacturer's instructions.

If the closed cooling section is extremely dirty, use a pressure flushing device to flush out any remaining deposits. Flushing should be done in the direction opposite normal coolant flow to allow water to get behind deposits and force them out. For proper hookup and flushing procedures refer to the instructions that accompany the flushing device.

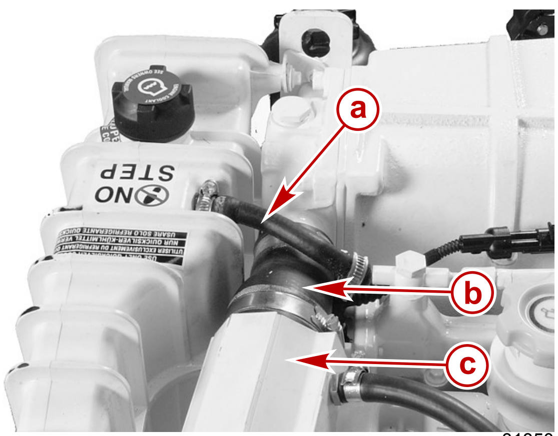
Coolant Expansion Tank and Reservoir

Removal

1. Allow the engine to cool.
2. Drain the seawater system.
3. Drain the closed cooling system. Dispose of the coolant properly.
4. Disconnect the turbocharger coolant vent hose.

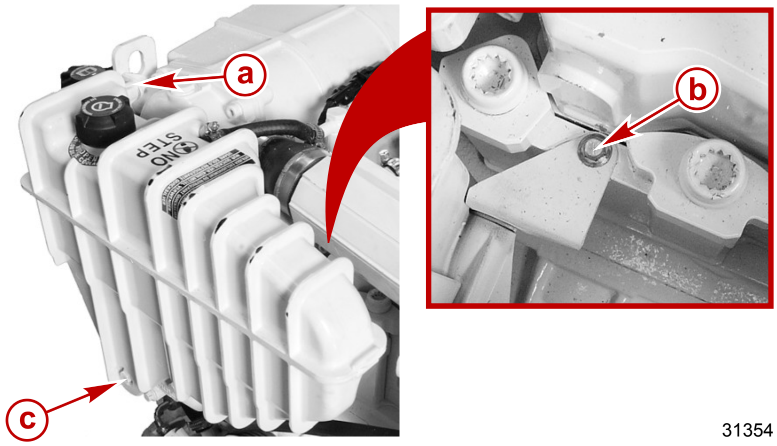
NOTE: *Removing the seawater hose in the next step will allow sufficient upward movement of the coolant expansion tank for removal from the engine water circulating pump.*

5. Remove the seawater hose from the aftercooler end cover and move the seawater hose and fuel cooler to the side.



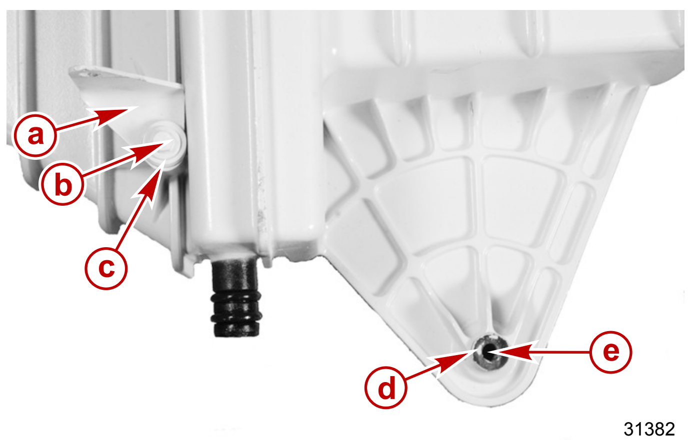
a - Turbocharger coolant vent hose
b - Seawater hose
c - Fuel cooler

6. Remove the two screws, and the screw and nut on the front engine lifting eye bracket, that retain the coolant expansion tank.



a - Screw and nut
b - Rear mounting screw
c - Front mounting screw

7. Lift the coolant expansion tank up and away from the engine water circulating pump fitting.
8. Locate and retain the coolant expansion tank mounting O-rings and hardware for use during installation.



a - Lower bracket
b - Screw and washer
c - Grommet
d - O-ring
e - Spacer

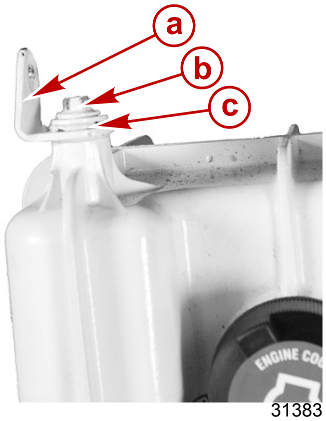
Cleaning And Inspection

1. Clean the coolant expansion tank in soap and water to remove any deposits and debris.
2. Inspect the coolant expansion tank for cracks, corrosion, or other damage. Replace as necessary.
3. Clean the exterior surfaces as required. On models equipped with a cast aluminum expansion tank, paint the exterior surfaces to prevent corrosion.

Installation

1. Install the rear bracket with O-ring isolators in position shown.

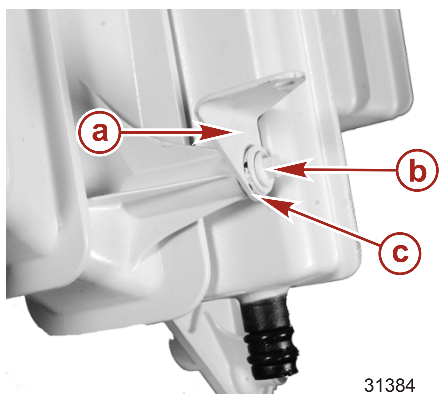
2. Install the grommet into the upper bracket and install the bracket onto the coolant reservoir using the washer and screw. Tighten to the specified torque.



a - Upper bracket
b - Washer and screw
c - Grommet

Description	Nm	lb. in.	lb. ft.
Upper bracket screw	10.8	95	–

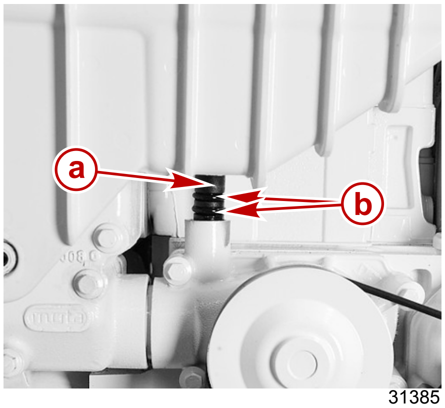
3. Install the grommet into the lower bracket and install the bracket onto the coolant reservoir using the washer and screw. Tighten to the specified torque.



a - Lower bracket
b - Washer and screw
c - Grommet

Description	Nm	lb. in.	lb. ft.
Lower bracket screw	10.8	95	–

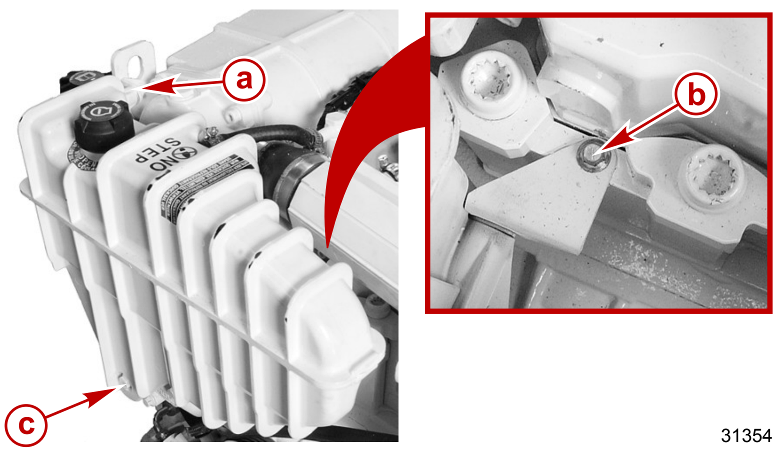
4. Install the new O-rings on the fitting used between the coolant reservoir and the engine water circulating pump.



4.2 show, 2.8 similar

a - Fitting
b - O-ring

5. Install the coolant expansion tank. Ensure that the fitting and O-rings used between the coolant expansion tank and the engine water circulating pump are properly seated.
6. With all mounting hardware in position, install the two screws and the screw and nut on the front engine lifting eye bracket that retain the coolant expansion tank. Tighten to the specified torque.

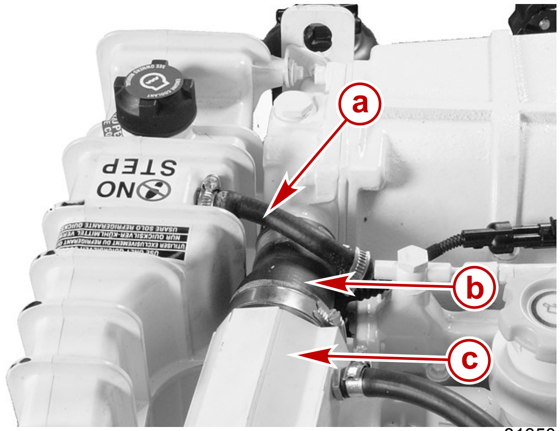


a - Screw and nut
b - Rear mounting screw
c - Front mounting screw

Description	Nm	lb. in.	lb. ft.
Coolant reservoir mounting screw and nut	10.8	95	–

7. Connect the turbocharger coolant vent hose.

8. Install the seawater hose on the fuel cooler to the aftercooler end cover.



a - Turbocharger coolant vent hose
b - Seawater hose
c - Fuel cooler

IMPORTANT: Use only specified coolant.

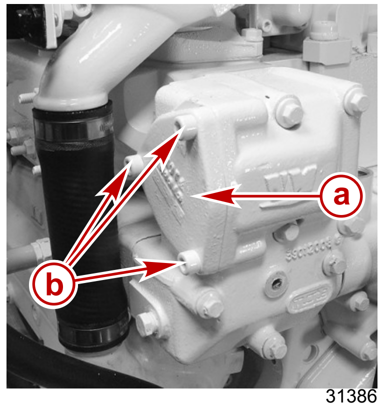
9. Fill the closed cooling system.
10. Open the seacock if equipped, or unplug and reconnect the seawater inlet hose.
11. Ensure the seawater pickup pump is supplied cooling water.
12. Connect the battery cables and start the engine.
13. Test the engine operation. Ensure that the engine operating temperature is normal. Check for leaks.
14. Stop the engine.
15. Check the engine coolant level. Fill to the proper level.

Thermostat

Removal

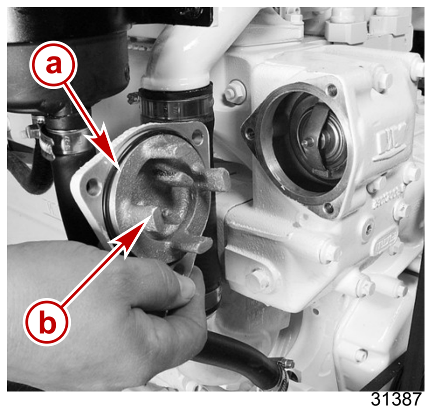
1. Allow the engine to cool.
2. Drain the seawater system.
3. Drain the closed cooling system. Dispose of the coolant properly.
4. Remove the coolant expansion tank.

5. Remove the three thermostat housing cover screws.



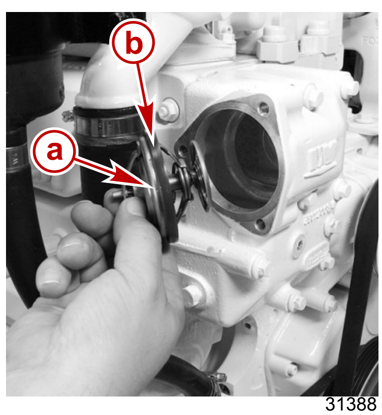
a - Thermostat housing cover
b - Screws

6. Remove the thermostat housing cover.
7. Remove and discard the old O-ring.



a - O-ring
b - Thermostat housing cover

8. Remove the thermostat and seal.



a - Thermostat
b - Seal

Cleaning

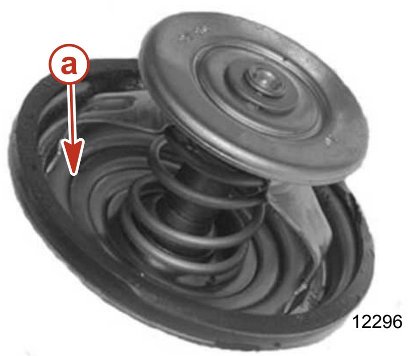
1. Remove and discard the old thermostat seal.

2. Clean the thermostat in soap and water to remove any deposits or debris.

Inspection

1. Inspect the thermostat for corrosion or other visible damage.
2. Check the thermostat for leaks by holding it up to a lighted background. Light visible around the thermostat valve indicates that the thermostat is not closing completely and should be replaced.

NOTE: *A few visible light leaks at one or two points around the thermostat valve perimeter are acceptable.*

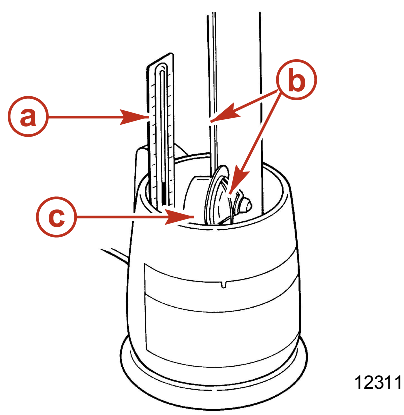


a - Thermostat valve perimeter

3. Replace the thermostat if damaged or leaking.

Testing

1. Remove the thermostat.
2. Following the usage recommendations of the manufacturer of a Thermostat Tester, check the opening and closing temperature of the thermostat. The thermostat opens when it drops off of the nylon string. The thermostat must open at the specified temperature stamped on the thermostat.



Typical Thermometer Tester in use

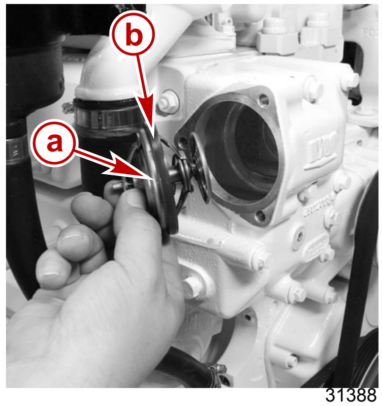
a - Thermometer
b - Nylon string
c - Thermostat

3. Continue to heat the water until a temperature 14° C (25° F) above opening temperature is reached. The thermostat valve must be completely open at this temperature.
4. Unplug the Thermostat Tester and allow the water to cool to a temperature 5° C (10° F) below the specified thermostat opening temperature. The thermostat must be completely closed at this temperature.

5. Replace the thermostat if it fails to meet specifications.

Installation

1. Install the seal around the thermostat.
2. Install the thermostat and the seal.

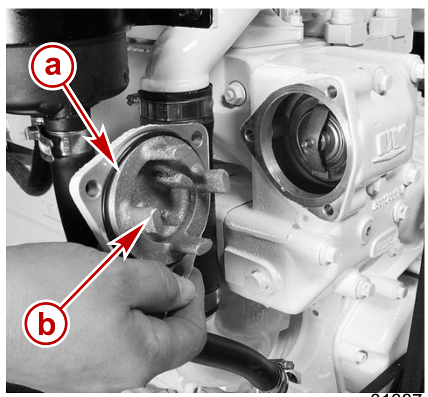


31388

a - Thermostat
b - Seal

NOTE: Always use a new thermostat housing cover O-ring.

3. Install a new thermostat housing cover O-ring.
4. Install the thermostat housing cover using the three screws.



31387

a - O-ring
b - Thermostat housing cover

5. Torque the thermostat housing cover screws evenly in a diagonal pattern.

Description	Nm	lb. in.	lb. ft.
Thermostat housing cover screw	24.5	–	18

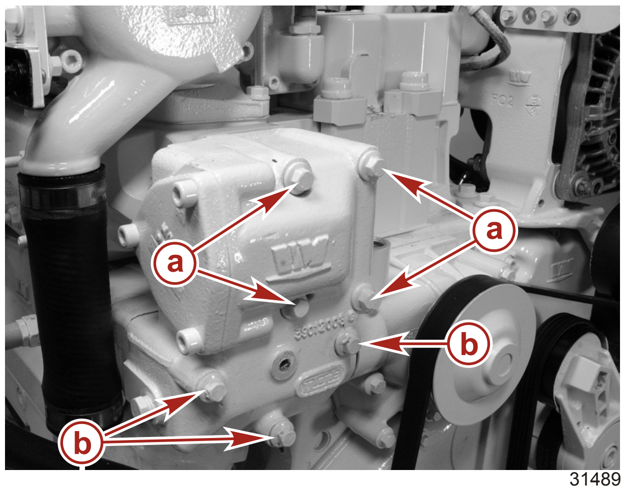
6. Install the coolant expansion tank.
7. Fill the closed cooling system.
8. Open the seacock if equipped, or unplug and reconnect the seawater inlet hose.
9. Ensure that the seawater pickup pump is supplied cooling water.
10. Connect the battery cables and start the engine.
11. Test the engine operation. Ensure that the engine operating temperature is normal. Check for leaks.
12. Stop the engine.

13. Check the engine coolant level. Fill to the proper level.

Thermostat Housing

Removal

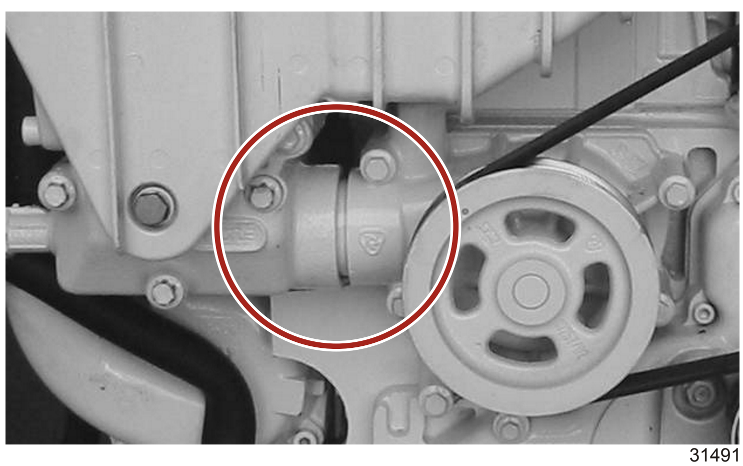
1. Allow the engine to cool.
2. Drain the seawater system.
3. Drain the closed cooling system. Dispose of the coolant properly.
4. Remove the serpentine drive belt.
5. Remove the coolant expansion tank.
6. Remove the four thermostat housing to intake and exhaust manifold screws.



a - Screws, thermostat housing to manifold
b - Screws, thermostat housing to heat exchanger

7. Remove the three thermostat housing to heat exchanger screws.

NOTE: *To disengage the water pump to thermostat housing water pipe slide the thermostat housing to starboard, away from the water pump.*



Water pump to thermostat housing water pipe

8. Remove the thermostat housing from the engine.

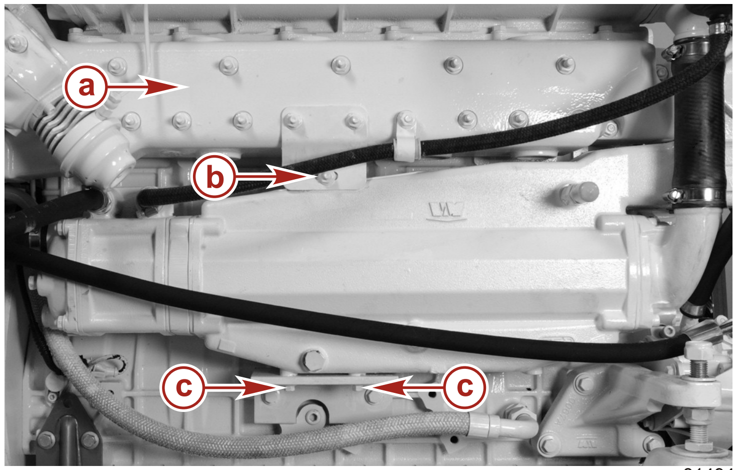
Cleaning and Inspection

1. Clean the gasket material from all surfaces.
2. Check the condition of the O-ring seals. Replace as needed.

3. Wash parts in solvent and allow to dry.
4. Inspect all parts carefully. Components can not be cracked and machined surfaces must be clean and unmarred to prevent leaks.

Installation

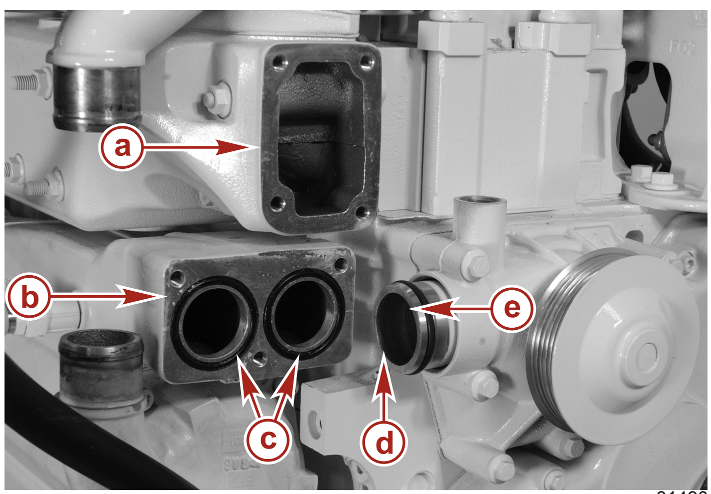
1. Loosen the heat exchanger mounting screws.



31494

a - Intake and exhaust manifold
b - Upper mounting screw
c - Lower mounting screw

2. Confirm that the water pipe between the water pump and the thermostat housing is pressed into both components evenly.
3. Lubricate the heat exchanger and water pipe O-ring seals.



31490

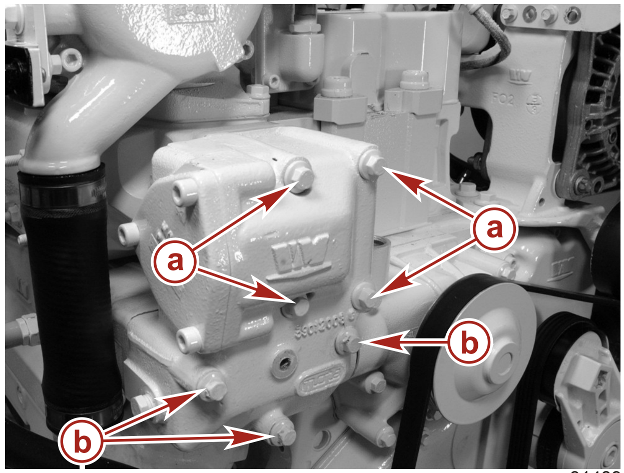
a - Intake and exhaust manifold
b - Heat exchanger
c - O-ring seals
d - Water pump to thermostat housing water pipe
e - O-ring seal

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	O-ring seals	Obtain Locally

4. Hand press the thermostat housing onto the water pipe.

NOTE: Adjust the position of the loosened heat exchanger to align the bottom three thermostat housing attaching screws.

5. Install, but do not tighten, the screws connecting the thermostat housing to the heat exchanger screws



31489

a - Screws, thermostat housing to manifold
b - Screws, thermostat housing to heat exchanger

6. Install the thermostat housing to the intake manifold gasket and four attaching screws.
7. Tighten the thermostat housing to intake manifold screws. Torque to specification.

Description	Nm	lb. in.	lb. ft.
Screws, thermostat housing to intake manifold	24.5	–	18

8. Torque the thermostat housing to heat exchanger screws. Torque to specification.

Description	Nm	lb. in.	lb. ft.
Screws, thermostat housing to heat exchanger	24.5	–	18

9. Tighten the heat exchanger mounting hardware.

Heat Exchanger and Fluid Cooler Assembly

Removal

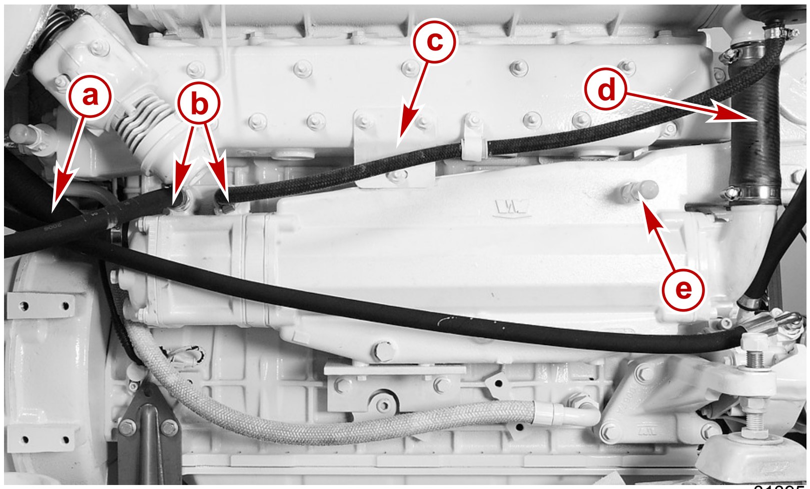
NOTICE
If the boat is at rest in the water with the engine off, an open seacock or water inlet hose could introduce water into the engine's cooling system or the boat. Keep the seacock or water inlet hose plugged until ready to start the engine. Attach a tag to the ignition switch or steering wheel to inform others of the water inlet connection.

1. Close the seacock, if equipped, or disconnect and plug the seawater inlet hose if the boat is to remain in the water.
2. Drain the seawater system.
3. Drain the closed cooling system. Dispose of the coolant properly.
4. Disconnect the cabin water heater fitting, if equipped.

5. Disconnect the seawater hose between the heat exchanger front cover and the aftercooler.

NOTE: Obtain clean, suitable material or plugs and plug hoses to avoid loss of fluid.

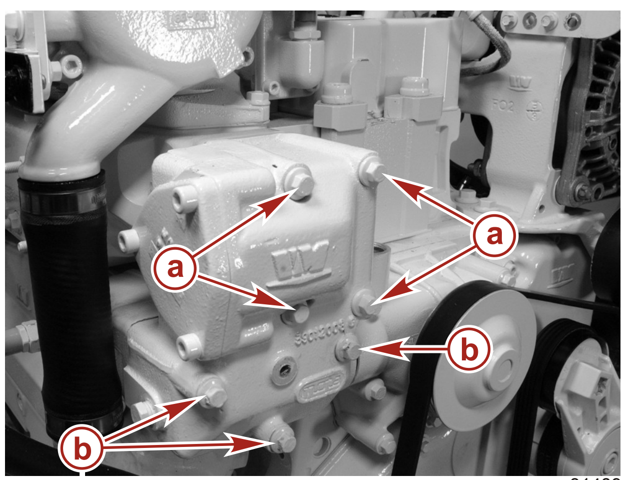
6. Disconnect the fluid lines from the fluid cooler fittings. Quickly plug the fluid lines.
7. Remove the heat exchanger to intake and exhaust manifold bracket.
8. Disconnect the seawater hose between the fluid cooler and exhaust system.



4.2 sterndrive shown, 2.8 and inboard similar

a - Seawater hose
b - Fluid lines
c - Heat exchanger to intake and exhaust manifold bracket
d - Cabin water heater fitting
e - Seawater hose

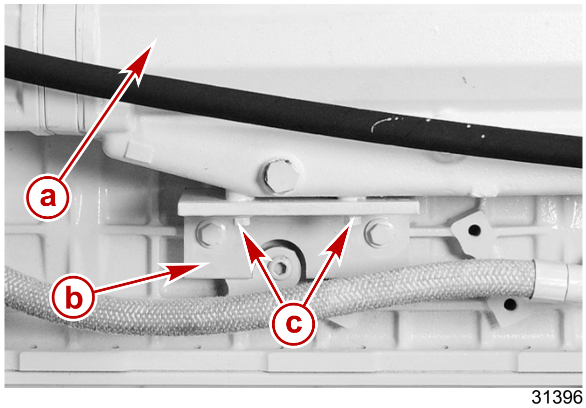
9. Remove the three thermostat housing to heat exchanger screws.



a - Screws, thermostat housing to manifold
b - Screws, thermostat housing to heat exchanger

10. Remove the two heat exchanger mounting screws

11. Lift and remove the combination heat exchanger and fluid cooler from the bracket.



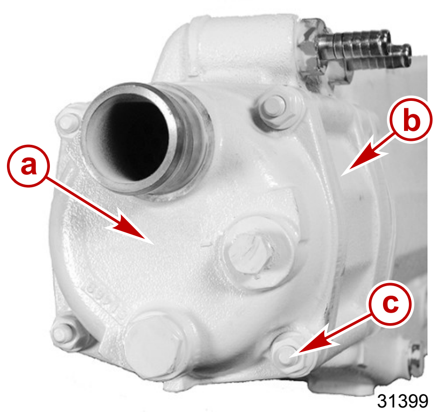
4.2 shown, 2.8 similar

a - Heat exchanger and fluid cooler
b - Bracket
c - Heat exchanger mounting screws

Disassembly

NOTICE
Engine coolant leaking into the seawater circuit could result in engine damage. Replace all O-ring seals whenever disassembling the heat exchanger or removing the radiator insert (core).

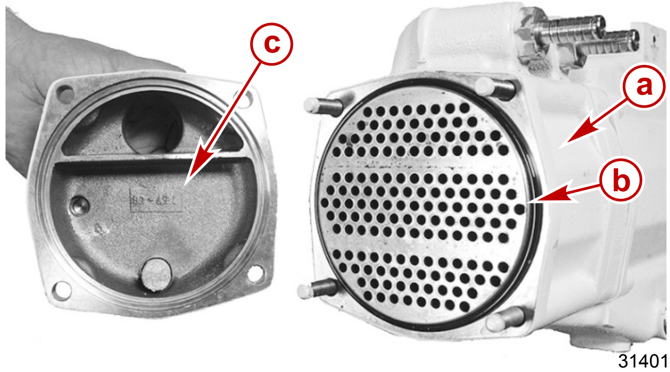
1. Remove the four flange nuts on the fluid cooler end cover .



a - End cover
b - Fluid cooler
c - Flange nuts

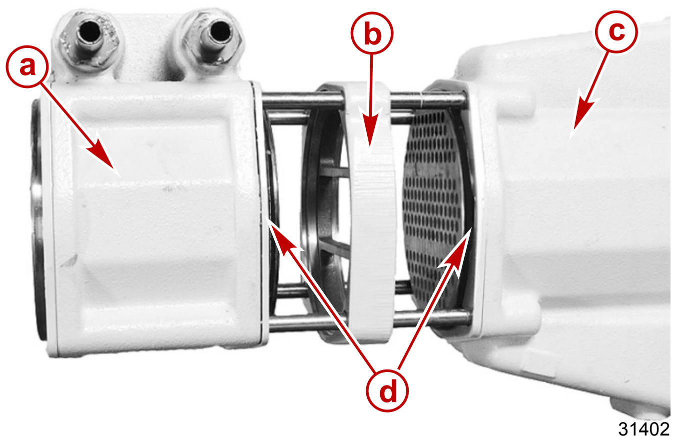
2. Remove the fluid cooler end cover.

NOTE: To aid in assembly using new O-rings, note the position of the old O-rings during disassembly.



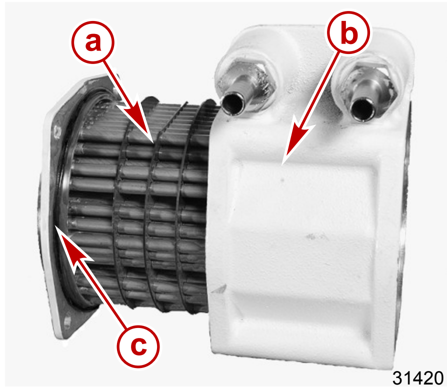
a - Fluid cooler assembly
b - O-ring
c - End cover

3. Separate the fluid cooler assembly from the spacer between the fluid cooler and heat exchanger.



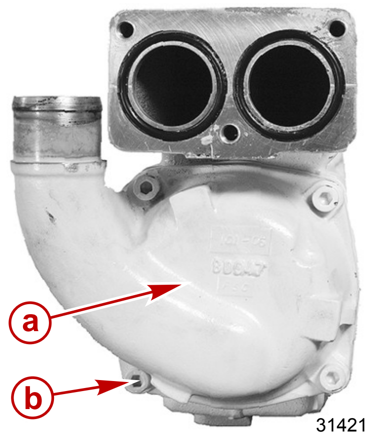
a - Fluid cooler assembly
b - Spacer
c - Heat exchanger
d - O-ring

4. Remove the radiator insert (core) from the fluid cooler housing.



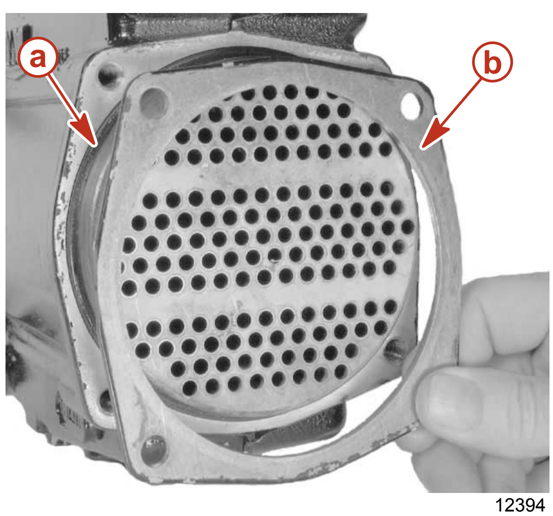
a - Radiator insert (core)
b - Fluid cooler housing
c - O-ring

5. Remove the heat exchanger front cover.



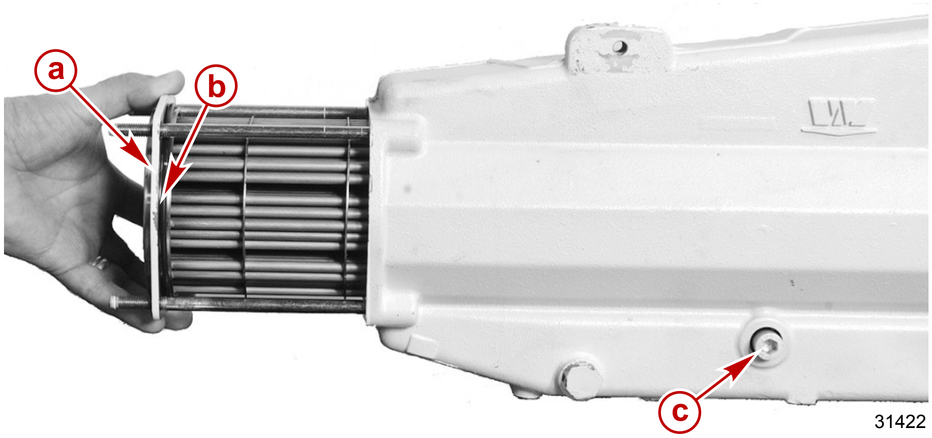
a - Heat exchanger front cover
b - Screw

6. Remove the plate and O-ring from around the heat exchanger radiator insert.



a - O-ring
b - Plate

7. *On 4.2 models*, loosen the heat exchanger radiator insert retaining screw.
8. Remove the heat exchanger radiator insert (core) from the rear of the heat exchanger housing. Note the position of the O-ring.



4.2 shown, 2.8 similar

a - O-ring
b - Heat exchanger radiator insert
c - Heat exchanger radiator insert retaining screw

Cleaning and Inspection

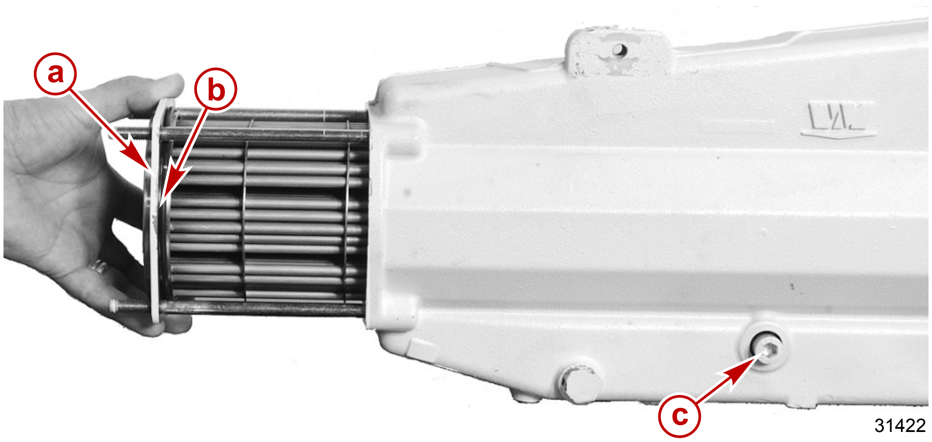
1. Remove the old O-rings and clean the sealing flanges.
2. Use a suitable long rod or brush to clean out the radiator insert tubes.
3. Inspect each part for cracks, corrosion, or other damage. Replace as necessary.
4. Clean and paint the exterior surfaces as required to prevent corrosion.

Assembly

IMPORTANT: Some components use O-rings to form seals. Rolling or twisting an O-ring during installation may form an improper seal resulting in component damage or failure causing additional problems that could be more serious. Do not roll or twist an O-ring during installation.

1. Place the O-ring around the heat exchanger radiator insert.
2. Insert the heat exchanger radiator insert (core) into the rear of the heat exchanger housing.

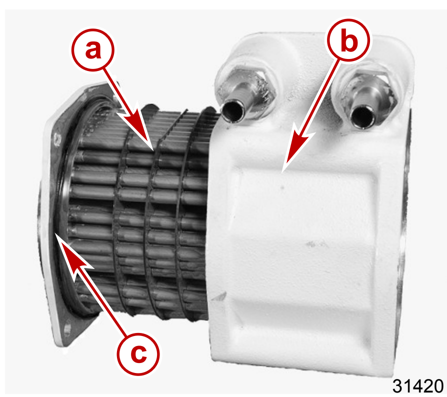
3. Tighten the heat exchanger radiator insert retaining screw.



