YAMAHA

BY series

SERVICE MANUAL

4BY2
6BY2

P/N: 0BBY0-U00200

MARINE ENGINES

This *Service Manual* has been developed for the exclusive use of service and repair professionals such as Yanmar authorized Distributors and Yanmar authorized Dealers. It is written with these professionals in mind and may not contain the necessary detail or safety statements that may be required for a non-professional to perform the service or repair properly and / or safely. Please contact an authorized Yanmar repair or service professional before working on your Yanmar product.

Disclaimers:

All information, illustrations and specifications in this manual are based on the latest information available at the time of publishing. The illustrations used in this manual are intended as representative reference views only. Moreover, because of our continuous product improvement policy, we may modify information, illustrations, and / or specifications to explain and / or exemplify a product, service, or maintenance improvement. We reserve the right to make any change at any time.

0409

California
Proposition 65 Warning

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

California
Proposition 65 Warning

Battery posts, terminals, and related accessories contain lead and lead compounds, chemicals known to the state of California to cause cancer and reproductive harm.
Wash hands after handling.

TABLE OF CONTENTS

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Section 1

INTRODUCTION

This manual gives specific instructions for the proper repair of Yanmar BY2 series marine engines.

Please follow the procedures carefully to ensure quality service.

Yanmar recommends that you read this *Service Manual* completely before starting repairs.

Along with standard tools, Yanmar recommends the use of special tools necessary to perform repairs correctly.

Yanmar products are continuously undergoing improvement. This *Service Manual* has been checked carefully in order to avoid errors. However Yanmar is not liable for any misrepresentations, errors of description or omissions. Contact the regional headquarters for any questions you have regarding this *Service Manual.*

REVISION HISTORY

This manual is a living document. Periodic manual revisions are published to document product improvements and changes. This practice ensures the manual has the most current information.

As manual revisions become necessary, individual pages are prepared and sent to those who need the information. If a page, or number of pages should be replaced, the replacement information is sent along with a revised Revision Control Table. Discard the older, obsolete information.

At times, the revision involves inserting additional pages in one or more sections. Replace the Revision Control Table and insert the new pages.

This method of revision control represents the most cost-effective solution to providing current, updated information as needed.

Revision Control Table

Revision Date Revision Number	New Page Numbers Involved	Remarks	Initiating Dept.
APR 2009	All	Initial release	YMI

Section 2

SAFETY

Yanmar is concerned for your safety and the condition of your marine engine. Safety statements are one of the primary ways to call your attention to the potential hazards associated with Yanmar Marine engines. Follow the precautions listed throughout the manual before operation, during operation and during periodic maintenance procedures for your safety, the safety of others and to protect the performance of your marine engine. Keep the decals from becoming dirty or torn and replace them if they are lost or damaged. Also, if a part needs to be replaced that has a decal attached to it, make sure to order the new part and decal at the same time.

This safety alert symbol appears with most safety statements. It means attention, become alert, your safety is involved! Please read and abide by the message that follows the safety alert symbol.

⚠ 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 can cause damage to the engine, personal property and / or the environment or cause the equipment to operate improperly.

SAFETY PRECAUTIONS

There is no substitute for common sense and careful practices. Improper practices or carelessness can cause burns, cuts, mutilation, asphyxiation, other bodily injury or death. This information contains general safety precautions and guidelines that must be followed to reduce risk to personal safety. Special safety precautions are listed in specific procedures. Read and understand all of the safety precautions before operating or performing repairs or maintenance.

⚠ DANGER

The safety messages that follow have DANGER level hazards.

NEVER permit anyone to install or operate the engine without proper training.

- Read and understand this *Service Manual* before operating or servicing the engine to ensure that safe operating practices and maintenance procedures are followed.
- Safety signs and decals are additional reminders for safe operating and maintenance techniques.
- Contact your Yanmar RHQ for additional training.

Crush Hazard

When attaching an engine to a repair stand, be sure to use a stand of adequate capacity to safely support the engine to be repaired, and that it is securely attached to the engine.

NEVER stand under a hoisted engine. If the hoist mechanism fails, the engine will fall on you.

ALWAYS secure the engine solidly to prevent the engine from falling during maintenance.

⚠ WARNING

The safety messages that follow have WARNING level hazards.

Explosion Hazard

While the engine is running or the battery is charging, hydrogen gas is being produced and can be easily ignited. Keep the area around the battery well-ventilated and keep sparks, open flame and any other form of ignition out of the area.

ALWAYS turn off the battery switch (if equipped) or disconnect the negative (-) battery cable before servicing the equipment.

Fire and Explosion Hazard

Diesel fuel is flammable and explosive under certain conditions.

NEVER use a shop rag to catch the fuel.

Wipe up all spills immediately.

NEVER refuel with the engine running.

Store any containers containing fuel in a well-ventilated area, away from any combustibles or sources of ignition.

⚠ WARNING

Fire Hazard

Have appropriate safety equipment available. Have all fire extinguishers checked periodically for proper operation and / or readiness.

ALWAYS read and follow safety-related precautions found on containers of hazardous substances like parts cleaners, primers, sealants and sealant removers.

Undersized wiring systems can cause an electrical fire.

Coolant may be flammable under certain conditions. NEVER allow coolant to come into contact with hot surfaces or insulation material.

Entanglement Hazard

NEVER leave the key in the key switch when servicing the engine. Attach a “Do Not Operate” tag near the key switch while performing maintenance on the equipment.

ALWAYS stop the engine before beginning service.

If the engine must be serviced while it is operating, remove all jewelry, tie back long hair and keep hands, other body parts and clothing away from moving / rotating parts.

Piercing Hazard

Avoid skin contact with high-pressure diesel fuel spray caused by a fuel system leak such as a broken fuel injection line. High-pressure fuel can penetrate your skin and result in serious injury. If you are exposed to high-pressure fuel spray, obtain prompt medical treatment.

NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard.

Flying Object Hazard

ALWAYS wear eye protection when servicing the engine or when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.

Coolant Hazard

Wear eye protection and rubber gloves when handling Long Life Coolant (LLC). If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.

⚠ WARNING

Sever Hazard

NEVER wear jewelry, unbuttoned cuffs, ties or loose-fitting clothing and ALWAYS tie long hair back when working near moving / rotating parts such as the flywheel or PTO shaft. Keep hands, feet and tools away from all moving parts.

The propeller may rotate during towing or if the engine is running at idle speed. NEVER service the engine while being towed or when the engine is running.

If the vessel has more than one engine, NEVER service an engine if either of the engines is running. In multi-engine configurations the propeller for an engine that is shut down may rotate if any of the other engines are running.

NEVER operate the engine without the guards in place.

NEVER operate the engine while wearing a headset to listen to music or radio because it will be difficult to hear the warning signals.

Electrical Hazard

Make welding repairs safely.

- ALWAYS turn off the battery switch (if equipped) or disconnect the negative (-) battery cable and the leads to the alternator when welding on the equipment.
- Remove the multi-pin connector to the engine control unit. Connect the weld clamp to the component to be welded and as close as possible to the welding point.
- NEVER connect the weld clamp to the engine or in a manner which would allow current to pass through a mounting bracket.
- When welding is complete, reconnect the leads to the alternator and engine control unit prior to reconnecting the batteries.

ALWAYS keep the electrical connectors and terminals clean. Check the electrical harnesses for cracks, abrasions and damaged or corroded connectors.

NEVER turn off the battery switch (if equipped) or short the battery cables during operation. Damage to the electrical system will result.

Exhaust Hazard

All internal combustion engines create carbon monoxide gas during operation and special precautions are required to avoid carbon monoxide poisoning.

- NEVER block windows, vents or other means of ventilation if the engine is operating in an enclosed area.
- ALWAYS ensure that all connections are tightened to specifications after repair is made to the exhaust system.

Burn Hazard

Some of the engine surfaces become very hot during operation and shortly after shutdown.

- Keep hands and other body parts away from hot engine surfaces.
- Handle hot components with heat-resistant gloves.

Sudden Movement Hazard

To prevent accidental equipment movement, NEVER start the engine in gear.

Shift the marine gear into the NEUTRAL position any time the engine is at idle.

⚠ WARNING

Lifting Hazard

The engine lifting eyes are engineered to lift the weight of the marine engine only. ALWAYS use the engine lifting eyes when lifting the engine.

Additional equipment is necessary to lift the marine engine and marine gear together. ALWAYS use lifting equipment with sufficient capacity to lift the marine engine.

If transport is needed for engine repair, have a helper assist in attaching it to a hoist and loading it onto a truck.

Alcohol and Drug Hazard

NEVER operate the engine while under the influence of alcohol, drugs or when ill.

Exposure Hazard

ALWAYS wear personal protective equipment including appropriate clothing, gloves, work shoes and eye and hearing protection as required by the task at hand.

Tool Hazard

ALWAYS remove any tools or shop rags used during maintenance from the area before operation.

⚠ CAUTION

The safety messages that follow have CAUTION level hazards.

Poor Lighting Hazard

Ensure that the work area is adequately illuminated. ALWAYS install wire cages on portable safety lamps.

Tool Hazard

ALWAYS use tools appropriate for the task at hand and use the correct size tool for loosening or tightening machine parts.

NOTICE

The safety messages that follow have NOTICE level hazards.

Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.

ALWAYS tighten components to the specified torque. Loose parts can cause equipment damage or cause it to operate improperly.

Only use replacement parts specified. Other replacement parts may affect warranty coverage.

NEVER attempt to modify the engine design or safety features such as defeating the engine speed limit control or the diesel fuel injection quantity control.

Modifications may impair the engine's safety and performance characteristics and shorten the engine's life. Any alterations to this engine may void its warranty. Be sure to use Yanmar genuine replacement parts.

Follow the guidelines of the EPA or other governmental agencies for the proper disposal of hazardous materials such as engine oil, diesel fuel and engine coolant. Consult the local authorities or reclamation facility.

NEVER dispose of hazardous materials by dumping them into a sewer, on the ground or into groundwater or waterways.

If any indicator illuminates during engine operation, stop the engine immediately. Determine the cause and repair the problem before continuing to operate the engine.

Make sure the engine is installed on a level surface. If a Yanmar Marine engine is installed at an angle that exceeds the specifications stated in the Yanmar Marine *Installation Manuals*, engine oil may enter the combustion chamber causing excessive engine speed, white exhaust smoke and serious engine damage. This applies to engines that run continuously or those that run for short periods of time.

Section 3

GENERAL SERVICE INFORMATION

Page

SAFETY PRECAUTIONS

⚠ WARNING

Fire Hazard

Undersized wiring systems can cause an electrical fire.

Electrical Hazard

ALWAYS keep the electrical connectors and terminals clean. Check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors.

NEVER turn off the battery switch (if equipped) or short the battery cables during operation. Damage to the electrical system will result.

ENGINE OUTLINE DRAWINGS

Note: All dimensions are metric. Contact Yanmar Marine for the most current drawings.

4BY2 (Inboard)

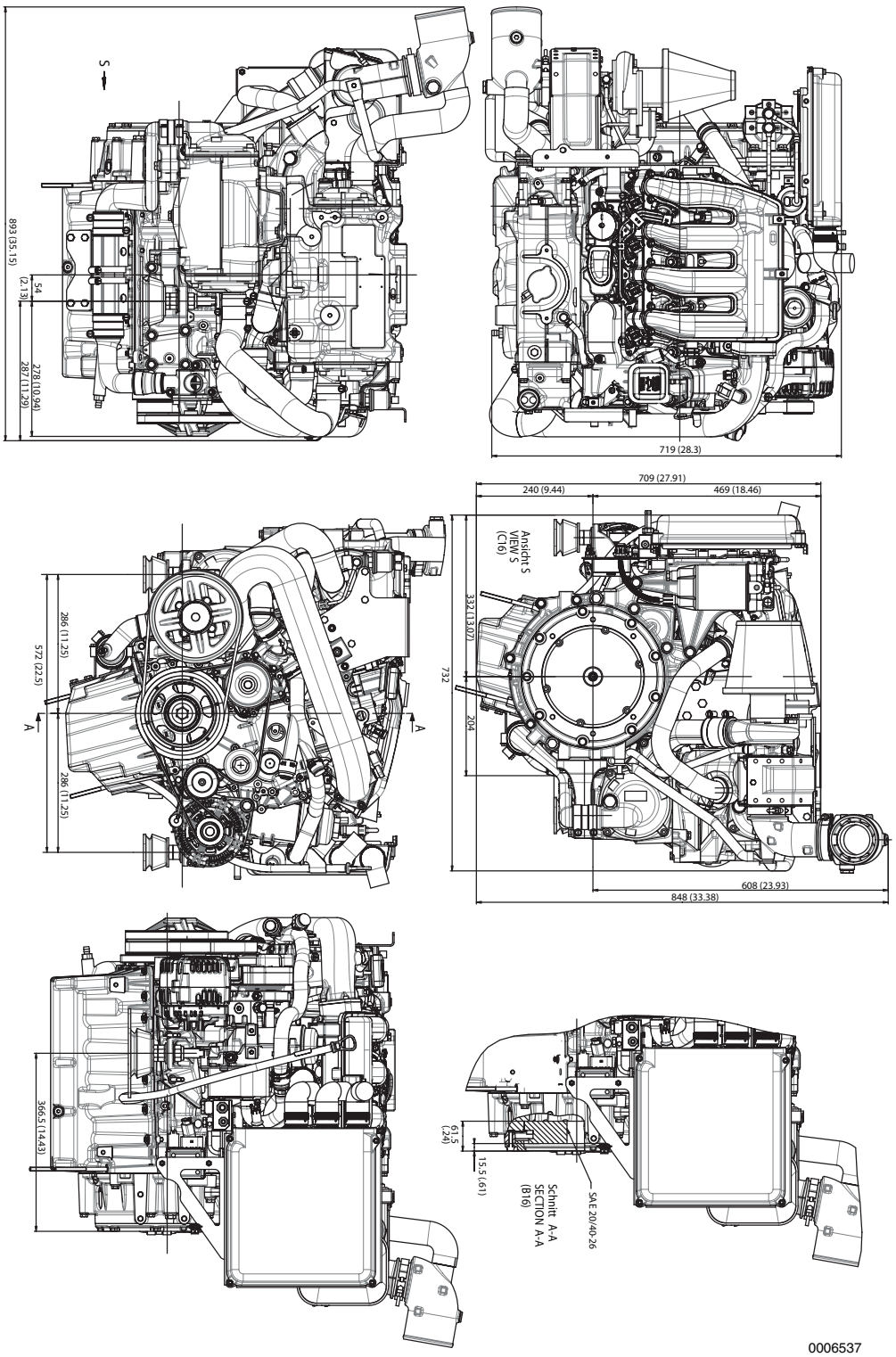

Figure 3-1

4BY2 (Stern Drive)

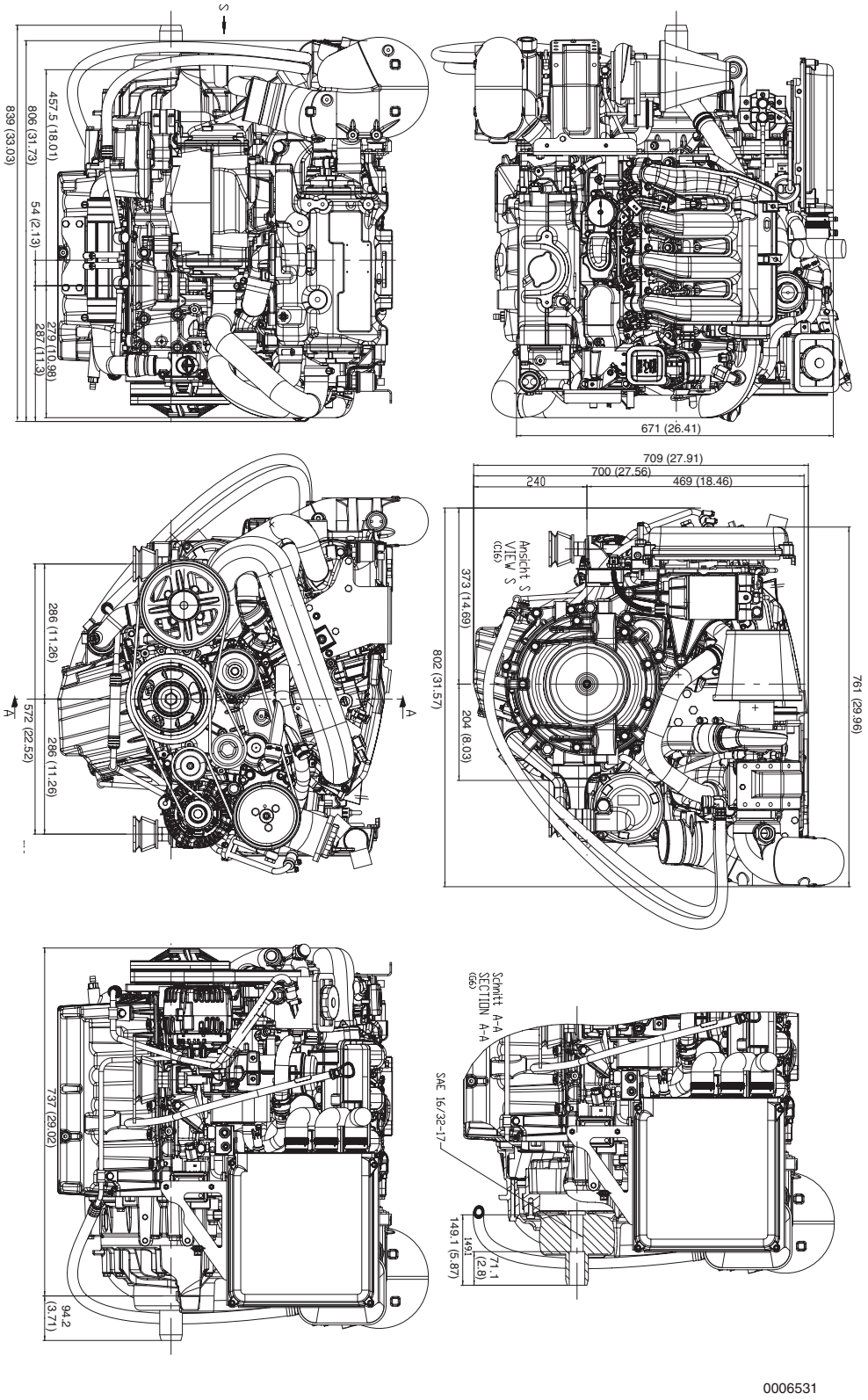

Figure 3-2

6BY2 (Inboard)