4.2 shown, 2.8 similar

a - O-ring
b - Heat exchanger radiator insert
c - Heat exchanger radiator insert retaining screw

4. Install an O-ring around the fluid cooler radiator insert (core).
5. Install the radiator insert into the fluid cooler housing.



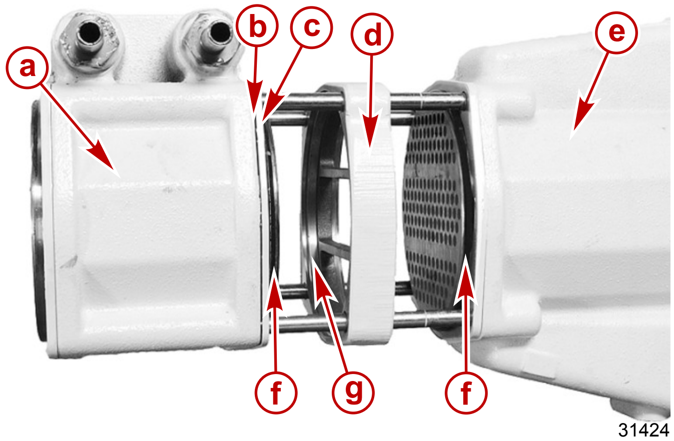
a - Radiator insert (core)
b - Fluid cooler housing
c - O-ring

6. Place an O-ring around the end of the heat exchanger radiator insert.
7. Place an O-ring around the fluid cooler radiator insert.
8. Install the plate around the fluid cooler radiator insert.
9. Install another O-ring around the end of the fluid cooler radiator insert next to the plate.

IMPORTANT: The spacer has a deeper relief cut on the side that faces the fluid cooler than on the side toward the heat exchanger. Ensure that the deep relief contacts the O-ring and plate near the fluid cooler.

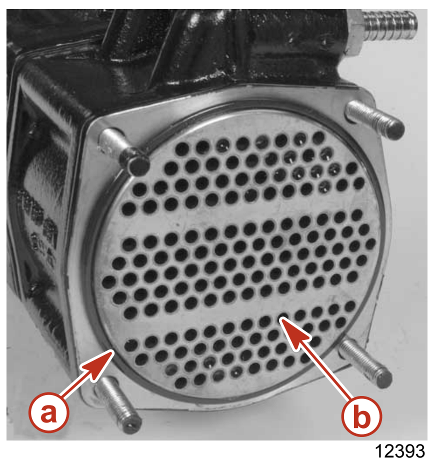
10. Slide the spacer onto the studs with the shallow relief cut facing the heat exchanger.
11. Ensure that the deeper relief cut of the spacer faces the plate on the end of the fluid cooler.

12. Install the fluid cooler, O-rings, and plate onto the heat exchanger studs.



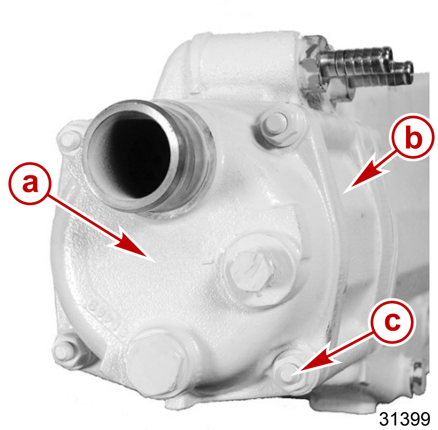
a - Fluid cooler
b - O-Ring (not visible here)
c - Plate
d - Spacer
e - Heat exchanger
f - O-ring
g - Deep relief cut

13. Push the parts together. Ensure that the O-rings remain in the proper positions and no unusual gaps exist between the components.
14. While holding the fluid cooler and heat exchanger parts assembled, place the O-ring around the aft end of the fluid cooler radiator insert.



a - O-ring
b - Fluid cooler radiator insert

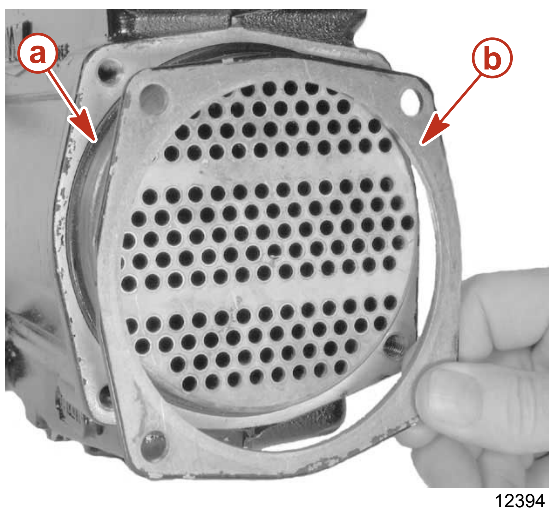
15. Install the fluid cooler end cover and the four flange nuts. Tighten the fluid cooler end cover flange nuts evenly, in a diagonal pattern. Torque to specification.



a - End cover
b - Fluid cooler
c - Flange nuts

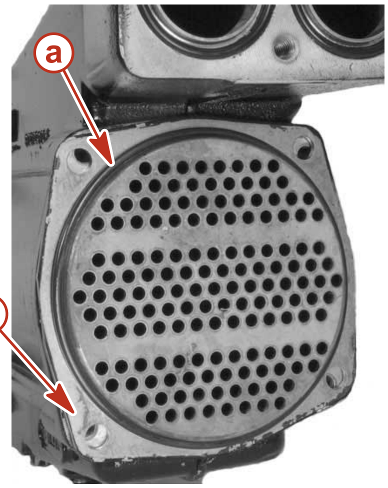
Description	Nm	lb. in.	lb. ft.
Fluid cooler end cover flange nuts	24.5	–	18

16. Place an O-ring around the front of the heat exchanger radiator insert.
17. Install the plate around the heat exchanger radiator insert.



a - O-ring
b - Plate

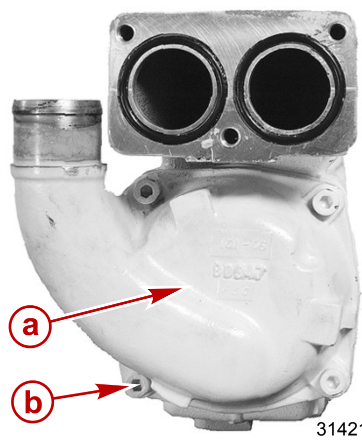
18. Place an O-ring around the front of the heat exchanger radiator insert and against the plate.



12450

a - O-ring
b - Plate

19. Install the heat exchanger front cover and the four front cover screws. Tighten the front cover screws evenly, in a diagonal pattern. Torque to specification.



31421

a - Heat exchanger front cover
b - Screw

Description	Nm	lb. in.	lb. ft.
Heat exchanger front cover screw	24.5	–	18

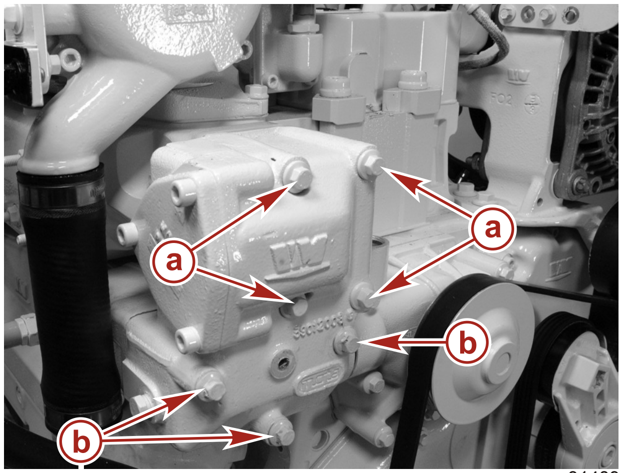
Installation

1. Inspect the O-ring seals and replace if damaged.
2. Lubricate the O-ring seals on the front of the heat exchanger.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Heat exchanger to thermostat housing O-ring seal	Obtain Locally

3. Install the O-rings seals.
4. Position the combination heat exchanger and fluid cooler on the bracket.

5. Install the three thermostat housing to heat exchanger screws.

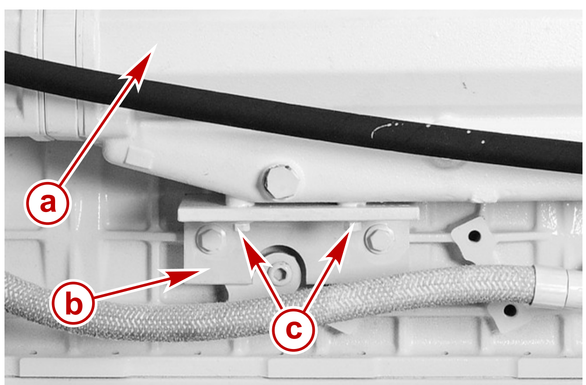


a - Screws, thermostat housing to manifold
b - Screws, thermostat housing to heat exchanger

6. Torque the thermostat housing to heat exchanger screws.

Description	Nm	lb. in.	lb. ft.
Thermostat housing to heat exchanger screws	24.5	–	18

7. Install the two heat exchanger mounting screws.



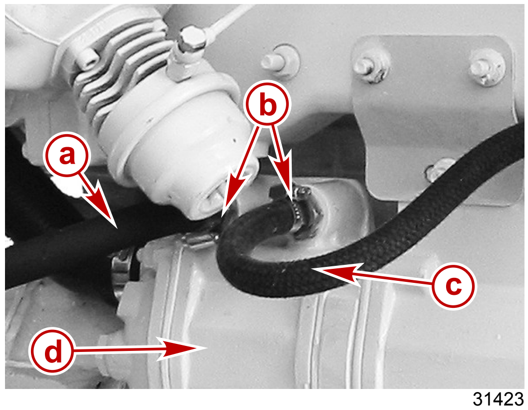
4.2 shown, 2.8 similar

a - Heat exchanger and fluid cooler
b - Bracket
c - Heat exchanger mounting screws

8. Torque the heat exchanger mounting screws to specification.

Description	Nm	lb. in.	lb. ft.
Heat exchanger mounting screw	19.6	173	–

9. Unplug and quickly connect the fluid lines to the appropriate fluid cooler fitting.



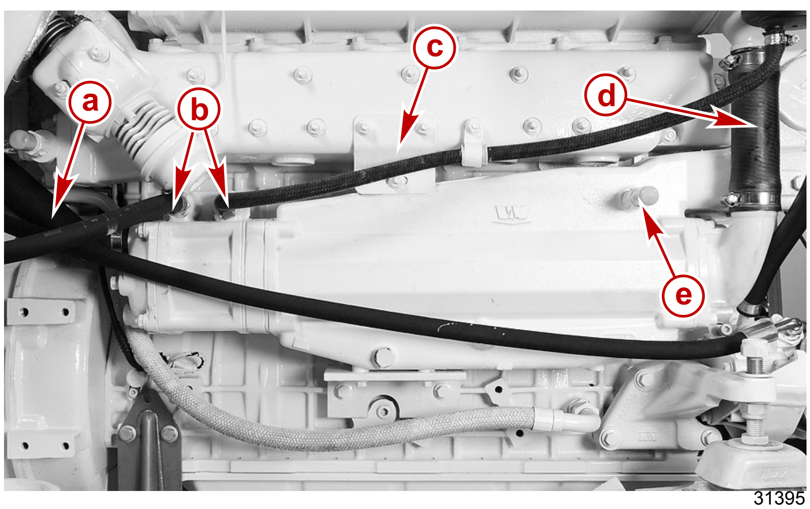
Sterndrive shown, inboard similar

a - Fluid line (from power steering control valve on sterndrive, or transmission on inboard)
b - Fluid cooler fittings
c - Fluid line (to fluid reservoir on sterndrive, or transmission on inboard)
d - Fluid cooler

10. Connect the seawater hose between the heat exchanger front cover and the aftercooler.
11. Connect the seawater hose between the fluid cooler and the exhaust system.
12. Install the heat exchanger to intake and exhaust manifold bracket.
13. Torque the three flange nuts.

Description	Nm	lb. in.	lb. ft.
Flange nut, heat exchanger to intake and exhaust manifold bracket	24.5	–	18

14. Connect the cabin water heater fitting, if necessary.



4.2 sterndrive shown, 2.8 and inboard similar

a - Seawater hose
b - Fluid lines
c - Heat exchanger to intake and exhaust manifold bracket
d - Cabin water heater fitting
e - Seawater hose

15. Ensure all drain plugs are installed and all drain valves closed.
16. Fill the closed cooling system.
17. Open the seacock if equipped, or unplug and reconnect the seawater inlet hose.
18. Ensure that the seawater pickup pump is supplied cooling water.
19. Connect the battery cables and start the engine.
20. Test the engine operation. Ensure that the engine operating temperature is normal and check for leaks.
21. Stop the engine.
22. Check the engine coolant level. Fill to the proper level.

Fuel Cooler

Inspection Before Removal

⚠ CAUTION
Water can enter the bilge when the drain system is open, damaging the engine or causing the boat to sink. Remove the boat from the water or close the seacock, disconnect and plug the seawater inlet hose, and ensure the bilge pump is operational before draining. Do not operate the engine with the drain system open.

1. Drain the seawater system.
2. Remove the hose clamp from the inlet end of the cooler. See **Seawater Flow Diagram**.
3. Inspect the passages. Clean if needed.
4. Install the hose. Securely tighten the hose clamp.

Cleaning Without Removal

⚠ CAUTION
Water can enter the bilge when the drain system is open, damaging the engine or causing the boat to sink. Remove the boat from the water or close the seacock, disconnect and plug the seawater inlet hose, and ensure the bilge pump is operational before draining. Do not operate the engine with the drain system open.

1. Drain the seawater system.
2. Remove the hoses from both ends of cooler.
3. Temporarily attach a suitable hose to the inlet end of cooler and place the end of the hose in a suitable container to collect the water in the following.
4. Attach a suitable adapter to the outlet end of cooler to which a tap water hose may be connected.
5. Open tap water faucet and back-flush cooler until the discharge water is clean.
6. Remove the temporary hose and the adapter.
7. Install the hoses. Securely tighten the hose clamps.

Removal

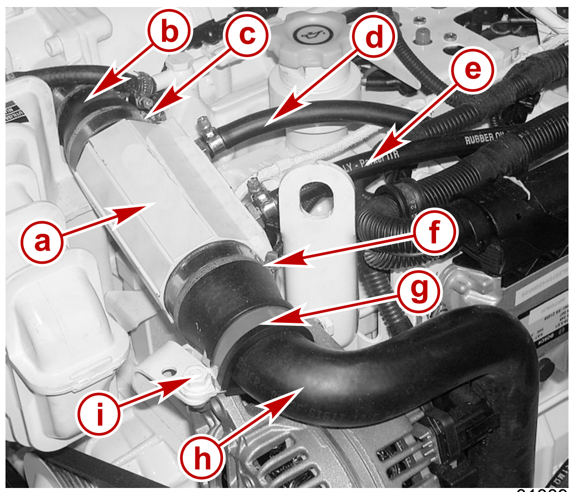
⚠ CAUTION

Water can enter the bilge when the drain system is open, damaging the engine or causing the boat to sink. Remove the boat from the water or close the seacock, disconnect and plug the seawater inlet hose, and ensure the bilge pump is operational before draining. Do not operate the engine with the drain system open.

1. Drain the seawater system.
2. Remove the fuel cooler seawater hose bracket.
3. Disconnect the fuel cooler seawater inlet and outlet hoses.
4. Mark the fuel hoses to aid in assembly.

NOTE: Cap all disconnected fuel lines.

5. Disconnect the fuel inlet and return hoses. Plug the hoses quickly.
6. Remove the fuel cooler.



a - Fuel cooler
b - Fuel cooler seawater outlet hose
c - Seawater hose clamp
d - Upper fuel hose
e - Lower fuel hose
f - Seawater hose clamp
g - Seawater hose bracket
h - Seawater inlet hose
i - Seawater inlet hose clamp screw and nut

Inspection and Cleaning

IMPORTANT: CMD does not recommend the immersion of fluid coolers in cleaning solutions. If back-flushing and wire brushing the cooler passages does not satisfactorily clear the passages, replacement of the cooler is recommended.

1. Inspect for any blockage in the seawater circuit. If the passages are obstructed, clean the tubes with a suitable wire brush of the proper size through each tube.
2. Rinse out the seawater circuit of the cooler and cooler tubes with tap water to remove loosened particles.
3. Inspect the tubes close inside the fuel fittings. Because the complete fuel circuit of the cooler cannot be inspected, the fuel cooler should be replaced if fuel circuit blockage is suspected.
4. Replace the unit if it cannot be satisfactorily cleaned.

Installation

1. Apply sealant to the threads of the fuel cooler fittings if they were removed or the fuel cooler is being replaced.

Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	Fuel cooler fittings	92-809822

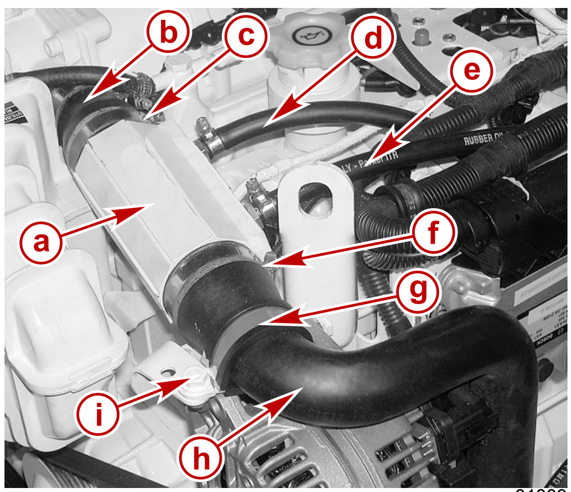
2. Install the two fuel cooler fittings using sealing washers. Tighten and torque to specification.

Description	Nm	lb. in.	lb. ft.
Fuel cooler fittings	10.8	95	–

3. Position the fuel cooler on the engine and connect the seawater inlet and outlet hoses. Tighten and torque the hose clamps to specification.
4. Connect the previously marked fuel hoses. Tighten and torque to specification.

Description	Nm	lb. in.	lb. ft.
Fuel cooler seawater hose clamp	4.6	40	–
Fuel hose clamp	4.6	40	–

5. Install the seawater hose bracket.



31389

a - Fuel cooler
b - Fuel cooler seawater outlet hose
c - Seawater hose clamp
d - Upper fuel hose
e - Lower fuel hose
f - Seawater hose clamp
g - Seawater hose bracket
h - Seawater inlet hose
i - Seawater inlet hose clamp screw and nut

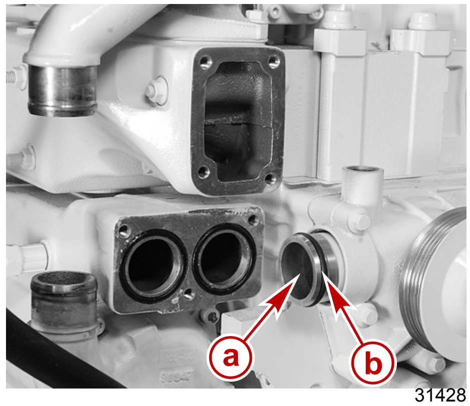
6. Tighten the seawater hose bracket screw.
7. Start the engine and inspect for any leaks.

Engine Water Circulating Pump

Removal

1. Allow the engine to cool.
2. Drain the seawater system.
3. Drain the closed cooling system. Dispose of the coolant properly.

4. Remove the serpentine drive belt.
5. Remove the coolant expansion tank.
6. Remove the thermostat housing.
7. Remove the water pipe between the water pump and thermostat housing. Confirm that both water pipe O-ring seals are extracted with the pipe.



31428

a - Water pump to thermostat housing water pipe
b - O-rings (one not visible)

8. Remove the water circulating pump.

31431

Flange screw (six)

Cleaning

IMPORTANT: Debris, such as old gasket material, might foul the cooling system passages. Do not allow debris inside the engine block during cleaning.

1. Remove all traces of old gasket material from the water circulating pump body.
2. Remove all traces of old gasket material from the engine block.

Inspection

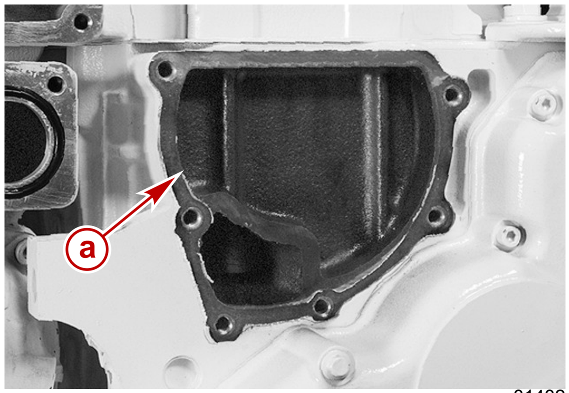
1. Inspect the water circulating pump body for blockage, cracks, sand holes, corrosion, or other damage.
2. Inspect the impeller for cracks, corrosion, or damage.
3. Inspect the impeller shaft and bearings for excessive side play, abnormal noise when turning, or wear.
4. Inspect the pulley for bends, cracks, corrosion, improper runout, or other damage.
5. Replace the complete water circulating pump for failure to pass any of these inspections.

Installation

1. Apply sealant to both both sides of the new water circulating pump gasket.

Tube Ref No.	Description	Where Used	Part No.
 12	Loctite Master Gasket Kit	Water circulating pump gasket	92-12564 2

2. Install the new new water circulating pump gasket on the engine block.



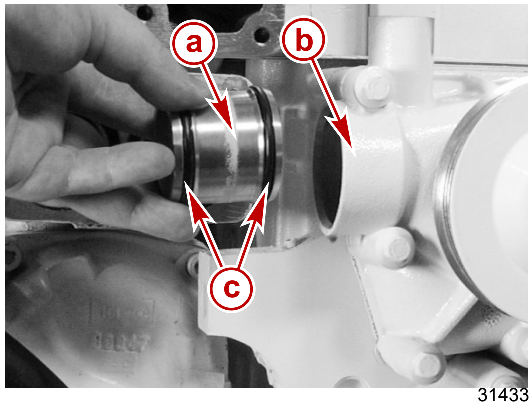
a - Water circulating pump gasket

3. Install the water circulating pump.
4. Tighten the six flange screws of the water circulating pump evenly in a diagonal pattern. Torque to specification.

The six flange screws

Description	Nm	lb. in.	lb. ft.
Water circulating pump flange screw	32.4	–	23

5. Install the water pump to thermostat housing water pipe with new O-rings into the water circulating pump.

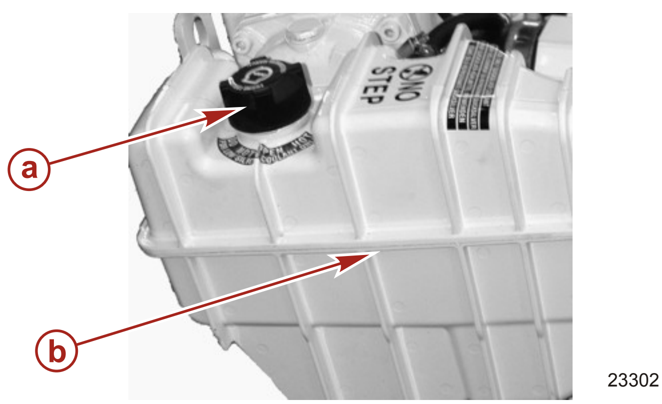


a - Water pump to thermostat housing water pipe
b - Water circulating pump.
c - O-rings

6. Install the thermostat housing. Refer to **Section 6A: Thermostat Housing**
7. Install the coolant expansion tank.
8. Install the serpentine drive belt.
9. Fill the closed cooling system.
10. Open the seacock if equipped, or unplug and reconnect the seawater inlet hose.
11. Ensure that the seawater pickup pump is supplied cooling water.
12. Connect the battery cables and start the engine.
13. Test the engine operation. Ensure that the engine operating temperature is normal and check for leaks.
14. Stop the engine.
15. Check the engine coolant level. Fill to the proper level.

Filling the Closed Cooling System

1. Remove the pressure cap.

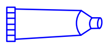


a - Pressure cap
b - Coolant expansion tank

IMPORTANT: Use only the specified coolant.

2. If the coolant is being replaced or the level is low, slowly add the specified coolant to the level indicated in the table.

Coolant level in expansion tank	
All models	Within 25 mm (1 in.) of the bottom of the filler neck, or between the upper and lower marks, if marked

Tube Ref No.	Description	Where Used	Part No.
	Marine Engine Coolant (Only available in Europe)	Closed cooling system	92-813054A2
	Fleetguard Compleat with DCA4, Fleetguard Part Number CC2825	Closed cooling system	Obtain Locally

NOTICE
Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

3. Ensure that the seawater pickup pump is supplied cooling water.
4. Do not install the pressure cap. Start and operate the engine at fast idle (1500–1800 RPM). Add coolant if necessary to maintain the coolant at the level specified previously.

IMPORTANT: When installing the pressure cap, be sure to tighten it securely to avoid coolant loss.

5. Install the pressure cap after the engine has reached normal operating temperature (with the thermostat fully open) and the coolant level remains constant.
6. Test the engine operation. Observe the temperature gauge and check the engine for coolant leaks. If the temperature gauge indicates the presence of excessive temperature or coolant is leaking, stop the engine immediately and inspect for the cause.
7. After the first operation, allow the engine to cool.
8. Remove the pressure cap and add the specified coolant to the level indicated in the table.

Coolant level in expansion tank	
All models	Within 25 mm (1 in.) of the bottom of the filler neck, or between the upper and lower marks, if marked

9. Install and securely tighten the pressure cap.

Intake and Exhaust System

Section 7A - Aftercooler

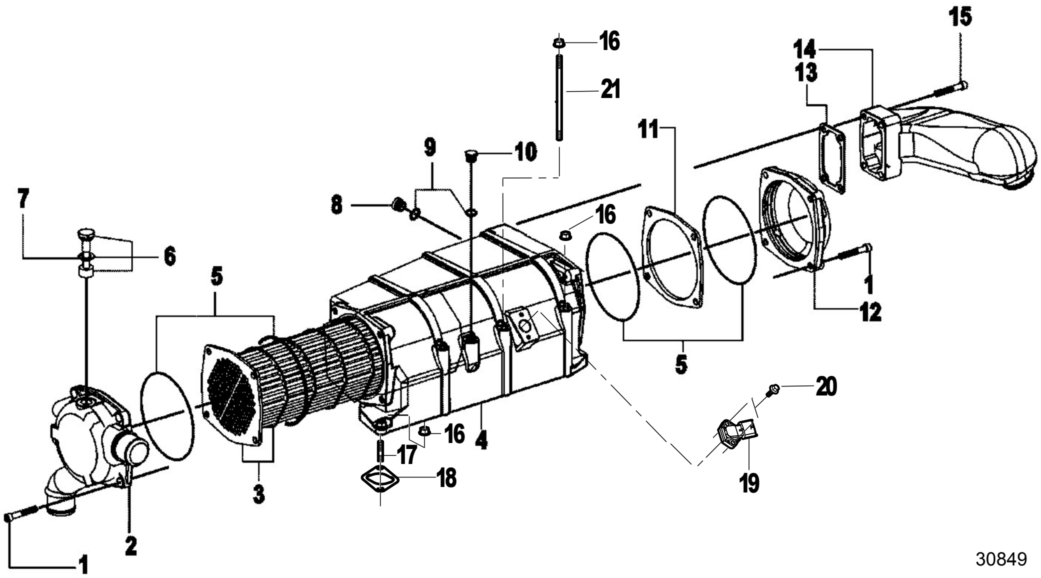
Table of Contents

7
A

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Intake duct to aftercooler housing surface	92-12564 2

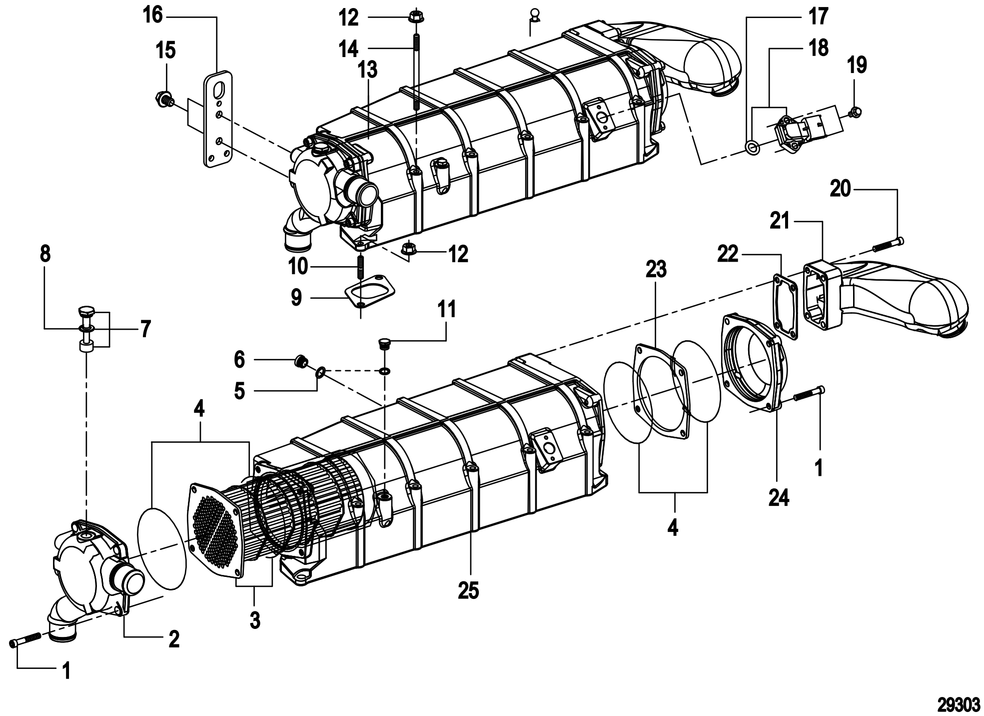
Exploded View—2.8 QSD Aftercooler



Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	8	Allen-head cover screw	40	–	30
2	1	Front cover			
3	1	Aftercooler insert (element)			
4	1	Aftercooler housing			
5	4	O-ring			
6	1	Anode plug assembly			
7	2	Sealing washer			
8	1	Drain plug			
9	2	Sealing washer			
10	1	Screw			
11	1	Plate			
12	1	Rear cover			
13	1	Intake duct gasket			
14	1	Intake duct			
15	4	Intake duct screws	10	84	–
16	8	Flange nut	24.5	–	18
17	5	Studs	24.5	–	18
18	4	Intake port gasket			
19	1	MAP/IAT sensor			
20	2	MAP/IAT sensor screw and washer			
21	3	Stud			

Notes:

Exploded View—4.2 QSD Aftercooler



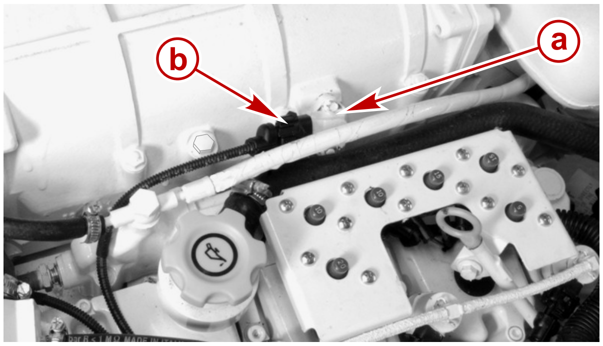
Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	8	Allen-head cover screw	40	–	30
2	1	Front cover			
3	1	Aftercooler insert (element)			
4	1	O-ring			
5	2	Sealing washer			
6	1	Drain plug			
7	1	Anode plug assembly	17	150	–
8	1	Sealing washer			
9	6	Intake port gasket			
10	7	Stud			
11	1	Plug			
12	12	Flange nut	24.5	–	18
13	1	Aftercooler			
14	5	Studs			
15	2	Screws	47.1	–	34
16	1	Lifting eye	–	–	–
17	1	Washer	24.5	–	18
18	1	MAP/IAT sensor	–	–	–
19	1	MAP/IAT sensor flange screw	5.6	49	–
20	4	Intake duct Allen-head screw	10	84	–
21	1	Intake duct			
22	1	Gasket			
23	1	Plate			
24	1	Rear cover			
25	1	Aftercooler housing			

Aftercooler

Removal

1. Remove the engine cover.
2. Drain the seawater system.
3. Drain the closed cooling system.
4. Remove the coolant expansion tank.

5. Disconnect the MAP/IAT sensor.



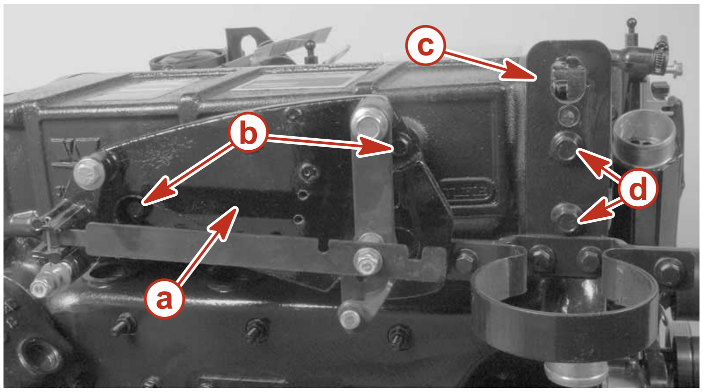
2.8 shown, 4.2 similar

a - MAP/IAT sensor
b - MAP/IAT sensor connector

6. **On sterndrive engines:**
   a. Remove the sterndrive shift bracket.

NOTE: In the following the power steering reservoir is shown removed for visual clarity only. Set the reservoir and bracket aside after removal.

   b. Remove the engine lifting eye bracket, with the fluid reservoir bracket if equipped, from aftercooler end cover.

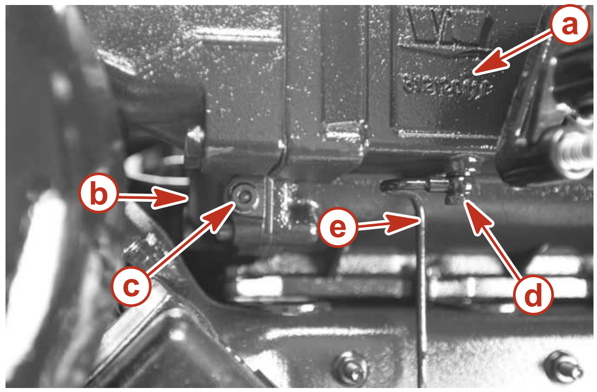


Typical sterndrive shown, all similar

a - Shift bracket
b - Shift bracket flange screws
c - Engine lifting eye bracket
d - Engine lifting eye bracket flange screws

7. Remove the drain plug and sealing washer from the rear cover of the aftercooler.

8. Remove the hollow bolt and sealing washers from the wastegate valve pressure line.

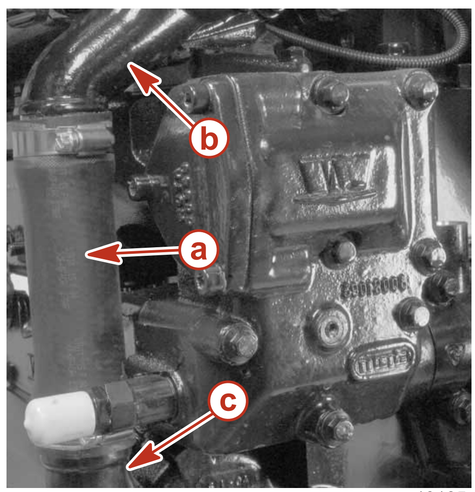


13184

Sterndrive shown, inboard similar

a - Aftercooler
b - Rear cover
c - Drain plug with sealing washer
d - Hollow bolt and sealing washers
e - Pressure line

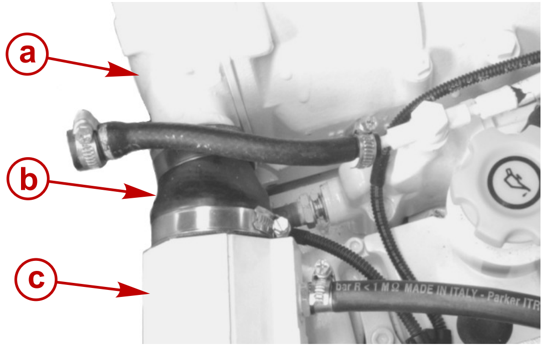
9. Disconnect the seawater hose from the aftercooler to the heat exchanger.



13185

a - Seawater hose
b - Aftercooler
c - Heat exchanger

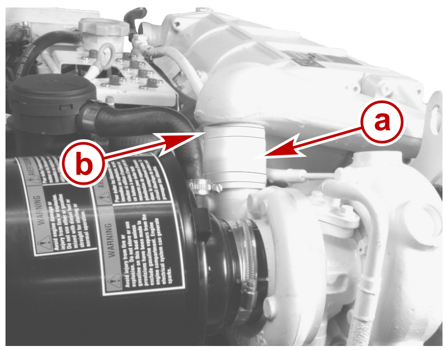
10. Disconnect the seawater hose from the fuel cooler to the aftercooler.



2.8 sterndrive shown, all similar

a - Aftercooler
b - Seawater hose
c - Fuel cooler

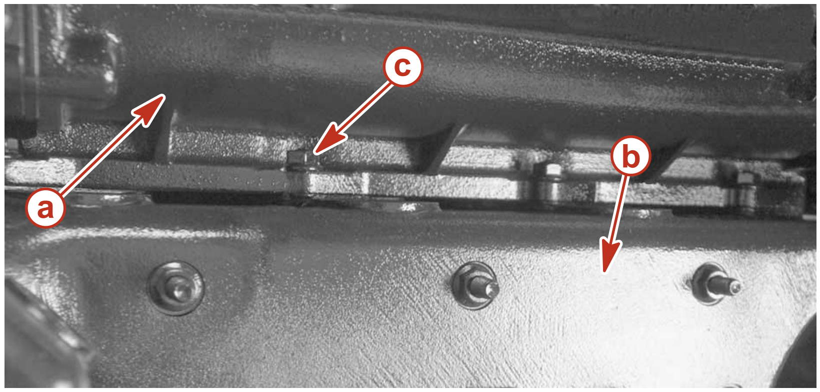
11. Loosen the hose clamp on the hose from the intake duct to the turbocharger.



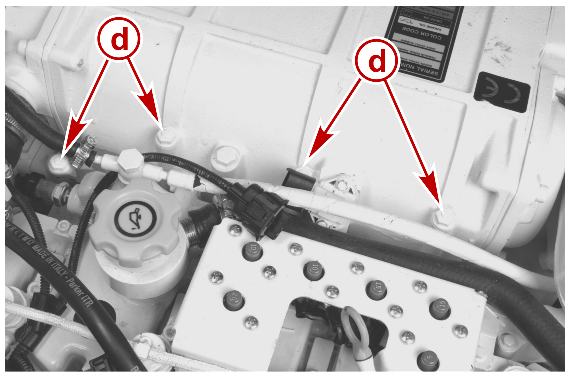
2.8 sterndrive shown, all similar

a - Hose
b - Hose clamp

12. Remove the four (on 2.8) and six (on 4.2) inner and outer flange nuts that retain the aftercooler housing to the intake and exhaust manifold.



13201



30838

2.8 sterndrive shown, all similar

a - Aftercooler housing
b - Intake and exhaust manifold
c - Outer flange nut
d - Inner flange nut

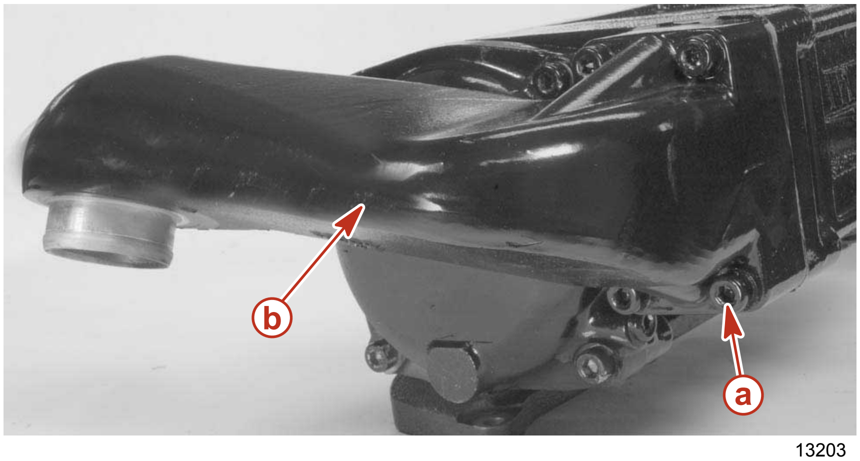
13. Remove the aftercooler.

Disassembly

NOTICE
Seawater leaking into the air intake system will result in severe engine damage. Replace all O-ring seals whenever disassembling the aftercooler or removing the radiator insert (aftercooler core).

1. Loosen the two screws with washers, and remove the MAP/IAT sensor from the aftercooler.

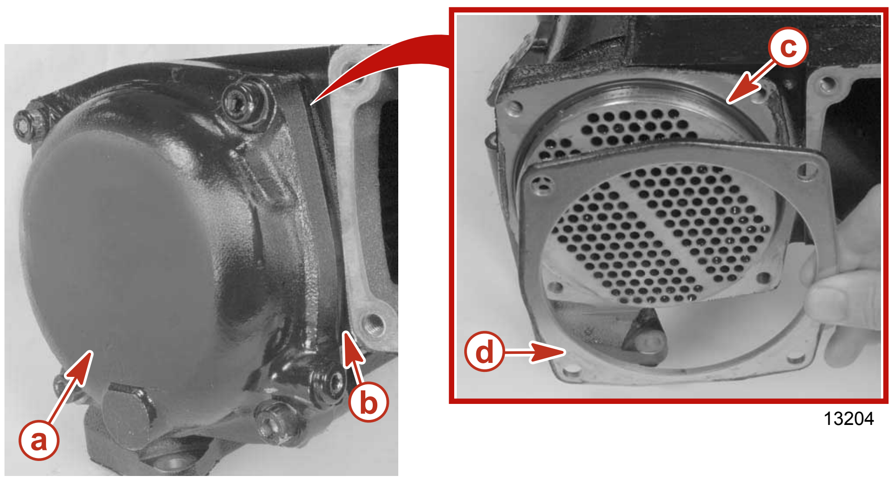
2. Remove the intake duct from rear of the aftercooler.



2.8 shown, 4.2 similar

a - Intake duct screws (4)
b - Intake duct

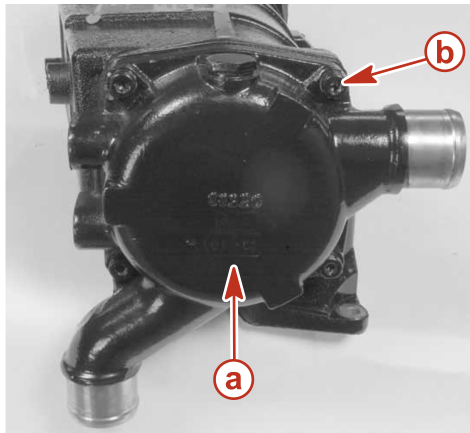
3. Remove the rear cover. Note the position of the O-ring in the cover, the plate, and second O-ring.



Typical

a - Rear cover
b - Rear cover screws
c - O-ring in rear cover (not shown)
d - O-ring, behind plate (shown)
e - Plate

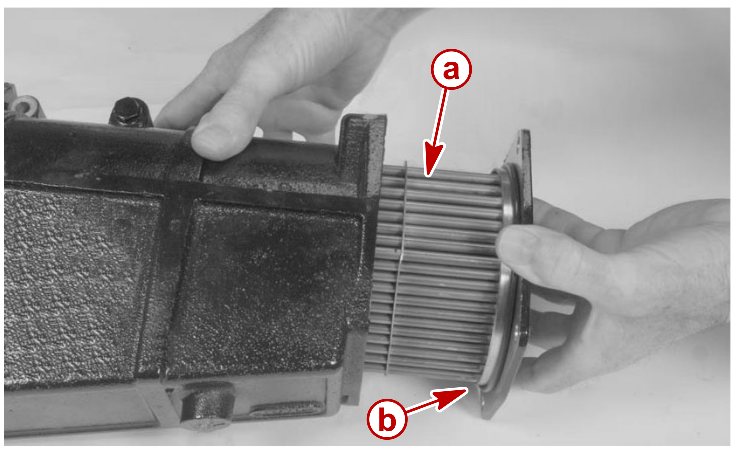
4. Remove the front cover. Note the position of the O-ring.



13205

a - Front cover
b - Front cover screws

5. Slide the aftercooler insert (core) out of the front of the aftercooler housing. Note the position of the O-ring.



30846

a - Aftercooler insert
b - O-ring

Cleaning and Inspection

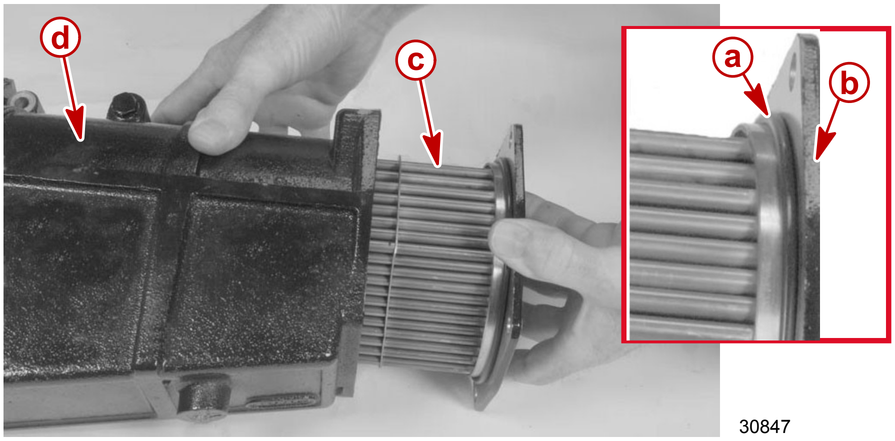
IMPORTANT: Be careful not to drop anything into the intake ports.

1. Clean the old gasket material from the aftercooler housing flanges and the intake and exhaust manifold. Do not nick or gouge the surfaces, which would cause intake or water leaks.
2. Use a 4.4 mm by 610 mm (11/64 in. by 24 in.) diameter long rod to clean out the aftercooler insert (core) tubes, or take to a radiator shop for cleaning.
3. Inspect each part for cracks or other damage that would render it unserviceable.
4. See Section 1B - Check the anodes.
5. Clean and paint the exterior surfaces as required to prevent corrosion.

Assembly

IMPORTANT: Some components use O-rings to form seals. Rolling or twisting an O-ring during installation may form an improper seal resulting in component damage or failure causing additional problems that could be more serious. Do not roll or twist an O-ring during installation.

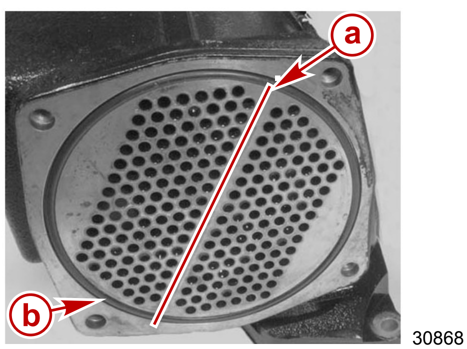
1. Install the O-ring on the aftercooler insert against the front flange.
2. Install the aftercooler insert into the aftercooler housing.



2.8 aftercooler shown, 4.2 similar

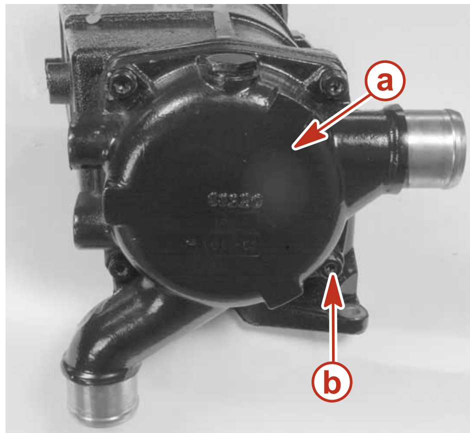
a - O-ring
b - Front flange
c - Aftercooler insert
d - Housing

3. Align the insert passages as shown. Place the O-ring into the groove on the front of the aftercooler insert.



a - Alignment reference
b - O-ring

4. Install the front cover. Tighten the four front cover screws to specified torque, in a cross pattern.



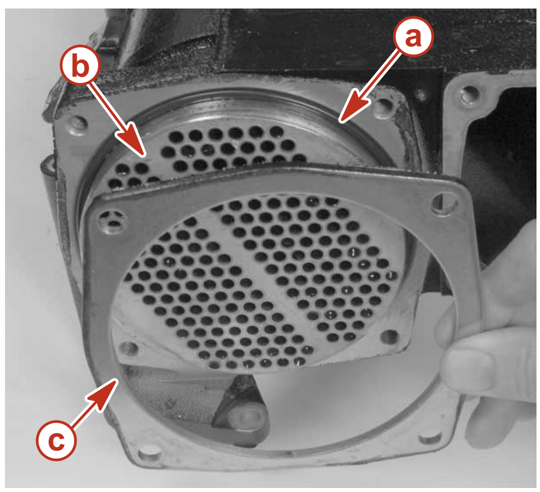
13209

Typical

a - Front cover
b - Front cover screw

Description	Nm	lb. in.	lb. ft.
Front cover screw	40	–	30

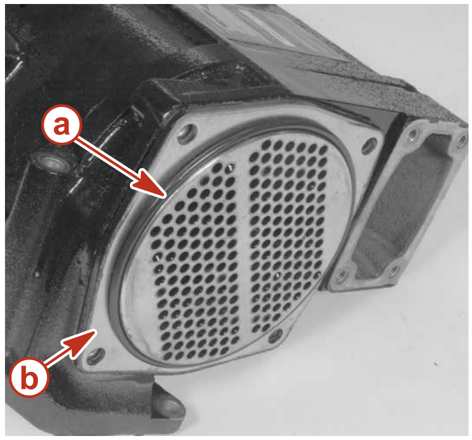
5. Install the O-ring around the rear of the aftercooler insert.
6. Install the plate on the rear of the aftercooler.



13210

a - O-ring
b - Rear of aftercooler insert
c - Plate

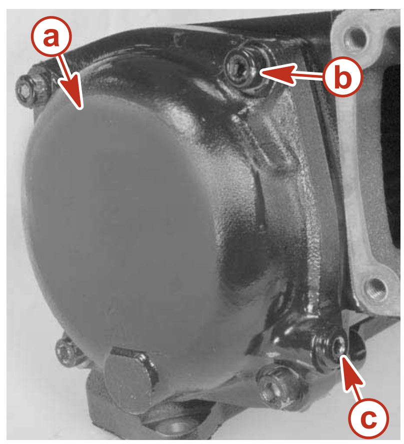
7. Install the second O-ring around the aftercooler insert and against the plate.



13211

a - O-ring
b - Plate

8. Install the rear cover. Tighten the four rear cover screws to specified torque , in a cross pattern.
9. Install the drain plug with a new sealing washer.



13212

Typical

a - Rear cover
b - Rear cover screws
c - Drain plug and sealing washer

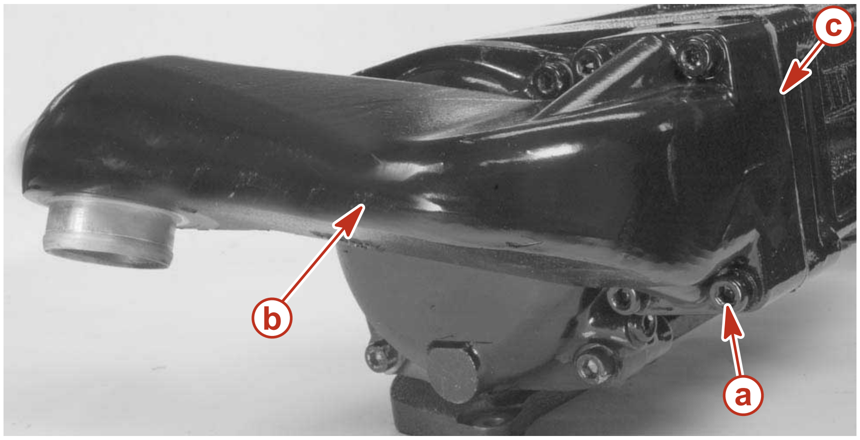
Description	Nm	lb. in.	lb. ft.
Rear cover screw	40	–	30

10. Apply sealant on the aftercooler housing mating surface for the intake duct.

Tube Ref No.	Description	Where Used	Part No.
12	Loctite Master Gasket Kit	Intake duct to aftercooler housing surface	92-12564 2

11. Install the intake duct gasket.

12. Install the intake duct. Tighten the four intake duct screws to specified torque .



13213

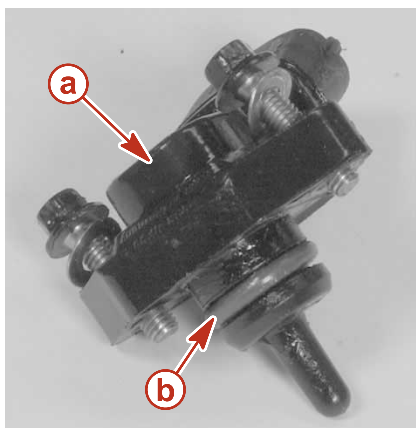
2.8 aftercooler shown, 4.2 similar

a - Intake duct screw
b - Intake duct
c - Gasket (not visible in this view)

Description	Nm	lb. in.	lb. ft.
Intake duct screw	10	84	–

Installation

1. If the MAP/IAT sensor was removed previously, install a new O-ring.
2. Install the sensor in the aftercooler using the two flange screws. Torque the MAP/IAT sensor screws.

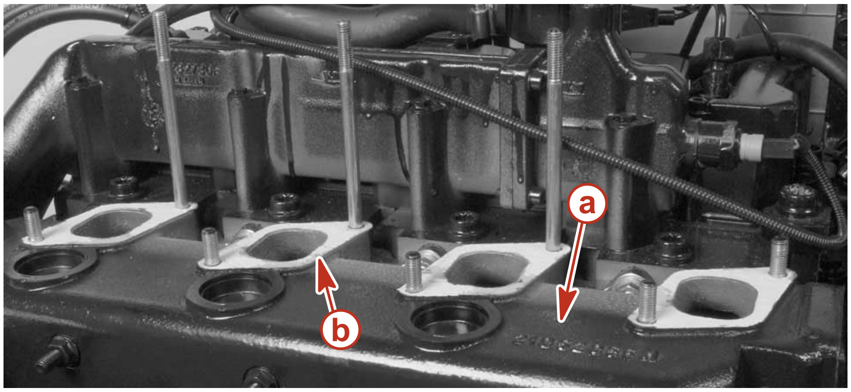


13215

a - MAP/IAT sensor
b - O-ring

Description	Nm	lb. in.	lb. ft.
MAP/IAT sensor flange screw	5.6	49	

3. Install new intake port gaskets.



13214

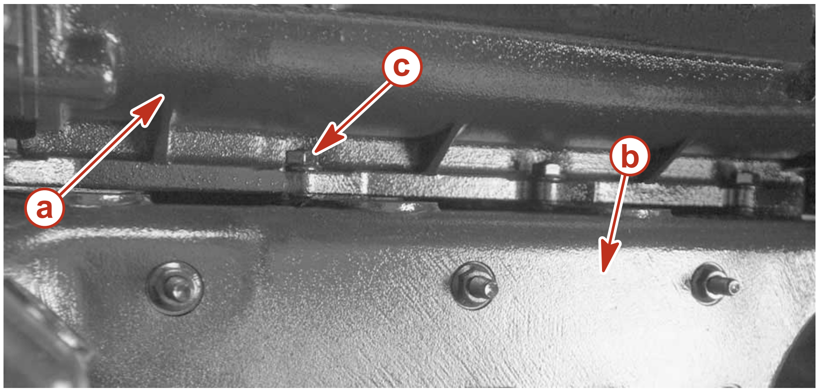
2.8 shown, 4.2 similar

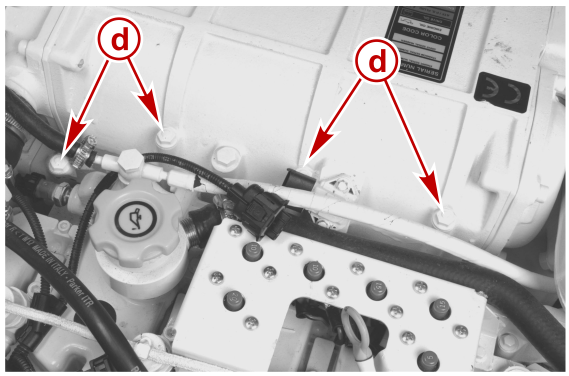
a - Intake and exhaust manifold

b - Intake port gaskets (four)

4. Align the intake duct with the turbocharger to the intake duct hose and install the aftercooler.

5. Install the aftercooler flange nuts where previously removed. Torque the aftercooler flange nuts.



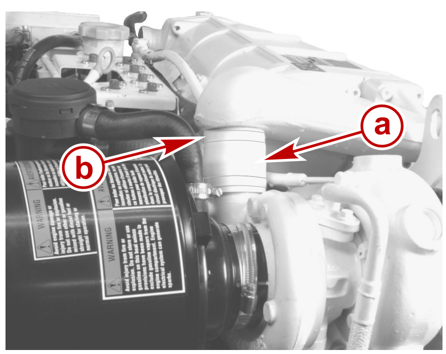


2.8 shown, 4.2 similar

a - Aftercooler housing
b - Intake and exhaust manifold
c - Outer flange nuts
d - Inner flange nuts

Description	Nm	lb. in.	lb. ft.
Aftercooler flange nut	24.5		18

6. Securely tighten the hose clamp on the turbocharger to the intake duct hose.

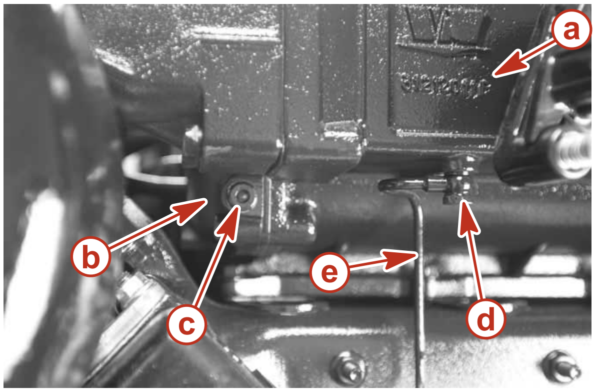


2.8 shown, 4.2 similar

a - Hose
b - Hose clamp

7. Install the aftercooler rear cover drain plug, using a new sealing washer.

8. Connect the wastegate valve pressure line using the hollow bolt with two new sealing washers. Torque the hollow bolt.

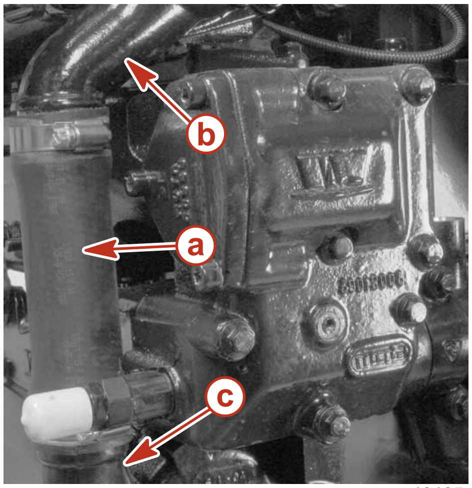


Typical sterndrive shown, inboard similar

a - Aftercooler
b - Rear cover
c - Drain plug with sealing washer
d - Hollow bolt and sealing washers
e - Pressure line

Description	Nm	lb. in.	lb. ft.
Pressure line hollow bolt	14.7	130	

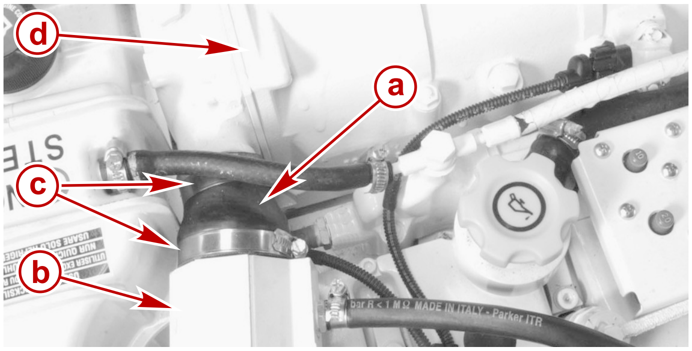
9. Connect the seawater hose from the aftercooler to the heat exchanger.



a - Seawater hose
b - Aftercooler
c - Heat exchanger

10. Install the coolant expansion tank. See **Section 6A**.

11. Connect the seawater hose from the fuel cooler to the aftercooler. Tighten the hose clamps securely.

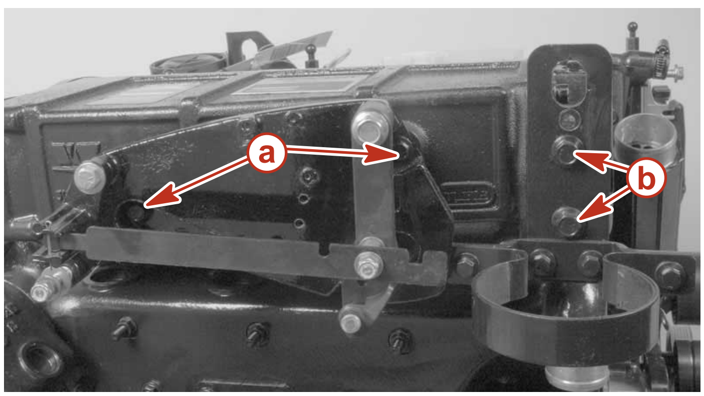


30848

2.8 shown, 4.2 similar

a - Seawater hose
b - Fuel cooler
c - Hose clamp
d - Aftercooler

12. **On sterndrive engines:**
    a. Install the sterndrive shift bracket onto the side of aftercooler. Tighten the shift bracket screws securely.
    b. Install the engine lifting eye bracket with the fluid reservoir and bracket if equipped, onto aftercooler end cover. Torque the engine lifting eye bracket screws.



13218

Typical 2.8 shown, all similar

a - Shift bracket screws
b - Engine lifting eye bracket screws

Description	Nm	lb. in.	lb. ft.
Engine lifting eye bracket screw	47.1		34

13. Check the power steering fluid level and correct if needed.
14. Fill the closed cooling system.
15. Open the seacock if equipped, or unplug and connect the seawater inlet hose.
16. Ensure that the seawater pickup is supplied cooling water.
17. Connect the battery cables and start the engine.
18. Test the engine operation. Ensure that the engine operating temperature is normal and check for leaks. Stop the engine immediately in the event of leaking or overheating, and repair as needed.

19. Stop the engine.
20. Check the engine coolant level. Fill to the proper level.
21. Install the engine cover.

Intake and Exhaust System

Section 7B - Elbows, Risers, Intake and Exhaust Manifold

Table of Contents

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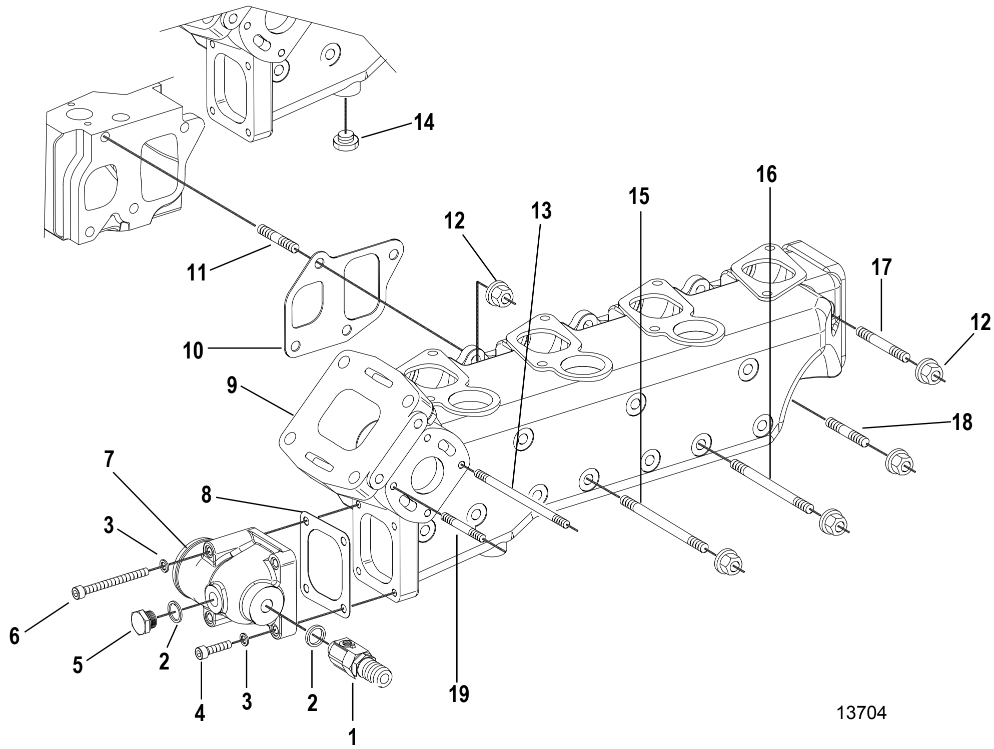
B

Description

All diesel engines covered in this manual use an exhaust manifold that incorporates air passages for both intake and exhaust in a single unit. Fresh water from the closed cooling system is pumped by the engine water circulating pump through the combined intake and exhaust manifold when the engine is operating. When reference is made to the exhaust manifold, keep in mind that it includes the intake air passages (or intake manifold). Additionally, the engines exhaust manifold includes a flange for mounting a turbocharger wastegate and valve assembly.

Exploded Views

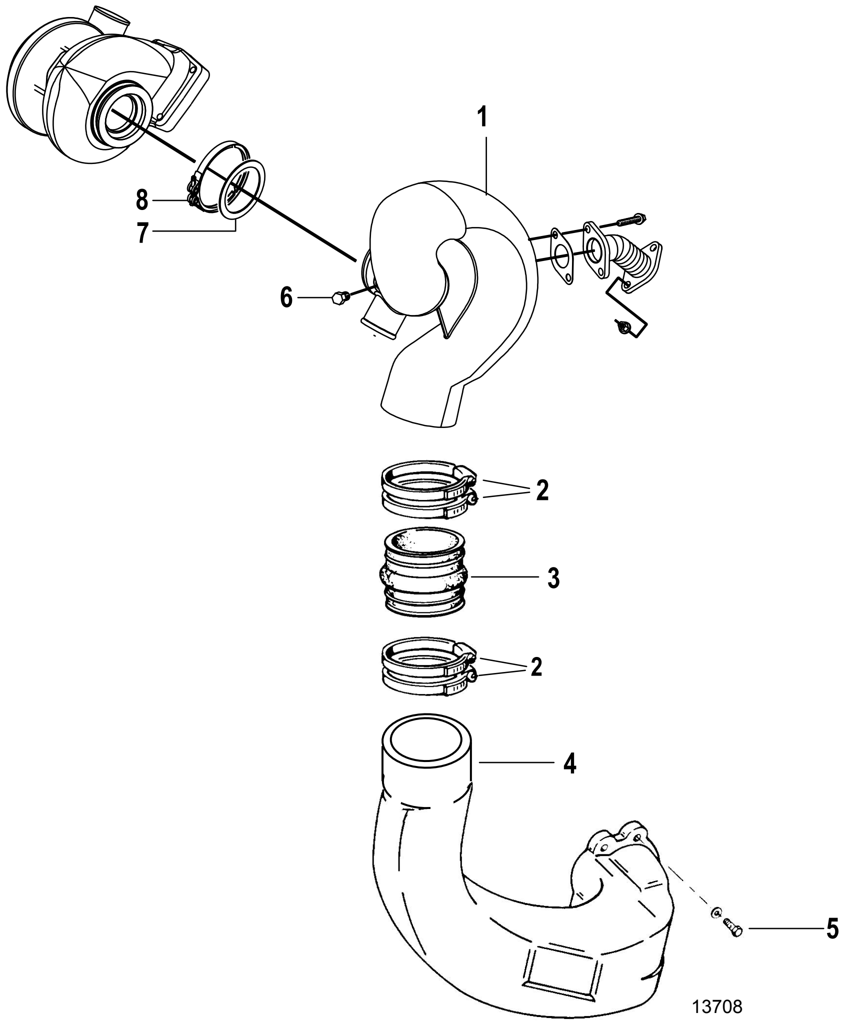
Typical Intake And Exhaust Manifold



Typical Intake And Exhaust Manifold

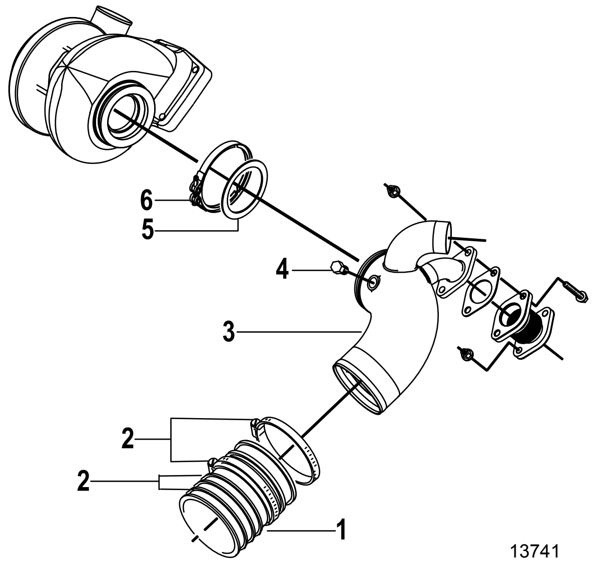
Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Hot water supply bayonet fitting with valve	24.5		18
2	2	Sealing washer			
3	4	Washer			
4	2	Rear cover screw (M6)	10.8	95	
5	1	Screw plug	37.3		27
6	2	Rear cover screw (M6)	10.8	95	
7	1	Rear cover			
8	1	Gasket			
9	1	Intake and exhaust manifold, with wastegate flange			
10	4	Intake and exhaust gasket			
11	4	Stud			
12	12	Flange nut			
13	2	Stud			
14	1	Drain plug			
15	3	Stud			
16	7	Stud			
17	1	Stud			
18	1	Stud			
19	2	Stud			

Sterndrive Exhaust Systems



Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Exhaust riser			
2	2	Hose clamp			
3	1	Exhaust tube			
4	1	Exhaust pipe			
5	4	Special bolt and thick lockwasher	34		25
6	1	Screw plug	11.8	104	
7	1	Gasket			
8	1	Exhaust riser clamp	6.9	61	

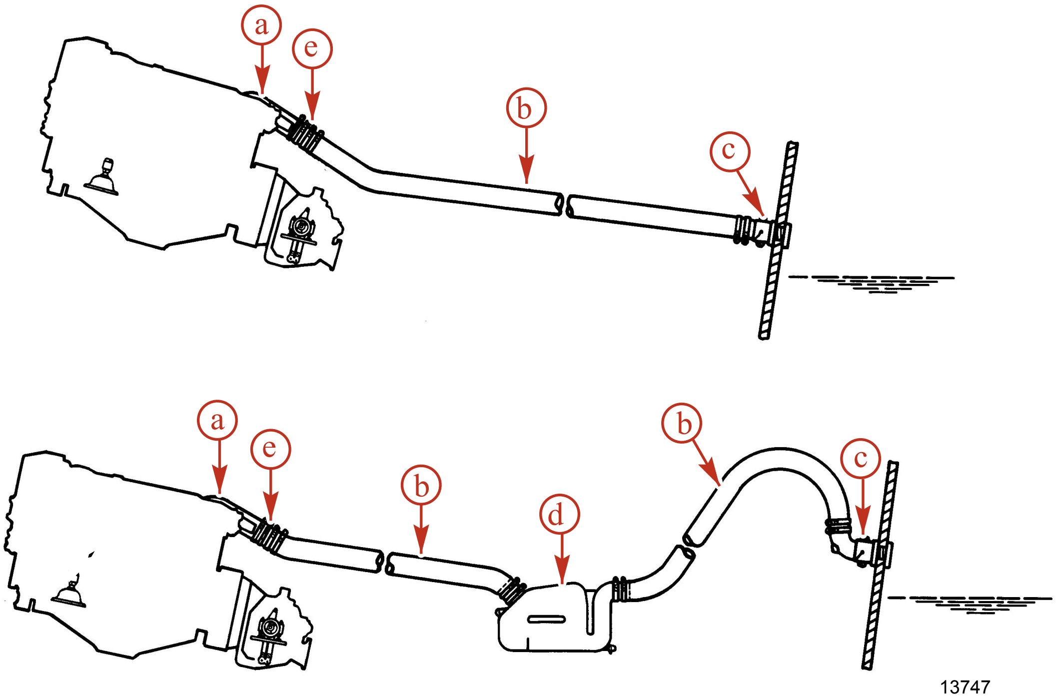
Inboard Exhaust Systems



Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Exhaust tube			
2	4	Hose clamps (two not shown)			
3	1	Exhaust elbow			
4	1	Screw plug	11.8	104	
5	1	Gasket			
6	1	Exhaust elbow clamp	6.9	61	

Representative Views Of Complete Inboard Exhaust Systems

NOTE: Use diagrams for component identification only.



Typical

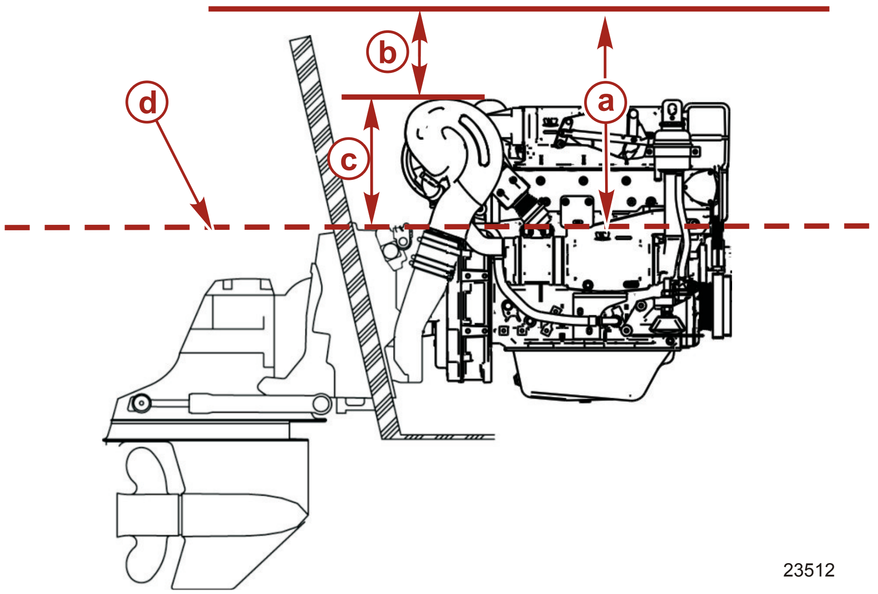
a - Exhaust elbow with gasket and clamp
b - Exhaust pipe
c - Outlet with water shutter and flapper
d - Water-lift muffler
e - Exhaust tube and hose clamps

Locating And Installing The Sterndrive Exhaust System

NOTE: It is the responsibility of the boat manufacturer or installing dealer to properly locate the engine and install the exhaust system. Improper installation may allow water to enter the exhaust manifolds and combustion chambers and severely damage the engine. Damage caused by water in the engine will not be covered by Cummins MerCruiser Diesel Warranty unless this damage is the result of defective parts.