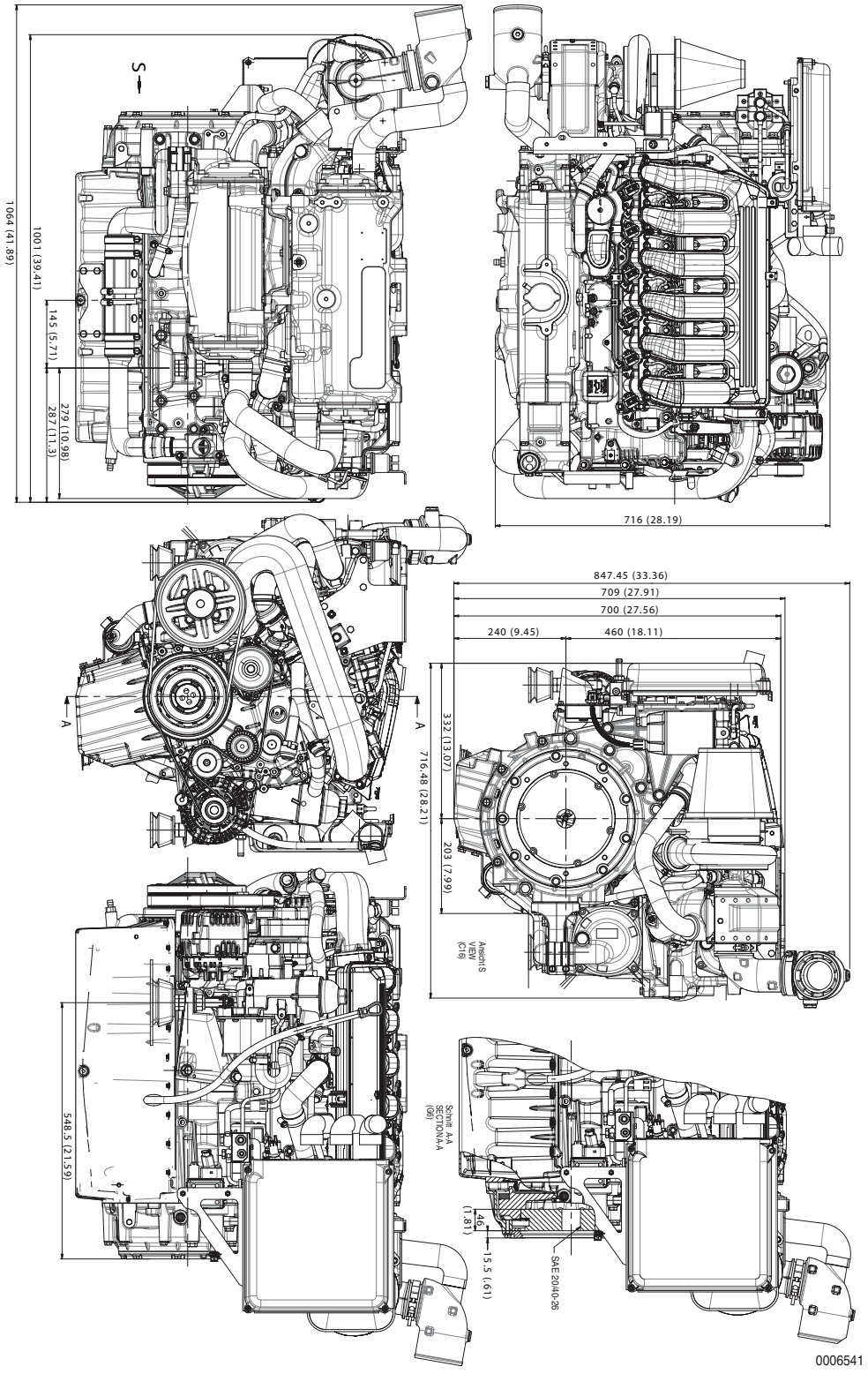

Figure 3-3

6BY2 (Stern Drive)

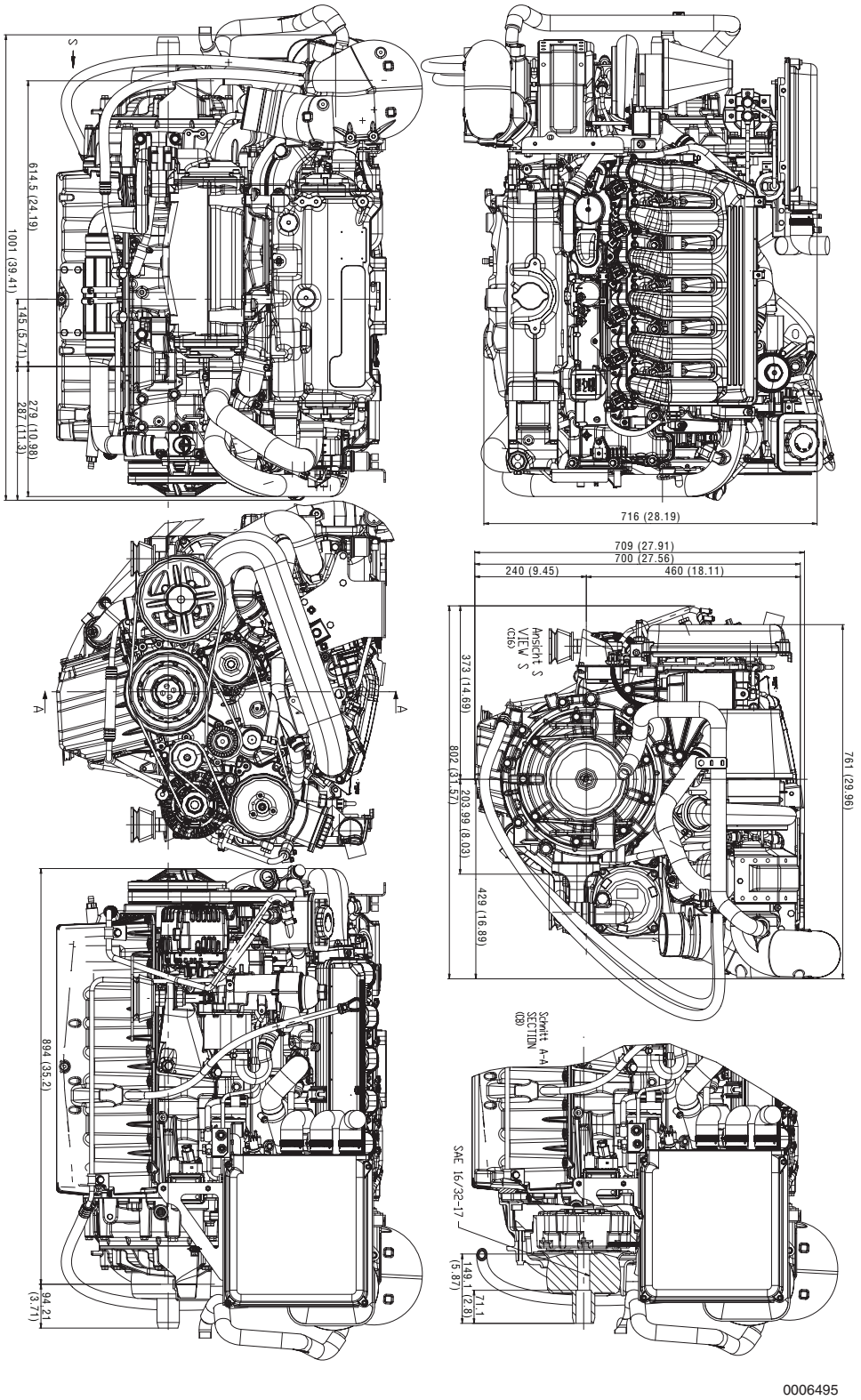

Figure 3-4

ENGINE PIPING DIAGRAMS

4BY2

Fuel Flow

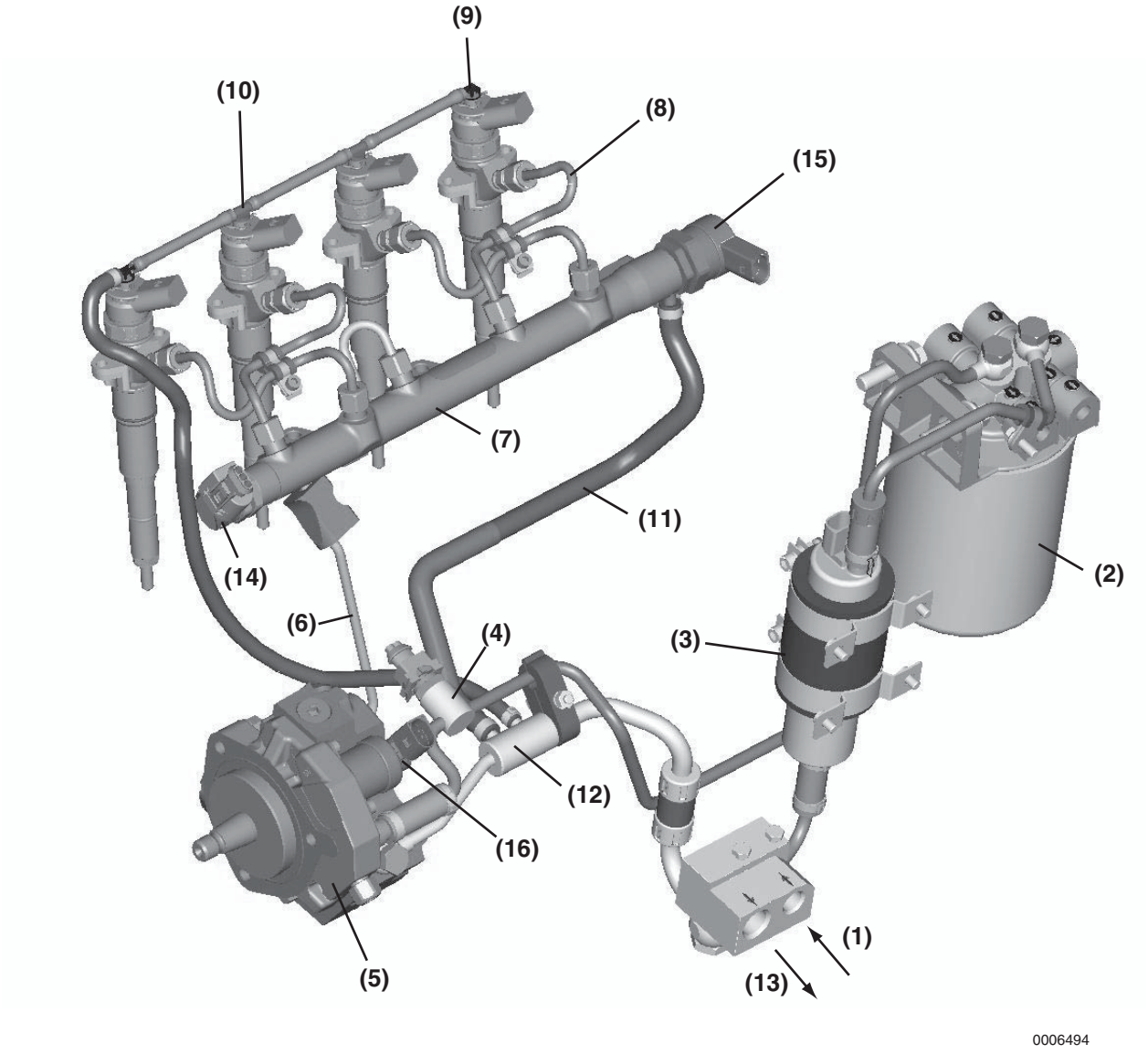

Figure 3-5

1 – Fuel Inlet from Tank
2 – Fuel Fine Filter
3 – Fuel Feed Pump
4 – Inlet Fuel Temperature Sensor
5 – High-Pressure Fuel Pump
6 – High-Pressure Fuel Supply Line
7 – High-Pressure Fuel Common Rail
8 – Fuel Injection Line
9 – Fuel Injector
10 – Fuel Injector Return Hose
11 – Common Rail Return Line
12 – Return Fuel Tee with Back Pressure Valve
13 – Return Fuel to Fuel Tank with Over Pressure Valve
14 – High-Pressure Fuel Rail Pressure Sensor
15 – High-Pressure Fuel Regulator (ECU-Controlled)
16 – Fuel Volume Regulator (ECU-Controlled)

6BY2

Fuel Flow

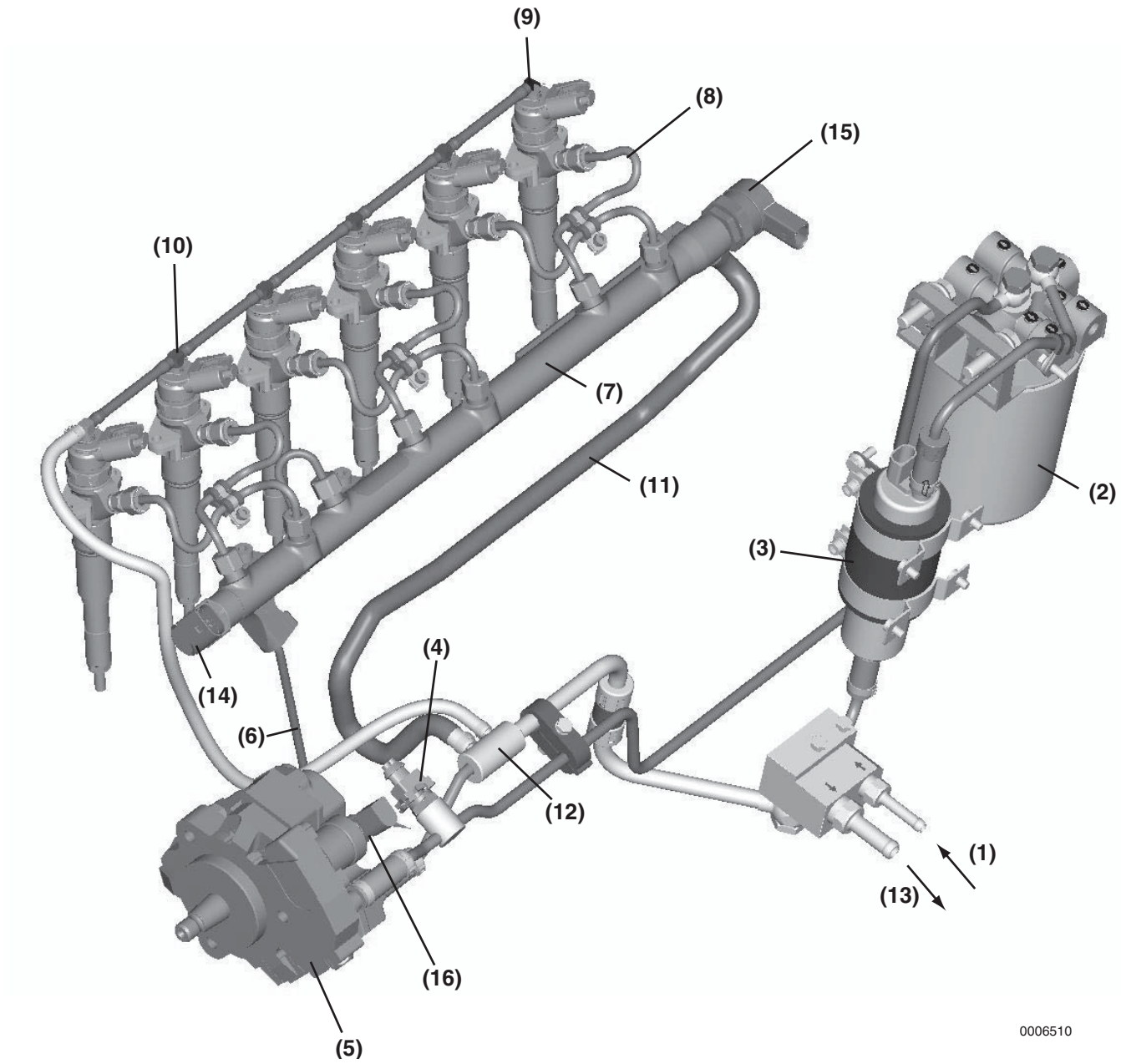

Figure 3-6

1 – Fuel Inlet from Tank
2 – Fuel Fine Filter
3 – Fuel Feed Pump
4 – Inlet Fuel Temperature Sensor
5 – High-Pressure Fuel Pump
6 – High-Pressure Fuel Supply Line
7 – High-Pressure Fuel Rail
8 – Fuel Injection Line
9 – Fuel Injector
10 – Fuel Injector Return Hose
11 – Common Rail Return Line
12 – Return Fuel Tee with Back Pressure Valve
13 – Return Fuel to Fuel Tank with Over Pressure Valve
14 – High-Pressure Fuel Rail Pressure Sensor
15 – High-Pressure Fuel Regulator (ECU-Controlled)
16 – Fuel Volume Regulator (ECU-Controlled)