Determine if a water lift muffler kit is required by taking measurements **a** and **b**, with the boat at rest in the water and maximum load aboard. Subtract **b** from **a** to find **c**. If **c** is less than specified in the chart, an exhaust riser kit must be installed.

Model	**c** = **a** minus **b**
All models	**c** must be 11 in. (279 mm) or more



Typical sterndrive engine

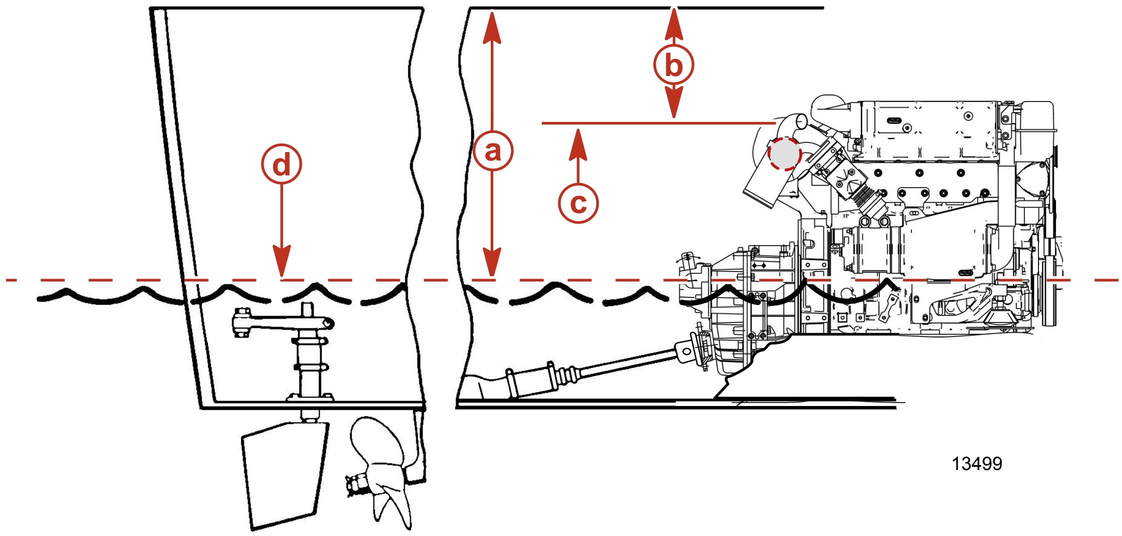
a - From waterline to top of transom
b - From highest point on exhaust riser to top of transom
c - Distance found by subtracting **b** from **a**
d - Waterline at rest

Locating And Installing The Inboard Exhaust System

IMPORTANT: It is the responsibility of the boat manufacturer or installing dealer to properly locate the engine and install the exhaust system. Improper installation may allow water to enter the exhaust manifolds and combustion chambers and severely damage the engine. Damage caused by water in the engine will not be covered by Cummins MerCruiser Diesel Warranty unless this damage is the result of defective parts.

Determine if an exhaust riser kit or a water lift muffler kit is required by taking measurements **a** and **b**, with the boat at rest in the water and maximum load aboard. Subtract **b** from **a** to find **c**. If **c** is less than specified in the chart, an exhaust riser kit or a water lift muffler kit must be installed.

Models	c = a minus b
All models	**c** Must be 279 mm (11 in.) or more



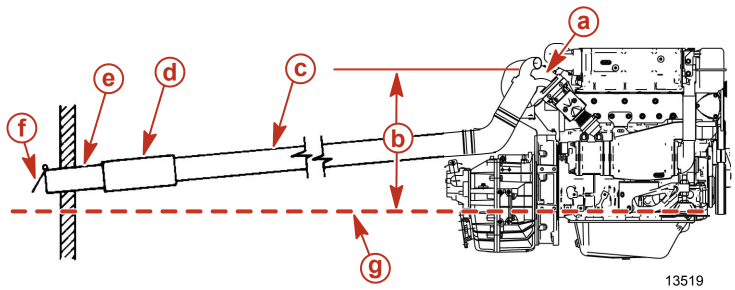
Typical inboard engines

a - From waterline to top of transom
b - From highest point on exhaust elbow to top of transom
c - Distance found by subtracting **b** from **a**
d - Waterline at rest

Additional Information

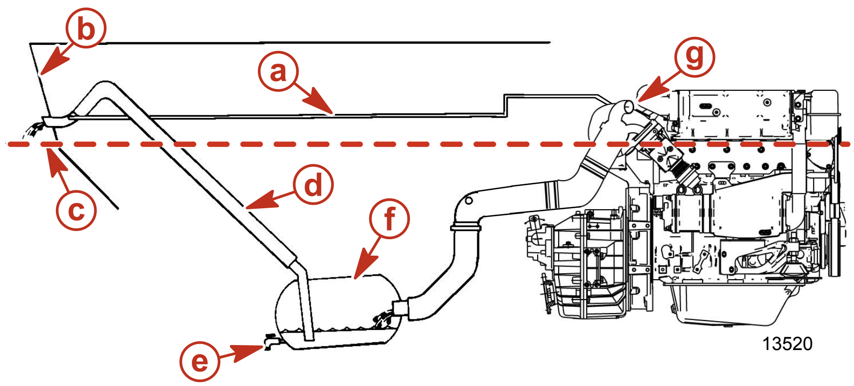
- If no exhaust riser or a water lift muffler kit is required, the exhaust outlet (for routing exhaust outside of the boat) must be located so that a minimum of 13 mm (1/2 in.) per 305 mm (12 in.) downward pitch exists in the exhaust hose or pipe from the engine exhaust elbow to the outlet.
- The exhaust hose or pipe must drop a minimum of 100 mm (4 in.) overall according to American Boat and Yacht Council recommendations. The drop must be constant so that a low spot does not exist at any point in the exhaust hose or pipe.
- The exhaust outlet must be slightly above the water line with boat at rest in the water and a full load aboard.
- An exhaust flapper on each outlet is recommended.
- The minimum exhaust hose size is 102 mm (4 in.).
- No exhaust hose bends are allowed within 203 mm (8 in.) of the water inlet hose connection.

- System back pressure when measured at exhaust elbow outlets must not exceed a 1000 mm (39-1/2 in.) water column, or 76 mm (3 in.) of mercury when measured with a mercury manometer . The minimum exhaust hose size is 102 mm (4 in.).



Typical continuously sloping exhaust line

a - Exhaust elbow
b - Measurement 379 mm (11 in.) minimum
c - Exhaust hose or pipe (slope to specifications)
d - Muffler
e - Exhaust outlet internal shutter
f - Exhaust flapper valve
g - Waterline



Typical waterlift muffler exhaust system

a - Exhaust elbow
b - Vent line 6 mm (1/4 in.)
c - Waterlift muffler
d - Exhaust hose
e - Drain valve
f - Transom
g - Waterline

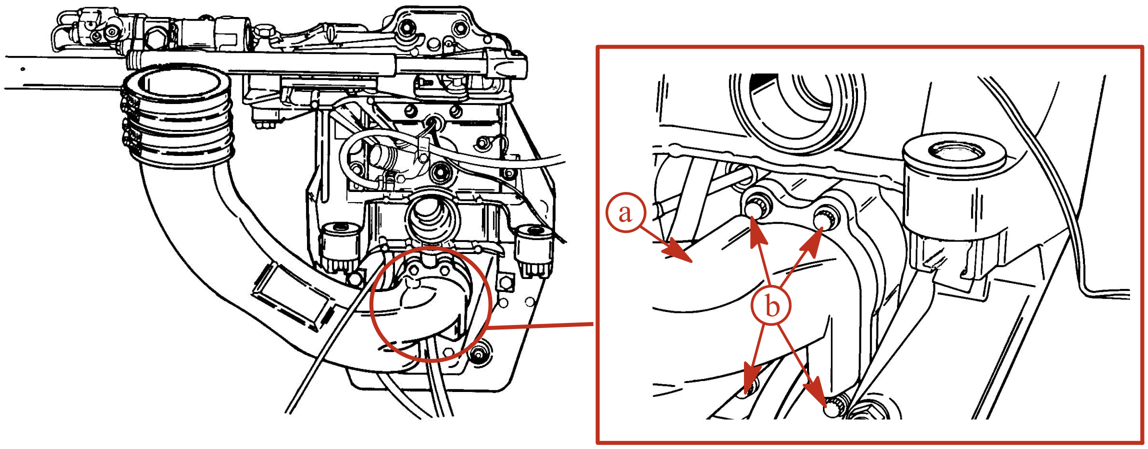
Exhaust Pipe—Sterndrive Models

Removal

IMPORTANT: The engine must be removed to gain access to exhaust pipe. See Section 2A for engine removal and installation procedures.

1. Remove the four bolts and thick lockwashers retaining the exhaust pipe to the gimbal housing.

2. Remove the exhaust pipe.



a - Exhaust pipe

b - Exhaust pipe bolts and thick lockwashers (four)

3. Remove the O-ring seal and discard.

Cleaning

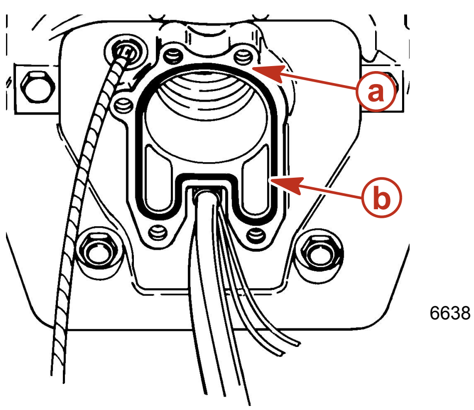
IMPORTANT: Exhaust pipe and gimbal housing assembly mating surfaces must be clean and free of nicks and scratches.

1. Clean the mating surfaces of the exhaust pipe.
2. Clean the mating surfaces of the gimbal housing.

Installation

IMPORTANT: Damaged O-rings can cause property damage from water leaks. Install all O-rings and seals properly before assembling components.

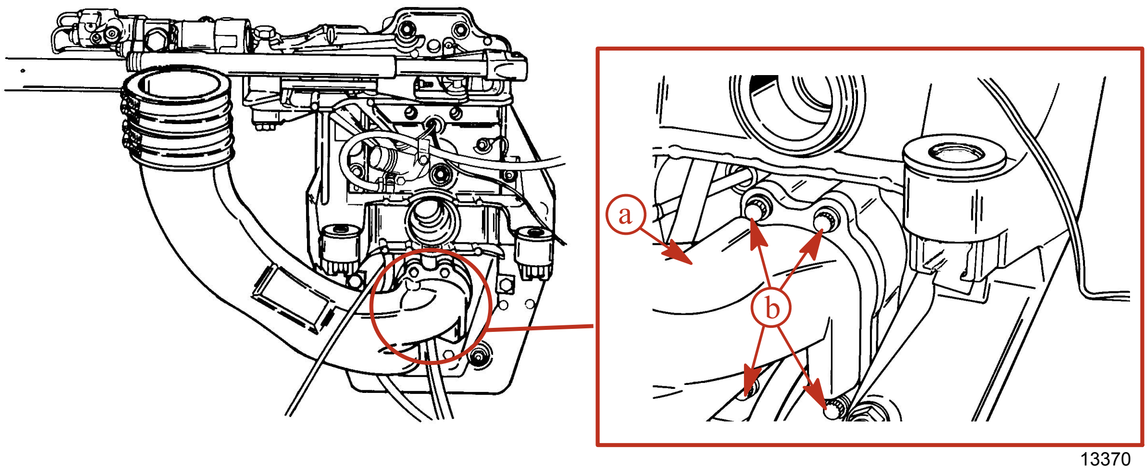
1. Install the new O-ring. Ensure that it is seated properly in the groove of the gimbal housing.



a - Gimbal housing

b - O-ring

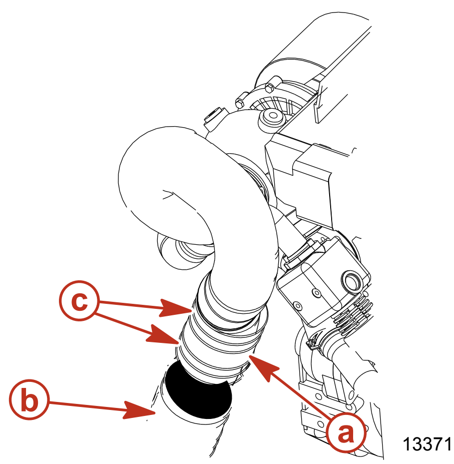
2. Hold the exhaust pipe in position. Install the four thick washers and the exhaust pipe bolts. Torque the exhaust pipe bolts evenly in a diagonal pattern to specification.



a - Exhaust pipe
b - Exhaust pipe bolts and thick lockwashers (four)

Description	Nm	lb. in.	lb. ft.
Exhaust pipe bolts	30		23

3. Lubricate the inside of the large end of the exhaust hose with a soap and water solution. Slide the exhaust hose over the exhaust pipe and install the four hose clamps.



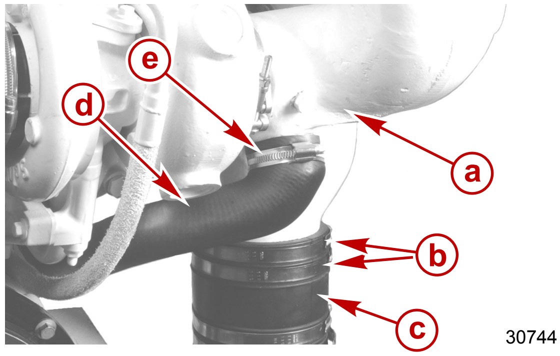
a - Exhaust hose
b - Exhaust pipe
c - Hose clamp (four total)

Exhaust Riser or Exhaust Elbow

Removal

1. Disconnect both battery cables from the battery terminals.
2. Drain the seawater cooling system.
3. Disconnect the seawater hose from the exhaust riser or the exhaust elbow depending upon the model.

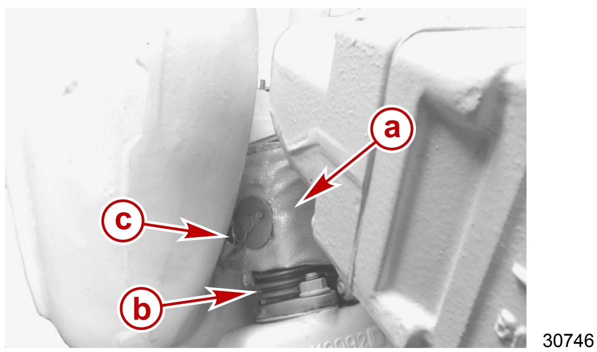
4. Loosen the hose clamps on the exhaust hose connected to the exhaust riser or exhaust elbow.



Sterndrive shown, inboard similar

a - Exhaust riser or exhaust elbow, depending upon the model
b - Exhaust hose clamp
c - Exhaust hose
d - Seawater hose
e - Seawater hose clamp

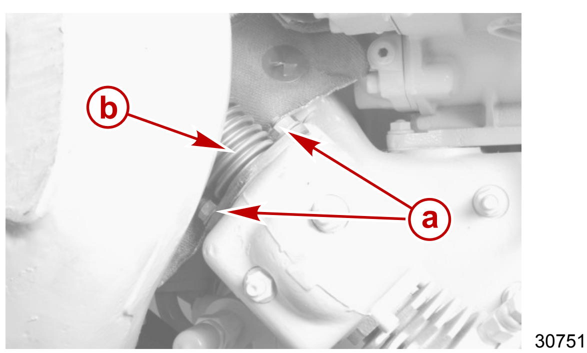
5. Loosen the spring retaining the heat-shield blanket around the wastegate exhaust pipe.



Sterndrive shown, inboard similar

a - Heat-shield blanket
b - Wastegate exhaust pipe
c - Spring

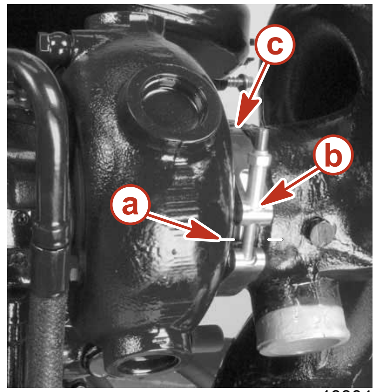
6. Remove the flange nuts connecting the wastegate exhaust pipe to the wastegate.



Sterndrive shown, inboard similar

a - Flange nut
b - Wastegate exhaust pipe

7. Mark alignment on the exhaust riser or exhaust elbow and the turbocharger housing for easy reassembly.
8. Loosen the clamp on the exhaust riser or exhaust elbow.
9. Remove the exhaust riser or exhaust elbow clamp and gasket.

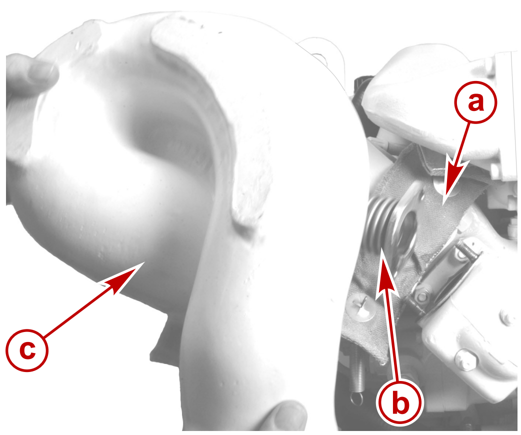


Sterndrive shown, inboard similar

a - Alignment marks
b - Clamp
c - Exhaust gasket (not visible)

NOTE: Do not allow debris to enter the turbocharger or wastegate opening during exhaust riser or elbow removal.

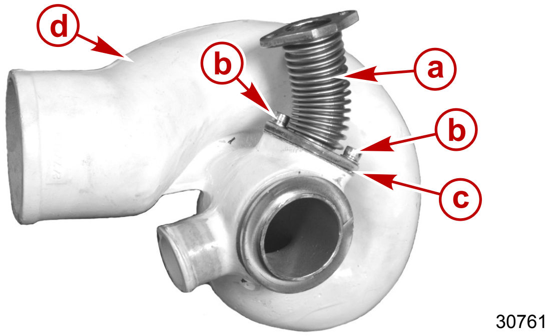
10. Remove the exhaust riser or elbow with the wastegate exhaust pipe attached.



Sterndrive shown, inboard similar

a - Heat-shield blanket
b - Wastegate exhaust pipe
c - Exhaust riser

11. Remove the wastegate exhaust pipe and gasket if the exhaust riser or elbow is being replaced.



Sterndrive exhaust riser shown, inboard exhaust elbow similar

a - Wastegate exhaust pipe
b - Allen-head screw with washer
c - Gasket
d - Exhaust riser

Cleaning and Inspection

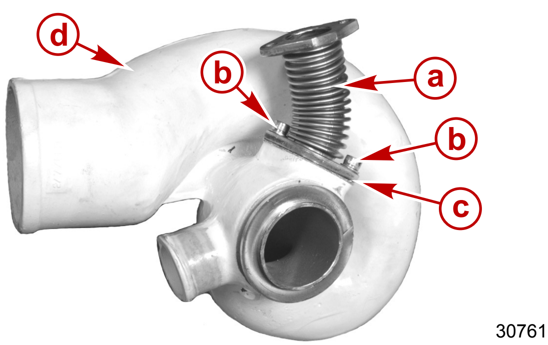
1. Clean the gasket material from all surfaces and wash parts in solvent.
2. Inspect all parts carefully. Machined surfaces must be clean and free of all marks and deep scratches to prevent water and exhaust leaks.
3. Check the water passages for contamination. Passages must be clean for efficient cooling.

IMPORTANT: If plugs are removed, coat threads with Perfect Seal before reinstalling.

4. Remove the plugs for a more thorough inspection.
5. Check for cracks.

Installation

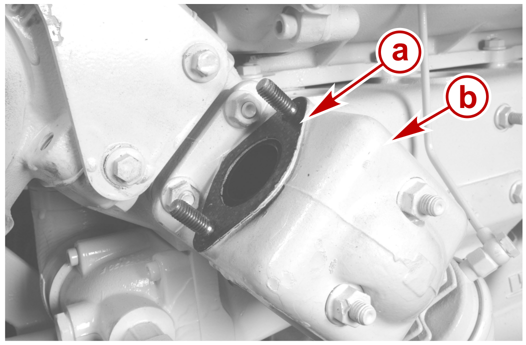
1. If the elbow was replaced, install a new gasket for the exhaust wastegate pipe on the exhaust riser or elbow flange.
2. Install the wastegate exhaust pipe using the washers and Allen-head screws. Torque the Allen-head screws.



Sterndrive exhaust riser shown, inboard exhaust elbow similar

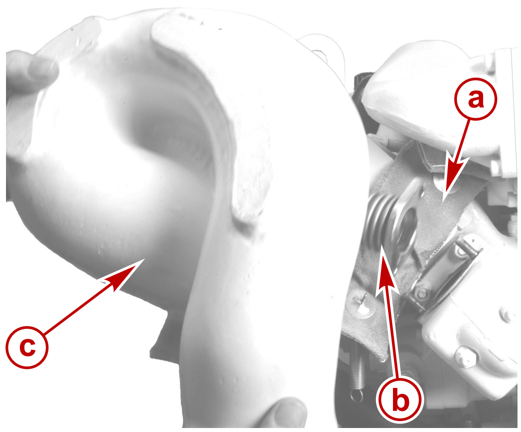
a - Wastegate exhaust pipe
b - Allen-head screw with washer
c - Gasket
d - Exhaust riser

3. Install a new gasket on the wastegate for the exhaust pipe.



a - Gasket
b - Wastegate

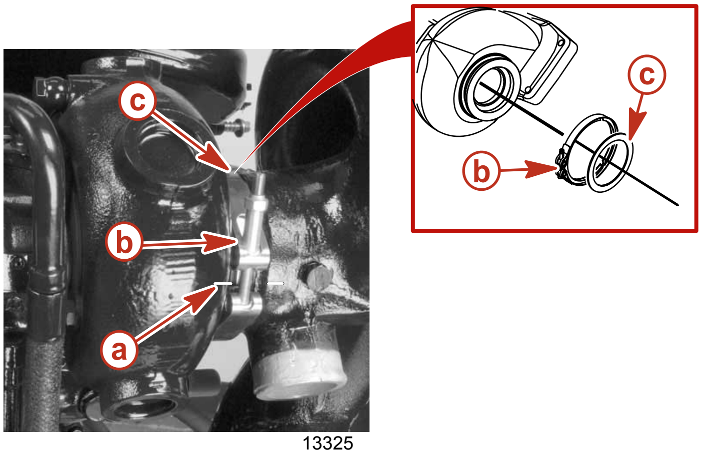
4. Position the heat-shield blanket between the turbocharger and the wastegate exhaust pipe.
5. Install the exhaust riser or elbow with the wastegate exhaust pipe attached.



Sterndrive shown, inboard similar

a - Heat-shield blanket
b - Wastegate exhaust pipe
c - Exhaust riser

6. Using a new gasket, install the exhaust riser or exhaust elbow and the alignment marks made prior to removal. Simultaneously, align the exhaust riser or exhaust elbow with the exhaust pipe. Tighten the exhaust elbow clamp to specified torque .

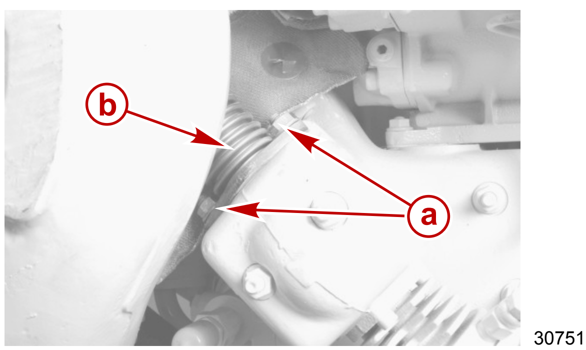


Sterndrive shown, inboard similar

a - Matching marks
b - Exhaust elbow clamp
c - Exhaust gasket

Description	Nm	lb. in.	lb. ft.
Exhaust elbow clamp	6.87	60	–

7. Install the flange nuts retaining the wastegate exhaust pipe to the wastegate.

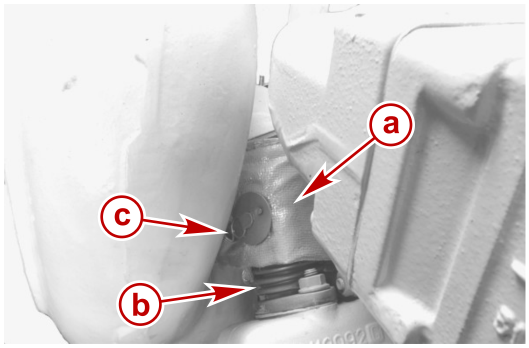


Sterndrive shown, inboard similar

a - Flange nut
b - Wastegate exhaust pipe

Description	Nm	lb. in.	lb. ft.
Wastegate exhaust pipe flange nut	10.8	95	–

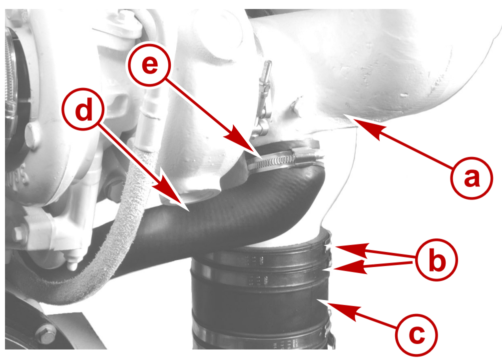
8. Wrap the heat shield blanket around the wastegate exhaust pipe. Fasten the spring to retain the .



Sterndrive shown, inboard similar

a - Heat-shield blanket
b - Wastegate exhaust pipe
c - Spring

9. Install the seawater hose from the fluid cooler to the exhaust riser or exhaust elbow. Tighten the hose clamp securely.
10. Position the exhaust hose as shown. Tighten the hose clamps securely.



Sterndrive shown, inboard similar

a - Exhaust riser or exhaust elbow, depending upon the model
b - Exhaust hose clamp
c - Exhaust hose
d - Seawater hose
e - Seawater hose clamp

11. Fill the closed cooling system.
12. Connect the battery cables to the battery.
13. Start the engine and check for leaks.

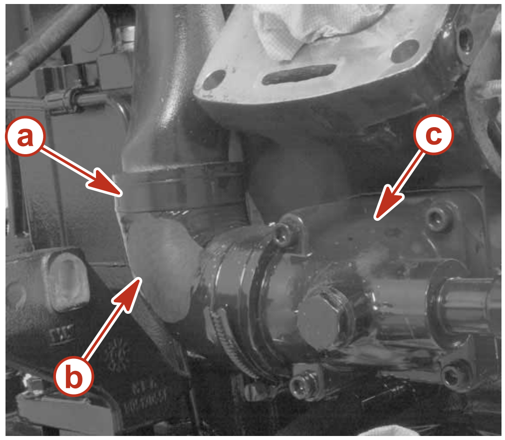
Intake And Exhaust Manifold

Removal

NOTE: See draining instructions in ***Section 1B*** *and refer to the precautions in this section before proceeding.*

1. Drain the seawater cooling system.
2. Drain the closed cooling system.
3. Remove the coolant expansion tank.

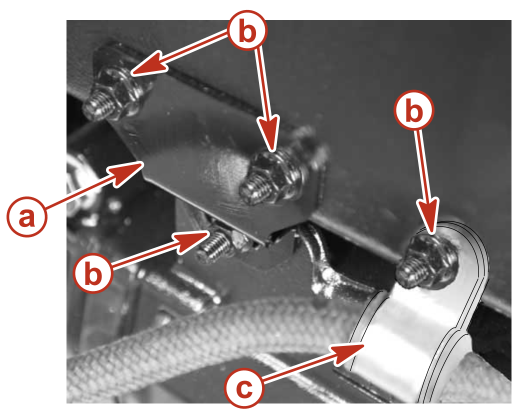
4. Remove the aftercooler.
5. Remove the wastegate and valve.
6. Remove the turbocharger.
7. Loosen the hose clamp on the hose from the coolant manifold strip connected to the intake and exhaust manifold rear cover.



13334

a - Hose clamp
b - Coolant manifold strip hose
c - Intake and exhaust manifold rear cover

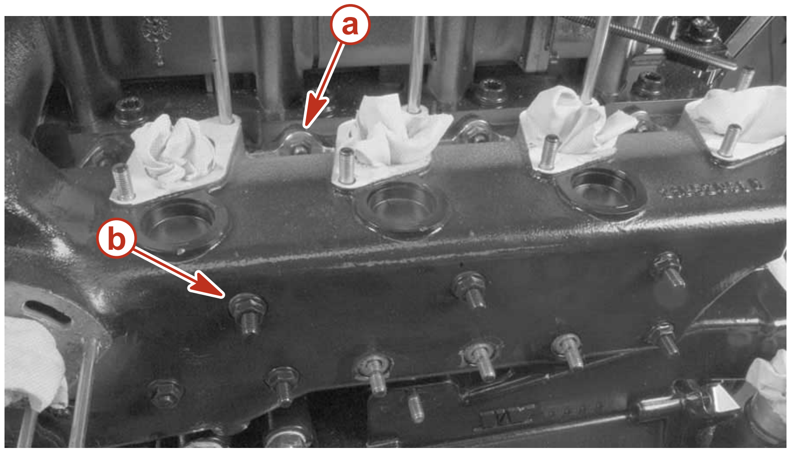
8. Remove the heat exchanger to intake and exhaust manifold support bracket.
9. **On sterndrive models.** Remove the J-clip and isolator with the power steering hose.



13333

a - Intake and exhaust manifold support bracket
b - Flange nut
c - J-clip and isolator

10. Remove the intake and exhaust manifold flange nuts from both short and long studs.



13331

a - Flange nut on short stud
b - Flange nut on long stud

Cleaning and Inspection

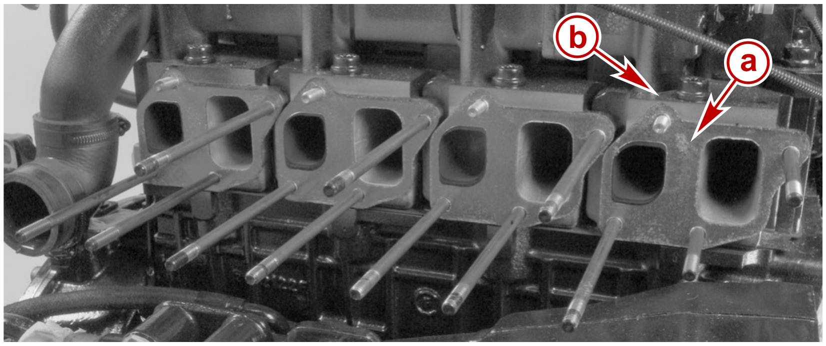
1. Clean the gasket material from all surfaces and wash parts in solvent.
2. Inspect all parts carefully. Machined surfaces must be clean and free of all marks and deep scratches or water and exhaust leaks may result.
3. Check the water passages for contamination. Passages must be clean for efficient cooling.

IMPORTANT: If plugs are removed, coat threads with Perfect Seal before reinstalling.

4. If a more thorough inspection is desired, the pipe plugs may be removed from exhaust manifold and exhaust elbow.
5. Check for cracks.
6. Ensure that the mating surfaces of the cylinder heads are clean and free of all old gasket material.
7. To test the manifold body for leaks use block-off plates, plugs, or short hoses with plugged ends. One block-off plate must have a threaded hole for attaching a compressed air hose. Use new gaskets when installing the block-off plate or plates. Apply 276 kPa (40 psi) of air pressure and submerge manifold in water. Air bubbles will indicate a leak.

Installation

1. Install new intake and exhaust manifold gaskets on each cylinder head.

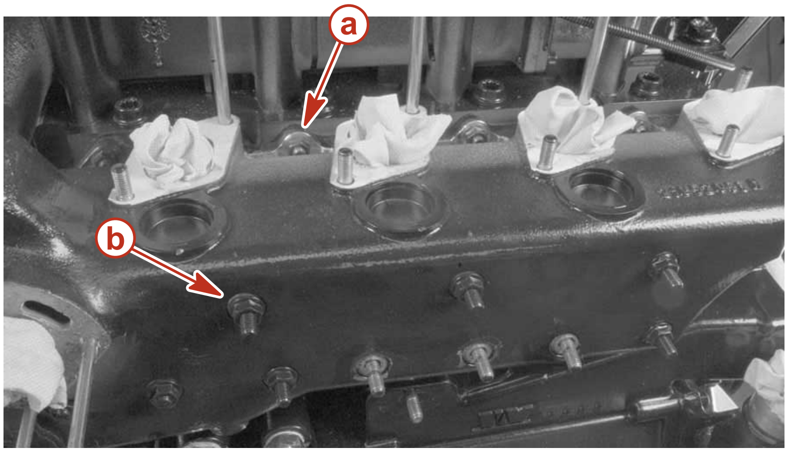


30865

2.8 shown, 4.2 similar

a - Gasket
b - Cylinder head

2. Install the intake and exhaust manifold on the intake and exhaust manifold studs.
3. Install the heat exchanger to intake and exhaust manifold support bracket.
4. Install the intake and exhaust manifold flange nuts on the short and long studs that do not have attachments.

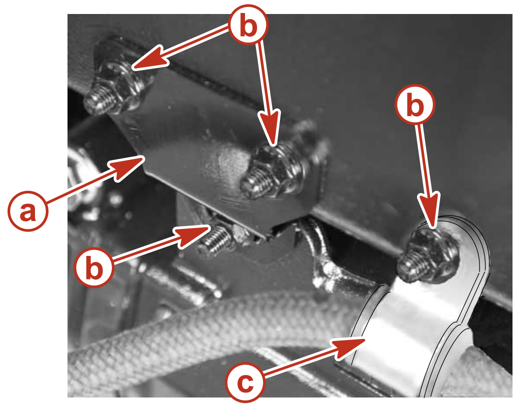


13331

a - Short studs
b - Long studs

5. Install the intake and exhaust manifold support bracket using the three flange nuts.

6. **On sterndrive models.** Install the J-clip and isolator with the power steering hose.



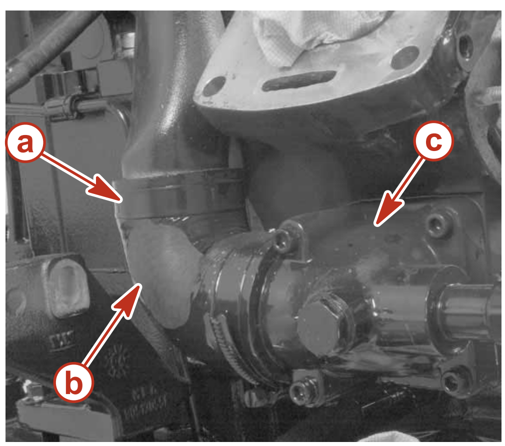
13333

a - Intake and exhaust manifold support bracket
b - Flange nut
c - J-clip and isolator

7. Ttighten the flange nut that secures the intake and exhaust support bracket to the heat exchanger.
8. Torque the intake and exhaust manifold nuts evenly in a diagonal pattern to specification.

Description	Nm	lb. in.	lb. ft.
Intake and exhaust manifold flange nut	32	–	24

9. Install the hose clamp on the hose from the coolant manifold strip connected to the intake and exhaust manifold rear cover.



13334

a - Hose clamp
b - Hose
c - Intake and exhaust manifold rear cover

10. Install the turbocharger.
11. Install the wastegate and valve.
12. Install the aftercooler.
13. Fill the closed cooling system.
14. Open the seacock, if equipped, or unplug and connect the seawater inlet hose.
15. Ensure that the seawater pickup is supplied with cooling water.
16. Connect the battery cables.

17. Start the engine and check for leaks.

Intake and Exhaust System

Section 7C - Turbocharger

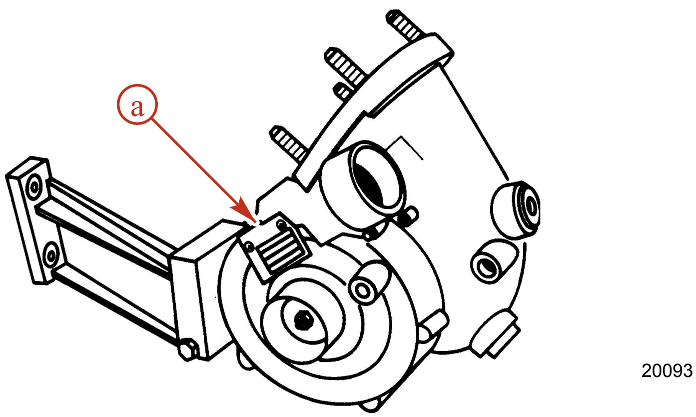
Table of Contents

Turbocharger Specifications

IMPORTANT: For complete engine performance data refer to the Cummins MerCruiser Diesel Performance Curves And Data Sheet at www.cmdmarine.com.

Model	QSD 2.8	QSD 4.2
Manufacturer	KKK - Kuhnle, Kopp and Kaush (Schwitzer)	
Quicksilver replacement Part No.	896101615	889341
Maximum boost	Refer to CMD's Marine Performance Curves And Data Sheet (www.Cummins.com)	
Wastegate	Equipped	

Turbocharger Identification



Typical

a - Identification number location

Description

Turbocharger

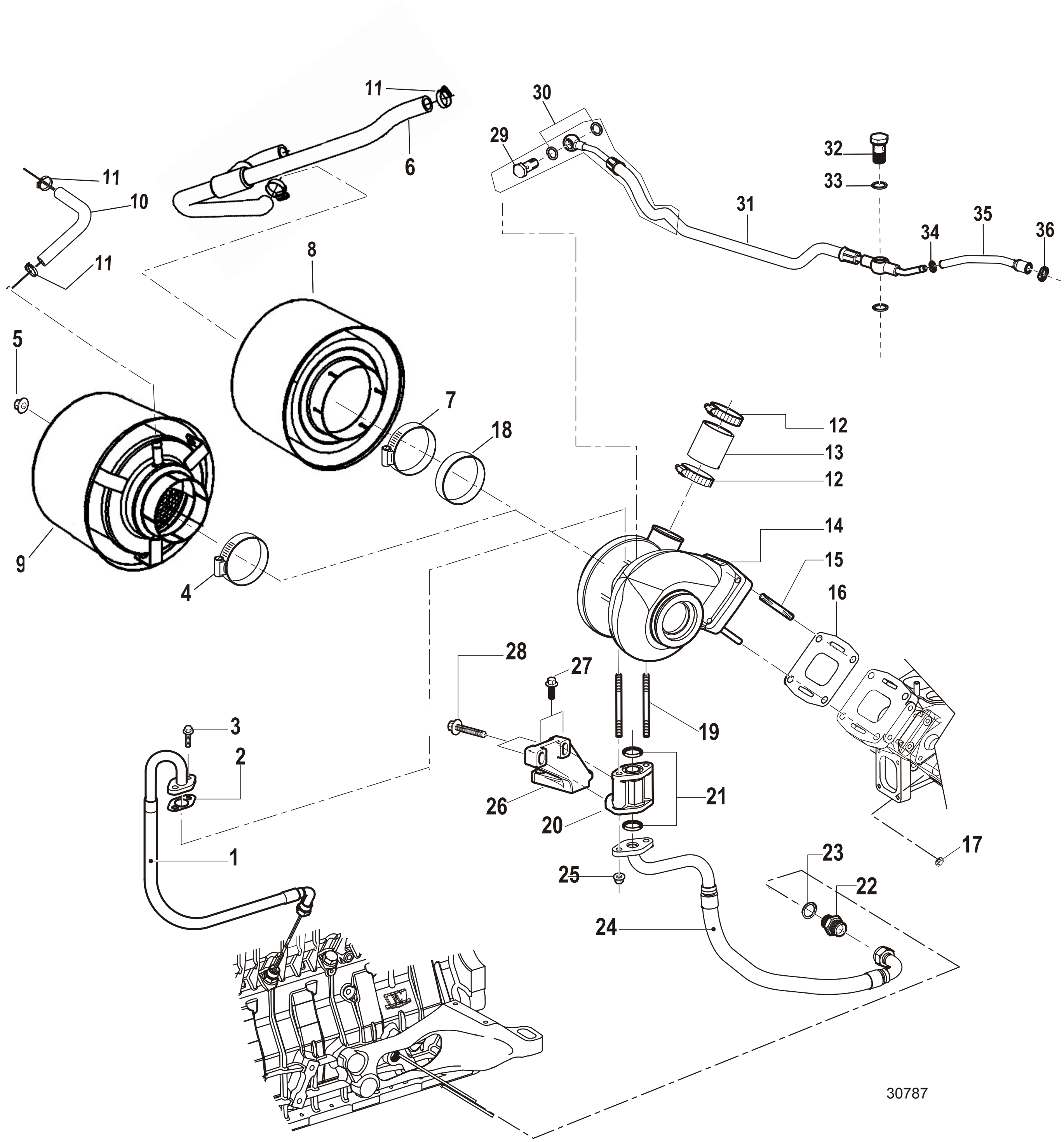
All diesel engines covered in this manual are equipped with a turbocharger to boost intake pressure resulting in increased horsepower. In one casing on the turbocharger, housing exhaust gases are used to spin the turbine up to 100,000 RPM. The compressor, which is installed on the same shaft but in a separate casing, draws in filtered air, compresses it, and delivers it to the engine through an intake duct and aftercooler. The turbo bearings are lubricated by engine oil. Coolant from the closed cooling system cools the turbocharger housing, while the exhaust elbow (or exhaust riser) is cooled by seawater flowing through it from the seawater system. Turbocharger pressure is limited by a boost pressure control valve (commonly called a wastegate) mounted on the combined exhaust / intake manifold.

Wastegate

When used in combination with the turbocharger, a higher torque output—even at low engine speeds—is obtained and allows the engine a wider operating speed range. The function of the wastegate is to limit the boost pressure generated by the turbocharger within a controlled tolerance band. When factory‑set boost pressure is exceeded, the valve opens and bypasses a part of the exhaust gas flow around the turbine. The resulting reduced mass‑flow produces a lower power output. The compressor output is reduced in proportion and the boost pressure falls to the predetermined level. This control process is repeated for each change in engine load. This allows the use of a smaller turbocharger turbine, which provides better acceleration and torque, as boost comes on more rapidly and turbo lag is reduced.

Exploded Views

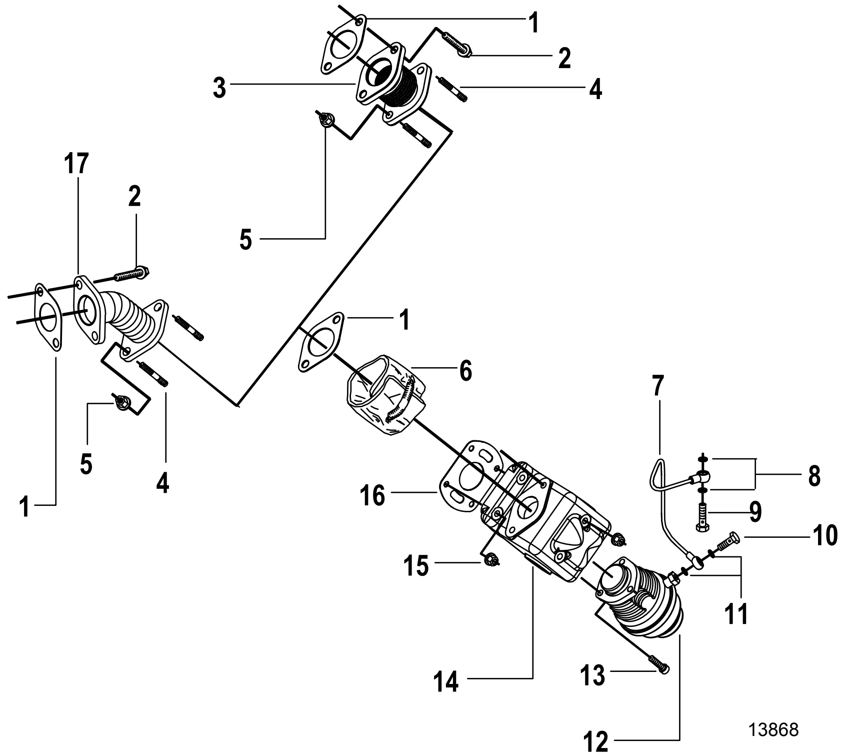
Exploded View: Turbocharger and Related Components



Exploded View: Turbocharger and Related Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Oil delivery pipe	–	–	–
2	1	Gasket	–	–	–
3	2	Oil delivery pipe flange screw	27.5	–	20
4	1	Air filter housing clamp	5.6	–	–
5	1	Air filter housing to bracket locknut, 2.8	10.8	95	–
6	1	Oil Separator hose, 4.2	–	–	–
7	1	Air filter housing clamp	5.6	–	50
8	1	Air filter housing, 4.2	–	–	–
9	1	Air filter housing, 2.8	–	–	–
10	1	Oil separator hose, 2.8	–	–	–
11	4	Clamp	4.6	–	41
12	2	Intake duct hose clamp	5.6	–	50
13	1	Intake duct hose	–	–	–
14	1	Turbocharger	–	–	–
15	4	Stud (M10 × 30 mm)	–	–	–
16	1	Turbocharger gasket	–	–	–
17	4	Turbocharger flange nut	49	–	36
18	1	Air filter housing gasket	–	–	–
19	2	Spacer stud	–	–	–
20	1	Spacer	–	–	–
21	2	O-ring	–	–	–
22	1	Connector	78.5	–	58
23	1	Connector O-ring	–	–	–
24	1	Oil drain pipe	–	–	–
25	2	Oil drain pipe nut	27.5	–	20
26	1	Turbocharger support bracket	–	–	–
27	2	Turbocharger support bracket flange screw	47.1	–	34
28	2	Spacer to support bracket flange screw	27.5	–	20
29	1	Hollow bolt	14.7	130	–
30	2	Sealing washer	–	–	–
31	1	Coolant vent line	–	–	–
32	1	Hollow bolt	27.5	–	20
33	2	Sealing washer	–	–	–
34	1	Clamp	5.6	–	50
35	1	Coolant vent hose	–	–	–
36	1	Clamp	5.6	–	50

Exploded View: Boost Pressure Control (Wastegate) Components



Exploded View: Boost Pressure Control (Wastegate) Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	2	Gasket	–	–	–
2	2	Allen-head screw	10.8	95	–
3	1	Inboard wastegate exhaust pipe	–	–	–
4	2	Stud	–	–	–
5	2	Exhaust pipe flange nut	10.8	95	–
6	1	Heat-shield blanket	–	–	–
7	1	Boost pressure line	–	–	–
8	2	Sealing washer	–	–	–
9	1	Hollow bolt	14.7	130	–
10	1	Hollow bolt	14.7	130	–
11	2	Sealing washer	–	–	–
12	1	Boost pressure value	–	–	–
13	3	Screw, M6 × 16	10.8	96	–
14	1	Wastegate	–	–	–
15	4	Flange nut	10.8	96	–
16	1	Gasket	–	–	–
17	1	Sterndrive wastegate exhaust pipe	–	–	–

Turbocharger

IMPORTANT: Before suspecting the turbocharger for engine operating problems, the fuel injection system and engine mechanical (valves, camshaft, etc.) must be in good working order.

Checking the Turbine Bearings—Assembled

1. Refer to **Section 7B–Exhaust Riser or Elbow** and remove the exhaust riser or exhaust elbow as outlined.
2. Rotate the turbine impeller by hand to see that it turns smoothly. If not, a problem exists in the turbine bearings or the impeller.

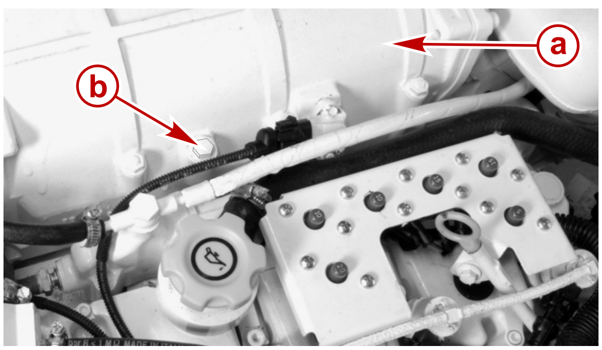
Testing the Turbocharger Boost Pressure

⚠ CAUTION
The sudden release of pressurized air can cause injury. When testing the turbocharger boost pressure, wear proper safety protection.

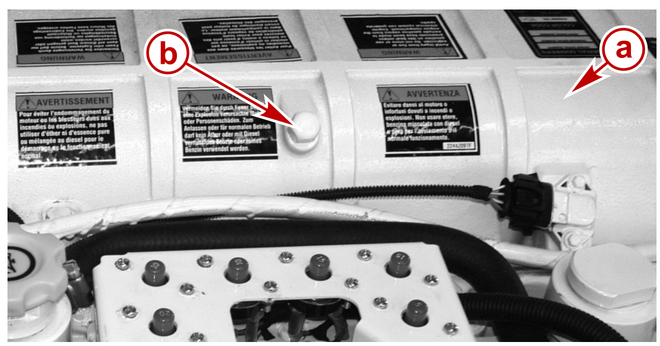
IMPORTANT: For complete engine performance data refer to the Cummins MerCruiser Diesel Performance Curves and Datasheets at www cmdmarine.com.

Prior to testing the engine should be at normal operating temperature and the engine air filter should be cleaned (or replaced if it cannot be cleaned).

1. Remove the plug and sealing washer from the aftercooler housing.



2.8 plug



4.2 plug

a - Aftercooler
b - Plug and sealing washer

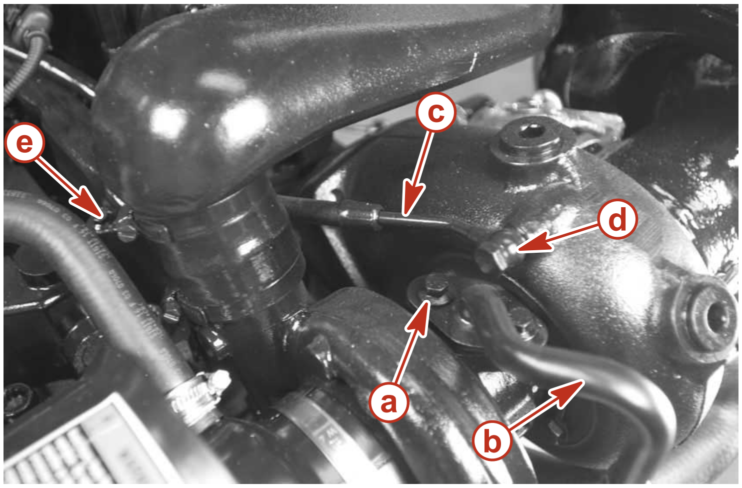
2. Install a 0–175 kPa (0–25 psi) pressure gauge into the aftercooler where the plug was removed in step 1.
3. Start the engine and observe the pressure gauge. Maximum boost should be as specified.

Turbocharger boost pressure	
Maximum pressure at 3800 RPM	For complete engine performance data refer to the **Cummins MerCruiser Diesel Performance Curves and Datasheets at www cmdmarine.com.**

If no engine problem exists, such as incorrect valve operation or a blockage in the exhaust system, readings lower than specified above indicate possible turbocharger problems or boost pressure control system problems. Refer to the appropriate sections in this manual, including **Troubleshooting**. No boost pressure indicates a faulty turbocharger that requires replacement.

Removal

1. Drain the closed cooling system.
2. Remove the exhaust riser or elbow. See **Section 7B–Exhaust Riser or Elbow**.
3. Remove the air filter and housing from the turbocharger. Refer to **Section 1–Maintenance**.
4. Remove the turbocharger oil delivery pipe.
5. Remove the hollow bolt and sealing washers from coolant vent pipe at the turbocharger.
6. Loosen the aftercooler intake duct hose clamps.

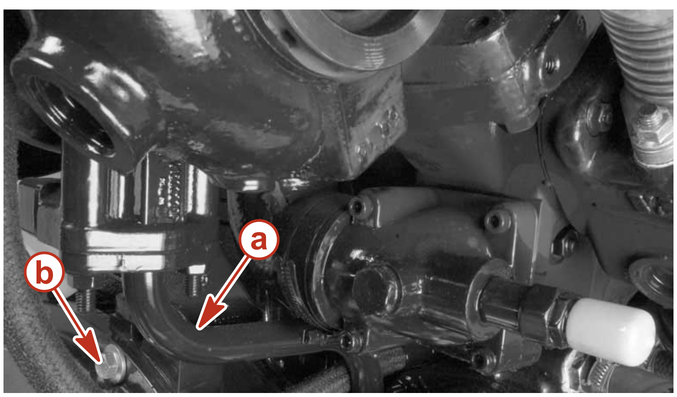


12895

Typical

a - Flange screw
b - Oil delivery pipe
c - Coolant vent pipe
d - Hollow bolt and sealing washers
e - Intake duct hose clamp

7. Remove the oil drain pipe on the bottom of the turbocharger.

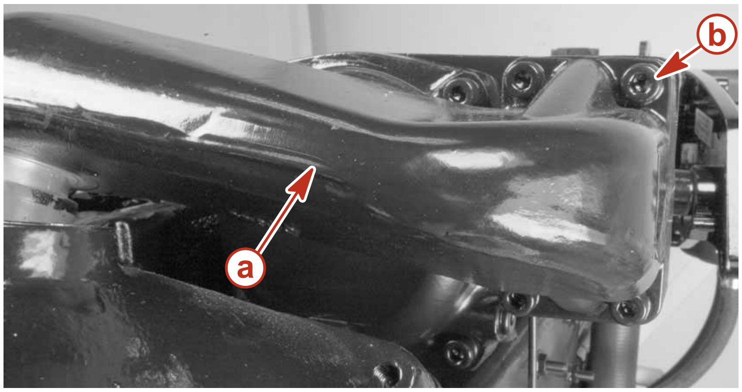


12896

a - Oil drain pipe
b - Flange nut

IMPORTANT: In the event that turbocharger mounting nuts are corroded or otherwise resist loosening, it might be necessary to completely remove the aftercooler housing to gain better access to mounting nuts. See Section 7A—Aftercooler, for instructions on removal and installation of the aftercooler housing.

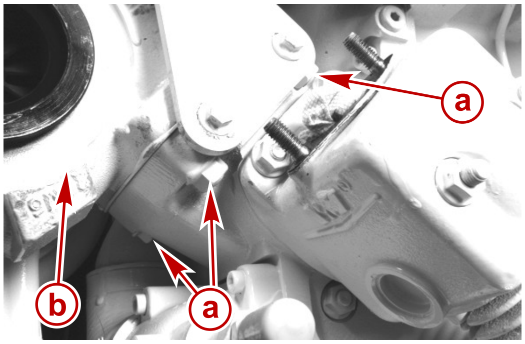
8. Remove the aftercooler intake duct.



12897

a - Aftercooler intake duct
b - Screw (4)

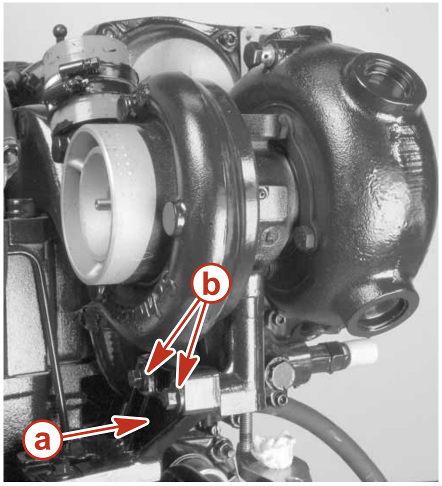
9. Remove the flange nuts that connect the turbocharger to the exhaust manifold.



30782

a - Flange nuts (4)
b - Turbocharger

10. Remove the two support bracket flange screws as shown.



12899

a - Support bracket
b - Flange screws

11. Remove the turbocharger unit.

Cleaning

IMPORTANT: Never use a caustic cleaning solution, as it may damage the aluminum. Never use a wire brush, which could damage impeller or mating surfaces.

1. Before cleaning, inspect the disassembled parts for burned areas, abrasion, carbon deposits, and gas and oil leakage.

⚠ CAUTION
Using compressed air can cause serious injury. Always wear eye protection when working with compressed air to prevent injury from ruptured hoses or flying debris.

⚠ WARNING
Do not allow rotating parts to spin while drying them with compressed air. If spun during drying, bearings can explode and turbine blades will cut or sever if contacted causing serious injury. Spinning the turbine dry will also damage the turbine shaft bearings.

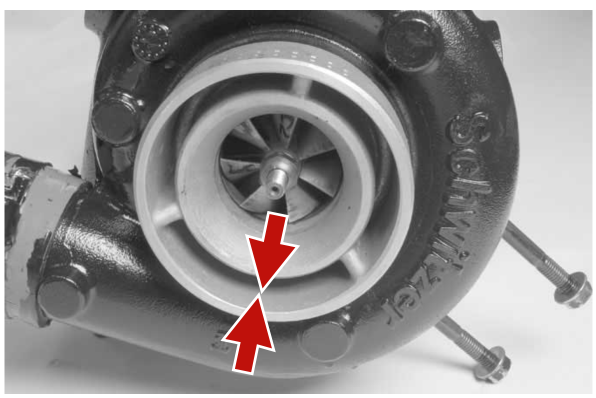
2. Thoroughly clean all the parts with clean diesel fuel, using a soft brush. Dry with compressed air.

Inspection

IMPORTANT: Replace the turbocharger if the impeller does not turn freely without sticking.

Checking the Axial (End) Play

1. Place the turbocharger in a vise and push the turbocharger shaft in one direction. Verify that the blades rotate freely and do not rub.
2. Repeat the test with the shaft pushed in the opposite direction. Verify that the blades rotate freely and do not rub.
3. If in step 1 or 2, the blades rub or do not rotate freely, replace the turbocharger.



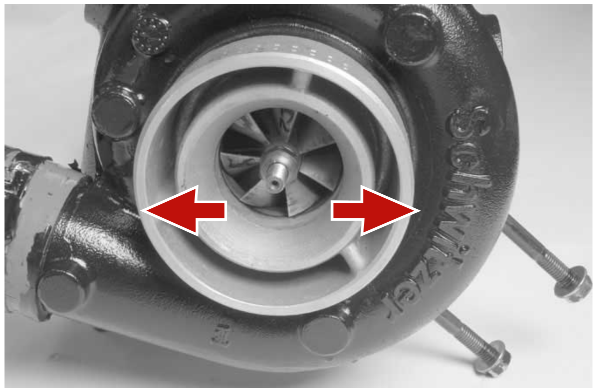
12901

Checking axial (end) play

Measuring the Radial (Side) Play

1. Place the turbocharger in a vise and push the turbocharger shaft to the side. Verify that the blades rotate freely and do not rub.
2. Repeat the test with the shaft pushed in the opposite direction. Verify that the blades rotate freely and do not rub.

3. Replace the turbocharger if the blades rub or do not rotate freely.



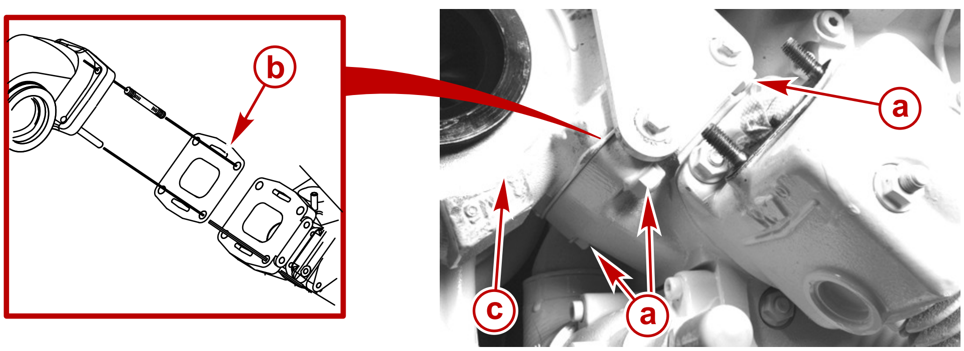
12903

Checking radial (side) play

Installation

IMPORTANT: When installing the turbocharger, it may be necessary to turn the intake and exhaust housings to line up with the intake air duct and exhaust manifold on the engine.

1. Install a new gasket on the intake and exhaust manifold.
2. Install the turbocharger on the intake and exhaust manifold. Torque the flange nuts evenly, in a diagonal pattern.

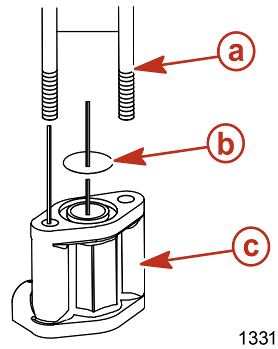


30784

a - Flange nuts (4)
b - Gasket
c - Turbocharger

Description	Nm	lb. in.	lb. ft.
Turbocharger flange nut	24	–	18

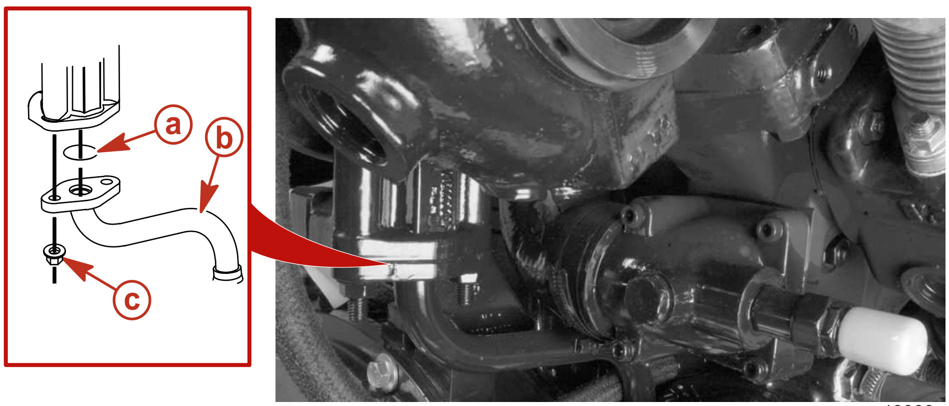
3. Install a new O-ring on top of the spacer and slide it on the studs of the turbocharger.



13311

a - Studs
b - O-ring
c - Spacer

4. Using a new O-ring, install the oil drain pipe on the bottom of the turbocharger. Torque the oil drain pipe flange nuts.

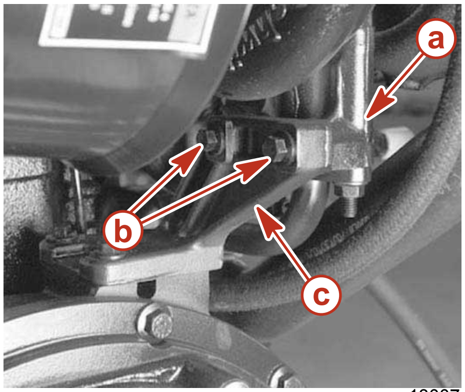


13308

a - O-ring
b - Oil drain pipe
c - Flange nut

Description	Nm	lb. in.	lb. ft.
Oil drain pipe flange nut	27.5	–	20

5. Install the spacer to the support bracket. Torque the spacer to support bracket flange screws.



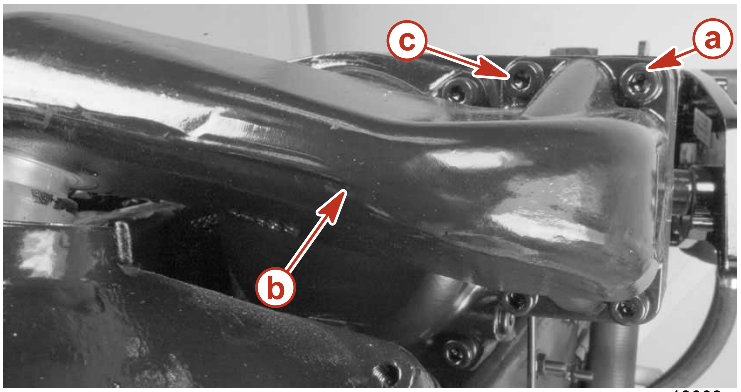
13007

a - Spacer
b - Spacer to support bracket flange screw
c - Support bracket

Description	Nm	lb. in.	lb. ft.
Spacer to support bracket flange screw	27.5	–	20

IMPORTANT: If the entire aftercooler housing was removed from the intake and exhaust manifold during disassembly (to gain better access to turbocharger mounting nuts) see Section 7A–Aftercooler first for proper aftercooler installation.

6. Install a new gasket on the aftercooler and install the intake duct. Torque the hex head screws evenly, in a diagonal pattern.



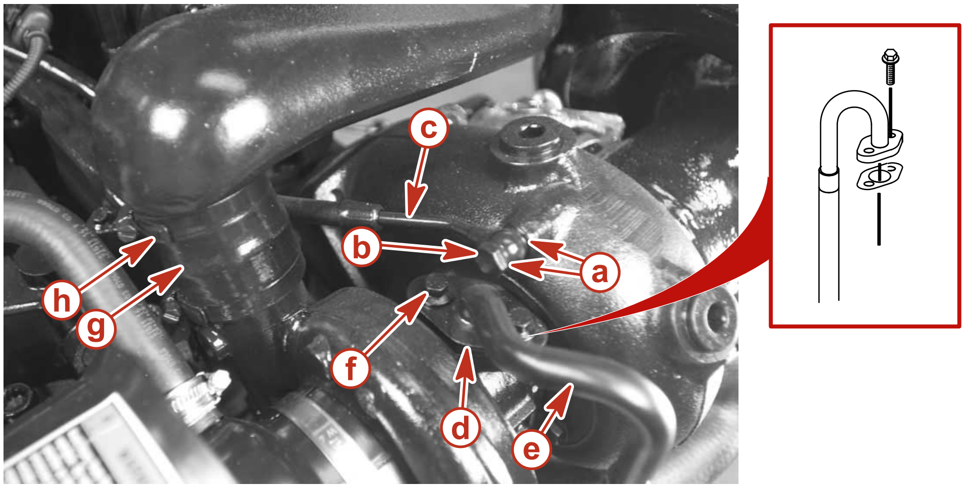
13009

a - Gasket (not visible in this view)
b - Intake duct
c - Screw

Description	Nm	lb. in.	lb. ft.
Aftercooler intake duct screw	10	–	7

7. Using new sealing washers on the hollow bolt, install the coolant vent line to turbocharger exhaust housing as shown. Torque the coolant vent line hollow bolt securely.
8. Clean the sealing surfaces and, using a new gasket, install the oil delivery pipe as shown. Torque the oil delivery pipe flange screws.

9. Position the turbocharger to intake duct hose as shown. Tighten the hose clamps securely.



13305

a - Sealing washer (2)	**e -** Oil delivery pipe
b - Coolant vent line hollow bolt	**f -** Screw (2)
c - Coolant vent line	**g -** Intake duct hose
d - Gasket	**h -** Clamp

Description	Nm	lb. in.	lb. ft.
Coolant vent line hollow bolt	14.7	130	–
Oil delivery pipe flange screw	27.5	–	20

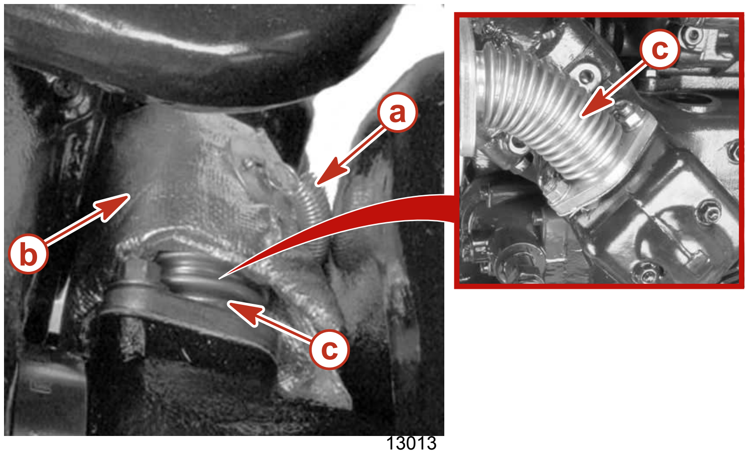
10. Install the air filter and housing onto the turbocharger. Refer to **Section 1–Maintenance**.
11. Install the exhaust riser or exhaust elbow. See **Section 7B–Exhaust Riser or Elbow**.
12. Fill the closed cooling system.
13. Connect the battery cables to the battery.
14. Start the engine and check for leaks.
15. Test the turbocharger boost pressure. Refer to**Testing the Turbocharger Boost Pressure**.

Boost Pressure Control

Inspection—Assembled

1. Loosen the spring holding the heat-shield blanket around the wastegate exhaust pipe.

2. Visually examine the exhaust pipe and convolutions for signs of cracking or leakage. Also, examine gaskets for signs of leakage. Repair as needed. (See **Removal** if required.)



Sterndrive shown, inboard similar

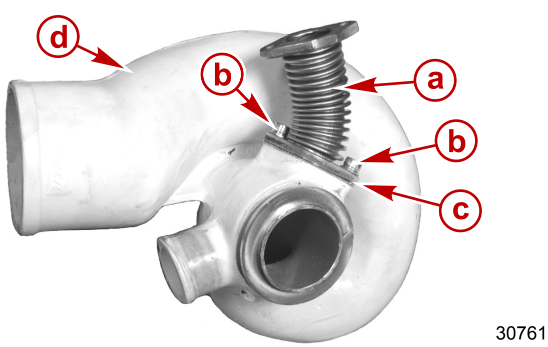
a - Spring
b - Heat-shield blanket
c - Pipe and convolutions

Removal

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

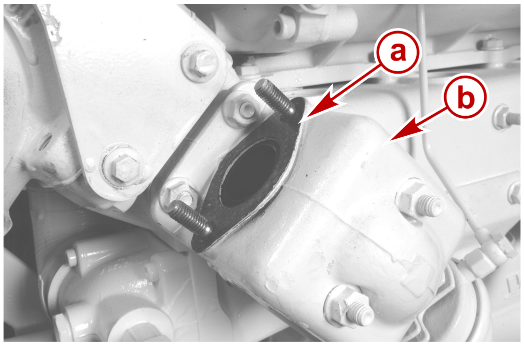
1. Disconnect both battery cables.
2. Remove the exhaust riser or exhaust elbow.
3. Remove the wastegate exhaust pipe and gasket.



Sterndrive exhaust riser shown, inboard exhaust elbow similar

a - Wastegate exhaust pipe
b - Allen-head screw with washer
c - Gasket
d - Exhaust riser

4. Remove the old exhaust pipe gasket on the wastegate. Do not allow debris to enter the wastegate opening.



30762

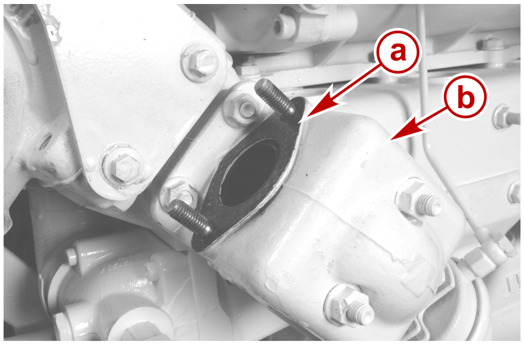
a - Gasket
b - Wastegate

Cleaning and Inspection

1. Visually examine the pipe and convolutions for signs of cracking or leakage. Replace if necessary.
2. Clean the old gasket material from the mating surfaces and wash the parts in solvent for reuse. Do not to distort the pipe or crack it.
3. Inspect all parts carefully. Machined surfaces must be clean and free of all marks and deep scratches or exhaust may leak.

Installation

1. Install a new gasket on the wastegate flange.



30762

a - Gasket
b - Wastegate

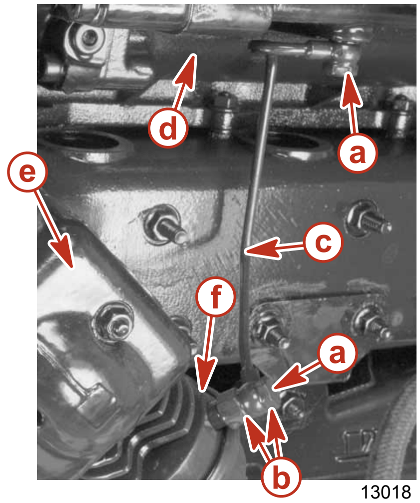
2. Install the exhaust riser or exhaust elbow, depending upon the model, with the exhaust wastegate pipe attached. Refer to **Section 7B–Exhaust Riser or Exhaust Elbow**.

Wastegate Valve

Removal

1. Remove the two hollow bolts with sealing washers from the pressure line on the bottom of the aftercooler housing.
2. Remove the two hollow bolts with sealing washers from the pressure line on the valve.

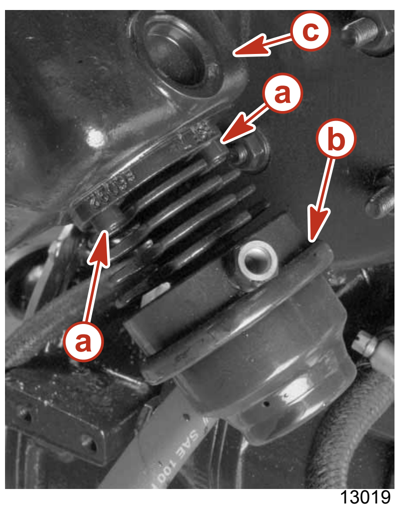
3. Remove the pressure line.



Typical

a - Hollow bolt	**d -** Aftercooler housing
b - Sealing washer (2)	**e -** Wastegate
c - Pressure line	**f -** Wastegate valve

4. Remove the screws and washers connecting the wastegate valve to the wastegate.
5. Remove the wastegate valve.

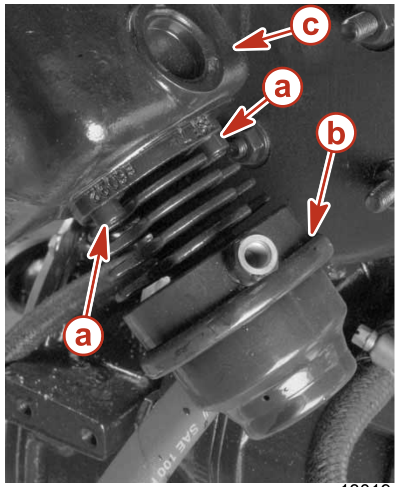


Typical

a - Screw with washer (3 total)
b - Valve
c - Wastegate

Installation

1. Install the wastegate valve on the wastegate using the Allen-head screws and washers. Position the pressure line fitting on the valve toward the front of the engine.

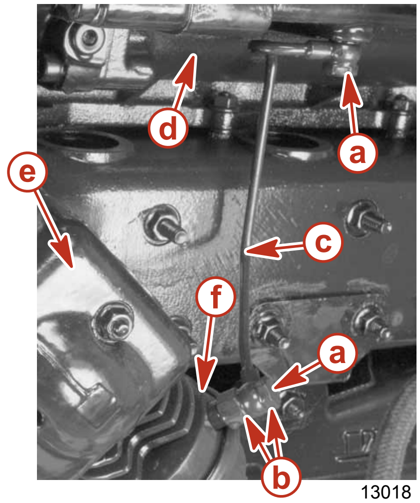


a - Screw with washer (3 total)
b - Wastegate valve
c - Wastegate

Description	Nm	lb. in.	lb. ft.
Wastegate valve Allen-head screws	10.8	95	–

2. Install the pressure line on the wastegate valve using the hollow bolt with new sealing washers. Finger-tighten the hollow bolt.
3. Install the pressure line on the aftercooler using the hollow bolt with new sealing washers. Finger-tighten the hollow bolt.