Cooling Flow

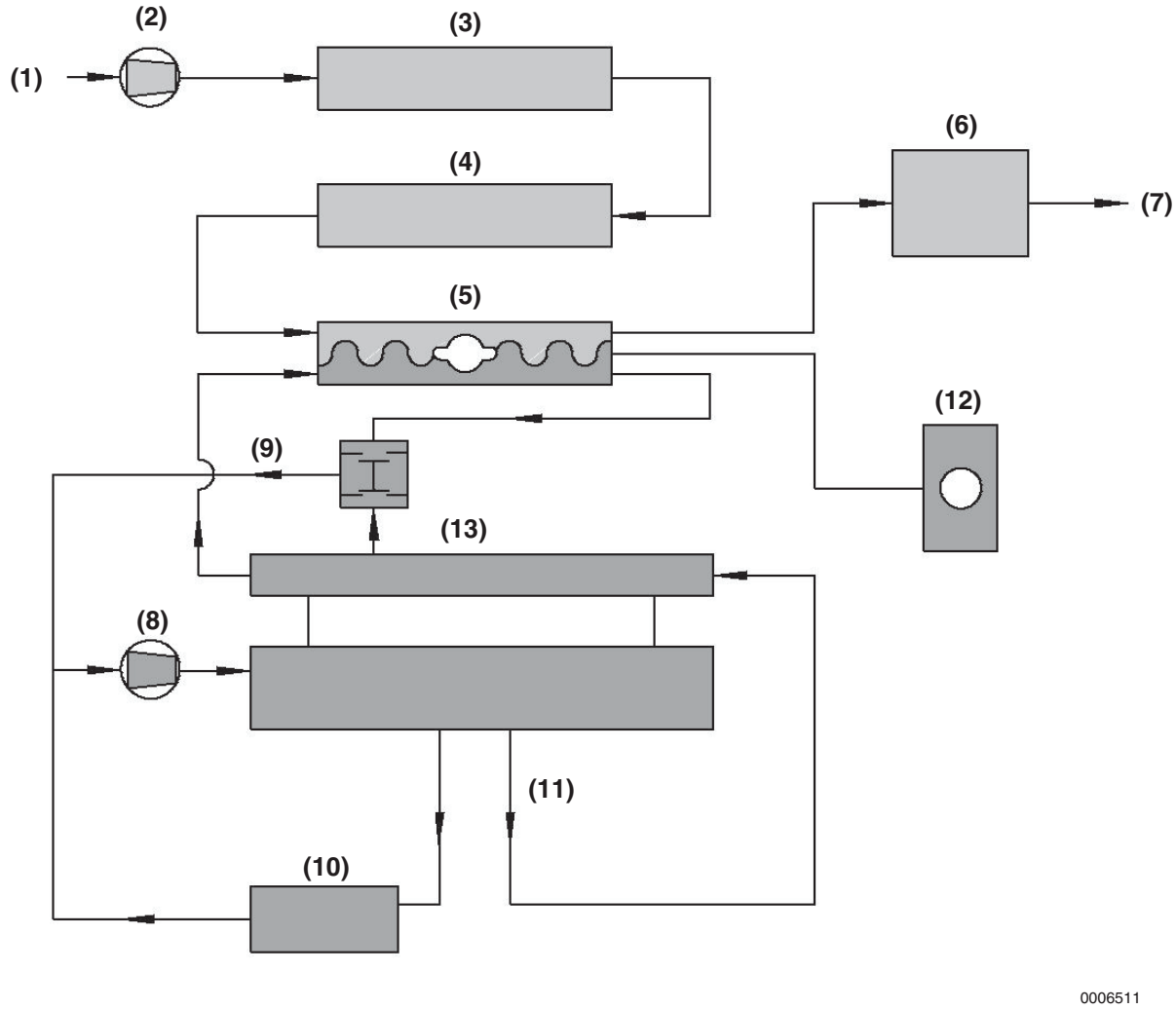

Figure 3-7

Note: Typical 4BY2 engine shown. 6BY2 is similar.

1 – Seawater Supply
2 – Seawater Pump
3 – Hydraulic Oil Cooler
4 – Charge Air Cooler
5 – Engine Heat Exchanger
6 – Exhaust Seawater Mixing Elbow
7 – Exhaust / Seawater Exit
8 – Engine Coolant Pump
9 – Thermostat
10 – Engine Oil Cooler
11 – Engine Coolant Passages
12 – Coolant Recovery Tank
13 – Water Cooled Exhaust Manifold

LOCATION OF NAMEPLATES

The following figures show the location of informational nameplates on Yanmar BY2 marine engines.

Engine Nameplates (Typical)

The typical location of the engine nameplates is shown for Yanmar 4BY2 Series marine engines **(Figure 3-8)**. 6BY2 engines are similar.

Engine Data and Drive Information Nameplates

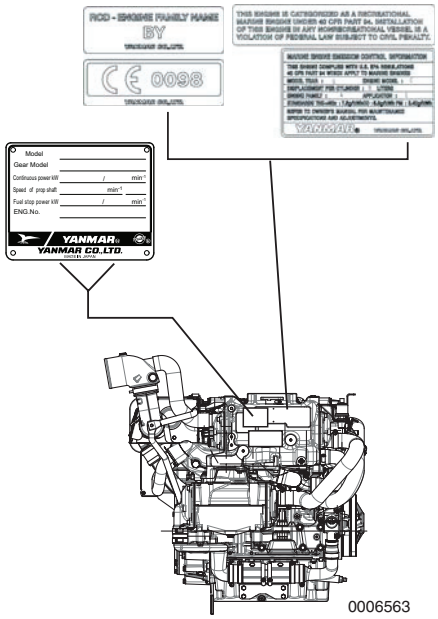

Figure 3-8

Engine Block Serial Identification

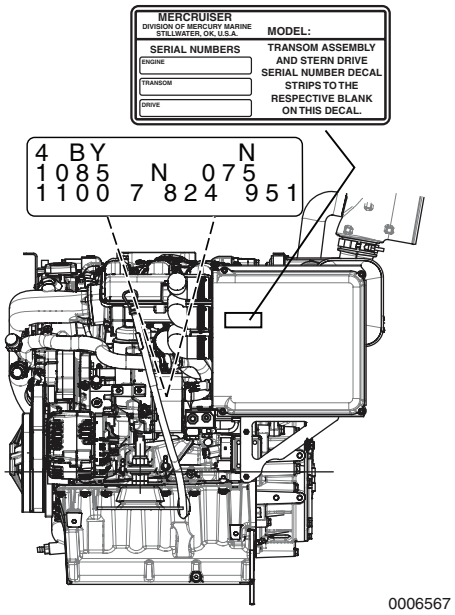

Figure 3-9

The engine block information identification is etched into the cylinder block and is located behind the engine oil cooler near the end of the starting motor.

DIESEL FUEL

Diesel Fuel Specifications

Diesel fuel should comply with the following specifications. The table lists several specifications for diesel fuels.

DIESEL FUEL SPECIFICATION	LOCATION
No. 2-D, No. 1-D, ASTM D975-94	USA
EN590:96	European Union

Additional Technical Fuel Requirements

- The fuel cetane number should be equal to 48 or higher.
- The sulfur content must not exceed 0.3% by volume. Less than 0.05% is preferred.
- Water and sediment in the fuel should not exceed 0.05% by volume.
- Ash content not to exceed 0.01% by mass.
- Carbon residue content not to exceed 0.35% by volume. Less than 0.1% is preferred.
- Total aromatics content should not exceed 35% by volume. Less than 30% is preferred.
- PAH (polycyclic aromatic hydrocarbons) content should be below 10% by volume.
- NEVER mix kerosene, used engine oil, or residual fuels with the diesel fuel.
- NEVER use Biocide or mix winter and summer fuels.
- Keep the fuel tank and fuel-handling equipment clean at all times.
- Poor quality fuel can reduce engine performance and / or cause engine damage.
- Fuel additives are not recommended. Some fuel additives may cause poor engine performance.

Biodiesel Fuels

Yanmar approves the use of biodiesel fuels that do not exceed a blend of 5% non-mineral oil based fuel with 95% standard diesel fuel. Such biodiesel fuels are known in the marketplace as B5 biodiesel fuels. B5 biodiesel fuel can reduce particulate matter and the emission of “greenhouse” gases compared to standard diesel fuel. *NOTICE: If the B5 biodiesel fuel used does not meet the approved specifications, it will cause abnormal wear of injectors, reduce the life of the engine and it may affect the warranty coverage of the engine.*

The biodiesel fuels must meet the minimum specifications for the country in which they are used:

- In Europe, biodiesel fuels must comply with the European Standard EN14214.
- In the United States, biodiesel fuels must comply with the American Standard ASTM D-6751.

Biodiesel should be purchased only from recognized and authorized diesel fuel suppliers.

Precautions and concerns regarding the use of bio-fuels:

- Biodiesel fuels have a higher content of methyl-esters, which may deteriorate certain metal, rubber and plastic components of the fuel system. The customer and / or boat builder are responsible to verify the usage of biodiesel compatible components on the vessel fuel supply and return systems.
- Free water in biodiesel may result in plugging of fuel filters and increased bacterial growth.
- High viscosity at low temperatures may result in fuel delivery problems, injection pump seizures and poor injection nozzle spray atomization.
- Biodiesel may have adverse effects on some elastomers (seal materials) and may result in fuel leakage and dilution of the engine lubricating oil.
- Even biodiesel fuels that comply with a suitable standard as delivered, will require additional care and attention to maintain the quality of the fuel in the equipment or other fuel tanks. It is important to maintain a supply of clean, fresh fuel. Regular flushing of the fuel system, and / or fuel storage containers, may be necessary.
- The use of biodiesel fuels that do not comply with the standards as agreed to by the diesel engine manufacturers and the diesel fuel injection equipment manufacturers, or biodiesel fuels that have degraded as per the precautions and concerns above, may affect the warranty coverage of the engine.

Diesel Fuel Lines

Shown is a typical installation of a boat fuel system. Fuel supply **(Figure 3-10, (2))** and return **(Figure 3-10, (4))** lines connect to fittings at the engine.

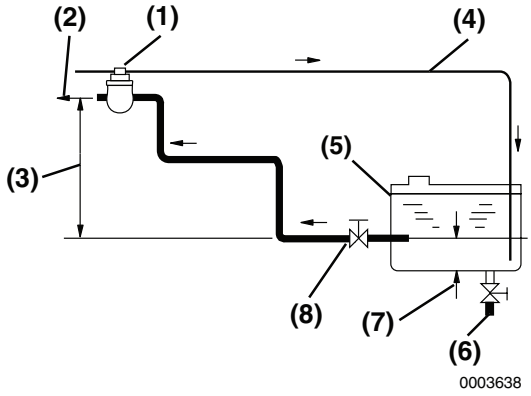

Figure 3-10

1 – Optional Boat Builder Installed Fuel Filter / Water Separator*
2 – To Fuel Feed Pump
3 – Less than 500 mm (19.68 in.)
4 – Fuel Return Line
5 – Fuel Tank
6 – Fuel Tank Drain Cock
7 – 20 to 30 mm (0.75 to 1.125 in.)
8 – Fuel Shutoff Valve

*Note: Yanmar supplies a water separating pre-filter for mounting by the installer. The engine is also equipped with an on-engine fine filter.

NOTICE: The fuel supply line between the fuel tank and engine must be a minimum diameter of 8 mm (0.315 in.).

Install a drain cock **(Figure 3-10, (6))** at the bottom of the fuel tank to remove water and contaminants.

Boat fuel supply system restriction must not exceed 1000 mmAq (39.37 in.Aq).

Boat fuel return system restriction must not exceed 200 mmAq (7.87 in.Aq).

Bleeding the Fuel System

The fuel system needs to be bled under certain conditions. *See Bleed the Fuel System on page 6-22.*

- Starting the engine for the first time.
- After running out of fuel and fuel has been added to the fuel tank.
- After fuel system maintenance such as changing fuel filters, draining the fuel filter / water separator, or replacing a fuel system component.

NOTICE: NEVER crank the engine using the starter motor to prime the fuel system. This may cause the starter motor to overheat and damage the starter.

ENGINE OIL

Engine Oil Specifications

NOTICE: Only use the engine oil specified. Other engine oils may affect warranty coverage, cause internal engine components to seize and / or shorten engine life. NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil.

Use a full-synthetic long-life engine oil that meets or exceeds the following guidelines and classifications:

Service Categories

- API Service Categories SM, SL, SJ, SH/CF and CF
- ACEA Service Categories A3, B3 and B4

Definitions

- API Classification (American Petroleum Institute)
- ACEA Classification (Association des Constructeurs Européens d'Automobilies)

NOTICE:

1. *Be sure the engine oil, engine oil storage containers and engine oil filling equipment are free of sediment and water.*
2. *Change the engine oil after the first 50 hours of operation and then at every 250 hours (or annually) thereafter.*
3. *Select the oil viscosity based on the ambient temperature where the engine is being operated. See the SAE Service Grade Viscosity Chart* ***(Figure 3-11)****.*
4. *Yanmar does not recommend the use of engine oil "additives."*

Engine Oil Viscosity

Select the appropriate engine oil viscosity based on the ambient temperature shown in the SAE Service Grade Viscosity Chart **(Figure 3-11)**.

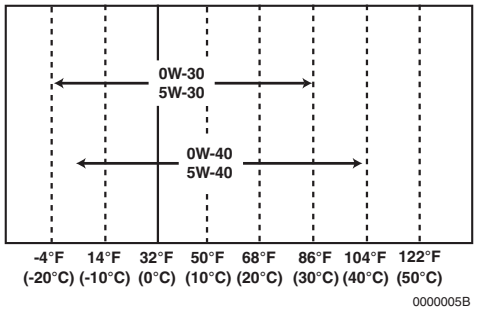

Figure 3-11

Note: Yanmar recommends using genuine Yanmar Marine oil, specifically formulated for the BY2 engine. *See Acceptable Engine Oil on page 3-16*.

NOTICE: If the equipment will be operated at temperatures outside the limits shown, special lubricants or starting aids must be used.

Acceptable Engine Oil

LongLife 01 Oils

Trade Name	Producer / Supplier
Addinol Super power MV 0537	Addinol Lube Oil GmbH
Agip Formula LL B 01	ENI S.p.A. Refining and Marketing Division
Agip Sint 2000 Evolution	ENI S.p.A. Refining and Marketing Division
Agip TECSINT SL	ENI S.p.A. Refining and Marketing Division
ALPINE Longlife	Mitan Mineralöl GmbH
Aral SuperTronic B	Aral
Aral SuperTronic G	Aral
AXCL S-Class Motor Oil	AXCL Gulf FZE
BMW Quality Longlife 01	BMW
BP Visco 7000	BP Oil International
BP Visco 7000 GM	BP Oil International
BP Visco 7000 Turbo Diesel	BP Oil International
Castrol Edge	Castrol Limited
Castrol Formula RS Power and Protection	Castrol Limited
Castrol Formula SLX	Castrol Limited
Castrol Formula SLX LL01	Castrol Limited
Castrol Formula SLX Long Tex	Castrol Limited
Castrol Formula SLX Turbodiesel	Castrol Limited
Castrol Syntec	Castrol Limited
Castrol Syntec 0W-30 European Formula	Castrol Limited
Castrol Super Racing 0W-40	Castrol Limited
Castrol TXT Softec LL01	Castrol Limited
Cepsa Star Mega Synthetic	Cepsa Lubricantes S.A.
Divinol Syntholight	Zeller+Gmelin
Elf Excellium Full-Tech	Total
Elf Excellium LDX	Total
Elf Excellium XLL	Total
Esso Ultron FE	ExxonMobil
Galp Formula XLD	Petrogal SA
Gulf Formula TLX	Total
Havoline Synthetic BM	Chevron Texaco
Havoline Ultra BM	Chevron Texaco
Igol Process Compact P	Igol France S.A.
INA Futura Compact P	INA Maziva Rijeka
Jet Top Level	ConocoPhillips GmbH
Labo RC	Fuchs Labo Auto S.A.
Liqui Moly Longtime High Tech	Liqui Moly

Trade Name	Producer / Supplier
Megol Motorenöl New Generation	Meguin GmbH
Mobil 1	ExxonMobil
Mobil 1 Turbo Diesel	ExxonMobil
Mobil 1 Spezial XS	ExxonMobil
Motorex Profile B-XL	Bucher AG
Motorex Select SP-X	Bucher AG
Motul Specific LL-01	Motul S.A.
OMV full syn plus	OMV AG
Opaljet Longlife	Unil Opal
Panolin Exclusive BD	Panolin AG
Pennzoil European Formula Ultra	Pennzoil-Quaker State
Pentospeed 0W-30 VS*	Deutsche Pentosin-Werke
Petronas Syntium 3000 LL	Petronas
Q8 Formula Special	Kuwait Petroleum
Quaker State European Formula Ultra	Pennzoil-Quaker State
Ravenol HCL	Ravensburger Schmierstoffvertrieb GmbH
Repsol Elite Common Rail	Repsol YPF
Shell Helix Ultra AB	Shell International Petroleum Company
Shell Helix Ultra AL	Shell International Petroleum Company
Statoli LazerWay B	Statoil Lubricants
Tecar Motorenöl Supersyn	Techno-Einkauf GmbH
Titan Supersyn SL	Fuchs Petrolub AG
Titan Supersyn SL Longlife	Fuchs Petrolub AG
Tor Synthetic LL	De Oliebron
Total Activa Expertise 9000	Total
Total Quartz Expertise 9000	Total
Valvoline SynPower MXL	Valvoline
Veedol Powertron LL01	Veedol International
Veedol Syntron	Veedol International
Veritas Syntolube	Ölwerke Julius Schindler GmbH
Wako's Super Synthe	Wako Chemical Co.Ltd
Wintershall VIVA 1 Longlife	SRS Schmierstoff Vertrieb GmbH
Yacco VX 1600	Yacco S.A.S.