4. Torque both of the hollow bolts.



Typical

a - Hollow bolt
b - Sealing washer (2)
c - Pressure line
d - Aftercooler housing
e - Wastegate
f - Valve

Description	Nm	lb. in.	lb. ft.
Pressure line hollow bolt	14.7	130	–

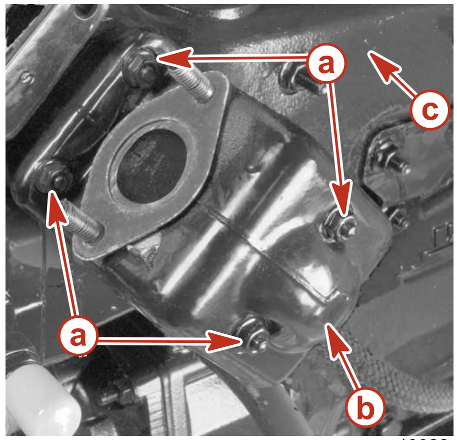
5. Start the engine and check for leaks.
6. Test the turbocharger boost pressure as previously outlined.

Wastegate

Removal

1. Drain the closed cooling system.
2. Remove the exhaust elbow.
3. Remove the wastegate exhaust pipe.
4. Remove the wastegate valve.

5. Remove the four flange nuts connecting the wastegate to the exhaust manifold.

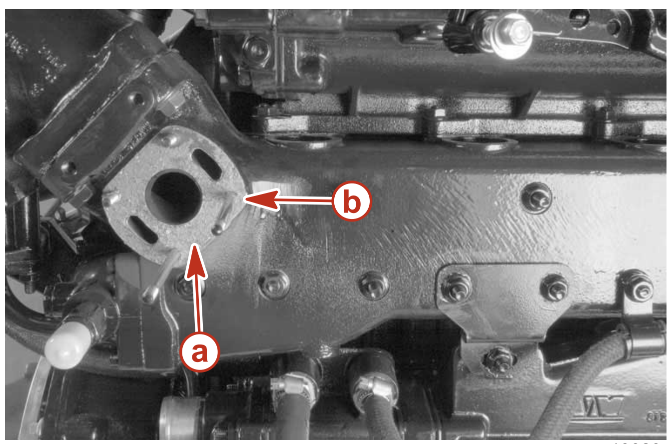


Typical

a - Flange nuts
b - Wastegate
c - Exhaust manifold

Cleaning

1. Clean all traces of old gasket material from the intake and exhaust manifold flange.



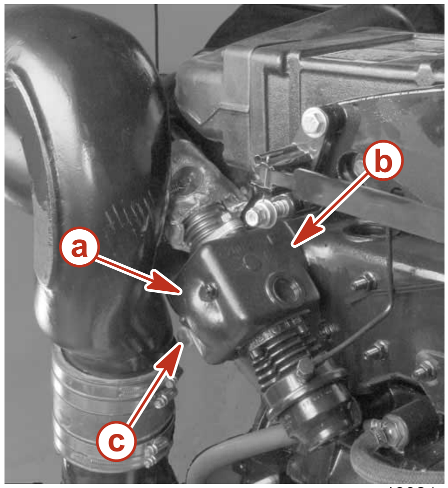
a - Gasket
b - Intake and exhaust manifold flange

2. Clean old gasket material from wastegate.

Installation

1. Using a new gasket, install the wastegate on the exhaust manifold as shown. Torque the four wastegate flange nuts.
2. Install the wastegate valve.
3. Install the wastegate exhaust pipe.

4. Install the exhaust elbow or riser.



Typical

a - Wastegate
b - Gasket
c - Wastegate flange nuts

Description	Nm	lb. in.	lb. ft.
Wastegate flange nuts	10.8	95	–

5. Start the engine and check for leaks.
6. Test turbocharger boost pressure.

Drive System

Section 8A - ZF Marine Transmissions

Table of Contents

8
A

Lubricant, Sealant, Adhesives

Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	Transmission fluid temperature switch threads and the service port plug	92-809822
25	Liquid Neoprene	Neutral start switch and fluid temperature switch wire connections	92- 25711 3
		Exposed electrical terminals and connections.	
28	Dexron III Automatic	Transmission	Obtain Locally
91	Engine Coupler Spline Grease	Transmission input shaft splines and engine drive plate splines	92-802869A1

Specifications

Operating Specifications

Description	Specification	
Operating Temperature	54–79° C (130–175° F)	
Temperature Switch Settings ± 10°	Open	Close
	87.8° C (190° F)	110° C (230° F)

Pressure Specifications

Description	Specification	
Shifting Pressure	Position A	21.5–23.5 bar (312–341 psi) at 2000 RPM
	Position B	

Fluid Specifications

IMPORTANT: All capacities are approximate fluid measures. ALWAYS use the dipstick to determine the exact fluid level.

NOTE: *Estimated fluid capacity includes the transmission fluid cooler for the ZF Marine 63A and 63IV transmissions.*

Manufacturer	Model	Capacity	Fluid Type
ZF Marine	45A	3.0 L (3 1/4 U.S. qt.)	Dexron III Automatic Transmission Fluid
	63A	4.5 L (4 3/4 U.S. qt.)	
	63IV	4.9 L (5 1/4 U.S. qt.)	

Important Information

Engine

All current production engines are left-hand rotation. Engine rotation is described when observed from the rear of the engine (transmission end) looking forward (water pump end). Installed angle of the transmission and the engine should not exceed a maximum of 12 degrees of the water line.

Propeller

Propeller rotation is described when observed from the rear of the boat (stern) looking forward (bow). The term left-hand (LH) refers to rotation in the counterclockwise (CCW) direction. The term right-hand (RH) refers to rotation in the clockwise (CW) direction. A LH propeller will move the boat forward when rotated counterclockwise. A RH propeller will move the boat forward when rotated clockwise.

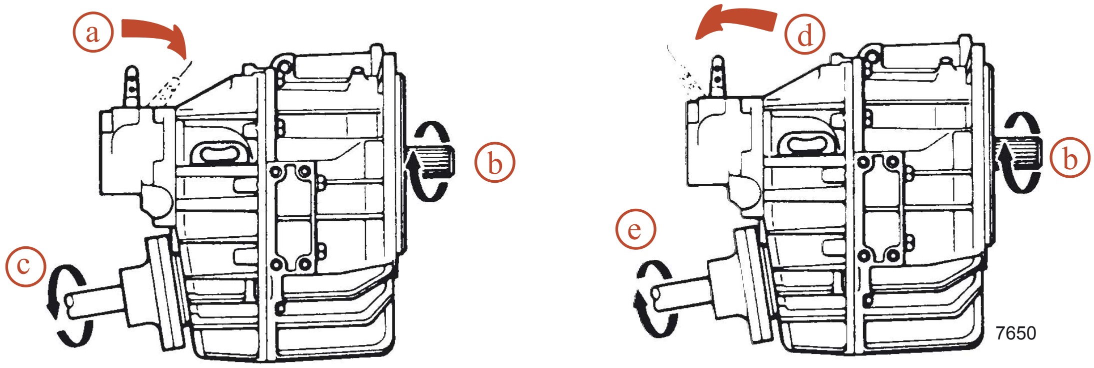
Precautions

The transmission gear ratio is marked on the transmission identification plate, which is located on the top of the transmission. Transmission rotation is described when viewed from the rear of transmission.

- Do not start or crank the engine without fluid in the transmission.
- Except in an emergency, never shift the transmission at engine speeds above 1000 RPM
- Free wheeling of one propeller (in a twin-engine boat) at trolling speeds will not cause damage to the transmission; however, boat operation above trolling speed should be avoided. Ensure that proper fluid level exists before free wheeling the propeller.
- Always repair or replace the oil cooler and hoses after a transmission failure or prior to installing a new or rebuilt transmission. Metallic particles from a failure tend to collect in the cooler and hoses and will gradually flow back into the fluid system and damage the transmission.
- Always use the specified oil cooler, hoses, and fittings.

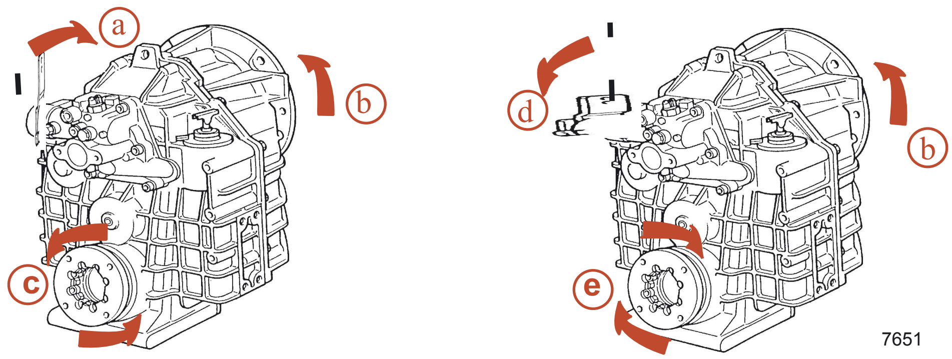
Transmission And Propeller Rotation

The ZF Marine transmissions are full power reversing transmissions, allowing a standard LH rotation engine to be used for both propeller rotations. Propeller rotation is determined by the shift cable attachment at the remote control. Use the correct rotation propeller and shift cable hookup for the direction desired.



ZF Marine 63A—8 degree down-angle transmission, 45A similar

a - Direction of shift lever engagement (toward flywheel)
b - Transmission input shaft rotation direction (LH)
c - Transmission output shaft rotation direction (RH)
d - Direction of shift lever engagement (away from flywheel)
e - Transmission output and propeller shaft rotation direction (LH)

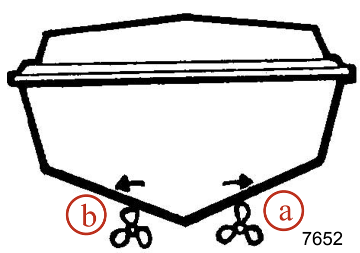


ZF Marine 63IV—V-drive transmissions

a - Direction of shift lever engagement (toward flywheel)
b - Transmission input shaft rotation direction (LH)
c - Transmission output shaft rotation direction (LH)
d - Direction of shift lever engagement (away from flywheel)
e - Transmission output and propeller shaft rotation direction (RH)

Propeller Rotation on Dual Installations

Best all-around performance usually is obtained by installing engines so that propellers turn outboard (looking at the stern).



Outboard Propeller Rotation

a - RH rotation
b - LH rotation

Transmission Fluid

Checking

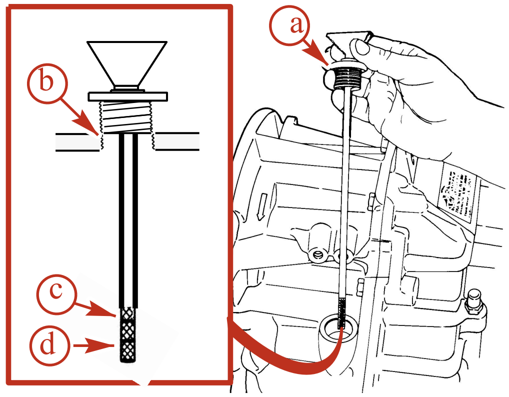
1. Remove the dipstick.

IMPORTANT: When checking the fluid level, rest the dipstick on top of the threaded housing hole. Do not screw the dipstick into the threaded housing hole.

2. Check the fluid level as indicated on the dipstick with the dipstick resting on the top of the threaded hole.

***NOTE:** The fluid level may be somewhat over the maximum mark, as some of the fluid from the transmission fluid cooler and hoses may have drained back into the transmission.*

3. If low, add transmission fluid to bring the level up to the maximum mark on the dipstick.



a - Dipstick
b - Threaded hole
c - Maximum fluid level
d - Minimum fluid level

Tube Ref No.	Description	Where Used	Part No.
28	Dexron III Automatic	Transmission	Obtain Locally

IMPORTANT: To accurately check the fluid level, the engine must be operated at 1500 RPM for 2 minutes immediately prior to checking the level.

4. Start the engine and operate at 1500 RPM for 2 minutes to fill all the hydraulic circuits.
5. Stop the engine and quickly check the fluid level with the dipstick resting on the top of the threaded hole.
6. If low, add transmission fluid to bring the level up to the maximum mark on the dipstick.

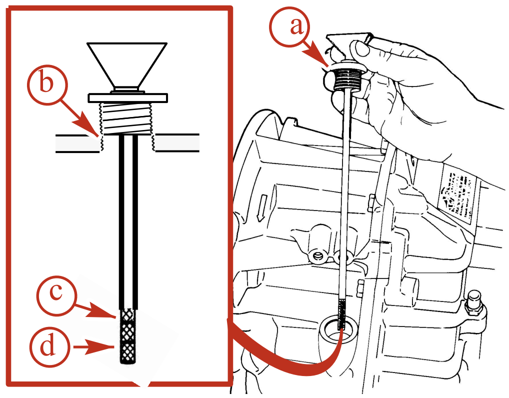
Tube Ref No.	Description	Where Used	Part No.
28	Dexron III Automatic	Transmission	Obtain Locally

7. Install the dipstick.

Filling

1. If necessary, add specified automatic transmission fluid through the dipstick threaded hole to bring the level up to the maximum mark on the dipstick.

IMPORTANT: Use only specified Automatic Transmission Fluid (ATF).



16604

a - Dipstick
b - Threaded hole
c - Maximum fluid level
d - Minimum fluid level

NOTE: *If the transmission fluid level was extremely low, contact your authorized Cummins MerCruiser Diesel dealer or distributor.*

Manufacturer	Model	Capacity[1.]	Fluid Type
ZF Marine (Hurth)	45A	3.0 liters (3-1/4 U.S. qt.)	Dexron III Automatic Transmission Fluid
	63A	4.5 liters (4-3/4 U.S. qt.)	
	63IV	4.9 liters (5-1/4 U.S. qt.)	

2. Install the dipstick.

IMPORTANT: To accurately check the fluid level, the engine must be run at 1500 RPM for 2 minutes immediately prior to checking the level.

3. See **Checking** and check the fluid level.

Changing

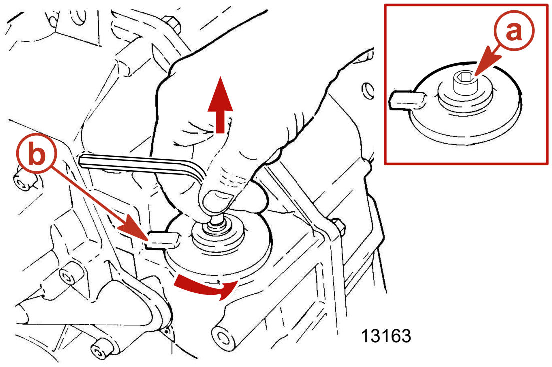
IMPORTANT: Do not start or crank the engine without fluid in the transmission.

NOTICE
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

1. Clean the exterior of the transmission around the fluid filter assembly.

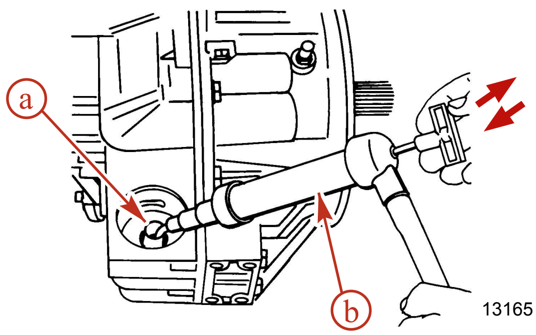
1. Always use the dipstick to determine the exact quantity of oil or fluid required.

2. Use a 6 mm Allen wrench and remove the fluid filter assembly by turning the assembly nut counterclockwise and pulling at the same time.



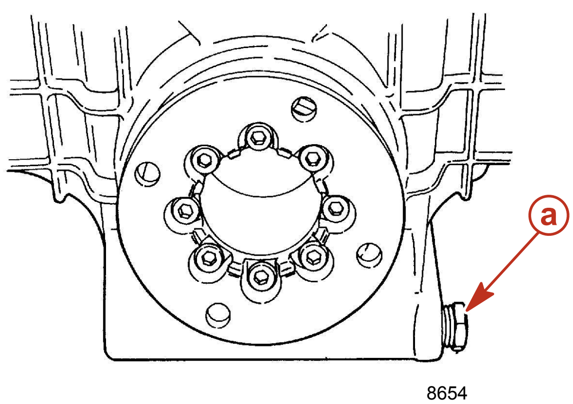
a - Fluid filter assembly
b - Assembly nut

3. **On 63A and 45A transmissions:**
   a. Push the hose of a suction pump through the suction pipe and down to the bottom of the housing.
   b. Pump the fluid from the housing into a suitable container. Dispose of fluid properly.



a - Suction pipe
b - Suction pump

4. **On 63IV transmissions:**
   a. Remove the drain plug from the transmission and allow the fluid to drain.

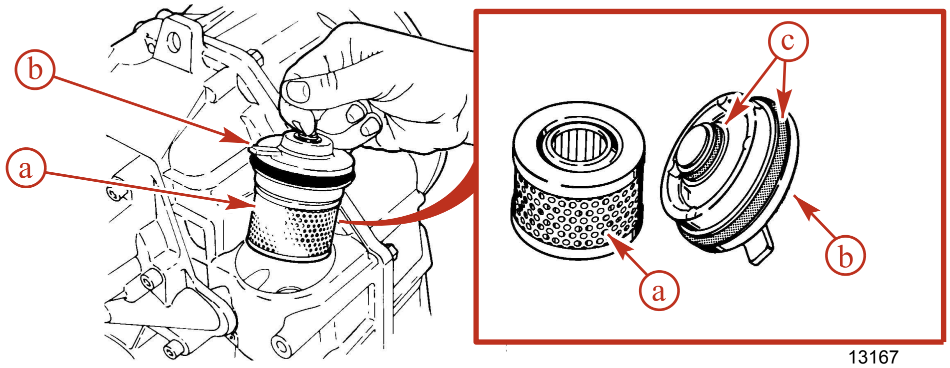


Typical 63IV transmission

a - Drain plug

   b. Install and securely tighten the drain plug after the transmission is drained.

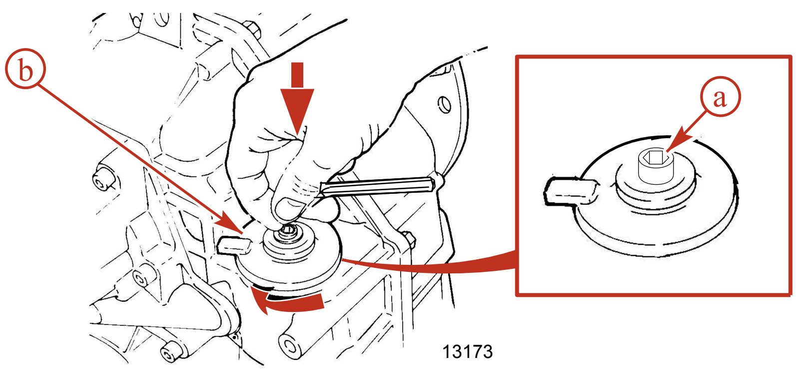
5. Check the fluid for the following foreign matter:
   - Metal particles—a few small particles are normal. Larger metal chips are an early sign of transmission failure, which may mean the transmission should be disassembled and inspected for internal damage.
   - Rubber particles—indication of cooler hose wear. The hoses should be inspected for cracks or fraying. Replace the damaged hoses.
6. Remove and discard the filter element and the O-rings.
7. Coat the new O-rings with transmission fluid.
8. Install the new O-rings and filter element.



a - Filter element
b - Cover
c - O-rings

NOTICE
Improper installation of the transmission fluid filter assembly may cause the fluid to foam or leak out, resulting in decreased efficiency and damage to the transmission. Properly seat the transmission fluid filter during installation.

9. Install the fluid filter assembly in the transmission cavity by turning it clockwise and pushing at the same time.
10. Using a 6 mm Allen wrench, turn the filter assembly nut clockwise to tighten. Torque the filter assembly nut.



a - Fluid filter assembly
b - Assembly nut

Description	Nm	lb. in.	lb. ft.
Filter assembly nut	5-8	48-72	

11. Fill the transmission to the proper level with the specified fluid. See **Filling**.

Removal

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

NOTICE

Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

NOTE: The following procedure describes removal of the transmission without removing the engine. If the engine must be removed, see ***Section 2****.*

1. Disconnect the battery cables from the battery.
2. If required, drain the transmission fluid.
3. Disconnect the transmission fluid cooler hoses.

NOTE: The fluid cooler should be removed with the transmission.

4. Disconnect the shift cable from the transmission.
5. Disconnect the wires from the neutral start switch.
6. Disconnect the wires from the transmission fluid temperature switch.
7. Loosen the trunnion clamping fasteners on the engine mounts (port and starboard).
8. Remove the nuts and bolts from the coupling and separate the propeller shaft coupler from the transmission output flange.
9. Remove the four rear engine mount to engine bed fasteners and hardware.
10. Support the rear part of the engine using a suitable hoist, or put wooden blocks under the flywheel housing.
11. Support the transmission with a hoist or by other suitable means through the lifting eye on the transmission case.
12. Remove the port and starboard rear mount brackets (with base and trunnion) from the transmission.

NOTICE

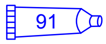
The weight of an unsupported transmission can bend the transmission input shaft or damage the engine coupler. Do not permit the splines of the input shaft or coupler to support the weight of the transmission. Completely support the transmission during removal, and until the attaching hardware is secured during installation.

13. Remove all hardware attaching the transmission to the flywheel housing.
14. Pull the transmission straight back and away from the engine to completely disengage the splines on the input shaft.
15. Carefully lift out the transmission.

Installation

1. Check the transmission output shaft rolling torque.

2. Apply lubricant to the transmission input shaft splines and engine drive plate splines.

Tube Ref No.	Description	Where Used	Part No.
	Engine Coupler Spline Grease	Transmission input shaft splines and engine drive plate splines	92-802869A1

3. Using a suitable hoist, position the transmission in the boat and align the transmission splines with the drive plate splines.
4. Push the transmission into place and secure with attaching hardware.

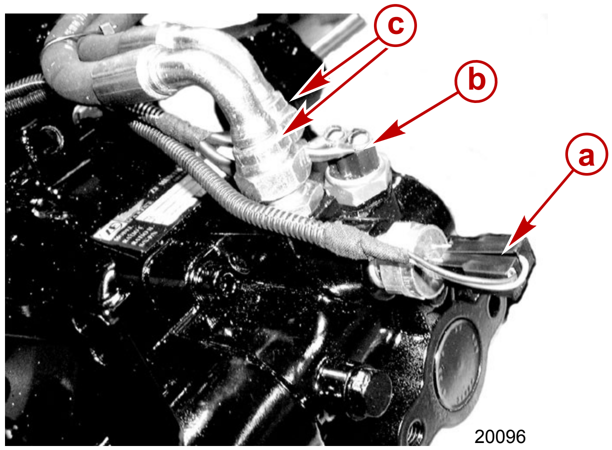
Description	Nm	lb. in.	lb. ft.
Transmission to flywheel housing fasteners	61		45

5. Remove the hoist.
6. Install the rear mount brackets to the transmission. Torque the fasteners and hardware.

Description	Nm	lb. in.	lb. ft.
Rear mount brackets to transmission fasteners	61		45

7. Using a hoist, raise the engine and transmission to remove blocks, if employed.
8. Lower the assembly to the engine bed.
9. Relieve hoist tension.
10. Securely tighten the four rear engine mount to bed fasteners with hardware.
11. Install the transmission fluid cooler hoses. Torque the hose fittings at the transmission housing.

12. Connect the neutral start switch and fluid temperature switch wiring. Coat the connections with sealant.



Typical

a - Fluid temperature switch
b - Neutral start switch
c - Transmission fluid cooler hose fitting

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Neutral start switch and fluid temperature switch wire connections	92- 25711 3

Description	Nm	lb. in.	lb. ft.
Transmission fluid cooler hose fitting	34		25

IMPORTANT: Improper shift cable adjustment can cause premature clutch failure.

13. Connect and adjust shift cables. See **Section 2B**.
14. Check engine final alignment. See **Section 2B**.

IMPORTANT: All coupler bolts must be SAE Grade 8 (Metric Grade 10.9) or better, with a shoulder (grip length) long enough to pass through the face mating plane of couplers.

15. After final engine and coupler alignment has been properly set (with the boat in the water), connect the propeller shaft coupler to the transmission output flange with bolts, lockwashers, and nuts. Torque the bolts.

Description	Nm	lb. in.	lb. ft.
Propeller shaft coupler to transmission output flange bolt	68		50

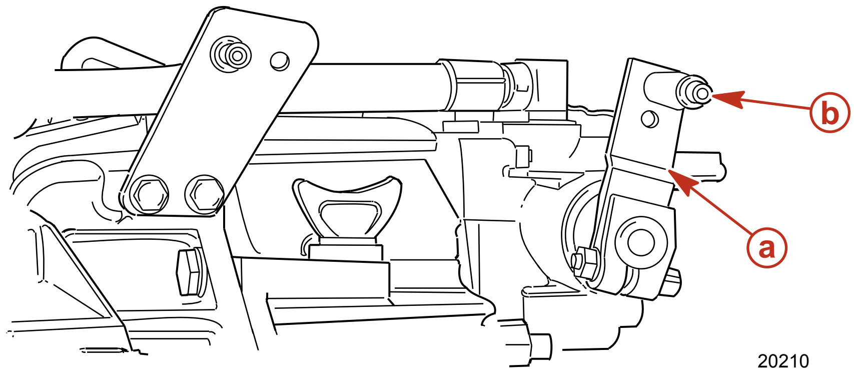
IMPORTANT: Be certain to torque the trunnion clamping fasteners on the engine mounts (port and starboard) that were loosened during removal.

16. Torque the trunnion clamping fasteners on the engine mounts (port and starboard) that were loosened during removal.
17. Refill the transmission with the specified fluid. See **Filling**.
18. Connect the battery cables.
19. Check for leaks and check the fluid level after the first engine start-up.

Shift Control And Cables

Transmission Shift Lever and Shift Cable Bracket

The shift lever has two holes. The shift cable anchor stud is installed in the top hole when using Quicksilver remote control cables.



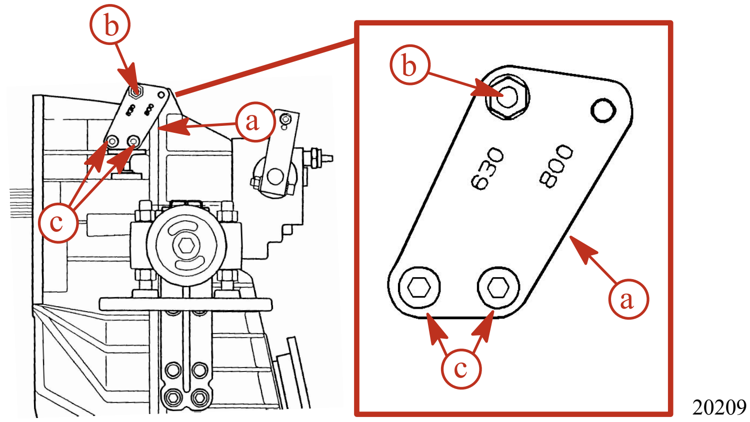
Typical

a - Shift lever

b - Quicksilver remote control shift cable anchor stud location

IMPORTANT: Install the shift cable anchor stud in the correct hole.

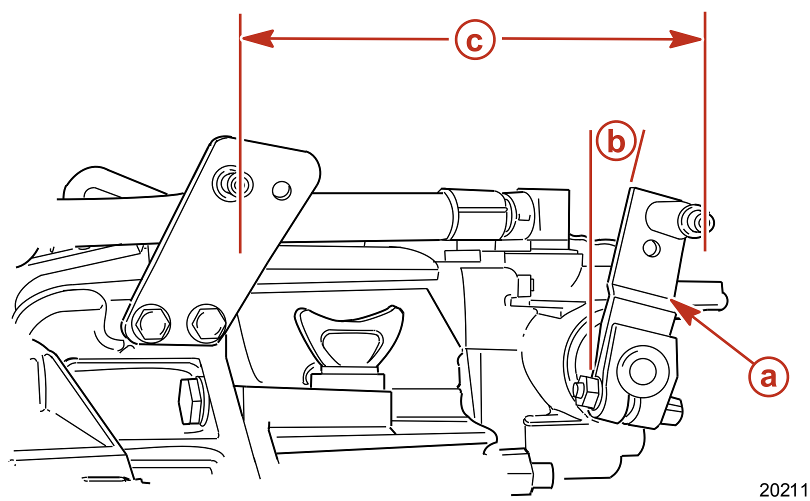
1. On a bracket with two anchor location holes: ensure that the anchor stud is installed in the correct hole for the application.



Shift cable bracket - anchor stud position shown for 630 transmission

a - Shift cable bracket
b - Shift cable anchor stud
c - Bracket fasteners

IMPORTANT: Ensure that the shift lever is positioned approximately 10 degrees aft of vertical as shown when in the neutral detent position. Also, ensure that the distance between the studs in the following is set at 181 mm (7-1/8 in.). If necessary, loosen the clamping bolt and position the lever so that dimension "c" is as shown when in the neutral detent position, and retighten the clamping bolt.



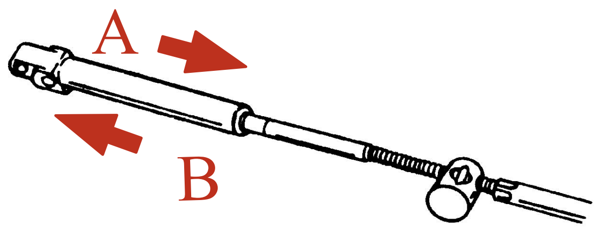
Typical ZF Marine Transmission shown

a - Shift lever
b - Shift lever in neutral detent
c - Dimensions between studs - 181 mm (7-1/8 in.)

IMPORTANT: Transmission propeller rotation is determined by the shift cable installation in the remote control.

For right-hand propeller rotation: the control cable must be installed in the remote control so that the cable end will move in direction "A" when the shift handle is placed in the forward position.

For left-hand propeller rotation: the control cable must be installed in the remote control so that the cable end will move in direction "B" when the shift handle is placed in the forward position.

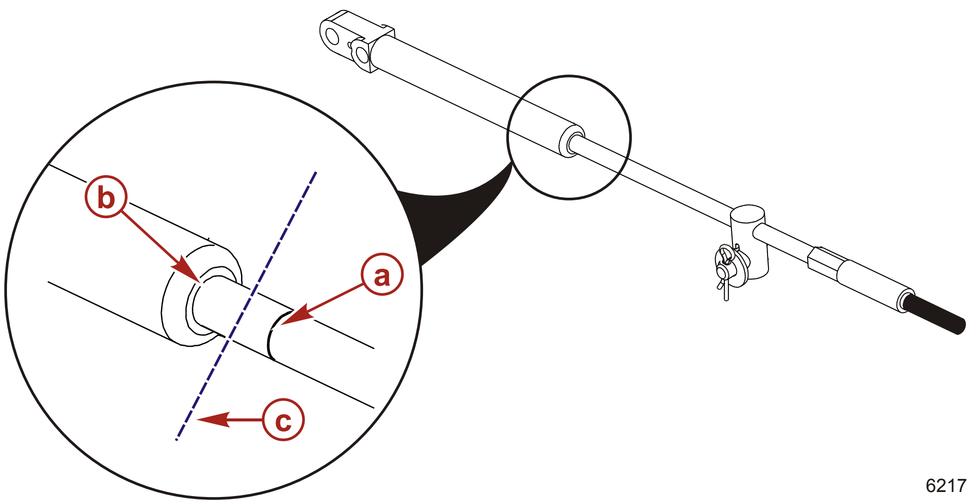


Installation and Adjustment

IMPORTANT: When installing shift cables, ensure that the cables are routed to avoid sharp bends and/or contact with moving parts. Do NOT fasten any items to the shift cables.

NOTE: On models with other than Quicksilver shift cables, refer to the shift cable manufacturer's instructions.

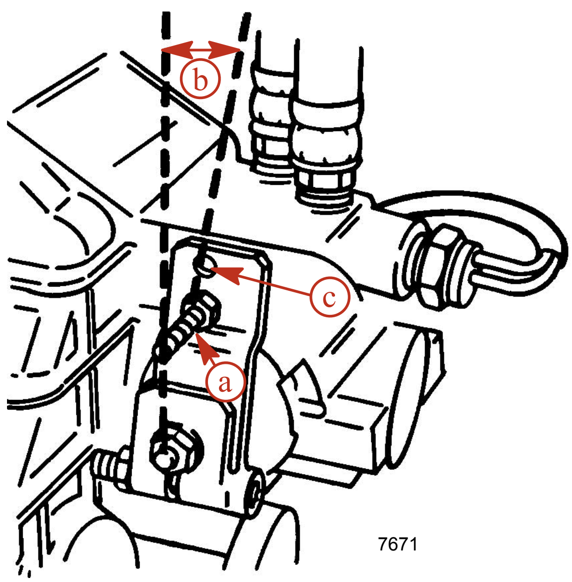
1. Place the remote control shift lever and transmission shift lever in the neutral position.
2. Remove the nuts and washers from the shift cable attaching studs.
3. Locate the center of the remote control and control shift cable play (backlash), as follows:
   a. Ensure that the remote control is in the neutral position.
   b. Push in on the control cable end with enough pressure to remove play; mark position "a" on the tube.
   c. Pull out on the control cable end with enough effort to remove play; mark position "b" on the tube.
   d. Measure the distance between marks "a" and "b;" mark position "c" halfway between marks "a" and "b."



4. Center the cable-end play, then adjust the cable barrel to align the holes in the barrel and in the cable end guide with attaching points on the transmission.
5. Temporarily install the shift cable. Do not secure at this time.

IMPORTANT: The transmission is fully in gear when the shift lever comes to a stop, in either direction.

6. Place the remote control shift lever in the forward gear position. Ensure that the transmission is fully in gear, as follows:
    a. Hold the shift lever in position.
    b. Carefully slide the shift cable off of the anchor points.
    c. Attempt to move the shift lever further.
    d. Temporarily install the shift cable. Do not secure the cable at this time.
7. Place the remote control shift lever in the reverse gear position. Ensure that the transmission is fully in gear as follows:
    a. Hold the shift lever in position.
    b. Carefully slide the shift cable off of the anchor points.
    c. Attempt to move the shift lever further.
    d. Temporarily install the shift cable. Do NOT secure the cable at this time.
8. If the transmission shift lever will position properly in one gear, but not in the other, recheck the shift cable adjustment. If the transmission shift lever will not position properly in either gear, move the transmission shift lever stud from the top hole in the shift lever to the bottom hole and recheck for proper positioning. If proper positioning is still not obtained, the remote control does not provide sufficient shift cable travel and must be replaced.



Typical

a - Shift lever stud (in bottom hole, if required)

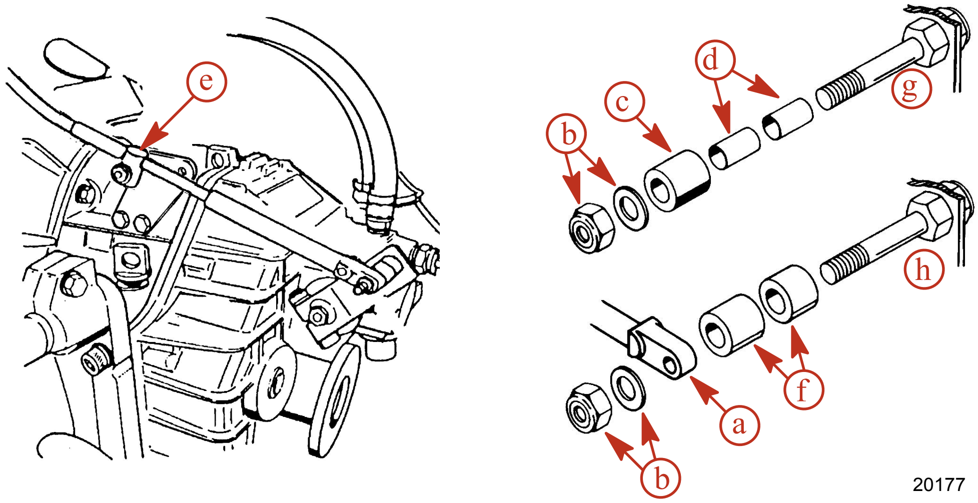
b - Lever, in neutral detent, must be approximately 10 degrees of vertical

c - Shift lever top hole

9. Install the nut and washer to the cable end guide stud. Tighten until the nuts contact, then loosen 1/2 turn.

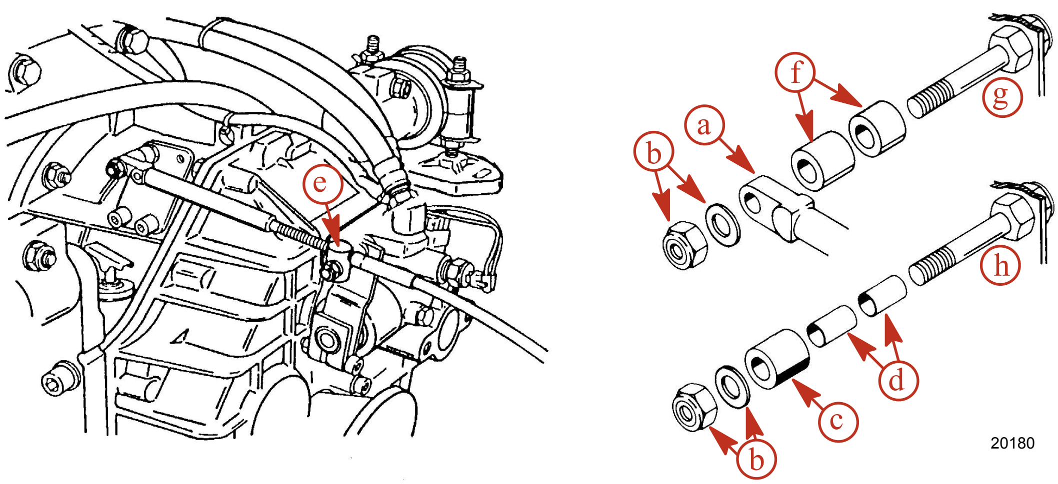
10. Install the nut and washer to the cable barrel stud. Tighten until the nuts contact, then loosen 1/2 turn.