LongLife 04 Oils

Trade Name	Producer / Supplier
Addinol Super power MV 0537	Addinol Lube Oil GmbH
Agip Formula MS B04	ENI S.p.A.
Aral SuperTronic	Aral
BMW Longlife-04	BMW
Castrol Edge Sport	Castrol Limited
Castrol Edge Turbo Diesel	Castrol Limited
Castrol Formula RS	Castrol Limited
Castrol GTX Magnatec	Castrol Limited
Castrol SLX LL-04	Castrol Limited
Castrol TXT LL-04	Castrol Limited
Elf Excellium LSX	Total
Galp Energy Ultra LS	Petrogal SA
Liqui Moly TopTec 4100	Liqui Moly
Midland ® Synova	Oel-Brack AG
Midland ® Synova	Oel-Brack AG
Mobil 1 ESP Formula	ExxonMobil
Motorenöl Low Emission	Meguin GmbH
Motul 1 Specific LL-04	Motul S.A.
OMV eco plus	OMV AG
Repsol Elite Evolution	Repsol YPF
Shell Helix Ultra AP	Shell International Petroleum Company
Titan GT1	Fuchs Petrolub AG
Wintershall VIVA 1 topsynth alpha LS	SRS Schmierstoff Vertrieb GmbH
York 848	Ginouves SAS

Recommended Marine Gear or Stern Drive Oil

Refer to the documentation supplied with each marine gear or stern drive.

Recommended Power Steering Fluid

Refer to the documentation supplied with each stern drive.

ENGINE COOLANT

WARNING! ***Fire Hazard. Coolant may be flammable under certain conditions. NEVER allow coolant to come into contact with hot surfaces or insulation material.***

CAUTION! ***Exposure Hazard. Wear protective rubber gloves and eye protection when handling Long Life Coolant Antifreeze. Flush eyes and exposed skin with water immediately after contact.***

Engine Coolant Specifications

Note: In the U.S., LLC is required for the warranty to be valid.

NOTICE: Following the manufacturer's recommendations, use a proper LLC which will not have any adverse effects on the materials (cast iron, aluminum, copper, etc.) of the engine's cooling system.

Engine Coolant Mixture

NOTICE: ALWAYS add LLC to soft water – especially when operating in cold weather. NEVER use hard water. Water should be clean and free from sludge or particles. Without LLC, cooling performance will decrease due to scale and rust in the coolant system. Water alone may freeze and form ice; it expands approximately 9% in volume. Use the proper amount of coolant concentrate for the ambient temperature as specified by the LLC manufacturer. LLC concentration should be a minimum of 30% to a maximum of 60%. Too much LLC will decrease the cooling efficiency. Excessive use of antifreeze also lowers the cooling efficiency of the engine. NEVER mix different types or brands of LLC, as a harmful sludge may form. Mixing different brands of antifreeze may cause chemical reactions, and may make the antifreeze useless or cause engine problems.

Remove scale from the cooling system periodically by flushing the system.

Acceptable Engine Coolant

Trade Name	Manufacturer
Addinol Antifreeze Super	Addinol Lube Oil GmbH
Aral Antifreeze Extra	Aral AG
AVIA Antifreeze APN	AVIA Mineralöl AG
BMW Coolant	BMW AG
BP anti-frost X 2270A	BP Schmierstoff GMBH, Hamburg
Caltex CX Engine Coolant	Caltex
Castrol ANTI-FREEZE NF	Castrol International
Fridex G48	Velena s.a.
Glacelf Plus	Total
Glyco Shell	Shell International
Glyco Star	Bremin Mineralöl GmbH & Co.
Glysantin G48-24 Engine Coolant	UNICO Ltd.
Glysantin Protect Plus / G48	BASF
GUSOFROST LV 505	Chemische Industrielle Gesellschaft
Mobil Frostchutz 600	Mobil Schmierstoff GmbH
Havoline AFC (BD04)	Chevron Texaco/Arteco
Mobil Frostschutz 600	ExxonMobil
OMV Kühlerfrostschutz	OMV AG
Total Thermofreeze Plus	Total

PRINCIPAL ENGINE SPECIFICATIONS

Engine Model	4BY2-150 / 150Z	4BY2-180 / 180Z	6BY2-220 / 220Z	6BY2-260 / 260Z
Application Design	Models numbers with no suffix letter are used in marine gear applications. Models having a “Z” suffix are used with stern drive.			
Number of Cylinders	In-line 4		In-line 6	
Type	4-cycle diesel, 15° inclined, dual overhead camshaft			
Combustion System	Direct injection			
Aspiration	Turbocharger with charge air cooler			
Bore x Stroke	84 mm x 90 mm (3.307 in. x 3.543 in.)			
Displacement	1.995 L (121.7 cu in.)		2.993 L (182.6 cu in.)	
Firing Order*	1-3-4-2-1		1-5-3-6-2-4-1	
Compression Ratio	16.5:1		16.5:1	
Rated Power Output**	4BY2-150 / 150Z	4BY2-180 / 180Z	6BY2-220 / 220Z	6BY2-260 / 260Z
Continuous Output (at 3600 rpm)	88 kW (114 hp)	102 kW (137 hp)	124 kW (166 hp)	153 kW (208 hp)
Maximum Output (at 4000 rpm)	110 kW (150 hp)	132 kW (180 hp)	162 kW (220 hp)	191 kW (260 hp)
Mean Pressure	1.66 MPa (240.76 psi)	1.98 MPa (287.2 psi)	1.62 MPa (234.96 psi)	1.92 MPa (278 psi)
Low Idle Speed (Warm Engine @ 88°C [190°F])***	750 rpm (ECU-controlled)		670 rpm (ECU-controlled)	
Cold Start Speed @ 20°C (68°F)	1200 rpm gradually decreasing to warm engine idle @ 88°C (190°F) (ECU-controlled)			
High Idle Speed	4600 rpm			
Rotation Direction	Counterclockwise (viewed from flywheel)			
No. of Valves per Cylinder	4			
Valve Adjustment	Hydraulic self-adjusting			
Turbocharger	MHI with pneumatic wastegate		HOLSET with pneumatic wastegate	
Charge Air Cooler	Seawater cooled			
Electrical System	12 V			
Starter	12 V / 2 kW (2.7 hp)			
Charging System	12 V / 150 A			
Battery Capacity - Recommended	12 V / 85 Ah / 680 CCA (cold cranking amps)			
Fuel Injection System	Common rail (ECU-controlled)			
Fuel Injection Pressure	Variable depending on rpm; 250 to 1600 bar (3626 to 23,206 psi)			
Injection Timing	Variable (ECU-controlled)			
ECU Threshold Voltage	7.8 V			
Cooling System	Closed cooling system with heat exchanger			
Coolant Capacity (Approximate)	10.0 L (10.6 qt)		13.0 L (13.7 qt)	

Engine Model	4BY2-150 / 150Z	4BY2-180 / 180Z	6BY2-220 / 220Z	6BY2-260 / 260Z
Seawater Pump	Rubber impeller, belt driven			
Capacity	165 L / minute minimum (174 qt. / minute minimum) at maximum rated engine rpm			
Maximum Lift	2000 mm (78.75 in.)			
Hydraulic Oil Cooler	Seawater cooled			
Lubrication System	Totally enclosed, forced lube system			
Oil Cooler	Engine coolant system			
Lube Oil Pressure at 4000 rpm	3.5 to 6.0 bar (51 to 87 psi)			
Lube Oil Pressure at 1000 rpm	0.6 to1.0 bar (8.7 to 14.5 psi)			
Lube System Capacity****	8.0 L (8.45 qt)		11.0 L (11.62 qt)	
Crankcase Ventilation	Closed, with filter			
Drive Options				
Stern Drive	ZT350 or MerCruiser Bravo-1, -2, -3			
Marine Gear	KMH40 or KMH50		KMH50	
Installation Angles: Static Angle				
Front-to-Rear	± 4°			
Left-to-Right	± 0°			
Operational Angles				
Continuous	Front-to-Rear: -5 to 20°, Side-to-Side: 20°			
Peak	Front-to-Rear: -10 to 25°, Side-to-Side: 30°			
Height	721 mm (28.4 in.)			
Length (without marine gear)				
Stern Drive (front-to-middle of engine mount)	736 mm (30.0 in.)		942 mm (37.1 in.)	
Marine Gear (front-to-marine gear mounting face)	644 mm (25.4 in.)		827.5 mm (32.5 in.)	
Overall Length	839 mm (33.0 in.)		1001 mm (39.4 in.)	
Width	670 mm (26.4 in.) (local exceeding)			
Dry Weight (without marine gear / drive or mixing elbow)				
For Stern Drive:	273.5 kg (603 lb)		338 kg (745 lb)	
For Marine Gear:	262.5 kg (578.7 lb)		319 kg (703 lb)	

* *Cylinder numbering starts at the coolant pump end of the engine.*
** *Rating condition: ISO 8665. Temperature of fuel: 40°C (104°F) at fuel pump inlet.*
Fuel condition: Density at 15°C (59°F) = 0.840 g/cm^3.
Fuel temperature at the inlet of the fuel injection pump.
1 hp (metric horsepower) = 0.7355 kW
*** *1080 rpm @ startup for alternator excitation.*
**** *Capacity may vary depending on installation angle.*

TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS

Tightening Fasteners

Use the correct amount of torque when tightening fasteners. Applying excessive torque may damage the fastener or component and not enough torque may cause a leak or component failure.

Hexagon Bolts and Nuts

Nominal Diameter	Grade (Lubricated)		
	8.8 or 8	10.9 or 10	12.9 or 12
M4	2.7 N·m (24 in.-lb)	3.88 N·m (34.3 in.-lb)	4.6 N·m (41 in.-lb)
M5	5.5 N·m (48.6 in.-lb)	8 N·m (71 in.-lb)	9.5 N·m (84 in.-lb)
M6	9.5 N·m (84 in.-lb)	13 N·m (115 in.-lb)	16 N·m (142 in.-lb)
M7	15 N·m (133 in.-lb)	22 N·m (195 in.-lb)	26 N·m (230 in.-lb)
M8	23 N·m (204 in.-lb)	32 N·m (24 ft-lb)	39 N·m (29 ft-lb)
M8 x 1	25 N·m (221 in.-lb)	35 N·m (26 ft-lb)	42 N·m (31 ft-lb)
M10	46 N·m (34 ft-lb)	64 N·m (47 ft-lb)	77 N·m (57 ft-lb)
M10 x 1.25	49 N·m (36 ft-lb)	68 N·m (50 ft-lb)	82 N·m (60 ft-lb)
M12	80 N·m (59 ft-lb)	110 N·m (81 ft-lb)	135 N·m (100 ft-lb)
M12 x 1.5	88 N·m (65 ft-lb)	125 N·m (92 ft-lb)	150 N·m (111 ft-lb)

Hose Clamps

NOTICE: NEVER reuse or retighten hose clamps. ALWAYS install new hose clamps.

Size	Specification
5 mm Hex Head	1.0 to 1.5 N·m (8.9 to 13 in.-lb)
6 mm Hex Head	2.5 to 3.5 N·m (22 to 31 in.-lb)

PREPARE ENGINE FOR LONG-TERM STORAGE

NOTICE: NEVER drain engine coolant for long-term storage. Antifreeze must be used to avoid freezing and damaging of components. Antifreeze will prevent rusting during long-term storage.

1. Change engine oil and filter. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.
2. Drain seawater cooling system. *See Drain and Refill Seawater Cooling System on page 7-8.*
3. Wipe off any dust or oil from the outside of the engine.
4. Drain fuel tank or fill the tank to prevent condensation.
5. Grease the exposed areas and joints of the remote control cables and the bearings of the remote control handle.
6. Seal the intake silencer, exhaust pipe, etc. to prevent moisture or contamination from entering engine.
7. Completely drain bilge in hull bottom.
8. Waterproof the engine room to prevent rain or seawater from entering.
9. Charge the battery once a month to compensate for battery's self-discharge.
10. Remove key from key switch and cover key switch with moisture cap (if equipped).

ABBREVIATIONS AND SYMBOLS

Abbreviations

A	ampere
AC	alternating current
ACEA	Association des Constructeurs Européens d'Automobilies
Ah	ampere-hour
API	American Petroleum Institute
ARB	Air Resources Board
ATDC	after top dead center
BTDC	before top dead center
°C	Celsius
CARB	California Air Resources Board
CCA	cold cranking amp
cm	centimeter
cm³	cubic centimeter
cm³/min	cubic centimeter per minute
cu. in.	cubic inch
DC	direct current
DI	direct injection
DVA	direct volt adapter
EPA	Environmental Protection Agency
ESG	electronic speed governor
°F	degree Fahrenheit
fl oz	fluid ounce (U.S.)
fl oz/min	fluid ounce (U.S.) per minute
ft	foot
ft-lb	foot pound*
ft·lbf/min	foot pound force per minute
g	gram
gal/hr	gallon (U.S.) per hour
gal	gallon (U.S.)
GL	gear lubricant
hp	horsepower (metric)
hrs	hours
I.D.	inside diameter
IDI	indirect injection
in.	inch
in.-lb	inch pound**
JASO	Japanese Automobile Standards Organization
kg	kilogram
kgf/cm²	kilogram force per square centimeter
kgf·m	kilogram force meter
km	kilometers
kPa	kilopascal
kW	kilowatt
L	liter
L/hr	liter per hour
lb	pound
lbf	pound-force
lb-ft	pound foot (Tightening Torque)
lb-in.	pound inch (Tightening Torque)
min	minute
mL	milliliter
mm	millimeter
MPa	megapascal
mV	millivolt
N	newton
N·m	newton meter
No.	number
O.D.	outside diameter
oz	ounce
PS	horsepower (Deutsch)
psi	pound per square inch
qt	quart (U.S.)
rpm	revolutions per minute
SAE	Society of Automotive Engineers
sec	second
t	short ton 2000lb
TBN	Total Base Number
TDC	top dead center
V	volt
VAC	volt alternating current
VDC	volt direct current
W	watt
WOT	Wide-Open Throttle

Symbols

°	angular degree
+	plus
-	minus
±	plus or minus
Ω	ohm
μ	micro
%	percent

* Work torque such as engine torque

** Work torque such as starter motor torque

UNIT CONVERSIONS

Unit Prefixes

Prefix	Symbol	Power
mega	M	x 1,000,000
kilo	k	x 1,000
centi	c	x 0.01
milli	m	x 0.001
micro	μ	x 0.000001

Units of Length

mile	x	1.6090	= km
ft	x	0.3050	= m
in	x	2.5400	= cm
in	x	25.4000	= mm
km	x	0.6210	= mile
m	x	3.2810	= ft
cm	x	0.3940	= in.
mm	x	0.0394	= in.

Units of Volume

gal (U.S.)	x	3.78540	= L
qt (U.S.)	x	0.94635	= L
cu in	x	0.01639	= L
cu in	x	16.38700	= mL
fl oz (U.S.)	x	0.02957	= L
fl oz (U.S.)	x	29.57000	= mL
cm^3	x	1.00000	= mL
cm^3	x	0.03382	= fl oz (U.S.)

Units of Mass

lb	x	0.45360	= kg
oz	x	28.35000	= g
kg	x	2.20500	= lb
g	x	0.03527	= oz

Units of Force

lbf	x	4.4480	= N
lbf	x	0.4536	= kgf
N	x	0.2248	= lbf
N	x	0.1020	= kgf
kgf	x	2.2050	= lbf
kgf	x	9.8070	= N

Units of Torque

lb-ft	x	1.3558	= N·m
lb-ft	x	0.1383	= kgf·m
lb-in.	x	0.1130	= N·m
lb-in.	x	0.0115	= kgf·m
kgf·m	x	7.2330	= lb-ft
kgf·m	x	86.8000	= lb-in.
kgf·m	x	9.8070	= N·m
N·m	x	0.7376	= lb-ft
N·m	x	8.8510	= lb-in.
N·m	x	0.1020	= kgf·m

Units of Pressure

psi	x	0.0689	= bar
psi	x	6.8950	= kPa
psi	x	0.0703	= kgf/cm^2
bar	x	14.5030	= psi
bar	x	100.0000	= kPa
bar	x	29.5300	= in Hg (60°F)
kPa	x	0.1450	= psi
kPa	x	0.0100	= bar
kPa	x	0.0102	= kgf/cm^2
kgf/cm^2	x	98.0700	= psi
kgf/cm^2	x	0.9807	= bar
kgf/cm^2	x	14.2200	= kPa
in Hg (60°)	x	0.0333	= bar
in Hg (60°)	x	3.3770	= kPa
in Hg (60°)	x	0.0344	= kgf/cm^2
psi	x	0.0689	= bar

Units of Power

hp (metric or PS)	x	0.9863201	= hp SAE
hp (metric or PS)	x	0.7354988	= kW
hp SAE	x	1.0138697	= hp (metric or PS)
hp SAE	x	0.7456999	= kW
kW	x	1.3596216	= hp (metric or PS)
kW	x	1.3410221	= hp SAE

Units of Temperature

°F = (1.8 x °C) + 32
°C = 0.556 x (°F - 32)

Section 4

PERIODIC MAINTENANCE

Page

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SAFETY PRECAUTIONS

Before servicing the BY2 marine engines, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures for proper care and maintenance of the engine.