NOTE: *To change the cable approach direction on single or dual station installations, only the spacers or bushings have to be switched to the opposite stud. The studs are identical.*



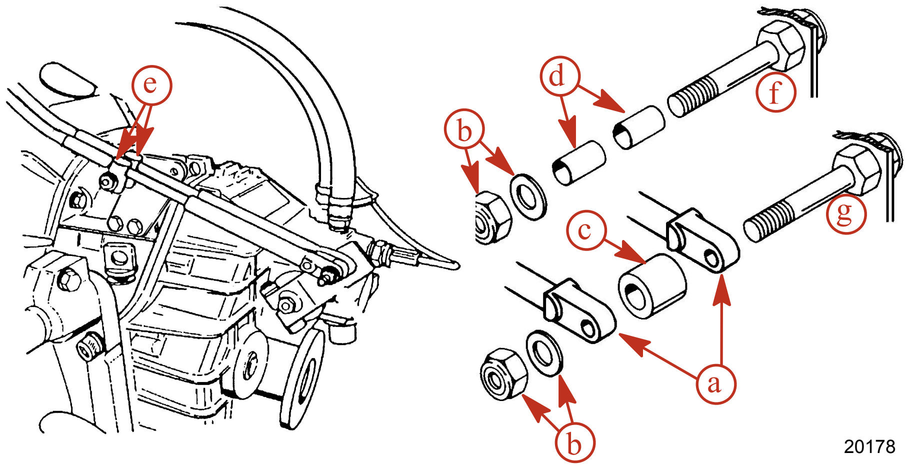
Typical single cable installation—forward approach

- **a -** Cable end guide
- **b -** Locknut and washer
- **c -** Spacer (fits over bushings)
- **d -** Bushing
- **e -** Cable barrel
- **f -** Spacers (fits over stud)
- **g -** Cable barrel stud
- **h -** Cable end guide stud



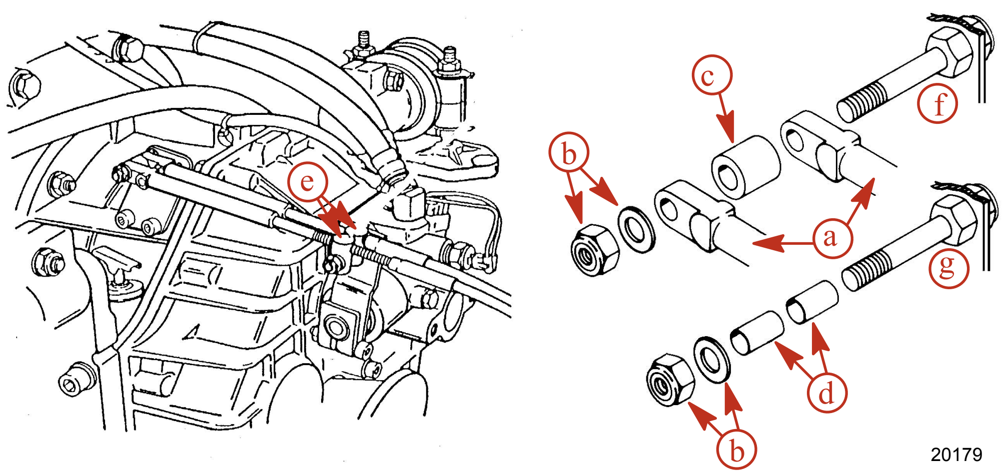
Typical single cable installation—rear approach

- **a -** Cable end guide
- **b -** Locknut and washer
- **c -** Spacer (fits over bushings)
- **d -** Bushing
- **e -** Cable barrel
- **f -** Spacers (fits over stud)
- **g -** Cable end guide stud
- **h -** Cable barrel stud



Typical dual cable installation—forward approach

a - Cable end guide
b - Locknut and washer
c - Spacer (fits over stud)
d - Bushing
e - Cable barrel
f - Cable barrel stud
g - Cable end guide stud



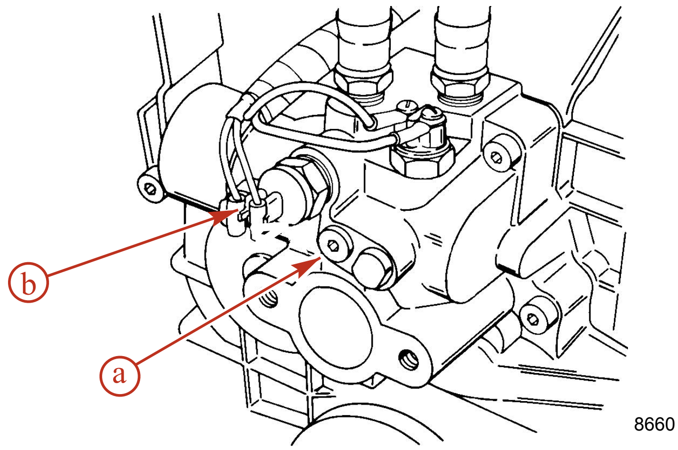
Typical dual cable installation—rear approach

a - Cable end guide
b - Locknut and washer
c - Spacer (fits over stud)
d - Bushing
e - Cable barrel
f - Cable barrel stud
g - Cable end guide stud

Pressure Test

1. Remove the pressure service port plug from Port A.
2. Connect a suitable pressure gauge to Port A.
3. Disconnect both wires and remove the fluid temperature switch from Port B.

4. Install a thermocouple in Port B.



Typical ZF Marine transmission

a - Service port plug—Port **A** **b -** Fluid temperature switch—Port **B**

5. Operate the boat with a normal load on board.
6. Ensure that the fluid temperature and shifting pressure are as specified.

Description	Specification	
Operating temperature	54–79 degrees C (130–175 degrees F)	
Shifting pressure	Position A	21.5–23.5 bar (312–341PSI) at 2000 RPM.
	Position B	

7. Repair or replace the transmission if measurements are not as specified.
8. Remove the pressure gauge and thermocouple.
9. Apply sealant to the fluid temperature switch threads and the service port plug.

Tube Ref No.	Description	Where Used	Part No.
9	Loctite 567 PST Pipe Sealant	Transmission fluid temperature switch threads and the service port plug	92-809822

10. Install and securely tighten the fluid temperature switch and service port plug.
11. Connect the two fluid temperature switch wires. Apply sealant to the exposed electrical terminals and connections.

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Exposed electrical terminals and connections.	92- 25711 3

12. Upon first operation, check for leaks.

Drive System

Section 8B - Technodrive Transmissions

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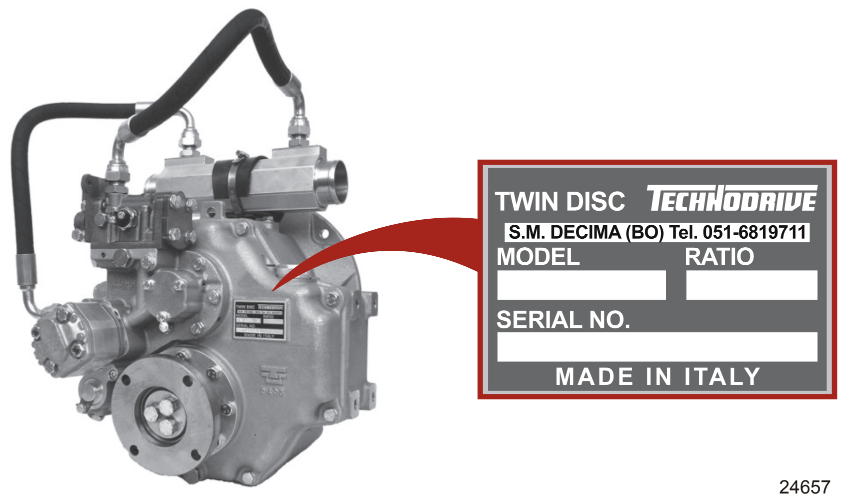
B

Lubricants, Sealants, Adhesives

Tube Ref No.	Description	Where Used	Part No.
	Cleaning solvent	Transmission filter element	Obtain Locally
25	Liquid Neoprene	Neutral start switch and fluid temperature switch wire connections	92- 25711 3
80	SAE Engine Oil 30W	Transmission filter element O-ring	Obtain Locally
91	Engine Coupler Spline Grease	Transmission input shaft splines and engine drive plate splines	92-802869A1

Technodrive Transmissions

On the Technodrive TM 485-A, the transmission identification plate indicates gear ratio, serial number, and model.



Typical Technodrive transmission shown

Precautions

To help extend the life of your transmission, Cummins MerCruiser Diesel provides the following precautions.

- Do not start or crank the engine without fluid in the transmission.
- Except in an emergency, never shift the transmission at engine speeds above 1000 RPM.
- Free wheeling of one propeller (in a twin-engine boat) at trolling speeds will not cause damage to the transmission; however avoid boat operation above trolling speed. Ensure that a proper fluid level exists before free wheeling the propeller.
- Always repair or replace the oil cooler and hoses after a transmission failure or prior to installing a new or rebuilt transmission. Metallic particles from a failure collect in the oil cooler and hoses and will contaminate and damage the transmission.
- Always use the specified oil cooler, hoses, and fittings.

Important Information

Engine

All current production engines are left-hand rotation. Engine rotation is described when observed from the rear of the engine (transmission end) looking forward (water pump end). The installed angle of the transmission and the engine should not exceed a maximum of 12 degrees of the water line.

Transmission

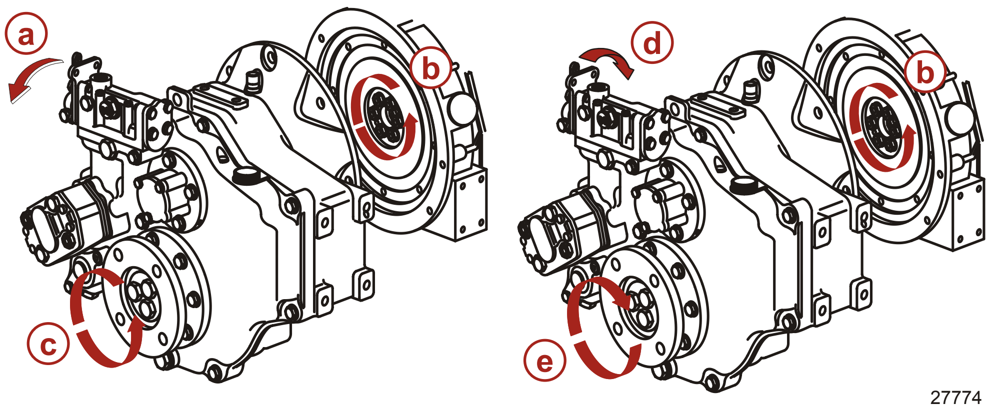
Transmission rotation is described when viewed from the rear of transmission.

Propeller

Propeller rotation is described when observed from the rear of the boat (stern) looking forward (bow). The term left-hand (LH) refers to rotation in the counterclockwise (CCW) direction. The term right-hand (RH) refers to rotation in the clockwise (CW) direction. A LH propeller will move the boat forward when rotated counterclockwise. A RH propeller will move the boat forward when rotated clockwise.

Technodrive Transmission And Propeller Rotation

Technodrive transmissions are full-power reversing transmissions, allowing a standard LH rotation engine for either propeller rotation. Shift cable attachment orientation at the remote control determines propeller rotation.

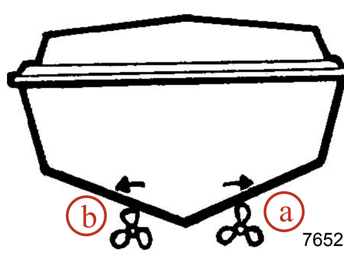


Technodrive 485-A transmission

a - Direction of shift lever engagement (away from flywheel)
b - Transmission input shaft rotation direction (LH)
c - Transmission output shaft rotation direction (LH)
d - Direction of shift lever engagement (toward flywheel)
e - Transmission output and propeller shaft rotation direction (RH)

Propeller Rotation on Dual Installations

Best all-around performance usually is obtained by installing engines so that propellers turn outboard (looking at the stern).



Outboard Propeller Rotation

a - RH rotation
b - LH rotation

Technodrive Transmission Fluid

Checking

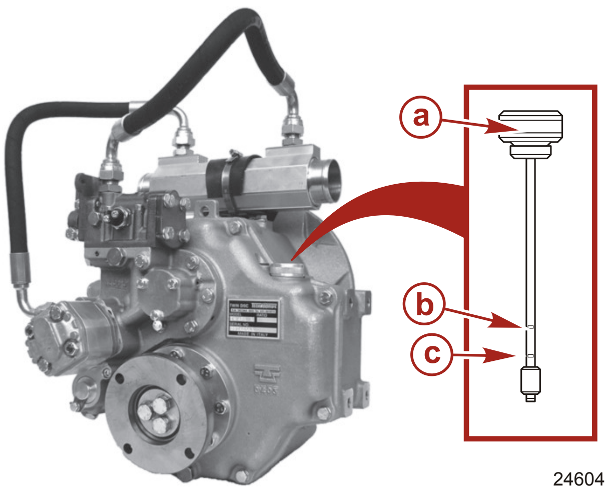
1. Remove the dipstick.

IMPORTANT: When checking the fluid level, rest the dipstick on top of the threaded housing hole. Do not screw the dipstick onto the threaded housing hole.

2. Check the fluid level as indicated on the dipstick with the dipstick resting on the top of the threaded hole.

NOTE: The fluid level may be somewhat over the maximum mark, as some of the fluid from the transmission fluid cooler and hoses may have drained back into the transmission.

3. If the fluid level is below the minimum mark on the dipstick, add transmission fluid. See **Filling**.



a - Dipstick
b - Maximum fluid level
c - Minimum fluid level

IMPORTANT: To accurately check the fluid level, operate the engine at 1500 RPM for 2 minutes immediately before checking the level.

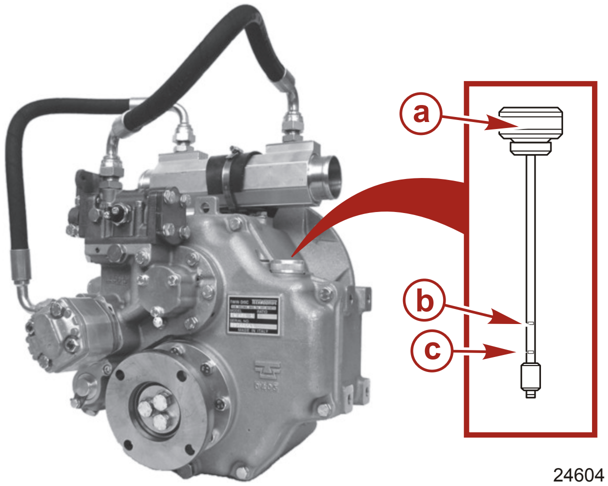
4. Start the engine and operate at 1500 RPM for 2 minutes to fill all the hydraulic circuits.
5. Stop the engine and quickly check the fluid level with the dipstick resting on the top of the threaded hole.
6. If the fluid level is low, add transmission fluid to bring the level up to the maximum mark on the dipstick. See **Filling**.

NOTE: If the transmission fluid level was extremely low, see your local Cummins MerCruiser Diesel Authorized Repair Facility.

7. Install the dipstick.

Filling

1. If necessary, add specified transmission fluid through the dipstick threaded hole to bring the level up to the maximum mark on the dipstick.



a - Dipstick
b - Maximum fluid level
c - Minimum fluid level

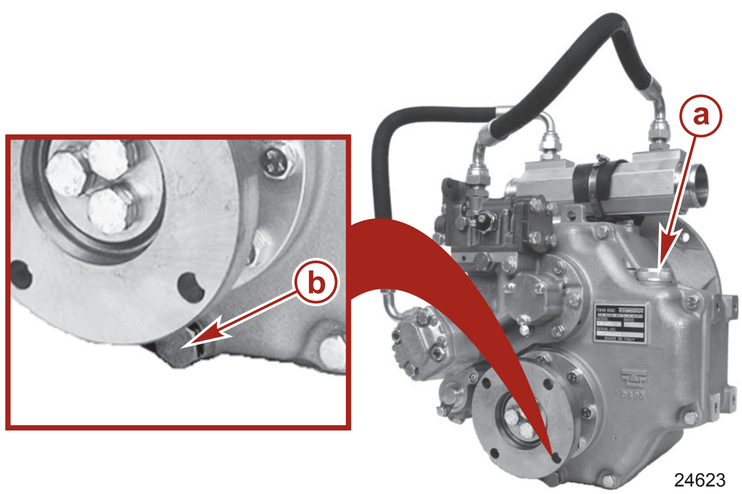
NOTE: *Always use the dipstick to determine the quantity of oil or fluid required.*

Model	Capacity	Fluid type	Part Number
Technodrive 485A	2.6 liters (2 ½ US qt)	SAE 20W - 40 or SAE 15W - 40 engine oil	Obtain Locally

2. Install the dipstick.
3. Check the fluid level. See **Checking**.

Changing

1. Remove the fill cap and dipstick.
2. Remove the transmission fluid drain plug and drain the transmission into a suitable container.



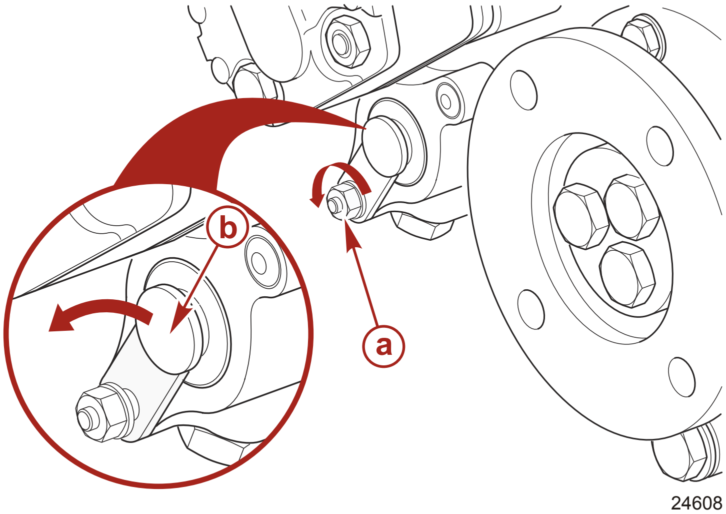
a - Fill cap and dipstick
b - Drain plug

3. Contain and dispose of the oil or oil waste as directed by local authorities.
4. Reinstall the transmission fluid drain plug.

5. Torque the drain plug.

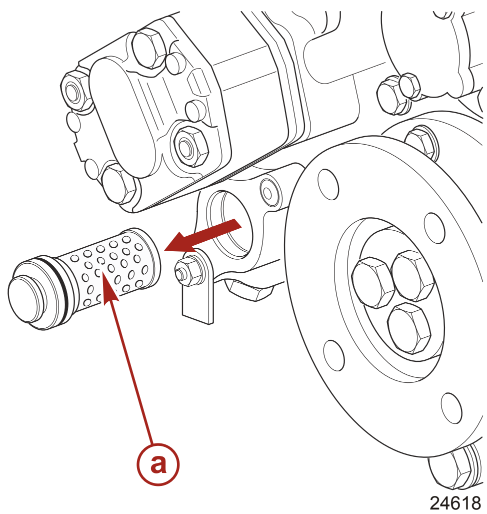
Description	Nm	lb. in.	lb. ft.
Transmission fluid drain plug	17		12.5

6. Clean the exterior of the transmission around the fluid filter assembly.
7. Loosen the assembly nut then rotate the securing tab in the direction shown.



a - Assembly nut **b -** Securing tab

8. Remove the filter element.



a - Filter element

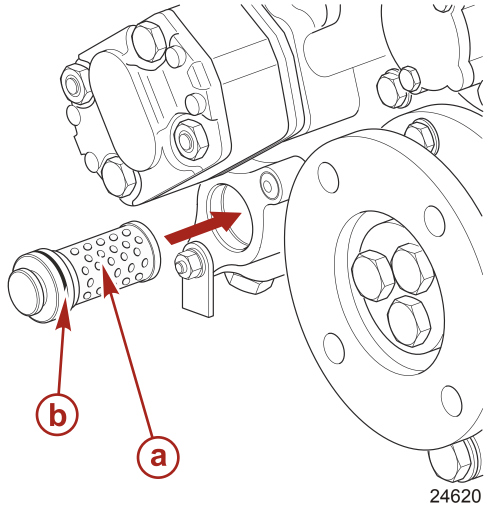
9. Clean the filter element using the cleaning solvent.

Tube Ref No.	Description	Where Used	Part No.
	Cleaning solvent	Transmission filter element	Obtain Locally

10. Lubricate the O-rings.

Tube Ref No.	Description	Where Used	Part No.
80	SAE Engine Oil 30W	Transmission filter element O-ring	Obtain Locally

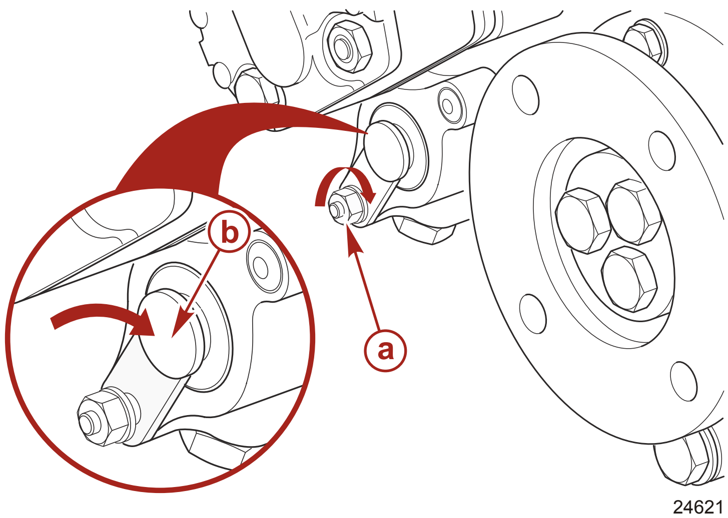
11. Reinstall the filter element.



a - Filter element **b -** O-ring

NOTICE
Improper installation of the transmission fluid filter assembly may cause the fluid to foam or leak out, resulting in decreased efficiency and damage to the transmission. Properly seat the transmission fluid filter during installation.

12. Replace the securing tab over the filter assembly by turning it clockwise.
13. Tighten the assembly nut. Torque the nut.



a - Assembly nut **b -** Securing tab

Description	Nm	lb. in.	lb. ft.
Assembly nut	5-8	48-72	

14. Fill the transmission to the proper level with the specified fluid. See **Filling**.

Technodrive Transmission Removal

*NOTE: The following procedure describes removal of the transmission without removing the engine. If the engine must be removed, refer to **Section 2**.*

⚠ WARNING

Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

1. Disconnect the battery cables from the battery.

NOTICE

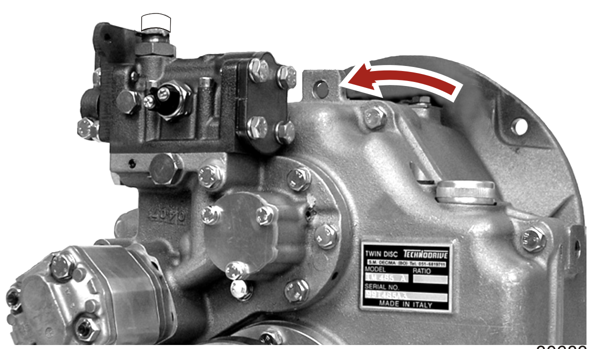
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

2. If required, drain the transmission fluid. See **Changing**.
3. Disconnect the transmission fluid cooler hoses.
4. Cap or plug all open hydraulic connections.
5. Disconnect the shift cable (or cables) from the transmission.
6. Disconnect the trolling valve cable from the transmission.
7. Disconnect the wires from the neutral start switch.
8. Disconnect the wires from the transmission fluid temperature switch.
9. Remove the nuts and bolts from the coupling and separate the propeller shaft coupler from the transmission output flange.

NOTICE

The weight of an unsupported transmission can bend the transmission input shaft or damage the engine coupler. Do not permit the splines of the input shaft or coupler to support the weight of the transmission. Completely support the transmission during removal, and until the attaching hardware is secured during installation.

10. Support the transmission with a hoist or by other suitable means through the lifting eye on the transmission case.



Lifting eye location

11. Remove all hardware attaching the transmission to the flywheel housing.
12. Pull the transmission straight back and away from the engine to completely disengage the splines on the input shaft.
13. Carefully lift the transmission out of the boat.

Technodrive Transmission Installation

1. Apply lubricant to the transmission input shaft splines and engine drive plate splines.

Tube Ref No.	Description	Where Used	Part No.
91	Engine Coupler Spline Grease	Transmission input shaft splines and engine drive plate splines	92-802869A1

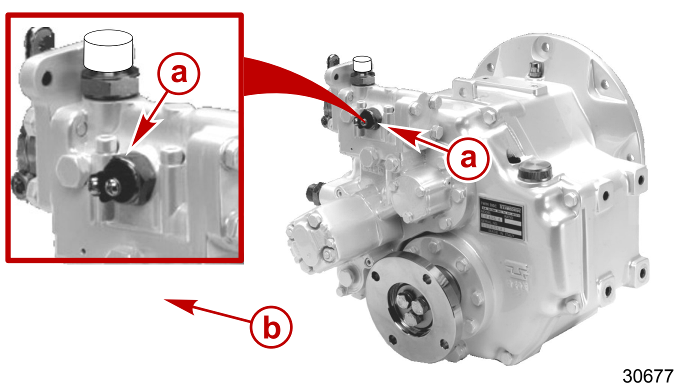
NOTICE

The weight of an unsupported transmission can bend the transmission input shaft or damage the engine coupler. Do not permit the splines of the input shaft or coupler to support the weight of the transmission. Completely support the transmission during removal, and until the attaching hardware is secured during installation.

2. Support the transmission with a hoist or by other suitable means through the lifting eye on the transmission case. See **Removal** for lifting eye location.
3. Using a suitable hoist, position the transmission in the boat and align the transmission splines with the drive plate splines.
4. Push the transmission into place and secure with the transmission to flywheel housing fasteners.

Description	Nm	lb. in.	lb. ft.
Transmission to flywheel housing fasteners	61	–	45

5. Relieve the hoist tension.
6. Remove the hoist.
7. Connect the neutral start switch and fluid temperature switch wiring. Coat the connections with sealant.



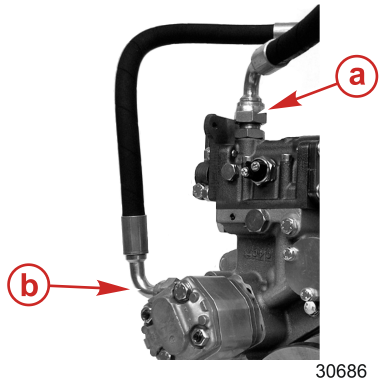
Typical

a - Neutral start switch
b - Location for optional fluid temperature switch

Tube Ref No.	Description	Where Used	Part No.
25	Liquid Neoprene	Neutral start switch and fluid temperature switch wire connections	92- 25711 3

IMPORTANT: Improper shift cable adjustment can cause premature clutch failure.

8. Remove any caps or plugs and install the transmission fluid cooler hoses onto the transmission. Torque the hose fittings.



Typical

a - Fluid cooler hose to / from cooler

b - Fluid cooler hose to / from cooler

Description	Nm	lb. in.	lb. ft.
Transmission fluid cooler hose fitting	34	–	25

9. Connect and adjust the shift cable or cables. Refer to **Section 2C**.
10. Connect and adjust the trolling valve push-pull cable. Refer to **Section 2C**. Once the cable is connected, check adjustment by repeatedly moving the control lever and ensure that the trolling valve lever moves as recommended.
11. Check engine final alignment. Refer to **Section 2C**.

IMPORTANT: All coupler bolts must be SAE Grade 8 (Metric Grade 10.9) or better, with a shoulder (grip length) long enough to pass through the face mating plane of couplers.

12. After final engine and coupler alignment has been properly set (with the boat in the water), connect the propeller shaft coupler to the transmission output flange with bolts, lockwashers, and nuts. Torque the nuts.

Description	Nm	lb. in.	lb. ft.
Propeller shaft coupler to transmission output flange nut	68	–	50

13. Refill the transmission with the specified fluid. See **Filling**.
14. Connect the battery cables.
15. Check for leaks and check the fluid level after the first engine start-up.

Drive System

Section 8C - Propeller Shaft Models

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8
C

Specifications

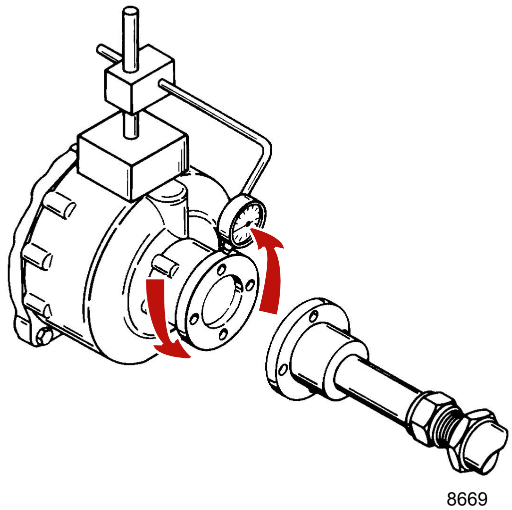
Description	
Propeller shaft runout	0.1mm (0.004 in.)

Checks Made With Boat In the Water

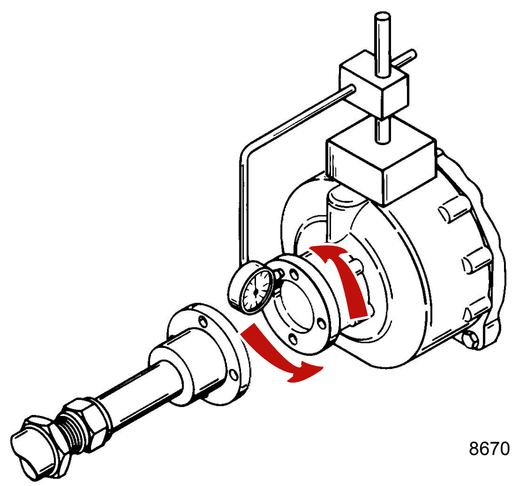
NOTE: *The following information can be used as a guide for determining vibration problems on boats powered by inboard engines. For installation, alignment and repairs to shafts, struts, shaft logs and rudders refer to the boat manufacturer's service manual. If the boat is equipped with V-Drive or a remote mounted V-Drive refer to the boat manufacturer's service manual. For MIE engine installation and alignment, refer to SECTION 2B.*

1. Disconnect the propeller shaft and transmission coupling.
2. Check the fit of a straight-bore type coupler to the propeller shaft.
   a. Loosen the set screws.
   b. Try to move the coupler by hand. The bore of the coupler should be a semi-press fit to the shaft.
   c. Check the shaft for wear. If worn, replacement of the shaft may be necessary. If the shaft is not worn try another coupler.
3. Check the fit of a tapered-bore type coupler to the propeller shaft.
   a. Ensure that the nut on the shaft is tight.
   b. If the nut was loose, remove the coupler and check for damage to the taper on the shaft or in the coupler bore.
   c. Replace worn parts.
   d. Always ensure that the key is not sticking out of the coupler.
   - Install the coupler on the shaft without the key.
   - Mark the shaft behind the coupler. Remove the coupler.
   - Now install the key and the coupler. Ensure that the coupler still lines up with the mark. This ensures that the key is not oversize and holding the tapers apart.

4. Check the transmission output coupler. Rotate at least one complete revolution for each check.



Checking typical coupler outside diameter



Checking typical coupler face

5. If there is movement in step 4. replace the output coupler.
6. Replace damaged parts and realign the engine as outlined.
7. Torque the propeller shaft-to-transmission coupling bolts.

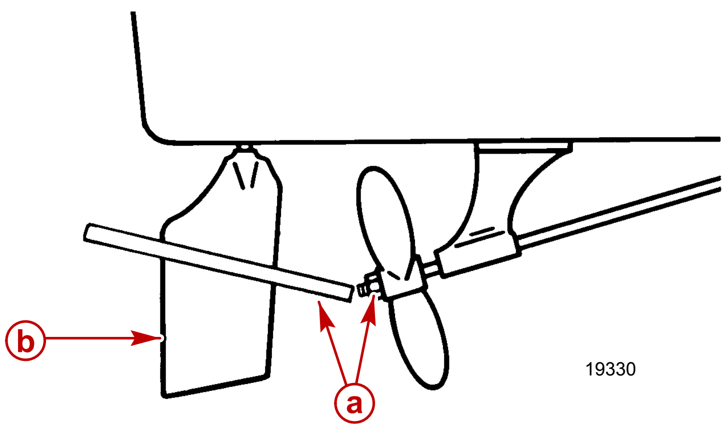
Description	Nm	lb. in.	lb. ft.
Propeller shaft-to-transmission coupling bolt	68		50

8. Tighten securely and safety wire the set screws, if equipped.

Checks Made With The Boat Out Of The Water And The Propeller Shaft Installed

Possible causes for vibration may be the propeller shaft, propeller-to-shaft fit, or the propeller. All 3 can be checked by using the rudder, a strong metal straight edge and a C-clamp.

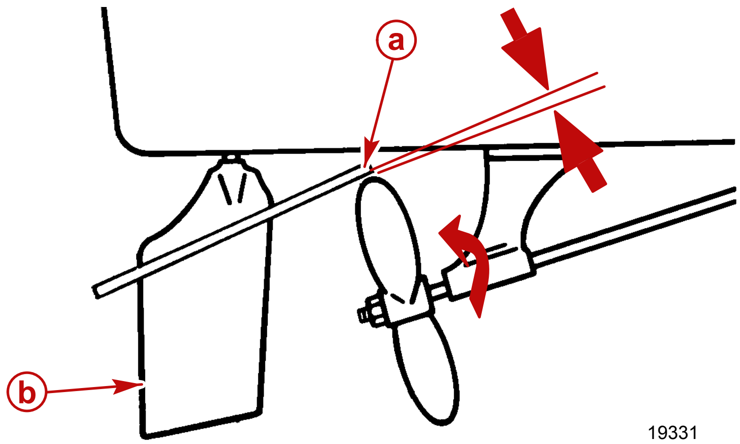
1. Check the installation and seating of the propeller to the shaft.
   a. Remove the propeller.
   b. Check for a chipped or cracked keyway in the propeller.
   c. Install the propeller on the shaft without the key.
   d. Mark the shaft (behind the propeller), then remove the propeller.
   e. Install the key and propeller. Ensure that the propeller still lines up with the mark. This ensures that the key is not oversized and holding the tapers apart. Retighten the propeller nut.
   f. Ensure that the key is not sticking out of the propeller.
2. Check the propeller shaft runout to ensure that the shaft is not bent aft of the strut.
   a. Position the corner of the straight edge at the center of the shaft.
   b. Rotate the shaft one complete revolution.
   c. If the shaft wobbles, shaft runout is not correct. Replace the shaft.



a - Metal straight edge (held to the rudder with a C-clamp)

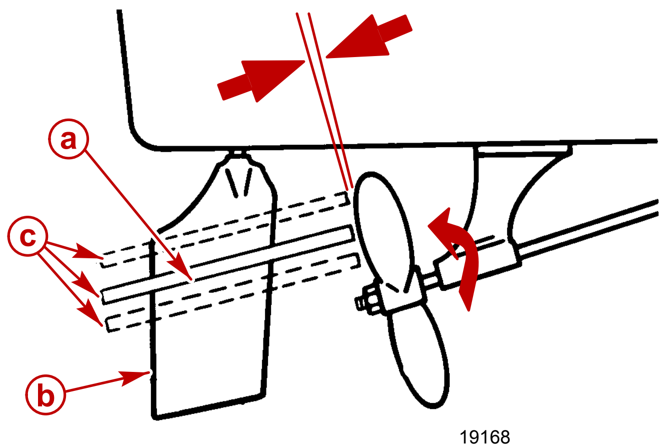
b - Rudder

3. Compare the diameter of all propeller blades. If they are not the same, repair or replace the propeller.



a - Metal straight edge (held to the rudder with a C-clamp)
b - Rudder

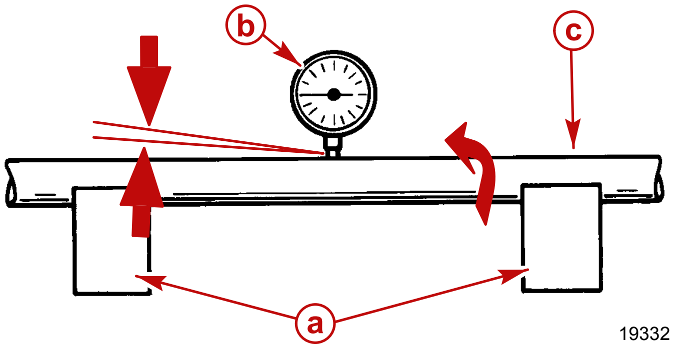
4. Ensure that all propeller blades are the same pitch. Reference at three different points on each blade. If each blade pitch is not the same, repair or replace the propeller.



a - Metal straight edge (held to the rudder with a C-clamp)
b - Rudder
c - Three points of reference

Checks Made With the Propeller Shaft Removed From the Boat

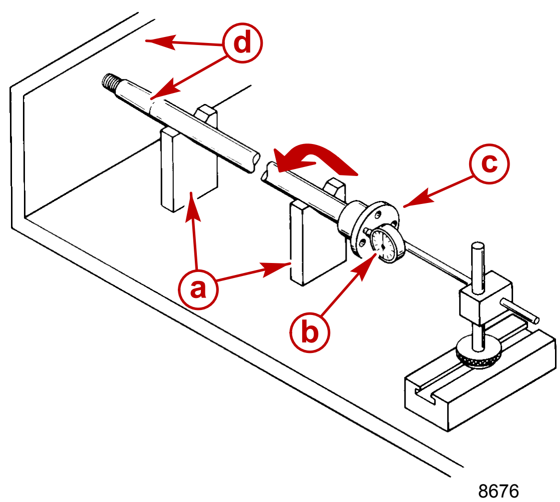
1. Check the propeller shaft runout. Check through one complete revolution, at three or four places. Replace the shaft if the measured value is greater than specified.



a - V-blocks
b - Dial indicator
c - Shaft

Description	
Propeller shaft runout	0.1mm (0.004 in.)