The Importance of Periodic Maintenance

Engine deterioration and wear occurs in proportion to length of time the engine has been in service and the conditions the engine is subject to during operation. Periodic maintenance prevents unexpected downtime, reduces the number of accidents due to poor machine performance and helps extend the life of the engine.

Performing Periodic Maintenance

Perform periodic maintenance procedures in an open, level area free from traffic. If possible, perform the procedures indoors to prevent environmental conditions such as rain, wind or snow from damaging the engine. **WARNING! *Exhaust Hazard. NEVER block windows, vents or other means of ventilation if the engine is operating in an enclosed area. All internal combustion engines create carbon monoxide gas during operation. Accumulation of this gas within an enclosure could cause illness or even death.***

Yanmar Replacement Parts

Yanmar recommends that you use genuine Yanmar parts when replacement parts are needed. Genuine replacement parts help ensure long engine life.

Required EPA Maintenance

To maintain optimum engine performance and compliance with the Environmental Protection Agency (EPA) Regulation Engines, it is essential that you follow the *Periodic Maintenance Schedule on page 4-5* and *Periodic Maintenance Procedures on page 4-9*.

EPA REQUIREMENTS

The EPA emission regulation is applicable only in USA.

Conditions to Ensure Compliance with EPA Emission Standards

This product is an EPA-approved engine.

The following are the conditions that must be met in order to ensure that the emissions during operation meet the EPA standards:

- Ambient temperature: -16° to +40°C (3° to 104°F)
- Relative humidity: 80% or lower

The fuel and lubricating oil used should be as follows:

- Diesel fuel: ASTM D975 No. 1-D or No. 2-D, or equivalent (minimum cetane No. 45)
- Lubricating oil: Type API, Class SM, SL, SJ, SH / CF and CF

Be sure to perform inspections as outlined in *Periodic Maintenance Procedures on page 4-9* and keep a record of the results.

Pay particular attention to these important points:

- Replacing the engine oil
- Replacing the lube oil filter
- Replacing the fuel filter
- Replacing the air filter

Note: Inspections are divided into two sections in accordance with who is responsible for performing the inspection: the user or the maker.

Inspection and Maintenance

See Inspection and Maintenance of EPA Emission-Related Parts on page 4-8.

Inspection and maintenance procedures not shown in the *Inspection and Maintenance of EPA Emission-Related Parts* section are covered in *Periodic Maintenance Schedule on page 4-5*.

This maintenance must be performed to keep the emission values of the engine in the standard values during the warranty period. The warranty period is determined by the age of the engine or the number of hours of operation.

PERIODIC MAINTENANCE SCHEDULE

Daily and periodic maintenance is important to keep the engine in good operating condition. The following is a summary of maintenance items by periodic maintenance intervals. Periodic maintenance intervals vary depending on engine application, loads, diesel fuel and engine oil used and are hard to establish definitively. The following should be treated only as a general guideline.

○: Check ◇: Replace

System	Item	Periodic Maintenance Interval					
		Daily	Every 50 hours or monthly whichever comes first	Every 250 hours or one year whichever comes first	Every 500 hours or 2 years whichever comes first	Every 1000 hours or 4 years whichever comes first	Every 2000 hours or 8 years whichever comes first
Whole	Visual inspection of engine exterior	○ Before starting					
Fuel System	Check for fuel leakage	○ Before starting					
	Check the fuel level and refill if necessary	○ Before starting					
	Drain water and sediment from fuel tank			○			
	Drain the fuel filter / water separator	○					
	Replace the fuel fine filter			◇			
	Replace fuel filter / water separator element			◇			
	Check the fuel pump and fuel lines				○		
Lubricating System	Check the engine oil level	○ Before starting					
	Change the engine oil and replace the oil filter element		◇ Initial 50	◇			
Cooling System - Engine Coolant	Visual inspection of cooling system	○ Before starting					
	Check coolant level and check for leaks	○ Before starting					
	Drain and refill closed cooling system (engine coolant)				◇		

○: Check ◇: Replace

System	Item	Periodic Maintenance Interval					
		Daily	Every 50 hours or monthly whichever comes first	Every 250 hours or one year whichever comes first	Every 500 hours or 2 years whichever comes first	Every 1000 hours or 4 years whichever comes first	Every 2000 hours or 8 years whichever comes first
Cooling System - Seawater Circuit	Visual inspection of cooling system	○ Before starting					
	Check the seawater outlet	○ Before starting					
	Check seawater pump belt for wear, replace if necessary			◇			
	Check seawater filter (if equipped) and inlet		○				
	Replace the anodes*			◇			
	Check or replace the seawater pump impeller			○		◇	
Air Intake and Exhaust System	Visual inspection	○ Before starting					
	Replace turbocharger heat shield			◇			
	Check the exhaust pipe	○					
	Check the air intake system		○				
	Check the exhaust / water mixing elbow			○			
	Replace the air filter element			○			
Electrical System	Check the electrolyte level in the battery (serviceable batteries only)		○				
	Check the wiring connectors	○ Before starting					
	Check alternator belt for wear or replace belt			○			◇

○: Check ◇: Replace

System	Item	Periodic Maintenance Interval					
		Daily	Every 50 hours or monthly whichever comes first	Every 250 hours or one year whichever comes first	Every 500 hours or 2 years whichever comes first	Every 1000 hours or 4 years whichever comes first	Every 2000 hours or 8 years whichever comes first
Miscellaneous Items	Check the alarm and indicators (if equipped)	○					
	Check or change power steering fluid	○		◇			
	Check for water or oil leakage	○ Before starting					
	Check shift cable adjustment		○ Initial 50	○			
	Adjust the propeller shaft alignment (if equipped with marine gear)		○ Initial 50	○			
	Check hydraulic oil cooler			○			
	Check and replace rubberized hoses (fuel and water)			◇			
	Check flexible engine mounts			○		○	

* *Check anodes periodically. Any anode having less than half its original size remaining should be replaced - use this to establish a regular replacement interval.*

Note: The above procedures are considered normal maintenance and are performed at the owner's expense.

Inspection and Maintenance of EPA Emission-Related Parts

Parts	Interval
Clean fuel injection nozzle	1500 hours
Check fuel injection nozzle adjustment	3000 hours
Check fuel injection pump adjustment	
Check turbocharger adjustment	
Check electronic engine control unit (ECU) and its associated sensors and actuators	

PERIODIC MAINTENANCE PROCEDURES

After Initial 50 Hours of Operation

Perform the following maintenance after the initial 50 hours of operation.

- **Changing the Engine Oil and Replacing the Engine Oil Filter**
- **Checking Shift Cable Adjustment**
- **Adjusting the Propeller Shaft Alignment (If Equipped with Marine Gear)**

Changing the Engine Oil and Replacing the Engine Oil Filter

The engine oil on a new engine becomes contaminated from the initial break-in of internal parts. It is very important that the initial oil replacement is performed as scheduled.

It is easiest and most effective to drain the engine oil after operation while the engine is still warm. **WARNING!** ***Burn Hazard. Avoid contact with hot engine oil. Wear protective clothing when handling hot engine oil.***

1. Turn engine OFF.
2. Remove engine cover.
3. *NOTICE: Prevent dirt and debris from contaminating engine oil. Carefully clean the dipstick and the surrounding area before you remove the cap.* Loosen the engine oil filter cap **(Figure 4-1, (2))** 1- 2 turns with a socket wrench. Allow to sit a few minutes to allow oil to drain into crankcase.

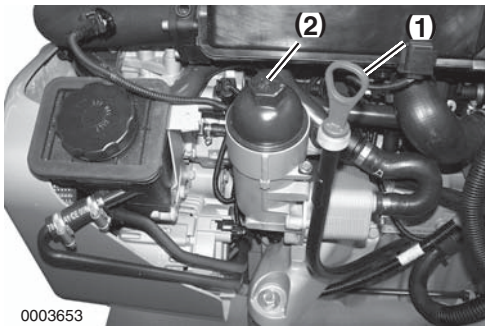

Figure 4-1

4. Remove the engine oil dipstick **(Figure 4-1, (1))**. Attach an oil drain pump and pump out the oil. Dispose of waste properly.
5. Remove the engine oil filter cap and filter assembly.
6. Remove the filter element from stem.
7. Replace the three O-rings **(Figure 4-2, (1))** on the stem.

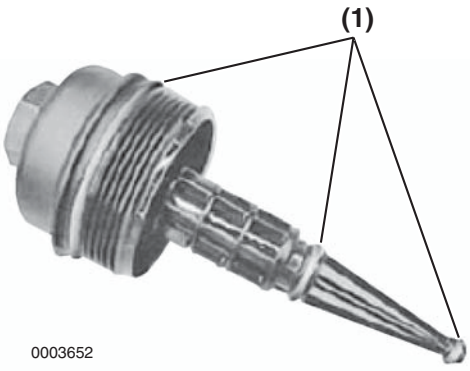

Figure 4-2

8. Install a new filter element. Ensure the filter fits snugly in the filter cap.
9. Install the cap and filter assembly. Tighten cap by hand until the seal touches the housing.
10. Tighten to 25 N·m (225 in.-lb).

11. Fill with new engine oil. *NOTICE: NEVER mix different types of engine oil. This may adversely affect the lubricating properties of the engine oil. NEVER overfill. Overfilling may result in white exhaust smoke, engine overspeed or internal damage.*
12. Perform a trial run and check for oil leaks.
13. Approximately 10 minutes after stopping the engine, remove the oil dipstick and check the oil level. Add oil if the level is too low.

Checking the Shift Cable Adjustment

Refer to the appropriate drive or gear manual for the correct procedure.

Adjusting the Propeller Shaft Alignment (If Equipped with Marine Gear)

The flexible engine mounts are slightly compressed during initial engine operation and may cause misalignment between the engine and the propeller shaft.

Every 50 Hours of Operation

After you complete the initial 50 hour maintenance procedures, perform the following procedures every 50 hours or monthly thereafter.

- **Checking Seawater Filter (If Equipped) and Inlet**
- **Checking the Air Intake Pipes**
- **Checking Battery Electrolyte Level (Serviceable Batteries Only)**

Checking Seawater Filter (If Equipped) and Inlet

Refer to boat builder's literature for information on the seawater filter.

Checking the Air Intake Pipes

Check the air intake system for damage or wear.

Checking Battery Electrolyte Level (Serviceable Batteries Only)

WARNING! ***Fire Hazard. ALWAYS turn off the battery switch or disconnect the negative (-) cable before inspecting the electrical system. Failure to do so could cause short-circuiting and fires. ALWAYS disconnect the negative (-) battery cable first. An accidental short-circuit may cause damage, fire and / or personal injury. ALWAYS connect the negative (-) battery cable (back onto the battery) LAST.***

WARNING! ***Fire Hazard. Keep the area around the battery well-ventilated, paying attention to keep the battery away from any fire source. During operation or charging, hydrogen gas is generated from the battery and can be easily ignited.***

WARNING! ***Exposure Hazard. Make sure your eyes and skin do not come in contact with the fluid. The battery electrolyte is dilute sulfuric acid and causes severe acid burns. If you come in contact with electrolyte, wash and rinse it off immediately with a large amount of fresh water and baking soda.***

NOTICE: NEVER turn off the battery switch (if equipped) or short the battery cables during operation. Damage to the electric system will result.

1. Turn the battery master switch to OFF (if equipped) or disconnect the negative (-) battery cable.
2. Do not operate with insufficient battery electrolyte as the battery will be destroyed.
3. *NOTICE: NEVER attempt to remove the covers or fill a maintenance-free battery.*

   Remove the caps and check the electrolyte level in all cells.
4. If the level is lower than the minimum fill level **(Figure 4-3, (1))**, fill with distilled water **(Figure 4-3, (2))** (available locally) up to the upper limit **(Figure 4-3, (3))** of the battery.

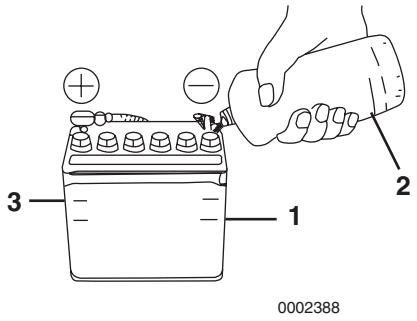

Figure 4-3

Note: The maximum fill level is approximately 10 to 15 mm (3/8 to 9/16 in.) above the plates. Battery fluid tends to evaporate in high temperatures, especially in summer. In such conditions, inspect the battery more often.

Every 250 Hours of Operation

Perform the following maintenance every 250 hours of operation or one year, whichever comes first.

- **Draining Water and Sediment from Fuel Tank**
- **Replacing the Fuel Fine Filter**
- **Replacing the Fuel Filter / Water Separator Element**
- **Changing the Engine Oil and Replacing the Engine Oil Filter Element**
- **Checking / Replacing the Seawater Pump and Alternator Belts**
- **Replacing the Anodes**
- **Checking or Replacing the Seawater Pump Impeller**
- **Replacing the Turbocharger Heat Shield**
- **Checking the Exhaust / Water Mixing Elbow**
- **Replacing the Air Filter Element**
- **Cleaning the Turbocharger Blower**
- **Checking / Changing the Alternator Belt**
- **Checking / Changing the Power Steering Fluid**
- **Checking the Shift Cable Adjustment**
- **Adjusting the Propeller Shaft Alignment**
- **Checking the Hydraulic Oil Cooler**
- **Checking or Replacing Rubber Hoses**
- **Checking the Flexible Engine Mounts**

Draining Water and Sediment from Fuel Tank

WARNING! Fire and Explosion Hazard. When you are draining the fuel tank to perform maintenance, put an approved container under the opening to catch the fuel. NEVER use a shop rag to catch the fuel. Vapors from the rag are flammable and explosive. Wipe up any spills immediately. Wear eye protection. The fuel system is under pressure and fuel could spray out when you remove any fuel system component.

1. Turn engine off.
2. Put a container under the drain cock **(Figure 4-4, (2))** to catch fuel.

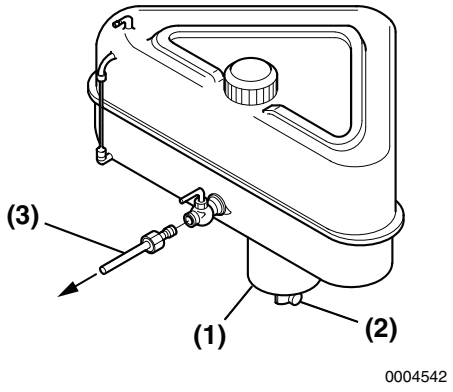

Figure 4-4

1 – Sediment Bowl
2 – Drain Cock
3 – Fuel Line to Engine

Note: Typical fuel tank shown. Actual equipment may differ.

3. Open the drain cock and drain water and sediment. Close the drain cock when the fuel is clean.
4. Dispose of waste properly.

Replacing the Fuel Fine Filter

1. Disconnect the battery negative (-) cable.
2. Close the fuel tank cock.
3. Unscrew and remove filter cartridge **(Figure 4-5, (1))**.

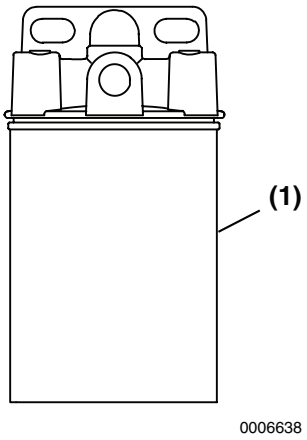

Figure 4-5

4. Replace rubber seal.
5. Replace filter. *NOTICE: When replacing fuel filters, always pre-fill them with fresh, clean fuel to improve the system's ability to be bled.*
6. Hand-tighten cartridge to filter.
7. Connect battery negative (-) cable.
8. Bleed the fuel system and check for leaks. *See Bleed the Fuel System on page 6-22*.

Replacing the Fuel Filter / Water Separator Element

Note: Yanmar supplies a water separating pre-filter separate from the engine. Location and type of filter may vary.

1. Disconnect the battery negative (-) cable.
2. Close the fuel tank cock.
3. Loosen the drain plug **(Figure 4-6, (4))** on the bottom of the fuel filter / water separator and drain off any water or sediment.

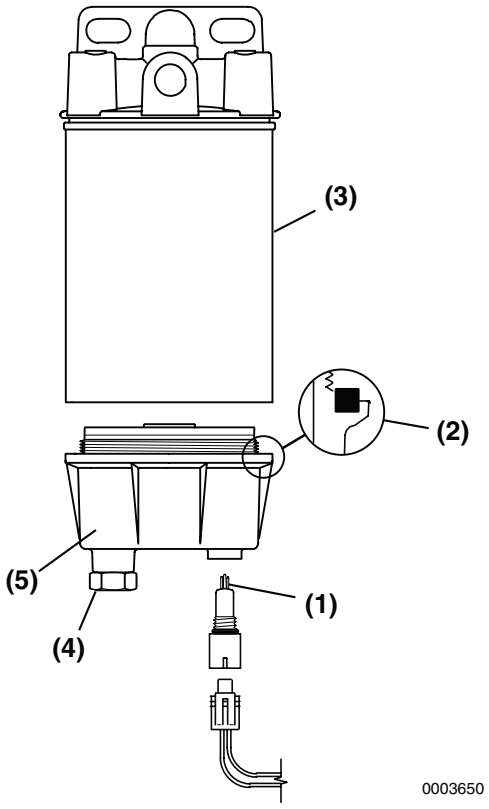

Figure 4-6

4. Disconnect water sensor **(Figure 4-6, (1))**.
5. Turn the filter bowl **(Figure 4-6, (5))** counterclockwise to remove.
6. Remove the old filter element.
7. Clean the filter bowl. Inspect the water sensor **(Figure 4-6, (1))** for damage. Inspect the bowl seal **(Figure 4-6, (2))**.

   NOTICE: When replacing fuel filters, always pre-fill them with fresh, clean fuel to improve the system's ability to be bled.

8. Lubricate the seal at the top of the new filter element **(Figure 4-6, (3))** and install.
9. Lubricate the filter bowl seal **(Figure 4-6, (2))** and install the filter bowl **(Figure 4-6, (5))**. Turn clockwise by hand to tighten.
10. Ensure drain plug **(Figure 4-6, (4))** is securely tightened.
11. Connect water sensor **(Figure 4-6, (1))**.
12. Open the fuel cock.
13. Connect the battery negative (-) cable.
14. Bleed air from the fuel system and check for leaks. *See Bleed the Fuel System on page 6-22*.

Changing the Engine Oil and Replacing the Engine Oil Filter Element

To change engine oil and replace the engine oil filter element, see *Changing the Engine Oil and Replacing the Engine Oil Filter on page 4-9*.

Checking / Replacing the Seawater Pump and Alternator Belts

1. Disconnect battery negative (-) cable from the battery.
2. Remove belt guard.
3. Check the seawater pump belt **(Figure 4-7, (1))** and alternator belt **(Figure 4-7, (2))** for wear, cracks or damage. *NOTICE: Avoid getting oil on the V-belt. Oil will cause the belt to slip, stretch and age prematurely.*

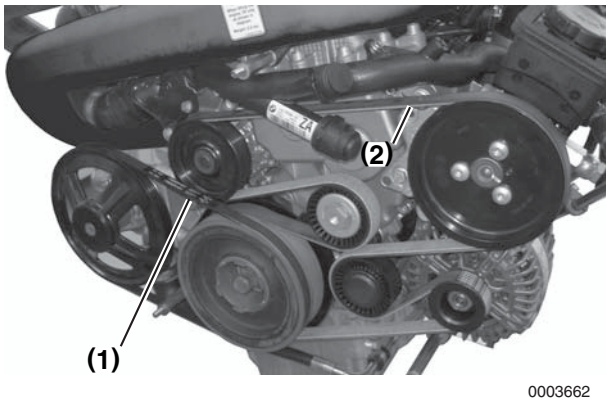

Figure 4-7

4. Replace if necessary. *See Replace Seawater Pump Belt on page 7-19*.
5. Install belt guard and connect battery negative (-) cable.

Replacing the Anodes

There are anodes in the seawater cooling system and they should be inspected and replaced periodically.

Anodes are located in the heat exchanger **(Figure 4-8, (1))** and the charge air cooler **(Figure 4-8, (2))**. An additional anode may also be located in the exhaust / water mixing elbow.

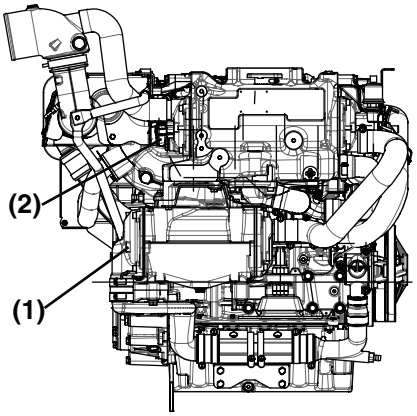

Figure 4-8

1. Disconnect battery negative (-) cable.
2. Remove each anode and inspect for corrosion. Any anode having less than half its original size remaining should be replaced. *NOTICE: NEVER use thread sealer or thread sealing tape when installing anodes. Anodes must make good metal-to-metal contact to perform properly.*
3. Install each anode using a new copper gasket and tighten to 25 N·m (18 ft-lb).
4. Start engine and check for water leaks.

Checking or Replacing the Seawater Pump Impeller

See Seawater Pump on page 7-18.

Replacing the Turbocharger Heat Shield

Remove bolts and replace the turbocharger heat shield.

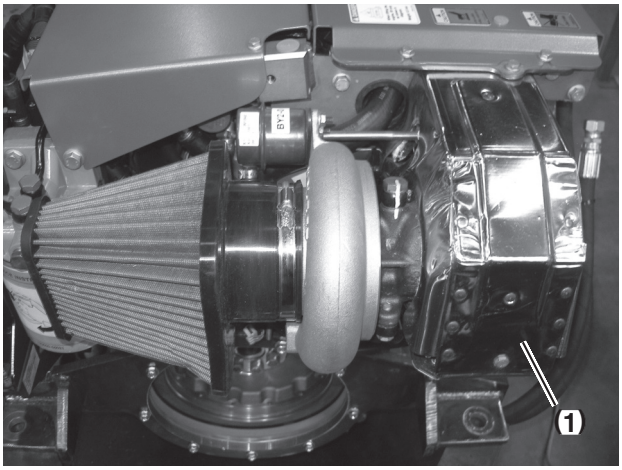

Figure 4-9

Cleaning the Exhaust / Water Mixing Elbow

The mixing elbow is attached to the turbocharger. The exhaust gas is mixed with seawater in the mixing elbow.

1. Clean dirt and scale out of the exhaust gas passage. Clean and clear the seawater passage in the mixing elbow.
2. Repair any cracks or damage to the mixing elbow by welding or replacement.
3. Inspect the gasket and replace if necessary.

Replacing the Air Filter Element

1. Turn engine off.
2. Remove engine cover.
3. Remove clamp **(Figure 4-10, (1))**.

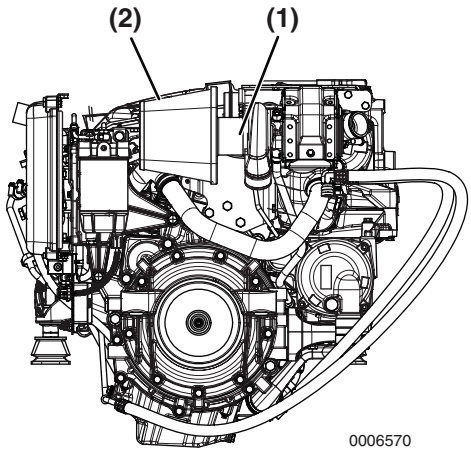

Figure 4-10

4. Remove air filter **(Figure 4-10, (2))**.
5. Replace air filter.

Checking / Changing the Alternator Belt

See Checking / Replacing the Seawater Pump and Alternator Belts on page 4-13.

Checking Shift Cable Adjustment

See Checking the Shift Cable Adjustment on page 4-10.

Adjusting the Propeller Shaft Alignment

See Adjusting the Propeller Shaft Alignment (If Equipped with Marine Gear) on page 4-10. Refer to the appropriate Marine Gear Service Manual for additional information.

Checking the Hydraulic Oil Cooler

See Inspect and Clean Hydraulic Oil Cooler on page 7-12.

Checking or Replacing Rubber Hoses

Check rubber water and fuel hoses for wear or damage.

Checking the Flexible Engine Mounts

Check the flexible engine mounts for wear or damage.

Every 500 Hours of Operation

Perform the following maintenance every 500 hours of operation or 2 years, whichever comes first.

- **Checking the Fuel Pump and Fuel Lines**
- **Draining and Refilling Closed Cooling System (Engine Coolant)**

Checking the Fuel Pump and Fuel Lines

See Fuel System on page 6-1.

Also *see Engine Piping Diagrams on page 3-8*.

Draining and Refilling Closed Cooling System (Engine Coolant)

1. Disconnect battery negative (-) cable.
2. Remove the engine cover.
3. Remove the coolant pressure cap from heat exchanger.
4. Remove the heat exchanger to access the cylinder block drain plug behind it.
5. **WARNING!** ***Burn Hazard. NEVER remove the coolant filler cap if the engine is hot. Steam and hot engine coolant will escape and seriously burn you. Allow the engine to cool down before attempting to remove the filler cap.*** Remove drain plug **(Figure 4-11, (1))** from the engine block. Allow coolant to drain into a container of appropriate size.

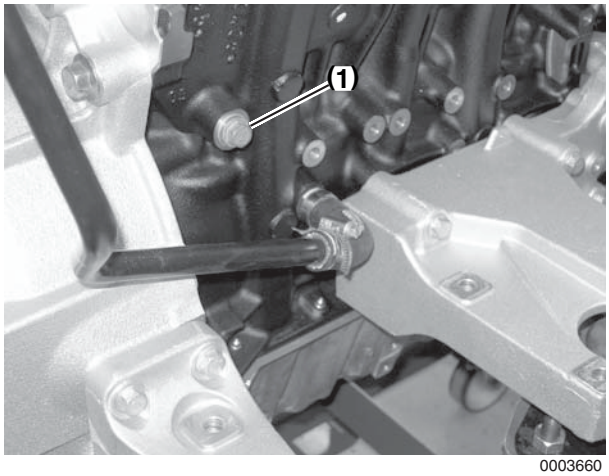

Figure 4-11

6. Install cylinder block drain plug with a new gasket.
7. Install heat exchanger. Ensure the drain cock **(Figure 4-12, (1))** on the heat exchanger is closed.

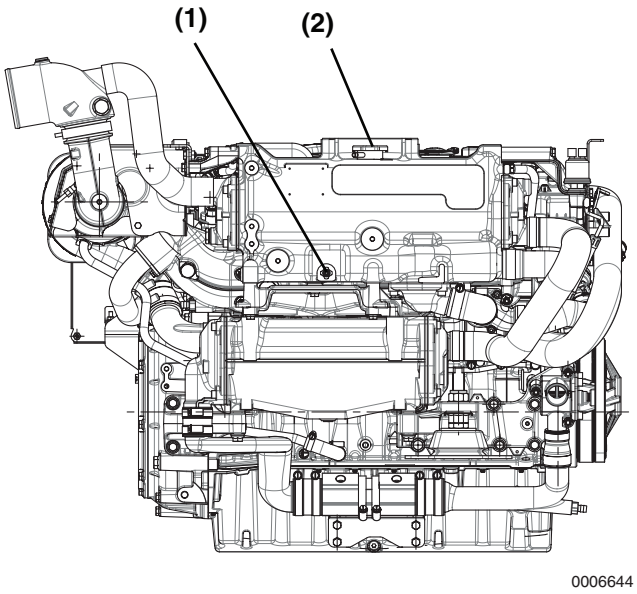

Figure 4-12

8. Remove the pressure cap **(Figure 4-12, (2))** from the heat exchanger.
9. Inspect the cap gasket and flange on the filler neck for damage. Replace if necessary.
10. Check the rubber hose connecting the coolant recovery tank to the heat exchanger. Be sure the hose is securely connected and there is no damage.
11. Pour coolant mix slowly into the heat exchanger to prevent the formation of air pockets. Fill until the heat exchanger is completely full. *NOTICE: Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale and / or shorten engine life. Prevent dirt and debris from contaminating engine coolant. Carefully clean the filler cap and the surrounding area before you remove the cap. NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.*
12. Install the pressure cap and tighten firmly. **WARNING!** ***Burn Hazard. ALWAYS tighten the filler cap securely after checking the coolant level. Steam can escape during engine operation if the cap is loose.***
13. Remove the coolant recovery tank cap and fill with coolant mix to approximately 50 mm (2 in.) below the full line. Replace cap. Never fill to the full line.
14. After filling an empty cooling system, test-run the engine for about five minutes and check the engine coolant level at the recovery tank again.

Every 1000 Hours of Operation

Perform the following maintenance every 1000 hours of operation or 4 years, whichever comes first.

- **Checking the Flexible Engine Mounts**
- **Replacing the Seawater Pump Impeller**

Checking the Flexible Engine Mounts

Check flexible engine mounts for damage, cracks or wear. *See Checking the Flexible Engine Mounts on page 4-15*.

Replacing the Seawater Pump Impeller

See Checking or Replacing the Seawater Pump Impeller on page 4-14.

Every 2000 Hours of Operation

Perform the following maintenance every 2000 hours of operation or 8 years, whichever comes first.

- **Replacing Alternator Belt**

Replacing Alternator Belt

See Checking / Replacing the Seawater Pump and Alternator Belts on page 4-13.

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Section 5

ENGINE

Page

SAFETY PRECAUTIONS

Before servicing the engine, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* describes the disassembly, inspection, and reassembly of the 4BY2 and 6BY2 engines.

SPECIFICATIONS

General Information

Engine Model	4BY2	6BY2
Number of Cylinders	In-Line 4	In-Line 6
Bore	84 mm (3.31 in.)	84 mm (3.31 in.)
Stroke	90 mm (3.54 in.)	90 mm (3.54 in.)
Effective Displacement	1.995 L (122 cu in.)	2.993 L (183 cu in.)
Compression Ratio	16.5:1	16.5:1

Test and Adjustment Specifications

Test Item	Remarks	Specification
Cylinder Compression Test	Compression Pressure	28 ±2 bar (406 ±29 psi)

Repair Specifications

Component	Remarks		Specification
Cylinder Head	Cylinder Head Must Not Be Machined		
	Valve Guides Are Not Available as Replacement Parts		
	Standard Valve Guide ID - Intake		6.0 +0.015 mm (0.2362 +0.0006 in.)
	Standard Valve Guide ID - Exhaust		6.0 +0.015 / +0.03 mm (0.2362 +0.0006 / +0.0012 in.)
	Valve Side Movement (Max.) (Valve-to-Guide Wear)		0.5 mm (0.020 in.)
	Camshaft Bearing Diameter		23 mm (0.906 in.)
	Camshaft Bearing Width	4BY2	15.85 -0.08 mm (0.6240 -0.003 in.)
		6BY2	18.85 -0.08 mm (0.742 -0.003 in.)
	Valve Seat Angle		45°
	Outer Correction Angle		15°
	Inner Correction Angle		60°
	Valve Seat Width - Intake		1.0 +0.1 mm (0.039 +0.004 in.)
	Valve Seat Width - Exhaust		1.2 +0.1 mm (0.047 +0.004 in.)
	Valve Seat Surface Outside Diameter - Intake		24.5 +0.1 mm (0.965 +0.004 in.)
	Valve Seat Surface Outside Diameter - Exhaust		24.4 +0.1 mm (0.961 +0.004 in.)
Camshaft	Thrust Bearing Width		19.000 +0.01 mm (0.748 +0.004 in.)
	Radial Runout		0.040 - 0.060 mm (0.0015 - 0.0024 in.)
	Axial Play		0.02 - 0.150 mm (0.0008 - 0.0059 in.)
Valves	Head Diameter - Intake		25.9 ±0.1 mm (1.020 ±0.004 in.)
	Head Diameter - Exhaust		25.9 ±0.1 mm (1.020 ±0.004 in.)
	Stem Diameter - Intake		5.92 ±0.02 mm (0.233 ±0.0008 in.)
	Stem Diameter - Exhaust		5.92 ±0.02 mm (0.233 ±0.0008 in.)

Component	Remarks	Specification
Crankshaft and Main Bearings	Standard Yellow	59.977 - 59.983 mm (2.3613 - 2.3615 in.)
	Standard Green	59.970 - 59.976 mm (2.3610 - 2.3613 in.)
	Standard White	59.964 - 59.969 mm (2.3608 - 2.3610 in.)
	Undersize 1 (U 0.25) Yellow	59.727 - 59.733 mm (2.3514 - 2.3517 in.)
	Undersize 1 (U 0.25) Green	59.720 - 59.726 mm (2.3512 - 2.3514 in.)
	Undersize 1 (U 0.25) White	59.714 - 59.719 mm (2.3509 - 2.3511 in.)
	Undersize 2 (U 0.50) Yellow	59.477 - 59.483 mm (2.3416 - 2.3418 in.)
	Undersize 2 (U 0.50) Green	59.470 - 59.476 mm (2.3413 - 2.3416 in.)
	Undersize 2 (U 0.50) White	59.464 - 59.469 mm (2.3411 - 2.3413 in.)
	Crankshaft Bearing Clearance, Radial	0.019 - 0.052 mm (0.0007 - 0.0020 in.)
Crankshaft Thrust Bearings	Standard	25.00 +0.020 / +0.066 mm (0.9842 +0.0008 / +0.0026 in.)
	Size 1	25.2 +0.020 / +0.066 mm (0.9921 +0.0008 / +0.0026 in.)
	Size 2	25.4 +0.020 / +0.066 mm (1.000 +0.0008 / +0.0026 in.)
	Crankshaft Axial Play	0.06 - 0.25 mm (0.0024 - 0.0098 in.)
Connecting Rod Journals	Standard	45.00 -0.009 / -0.025 mm (1.7716 -0.0004 / -0.0010 in.)
	Size 1	44.75 -0.009 / -0.025 mm (1.7618 -0.0004 / -0.0010 in.)
	Size 2	44.50 -0.009 / -0.025 mm (1.7520 -0.0004 / -0.0010 in.)
	Radial Bearing Play	0.015 - 0.050 mm (0.0006 - 0.0020 in.)
Engine Vibration Damper	Maximum Permitted Radial Runout	0.40 mm (0.016 in.)
	Maximum Permitted Axial Runout	0.40 mm (0.016 in.)

Component	Remarks		Specification
Engine Piston, Rings, Pins	1st Groove Side Clearance		0.12 - 0.16 mm (0.005 - 0.006 in.)
	1st Groove End Gap		0.20 - 0.35 mm (0.008 - 0.014 in.)
	2nd Groove Side Clearance		0.07 - 0.11 mm (0.003 - 0.004 in.)
	2nd Groove End Gap		0.30 - 0.45 mm (0.012 - 0.018 in.)
	3rd Groove		Cannot be measured
Engine Cylinder Block	Bore Diameter - stage 0*		84.007 ±0.007 mm (3.3074 ±0.0003 in.)
	Bore Diameter - stage 1*		84.257 ±0.007 mm (3.3172 ±0.0003 in.)
	Permitted out-of-round of cylinder bore*		0.005 mm (0.0002 in.)
	Permitted conicity of cylinder bore*		0.01 mm (0.0004 in.)
	Permitted total wear tolerance piston to cylinder		0.15 mm (0.006 in.)
Oil Change Volume**	Includes Oil Filters	4BY2	8.0 L (8.5 qt)
		6BY2	11.0 L (11.5 qt)

* *Values are for new or reconditioned cylinders.*
** *Capacity may vary depending on installation angle*

SPECIAL TORQUE CHART

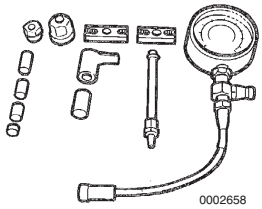
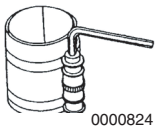
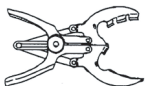
System	Component	Model	Thread	Comments	Specification
Engine Block	Main Bearing Replace, wash and oil	4BY2 6BY2	M10 x 80 Steel Bolts	Initial Torque Torque Angle	23 N·m (204 in.-lb) Plus 90°
	Coolant Drain Plug to Crankcase	4BY2 6B2Y	M14 x 1.5	Replace Sealing Ring	25 N·m (221 in.-lb)
	Clamping and Guide Rails to Crankcase	4BY2 6BY2	M14	Torque	20 N·m (177 in.-lb)
	Engine Mount Nut	4BY2 6BY2	M20	Torque	300 N·m (221 ft-lb)
Torsion Damper	Torsional Vibration Damper to Crankshaft	4BY2	M18 x 1.5	Initial Torque 1st Torque Angle 2nd Torque Angle 3rd Torque Angle	100 N·m (74 ft-lb) 60° 60° 30°
		6BY2	M10 x 86	Initial Torque 1st Torque Angle 2nd Torque Angle	40 N·m (30 ft-lb) 60° 60°
Connecting Rod and Bearing	Connecting Rod Bolts Replace, wash and oil	4BY2 6BY2	M10 x 80 Grade 12.9	Assembly Torque Initial Torque Torque angle	5 N·m (44 in.-lb) 20 N·m (177 in.-lb) 70°
Cylinder Head with Cover	Cylinder Head Bolts Replace, wash and oil	4BY2 6BY2	M12 x 1.5	Initial Torque then Loosen all bolts 180° 2nd Torque 1st Torque Angle 2nd Torque Angle	80 N·m (59 ft-lb) 50 N·m (37 ft-lb) 90° 90°
	Seal Plug Replace screws	4BY2 6BY2	M14 x 1.5	-	30 N·m (22 ft-lb)
Camshaft	Sprocket to Camshaft	4BY2 6BY2	M7 x 19	-	15 N·m (133 in.-lb)
	Camshaft Bearing Cap Bolt	4BY2 6BY2	-	-	10 N·m (89 in.-lb)
Oil Sump	Oil Drain Plug	6BY2	M12 x 1.5	Replace Seal	25 N·m (221 in.-lb)
	Oil Sump to Crankcase	6BY2	M8 x 26	-	20 N·m (177 in.-lb)
	Oil Deflector to Crankcase Lower Section	6BY2	M6 x 16	Thread-Tapping Screw	10 N·m (89 in.-lb)
Timing Case Covers	Timing Case Cover Bolt	4BY2 6BY2	-	Initial Torque of 5 N·m (44 in.-lb)	14 N·m (124 in.-lb)
	Guide Rail Pin	4BY2 6BY2	-	Apply Medium Strength Thread Lock and Sealer to the Threads	20 N·m (177 in.-lb)
	Plug to Timing Case Cover	4BY2 6BY2	M30 x 1	Replace Seal	70 N·m (52 ft-lb)
	Plug to Timing Case Cover	4BY2 6BY2	M40 x 1.5	Replace Seal	30 N·m (22 ft-lb)

System	Component	Model	Thread	Comments	Specification
Crankshaft and Bearings	Main Bearing Cap Replace Bolts Lightly oil threads	4BY2 6BY2	M10 x 80 Grade 12.9 PHR	Initial Torque Torque Angle	22 N·m (195 in.-lb) Plus 90°
Oil Pump	Oil Pick-Up to Oil Pump	4BY2 6BY2	M6 x 20	-	10 N·m (89 in.-lb)
	Reinforcement Shell	4BY2 6BY2	M6 x 16	-	10 N·m (89 in.-lb)
Oil Filter	Oil Filter Cap to Oil Filter Housing	4BY2 6BY2	-	-	25 N·m (221 in.-lb)
Thermostat and Connections	Coolant Return to Cylinder Head and Oil Filter Housing	4BY2 6BY2	M8 x 18	-	10 N·m (89 in.-lb)
Air Intake	Intake Manifold to Cylinder Head	4BY2 6BY2	M7 x 50	-	15 N·m (133 in.-lb)
Exhaust	Turbocharger to Exhaust Manifold	4BY2 6BY2	-	Apply Copper Anti-seize to Threads	23 N·m (204 in.-lb)
	Turbocharger Oil Supply Line	4BY2 6BY2	M10	Replace Banjo Bolt and Sealing Rings	22 N·m (195 in.-lb)
	Turbocharger Oil Return to Crankcase	4BY2 6BY2	-	Hose Clamp	3 N·m (27 in.-lb)
	Exhaust Manifold to Cylinder Head	4BY2	-	Apply Copper Anti-seize to Threads	19 N·m (168 in.-lb)
		6BY2	-		13 N·m (115 in.-lb)
Alternator	Wires to Alternator	4BY2	M8	-	13 N·m (115 in.-lb)
	Alternator to Crankcase	4BY2	M10	-	38 N·m (28 ft-lb)
	Belt Pulley with Free Wheel	4BY2	-	-	80 N·m (59 ft-lb)
Electrical System Engine Wiring Harness	Wiring Harness to Ground Holder	4BY2	M6	-	7 N·m (62 in.-lb)
	DDE Wiring Harness Pick Up to Battery Positive Terminal	4BY2 6BY2	M6	-	9 N·m (80 in.-lb)
	Injector Guide Strip to Cylinder Head Cover	4BY2 6BY2	-	-	3.5 N·m (31 in.-lb)
	Coolant Sensor to Cylinder Head	4BY2 6BY2	-	-	13.4 N·m (119 in.-lb)
	Camshaft Position Sensor Pickup	4BY2 6BY2	-	-	2.3 N·m (20 in.-lb)
Fuel System Injection Pump Drive	Sprocket to High-Pressure Pump	4BY2 6BY2	M14 x 1.5	-	65 N·m (48 ft-lb)
	Fuel Measuring Valve to High-Pressure Pump	4BY2 6BY2	M5 x 20	-	6.6 N·m (58 in.-lb)

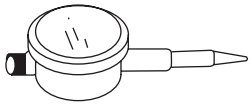
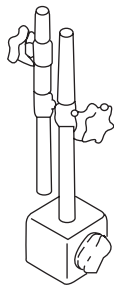
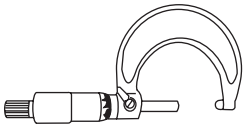
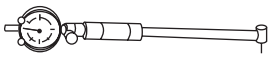
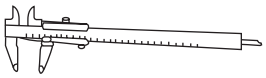
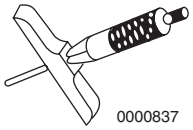
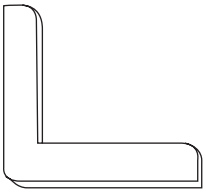
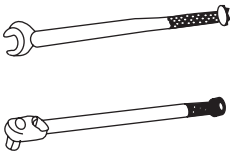
System	Component	Model	Thread	Comments	Specification
Fuel System Fuel Injection Nozzles and Lines	Fuel Injector in Cylinder Head Cover	4BY2 6BY2	M6	-	9 N·m (80 in.-lb)
	High-Pressure Line Union Nuts	4BY2 6BY2	M14 x 1.5	-	23 N·m (204 in.-lb)
	Pressure Sensor to Fuel Rail	4BY2 6BY2	-	-	70 N·m (52 ft-lb)
	Pressure Regulator to Fuel Rail	4BY2 6BY2	-	-	80 N·m (59 ft-lb)
	Fuel Return to Rail	4BY2 6BY2	Banjo Bolt	-	25 N·m (221 in.-lb)
Poly V-Belt Drive	Idler Pulley to Alternator Bracket	4BY2	M8 x 35 Grade 10.9	-	28 N·m (21 ft-lb)
Thermostat and Coolant Pipes	Coolant Return Pipe to Crankcase and Oil Filter Housing	4BY2	M8x18	-	11 N·m (97 in.-lb)
Glow Plugs	Glow Plugs	4BY2 6BY2	-	-	17.5 N·m (154 in.-lb)

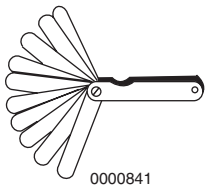
SPECIAL SERVICE TOOLS

Note: The tool numbers used in this section are either Yanmar or BMW part numbers. Yanmar part numbers are referred to as **Yanmar Part No.** and BMW part numbers are referred to as **OEM Part No.** Tools not having part numbers must be obtained locally.

No.	Tool Name	Applicable Model and Tool Size	Illustration
1	Valve Spring Compressor	OEM Part No. 11 9 000	
2	Valve Stem Seal Installer	OEM Part No. 11 6 370 Remover, 11 1 960 Protector, and 11 6 380 Installer	 0002663
3	Cylinder Compression Tester	OEM Part No. 11 0 222 and 11 0 236	 0002658
4	Piston Ring Compressor (For Installing Piston)	Obtain Locally	 0000824
5	Piston Ring Tool (For Removing/ Installing Piston Rings)	Obtain Locally	 0000825

MEASURING INSTRUMENTS

No.	Instrument Name	Application	Illustration
1	Dial Indicator	For measuring shaft bend and end play	 0000831
2	Magnetic Stand	For holding the dial indicator when measuring	 0000833
3	Micrometer	For measuring the outside diameters of crankshaft, pistons, piston pins, etc.	 0000834
4	Cylinder Bore Gauge	For measuring the inside diameters of cylinder bores, bearing bores, etc.	 0000835
5	Calipers	For measuring outside diameters, depth, thickness and width	 0000836
6	Depth Micrometer	For measuring valve recession	 0000837
7	Square	For measuring valve spring inclination and straightness of parts	 0000838
8	Torque Wrench	For tightening nuts and bolts to the specified torque	 0000840

No.	Instrument Name	Application	Illustration
9	Feeler Gauge	For measuring piston ring gaps and piston ring side clearance	 0000841

SEALANTS AND COMPOUNDS

Sealant Name	Use
Medium strength thread lock and sealer	Timing Case Cover - Guide Rail Pins
	Flywheel Bolts
Copper Anti-Seize	Exhaust Manifold - Mounting studs
Three Bond® 1207F (Yanmar Part No. 977770-1207F) or equivalent	Cylinder Head Cover
	Timing Case Cover - Gasket

TESTS AND ADJUSTMENTS

Test Compression

The compression tester is used to quickly and simply check wear and damage primarily to the cylinder head valves, but also to cylinders and piston rings.

The results are intended only for comparison between the cylinders. Lower compression in one or more of the cylinders is a sign of abnormal wear or damage.

NOTICE: The battery must have an adequate charge in order to carry out a reliable compression test. If necessary, connect an additional battery.

1. Remove all glow plugs. *See Remove and Install Glow Plugs on page 5-19.*
2. Disconnect electrical connectors from all fuel injectors.
3. Turn engine over several times using the starter motor to remove any loose debris in the cylinders.
4. Assemble special tools OEM No. 11 0 222 and 11 0 236 and install in glow plug port **(Figure 5-1)**.

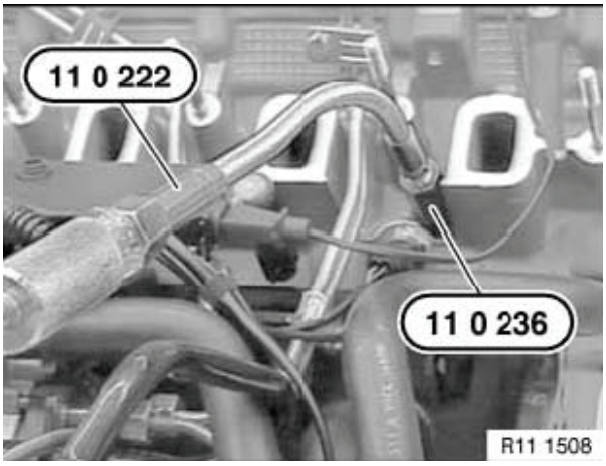


Figure 5-1

5. Turn engine with the starter motor until reading on gauge stabilizes. Note reading on the gauge.
6. Reset gauge and repeat procedure with the remaining cylinders.
7. Connect fuel injector electrical connectors.
8. Evaluate readings and assess if engine repair is necessary. If one or more cylinders has a lower compression pressure, components such as valves, cylinders and piston rings should be inspected.

Specification

Item	Specification
Cylinder Compression Pressure	28 ±2 bar (406 ±29 psi)

9. Install the glow plugs. *See Remove and Install Glow Plugs on page 5-19.*

REPAIR

Before performing any repair procedures, always do the following first:

1. Disconnect battery cables at the battery. Always disconnect negative (-) battery cable first.
2. Close all valves in the fuel supply system.
3. Remove electrical connections, intake and exhaust system connections, and fuel supply lines from engine. Cap or plug all open fuel connections.
4. Drain engine coolant from cylinder block.
5. Remove engine from boat. Mount engine to a suitable engine repair stand having adequate weight capacity.
6. Cap or plug all openings to prevent contamination.
7. Remove starter motor and alternator.
8. Clean engine by washing with solvent, air or steam cleaning. Carefully operate cleaning equipment so as to prevent any foreign matter or fluids from entering engine or damaging any fuel system or electrical components remaining on the engine.
9. Remove cooling system components from engine.
10. Drain engine oil into a suitable container. Remove oil filter.

CYLINDER HEAD

Cylinder Head Components

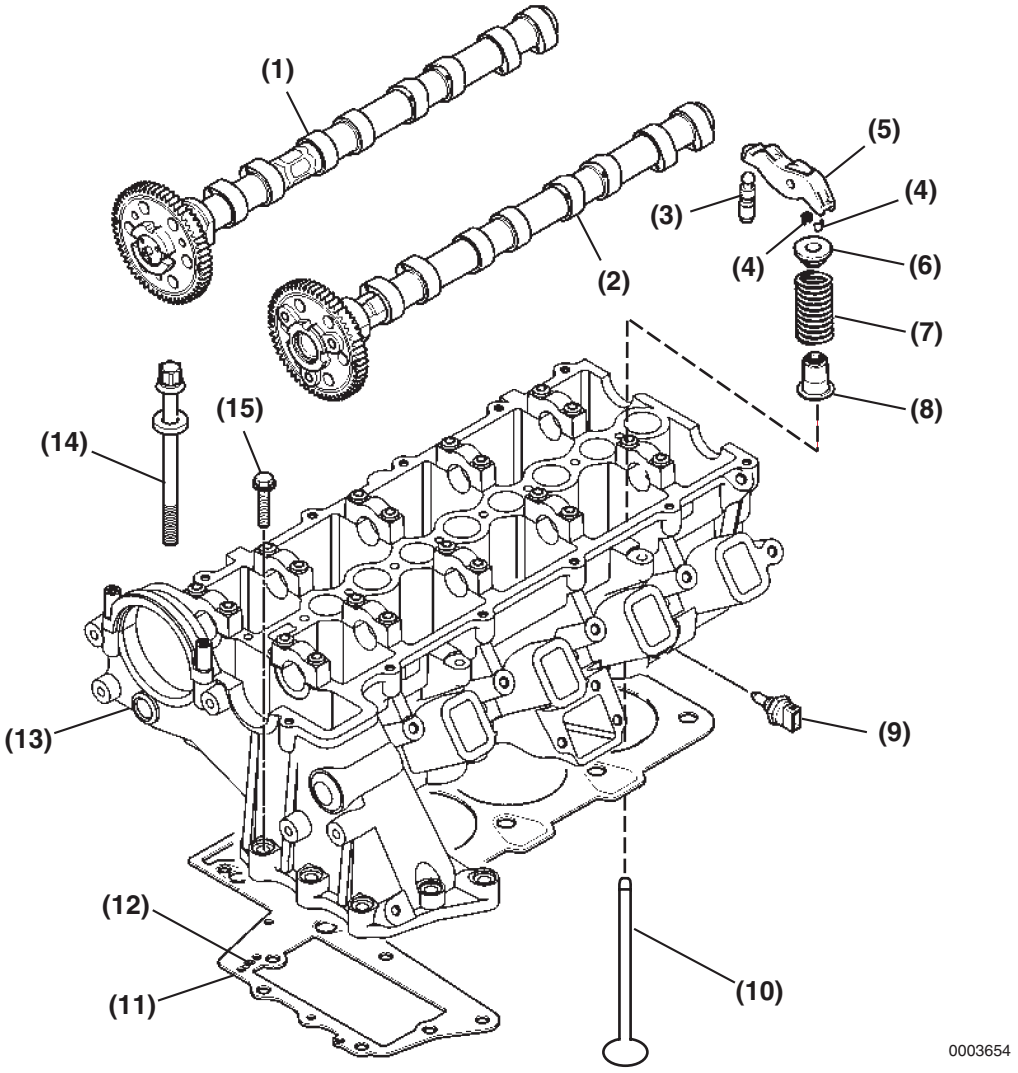


Figure 5-2

1 – Exhaust Camshaft
2 – Intake Camshaft
3 – Hydraulic Rocker Arm Pivot
4 – Valve Keeper (2 used each valve)
5 – Cam Follower
6 – Valve Spring Retainer
7 – Valve Spring
8 – Valve Stem Seal
9 – Coolant Temperature Sensor
10 – Valve
11 – Cylinder Head Gasket
12 – Head Gasket Identification Holes
13 – Cylinder Head
14 – Cylinder Head Bolt
15 – Bolt

General Guidelines

NOTICE: Mark all valve train components so they can be installed back in their original locations.

Note: Record all measurements taken during disassembly and inspection.

Remove and Install Cylinder Head Cover

Cylinder Head Cover Components

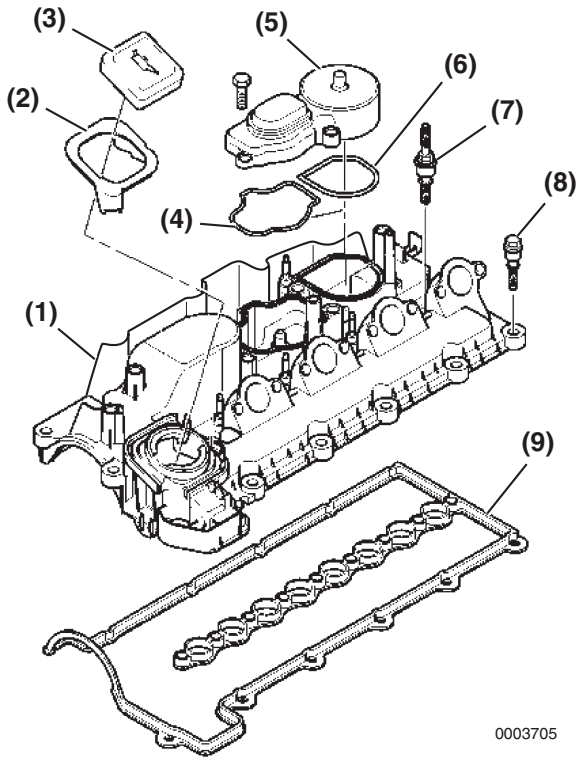


Figure 5-3

1 – **Cylinder Head Cover**
2 – **Rubber Gasket**
3 – **Oil Fill Cap**
4 – **Seal**
5 – **Crankcase Ventilation Diaphragm Housing**
6 – **Seal**
7 – **Double-Ended Bolt**
8 – **Bolt**
9 – **Profile Gasket**

NOTICE: When working on the oil, coolant or fuel systems you must protect the alternator from contamination. Cover alternator with suitable materials.

Removal

1. Disconnect negative (-) battery cable.
2. Remove upper engine cover.
3. Remove intake manifold. *See Intake Manifold on page 5-66.* Plug all intake ports to prevent contamination.
4. Clean the cylinder head cover and the surrounding area.
5. Disconnect high-pressure fuel lines **(Figure 5-4, (1))** and remove fuel injectors **(Figure 5-4, (2))**. *See Remove Fuel Injector on page 6-11*.

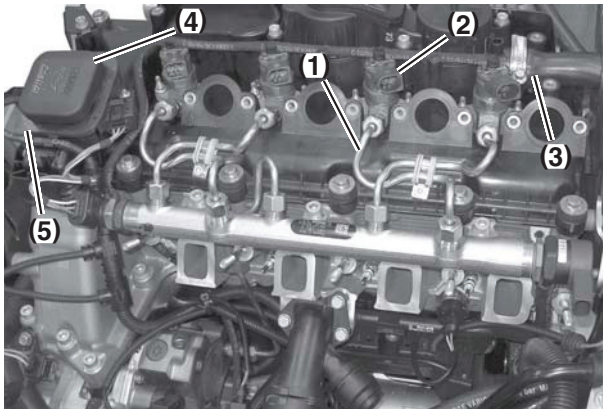


Figure 5-4

6. Disconnect breather hose **(Figure 5-4, (3))** from breather.
7. Remove oil fill cap **(Figure 5-4, (4))** and lift rubber gasket **(Figure 5-4, (5))** to access cover bolt located under the rubber gasket.
8. Remove the cylinder head cover bolts in sequence, working from the outer bolts toward the center.
9. Remove cylinder head cover.

Installation

1. Thoroughly clean all gasket residue from the mating surfaces.
2. Apply a thin uniform bead of Three Bond® 1207F (Yanmar part No. 977770-1207F) approximately 2 mm (0.079 in.) high and 2 mm (0.079 in.) wide at the transition to each end of the half-moon section **(Figure 5-5)**.

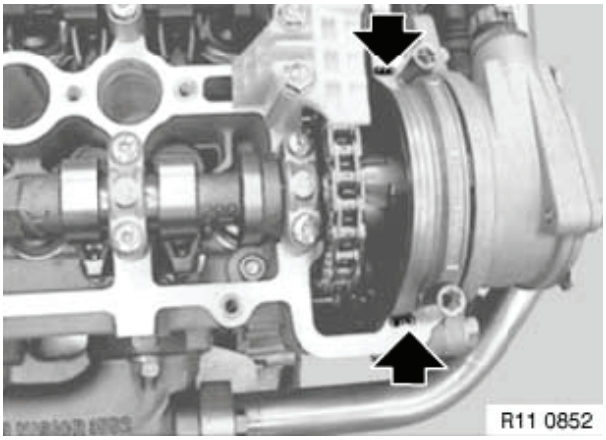


Figure 5-5

3. Install cylinder head cover gasket. Ensure gasket is correctly seated on rear of cylinder head.

Note: Double-ended bolts **(Figure 5-6, (1))** are used on the inner row only.

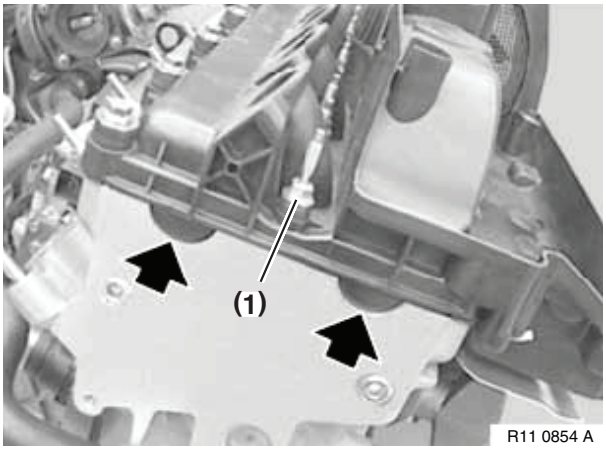


Figure 5-6

4. Install cylinder head cover. Tighten bolts in two stages to 9.5 N·m (84 in.-lb). Tighten inner row **(Figure 5-6, (1))** working evenly from the center towards each end. Tighten outer bolts evenly and diagonally.
5. Install rubber gasket and oil filler cap.
6. Breather / blow-by spacer is a two-part assembly, clean mating surfaces and seal the parts together. Apply a bead of Loctite 5970 gasket sealant to the upper side of the blow-by spacer as shown and assemble both halves.

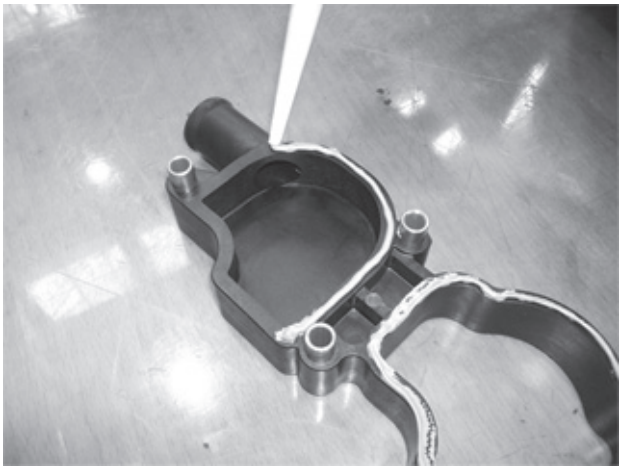


Figure 5-7

7. Install assembled breather housing to cylinder head and tighten bolts to the specified torque, *see Special Torque Chart on page 5-8*.
8. Connect breather hose to vacuum chamber.
9. Install fuel injectors and connect high-pressure fuel lines. *See Install Fuel Injector on page 6-13.*
10. Install intake manifold. *See Intake Manifold on page 5-66.*
11. Connect electrical connectors to the fuel injectors, camshaft sensor, intake air pressure sensor and intake air temperature sensor.
12. Install engine cover.

Remove and Install Glow Plugs

1. Disconnect battery negative (-) terminal.
2. Remove intake manifold. *See Intake Manifold on page 5-66.*
3. Release locks and remove connector **(Figure 5-8, (1))** from glow plug.

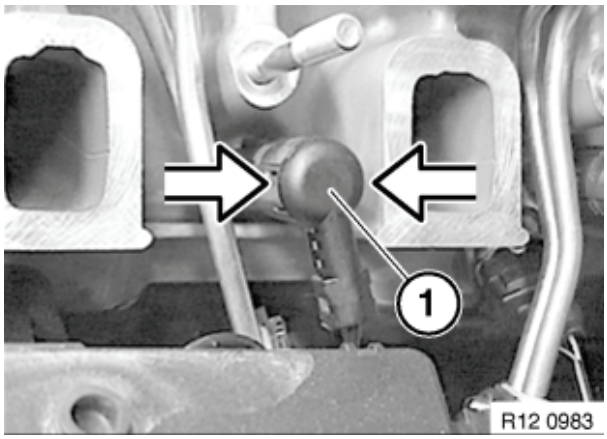


Figure 5-8

4. Use special tool OEM No. 11 6 050 to remove glow plug **(Figure 5-9, (1))** from cylinder head.

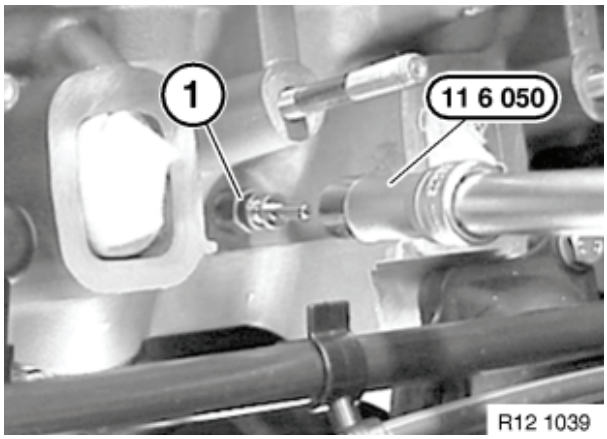


Figure 5-9

Note: If glow plug failure has occurred, it is essential to check condition of fuses.

5. Test and replace glow plug as necessary.
6. Install glow plug using special tool OEM No. 11 6 050. Tighten to 17.5 N·m (154 in.-lb).
7. Install and lock connector to glow plug.
8. Install intake manifold. *See Intake Manifold on page 5-66.*
9. Connect battery negative (-) terminal.
10. Check and delete any trouble codes that are registered in the ECU after the work has been completed. *See After Troubleshooting or Repair on page 13-14.*

Remove Cylinder Head

1. Disconnect negative (-) battery cable.
2. Drain the coolant from the engine. *NOTICE: When working on the oil, coolant or fuel systems protect the alternator from contamination. Cover alternator with suitable materials.*
3. Remove turbocharger. *See Remove Turbocharger on page 9-6.*
4. Remove the banjo bolt **(Figure 5-10, (1))** securing the oil pressure sender line to the front heat exchanger mount. Disconnect wires **(Figure 5-10, (2))** from oil pressure sender.

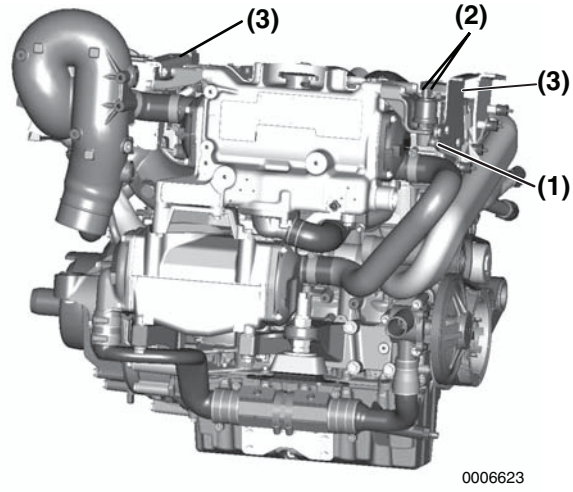


Figure 5-10

5. Remove heat exchanger. *See Remove and Install Heat Exchanger on page 7-13.*
6. Remove front and rear heat exchanger mounting brackets **(Figure 5-10, (3))**.
7. Remove exhaust manifold. *See Exhaust Manifold on page 5-69.*
8. Remove cylinder head cover. *See Remove and Install Cylinder Head Cover on page 5-17.*
9. Remove the intake manifold. *See Intake Manifold on page 5-66.*

10. Rotate crankshaft using the crankshaft dampener bolt until No. 1 cylinder is at TDC. Secure flywheel using flywheel holding tool OEM No. 11 5 180 **(Figure 5-11)**.

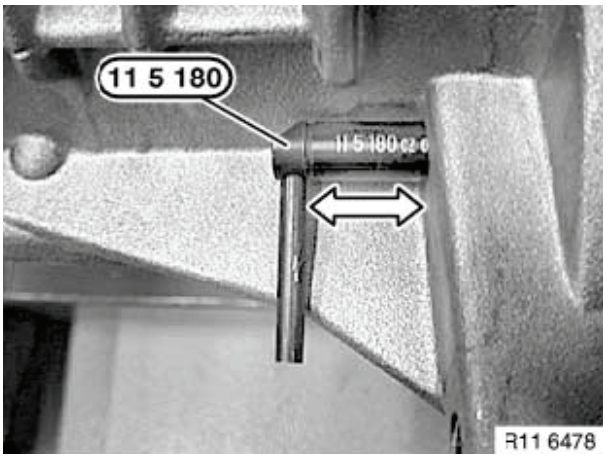


Figure 5-11

11. Remove both camshafts. *See Remove Camshafts on page 5-51.*
12. Remove all hydraulic rocker arm pivots and cam followers. *NOTICE: NEVER mix used valve train components. When removing any valve train components, be sure to identify their original location or store them in an order that will allow them to be installed in their original positions.*
13. Remove oil cooler return pipe screw **(Figure 5-12, (1))**.

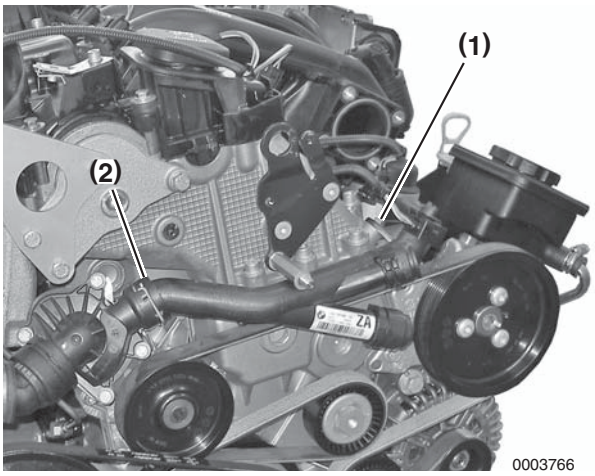


Figure 5-12

14. Release the locks and disconnect coolant return pipe **(Figure 5-12, (2))**. *See Disconnect and Connect Quick-Connect Fittings on page 7-11.*
15. Remove three bolts and the coolant branch fitting **(Figure 5-13, (1))**.

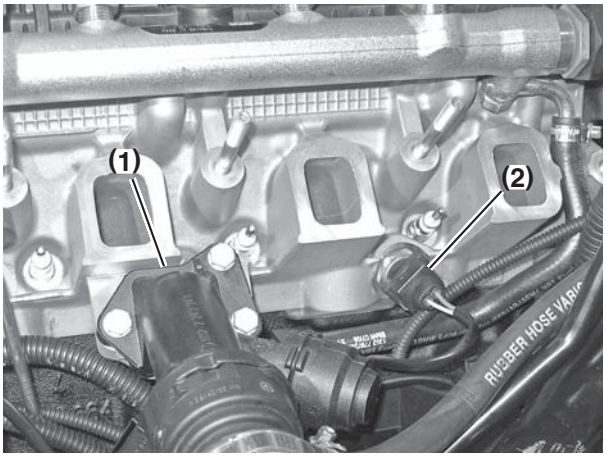


Figure 5-13

16. Disconnect electrical connector from the coolant temperature sensor **(Figure 5-13, (2))**.
17. Remove high-pressure fuel rail. *See Remove and Install Fuel Rail on page 6-20*.
18. Remove pump-to-fuel rail high-pressure line **(Figure 5-14, (1))**.