2. Ensure that the bore of the coupler is at 90° to the coupler flange. Check through one complete revolution. Replace the coupler if the measured value is less than or greater than specified.



a - V-blocks
b - Dial indicator
c - Coupler flange
d - Shaft (against block to prevent fore and aft movement)

Description	
Couple bore-to-face runout	0.00 mm (0.000 in.)

Strut

Refer to the boat manufacturer's service manual for alignment and replacement. Normally, the shaft should be centered in the cutlass bearing. Shims placed between the strut and the hull are used to align the strut to the shaft.

Power-Assisted Steering System

Section 9A - Power-Assisted Steering Pump and Related Components

Table of Contents

Power-Assisted Steering Specifications

IMPORTANT: Power-assisted steering pumps are considered non-repairable units and are intended to be removed and replaced with new units when found to be defective.

Power-assisted steering drive belt tension	
Belt deflection, with moderate hand pressure	5 mm (3/16 in.)

Lubricants, Sealants, Adhesives

Tube Ref No.	Description	Where Used	Part No.
28	Dexron III Automatic	Power-assisted steering system	Obtain Locally
114	Power Trim and Steering Fluid	Power-assisted steering system Power steering system	92-858074K01

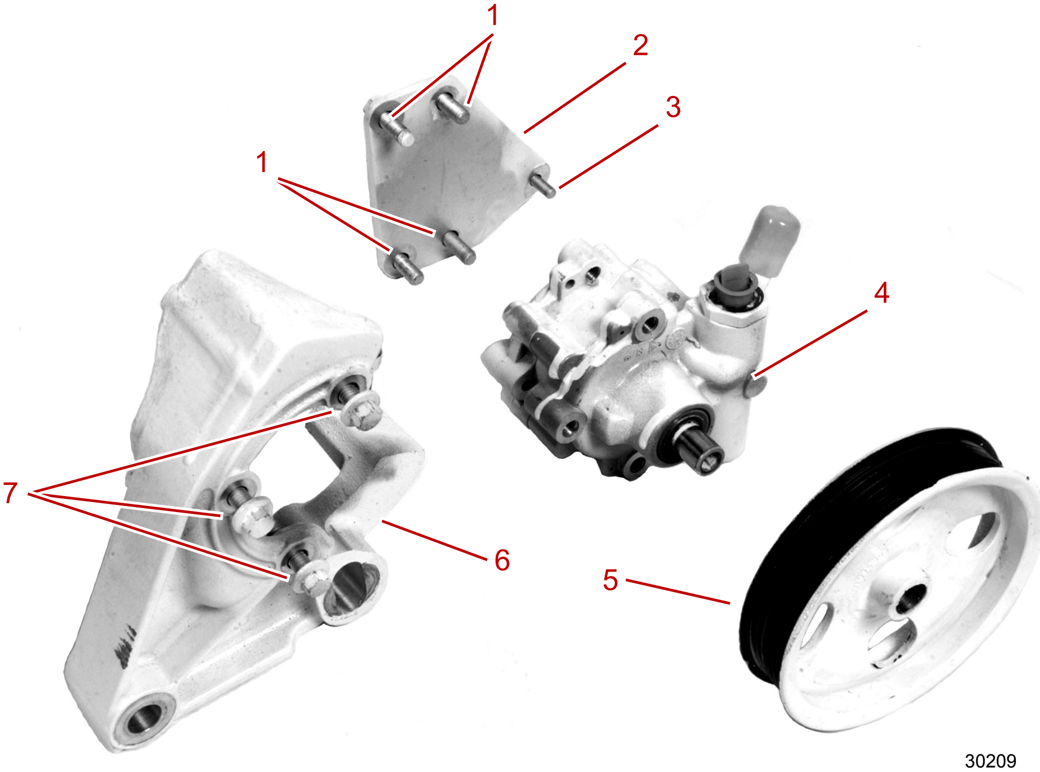
Fluid Specifications

Description	Fluid Type	Fluid Part Number
Power-assisted steering system	Dexron III Automatic	Obtain locally
	Power Trim and Steering Fluid	92–802880A1 or Q1

Notes:

Exploded Views

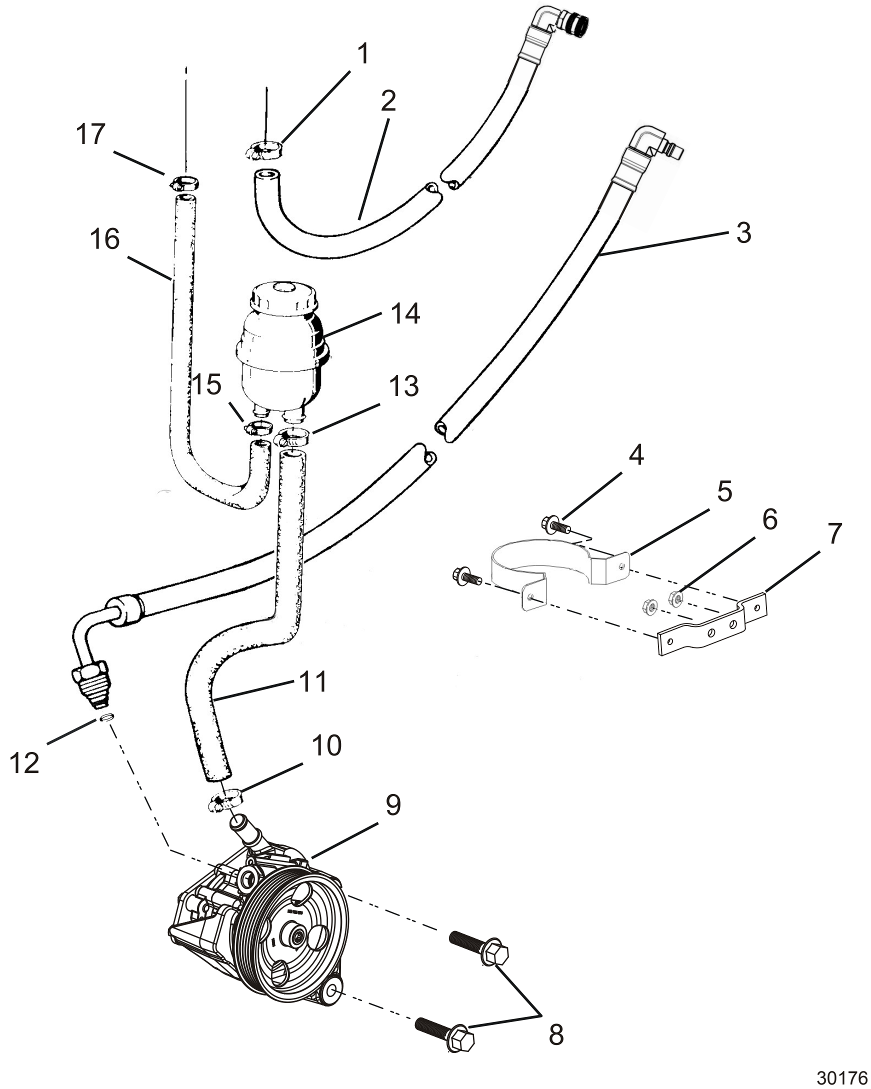
Power-Assisted Steering Pump Assembly



Power-Assisted Steering Pump Assembly

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	4	M8 flange screw	24.5	–	18
2	1	Back plate			
3	1	M6 flange screw	10.8	95	–
4	1	Power-assisted steering pump			
5	1	Pulley			
6	1	Bracket			
7	3	M8 flange screw	24.5	–	18

Related Power-Assisted Steering Components



Related Power-Assisted Steering Components

Ref. No.	Qty.	Description	Torque		
			Nm	lb. in.	lb. ft.
1	1	Hose clamp (inlet fitting—fluid cooler)			
2	1	Return hose (low-pressure—from control valve)			
3	1	High-pressure hydraulic hose (to control valve)	Finger-tight + 1 3/4 to 2 1/4 turns with a wrench. Do not overtighten.		
4	2	M8 flange screws	25	–	18
5	1	Fluid reservoir support			
6	2	M8 nuts	25	–	18
7	1	Fluid reservoir bracket			
8	2	M8 mounting screws for power-assisted steering pump	21	185	–
9	1	Power-assisted steering pump assembly			
10	1	Hose clamp			
11	1	Supply hose			
12	1	O-ring			
13	1	Hose clamp			
14	1	Fluid reservoir with cap and dipstick			
15	1	Hose clamp			
16	1	Return hose (from fluid cooler)			
17	1	Hose clamp (return fitting—fluid cooler)			

Power-Assisted Steering Pump

Removal

⚠ WARNING

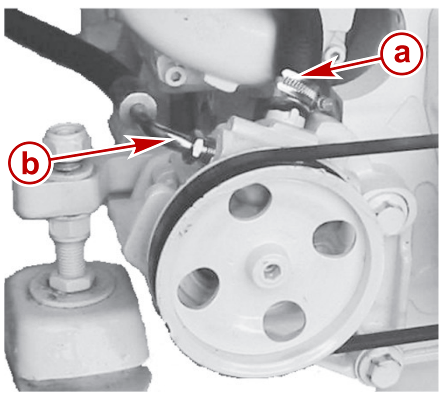
Performing service or maintenance without first disconnecting the battery can cause product damage, personal injury, or death due to fire, explosion, electrical shock, or unexpected engine starting. Always disconnect the battery cables from the battery before maintaining, servicing, installing, or removing engine or drive components.

1. Disconnect both battery cables from the battery.

⚠ CAUTION

Contamination can damage the hydraulic system or cause the system to malfunction. Failure of power trim or steering components can result in injury or product damage. Ensure that the work area, shop tools and all components are clean and lint free during reassembly.

2. Remove the belt for the power-assisted steering pump.
3. Remove the reservoir hose and pressure hose from the power-assisted steering pump. Drain the fluid into a suitable container. Do not reuse the fluid.
4.



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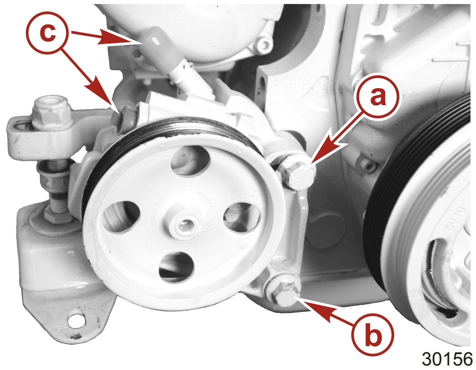
a - Reservoir hose and clamp
b - Pressure hose and fitting

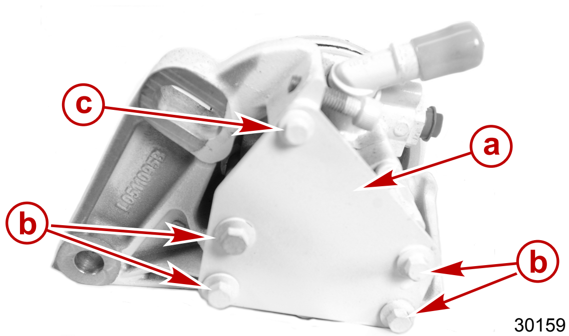
5. Cap or plug all open hydraulic connections.

6. Loosen the power-assisted steering pump mounting screws.



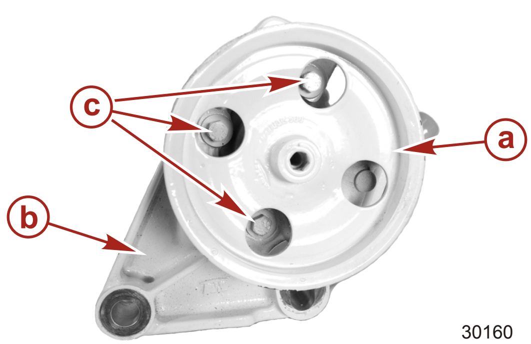
a - Upper mounting screw
b - Lower mounting screw
c - Typical plugs

7. Remove the power-assisted steering pump and bracket.
8. Remove the five screws and back plate from the power-assisted steering pump and bracket.



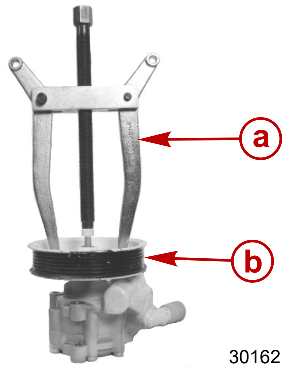
a - Back plate
b - M8 screws (4)
c - M6 screw (1)

9. Loosen the three front attaching screws and remove the power-assisted steering pump from the bracket.



a - Pump and pulley
b - Bracket
c - M8 screws (3)

10. Using a suitable puller, remove the pulley from the power-assisted steering pump shaft. Retain the pulley for installation.



a - Typical suitable puller
b - Pulley

NOTICE
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

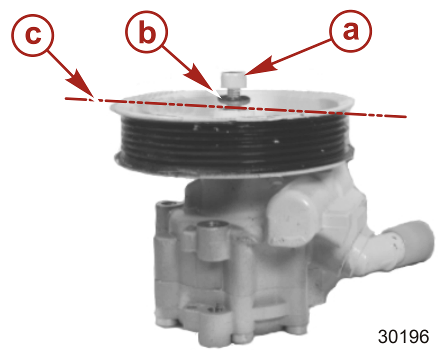
11. Drain the fluid from the power-assisted steering reservoir into a suitable container. Do not reuse the fluid.
12. Dispose of the fluid properly.

Installation

⚠ CAUTION

Contamination can damage the hydraulic system or cause the system to malfunction. Failure of power trim or steering components can result in injury or product damage. Ensure that the work area, shop tools and all components are clean and lint free during reassembly.

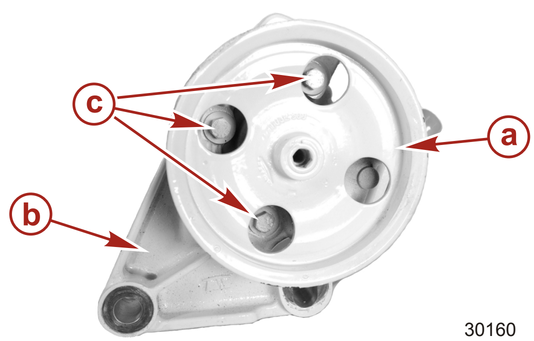
1. Using a suitable M8 × 1.5 screw and washer, push (install) the pulley onto the power-assisted steering pump shaft until the pulley hub is flush with the shaft end. The washer will make contact with the end of the shaft.



Pulley installed flush with shaft end

a - Screw
b - Washer
c - Flush with shaft end

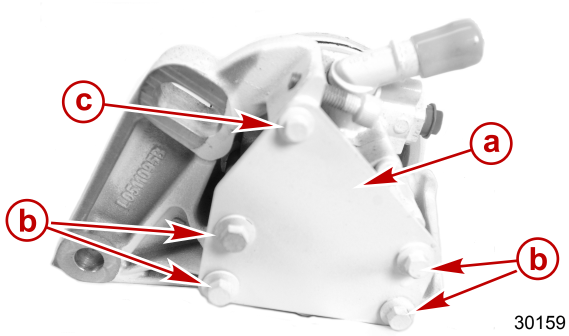
2. Mount the power-assisted steering pump on the bracket. Install the three front attaching screws. Torque the screws.



a - Pump and pulley
b - Bracket
c - M8 screws (3)

Description	Nm	lb. in.	lb. ft.
Power-assisted steering pump-to-bracket front attaching screws	25	–	18

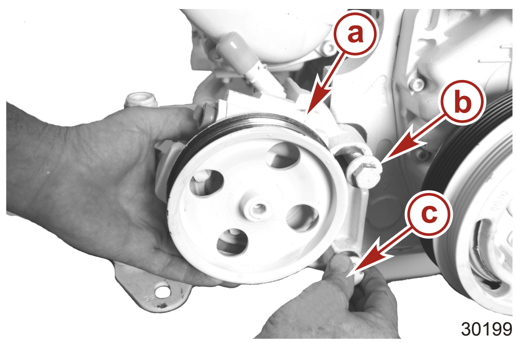
3. Using the five flange screws, install the back plate onto the power-assisted steering pump and bracket. Torque the screws as specified in a crisscross pattern.



a - Back plate
b - M8 flange screws (4)
c - M6 flange screw (1)

Description	Nm	lb. in.	lb. ft.
M8 back plate flange screw (4)	25	–	18
M6 back plate flange screw (1)	25	–	18

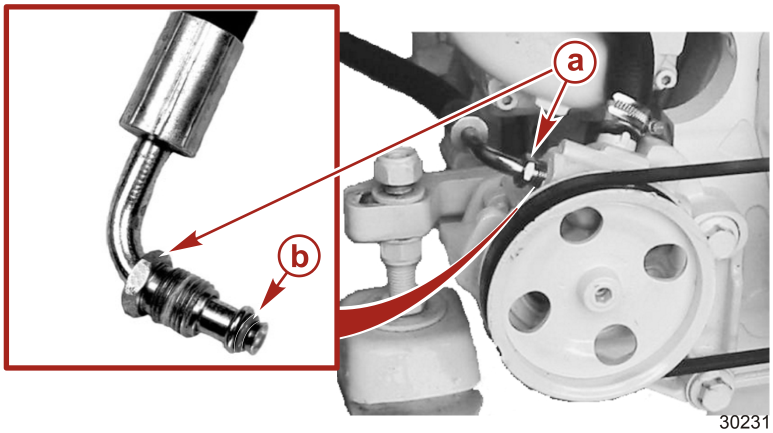
4. Install the power-assisted steering pump assembly onto the engine. Finger-tighten the mounting screws.

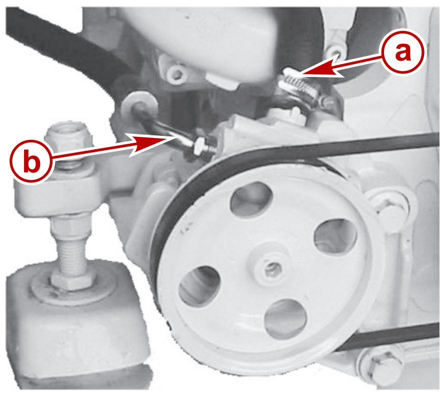


a - Power-assisted steering pump assembly
b - Upper mounting screw
c - Lower mounting screw

5. Install the reservoir supply hose and pressure hose on the pump as shown. Ensure that the O-ring is in position on the pressure hose fitting.
6. Tighten the reservoir hose clamp securely.

7. Tighten the pressure hose fitting securely. Do not overtighten.



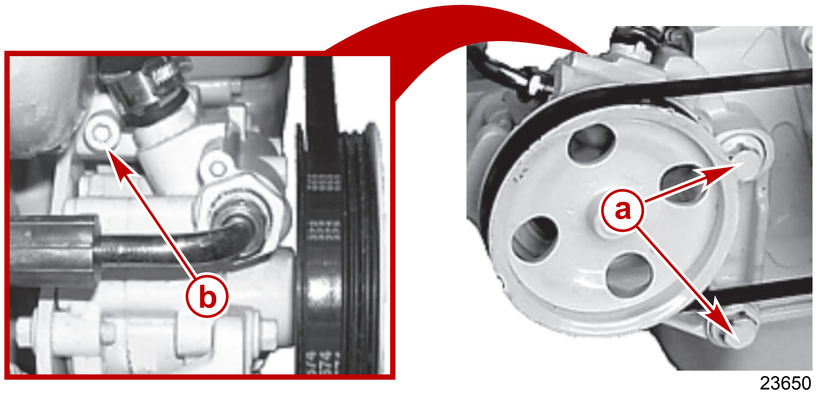


a - Reservoir hose with hose clamp
b - Pressure hose and fitting
c - O-ring

Description	Tightening procedure
Pressure hose fitting	Finger-tight + 1 3/4 to 2 1/4 turns with a wrench. Do not overtighten.

8. Install the power-assisted steering drive belt.

9. Use the adjustment screw to tension the power-assisted steering pump belt by moving the power-assisted steering pump.



a - Mounting screw
b - Adjustment screw

Power steering drive belt tension	
Belt deflection, with moderate hand pressure	5 mm (3/16 in.)

10. Tighten the upper and lower flange screws mounting the power-assisted steering pump assembly. Torque to specification.

Description	Nm	lb. in.	lb. ft.
Upper and lower mounting screw	21	185	–

NOTICE
Discharge of oil, coolant, or other engine/drive fluids into the environment is restricted by law. Use caution not to spill oil, coolant, or other fluids into the environment when using or servicing your boat. Be aware of the local restrictions governing the disposal or recycling of waste, and contain and dispose of fluids as required.

11. Ensure that the old fluid is completely drained from the power-assisted steering reservoir. Do not reuse fluid. Use a suitable container. Dispose of properly.
12. Fill the power-assisted steering reservoir with new power-assisted steering fluid.
13. Connect both battery cables.
14. Bleed the air from the power-assisted steering system. See **Filling and Bleeding**.

Hydraulic Hoses

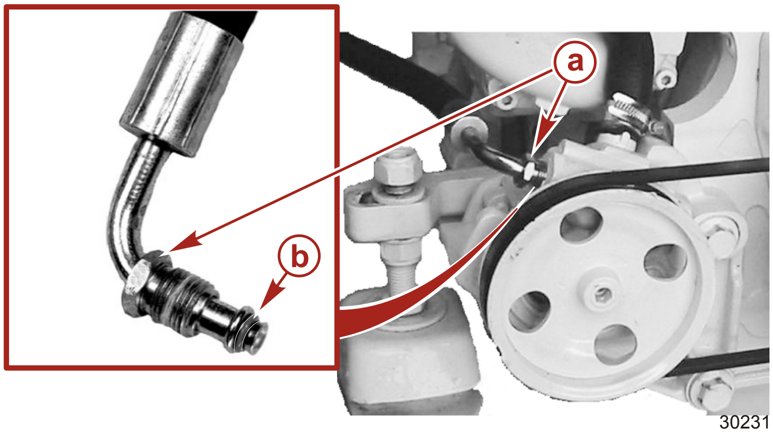
Pressure Hose—Pump to Control Valve

NOTE: Make fluid connections as quickly as possible to avoid fluid loss.

IMPORTANT: Cap or plug all open hydraulic connections.

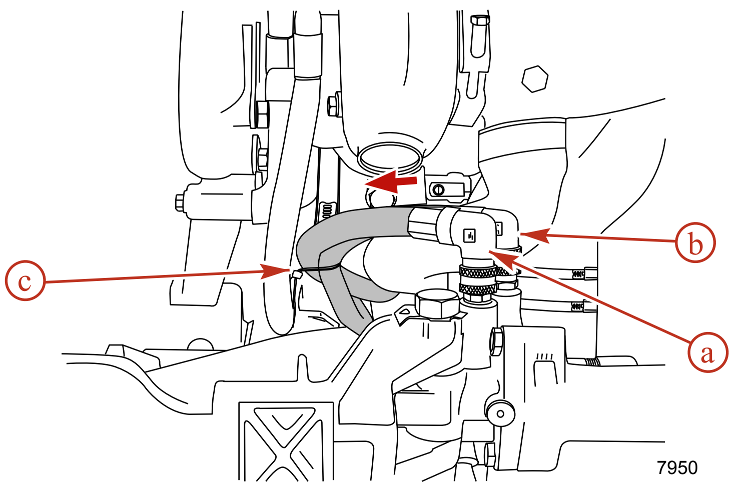
REMOVAL

1. Loosen the pressure hose fitting from the power-assisted steering pump. Note the position of the O-ring on the fitting.



a - Pressure hose
b - O-ring

2. Remove the pressure hose. Note the use of cable ties and the routing to the control valve.
3. Disconnect the pressure hose quick-connect fitting from the control valve.



a - Pressure hose—rear fitting
b - Return hose—front fitting
c - Cable tie

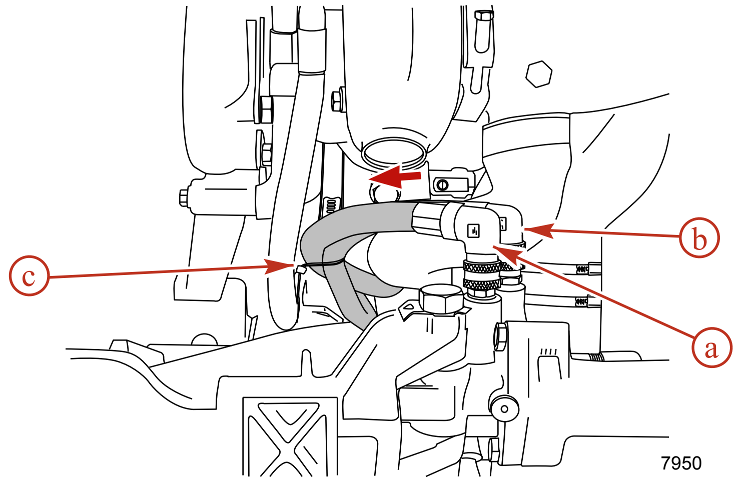
INSTALLATION

⚠ WARNING

Stress on hose fittings or kinks in the hoses can damage hydraulic steering components, leading to serious injury or death due to loss of boat control. Extreme heat can lower the hoses' burst pressure or melt the hose. Route hydraulic hoses to avoid kinks, heat sources, or stress on the hose fittings.

1. Route the hose as previously noted in removal, secure with cable ties.

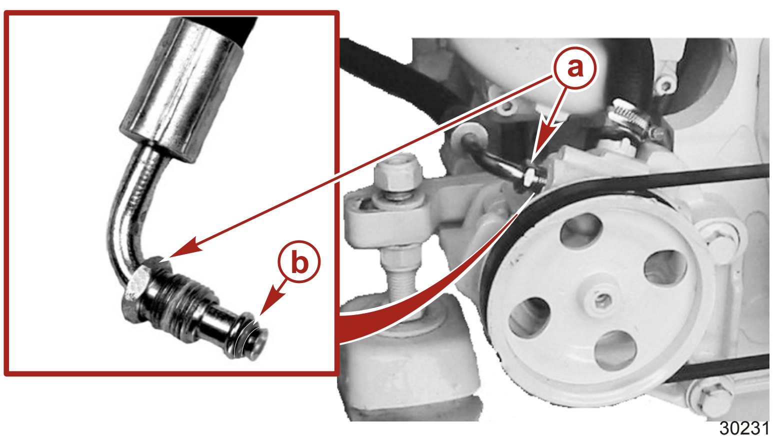
2. Connect the pressure hose to the control valve. Ensure that the quick-connect fitting snaps into place.



a - Pressure hose (rear fitting)
b - Return hose (front fitting)
c - Cable tie

IMPORTANT: Do not cross the threads or over-tighten the hose fitting.

3. Ensure there is a new O-ring on the pressure hose fitting. Install the fitting into the power-assisted steering pump.
4. Torque the pressure hose fitting.



a - Pressure hose fitting
b - O-ring

Description	Tightening procedure
Pressure hose fitting	Finger-tight + 1 3/4 to 2 1/4 turns with a wrench. Do not overtighten.

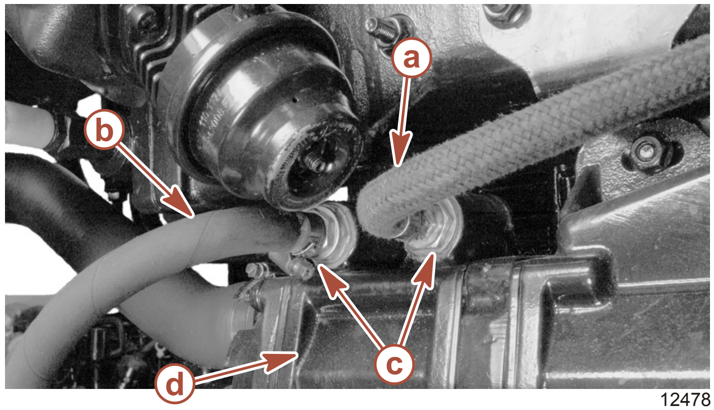
Return Hose—Control Valve to Fluid Cooler

NOTE: Make fluid connections as quickly as possible to avoid fluid loss.

IMPORTANT: Cap or plug all open hydraulic connections.

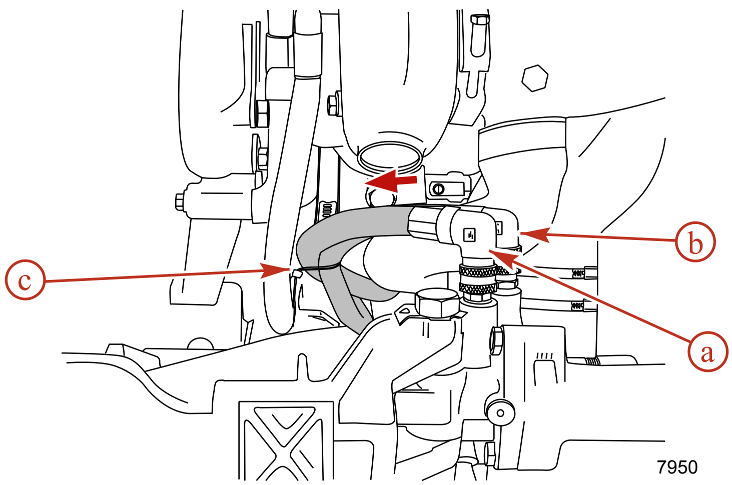
REMOVAL

1. Loosen the clamp on the return hose from the control valve at the fluid cooler for the power-assisted steering.



a - Return hose to fluid reservoir
b - Return hose from control valve
c - Fluid cooler fittings
d - Fluid cooler

2. Remove the return hose. Note the location of cable ties and the routing to the control valve.
3. Disconnect the return hose quick-connect fitting from the control valve.



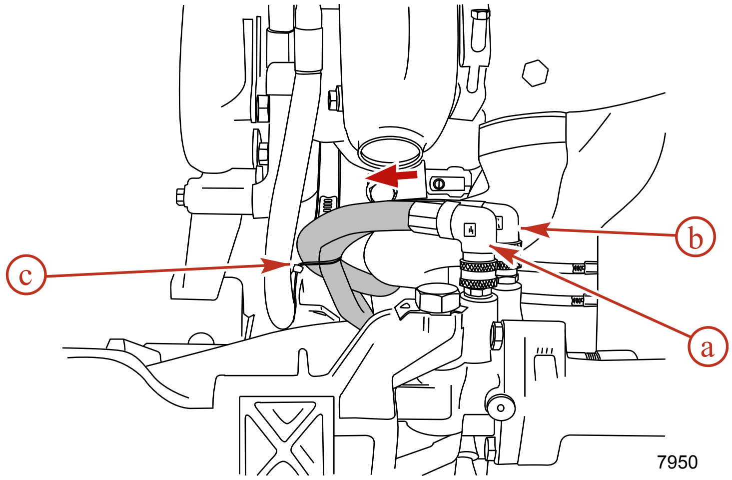
a - Pressure hose (rear fitting)
b - Return hose (front fitting)
c - Cable tie

INSTALLATION

> **⚠ WARNING**
>
> **Stress on hose fittings or kinks in the hoses can damage hydraulic steering components, leading to serious injury or death due to loss of boat control. Extreme heat can lower the hoses' burst pressure or melt the hose. Route hydraulic hoses to avoid kinks, heat sources, or stress on the hose fittings.**

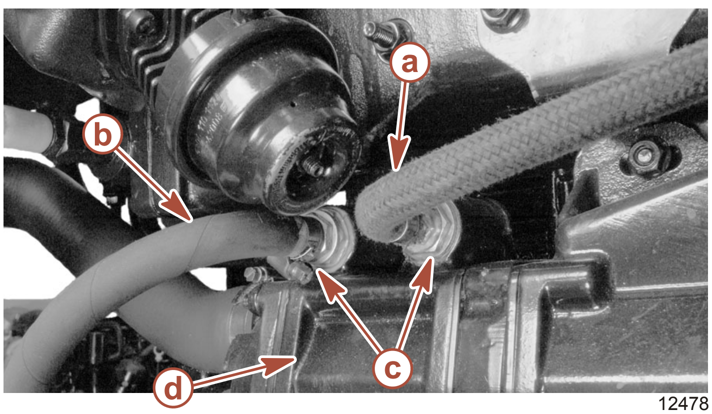
1. Route the hose as previously noted in removal, secure with cable ties.

2. Connect the return hose to the control valve. Ensure that the quick-connect fitting snaps into place.



a - Pressure hose (rear fitting)
b - Return hose (front fitting)
c - Cable tie

3. Install the return hose onto the fitting at the fluid cooler.
4. Securely tighten the clamp on the return hose.



a - Return hose to fluid reservoir
b - Return hose with clamp (from control valve)
c - Fluid cooler fittings
d - Fluid cooler

Fluid Cooler

For information and procedures regarding the removal, cleaning, inspection, and installation of the fluid cooler for the power-assisted steering system, refer to **Section 6**.

Fluid Level

Checking

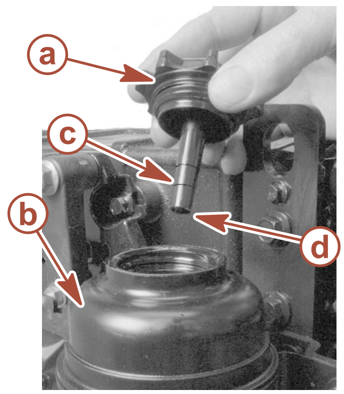
IMPORTANT: Use only Power Trim and Steering Fluid or automatic transmission fluid (ATF) Dexron III in the power-assisted steering system.

Tube Ref No.	Description	Where Used	Part No.
28	Dexron III Automatic	Power-assisted steering system	Obtain Locally

Tube Ref No.	Description	Where Used	Part No.
114	Power Trim and Steering Fluid	Power-assisted steering system	92-858074K01

CHECKING WITH THE ENGINE COLD

1. With the engine stopped, center the steering.
2. Remove the dipstick from the power-assisted steering fluid reservoir and observe the fluid level. The level should be between the full cold mark and the bottom of the dipstick.



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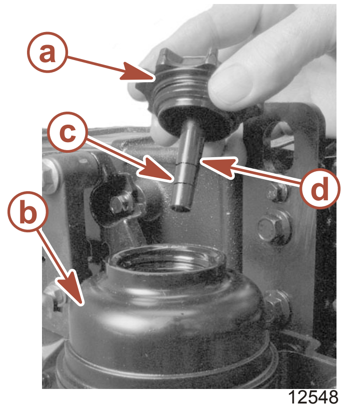
a - Dipstick
b - Power steering reservoir
c - Full cold mark
d - Bottom of dipstick

3. If the fluid level is below the bottom of the dipstick, but fluid is still visible in the reservoir, add the required amount of fluid to bring the level up to the full cold mark on the dipstick. Do not overfill.
4. If fluid is not visible in the reservoir, examine the system for leaks and correct as necessary.

CHECKING WITH THE ENGINE WARM

1. With the engine stopped, center the power-assisted steering.
2. Remove the dipstick from the power-assisted steering fluid reservoir and observe the fluid level.

3. The fluid level should be between the full hot mark and the full cold mark on the dipstick.



a - Dipstick
b - Power steering reservoir
c - Full cold mark
d - Full hot mark

4. If the fluid level is below the marks but fluid is visible in the reservoir, add fluid to bring the level up to the full hot mark on the dipstick. Do not overfill.
5. If fluid is not visible in the reservoir, examine the system for leaks and correct as necessary.

Filling and Bleeding

1. With the engine stopped, center the power-assisted steering.
2. Remove the dipstick from the power-assisted steering reservoir.

IMPORTANT: Use only Power Trim and Steering Fluid or automatic transmission fluid (ATF) Dexron III in the power-assisted steering system.

Tube Ref No.	Description	Where Used	Part No.
114	Power Trim and Steering Fluid	Power steering system	92-858074K01

Tube Ref No.	Description	Where Used	Part No.
28	Dexron III Automatic	Power-assisted steering system	Obtain Locally

3. Add the required amount of power-assisted steering fluid to bring the level up to the full cold mark on the dipstick. Do not overfill the reservoir.

IMPORTANT: All air must be removed from the system or the fluid in the pump may foam during operation and discharge from the pump reservoir. Foamy fluid can cause the power-assisted steering system to malfunction or result in poor steering assist.

4. With the engine stopped, turn the steering wheel at a moderate rate to the end of travel in each direction, pausing a few seconds at the end of travel to allow any air to bubble from the reservoir. Do this a minimum of five complete cycles. Recheck the fluid level and adjust if necessary.
5. Install the dipstick.

NOTICE
Without sufficient cooling water, the engine, the water pump, and other components will overheat and suffer damage. Provide a sufficient supply of water to the water inlets during operation.

6. Supply cooling water to the water inlet holes.

7. Start the engine and operate at a fast idle until the engine reaches normal operating temperature. During this time, slowly turn the steering wheel to the end of travel in each direction several times.

IMPORTANT: The sterndrive must be centered and power-assisted steering fluid must be hot to accurately check the fluid level.

8. With the engine stopped, center the steering. Remove the dipstick from the reservoir. Allow any foam in the pump reservoir to disperse, then check the fluid level. Do not overfill.
9. If the fluid is still foamy, repeat steps 6 and 7 until the fluid does not foam and the fluid level remains constant.
10. Install the dipstick.

Notes: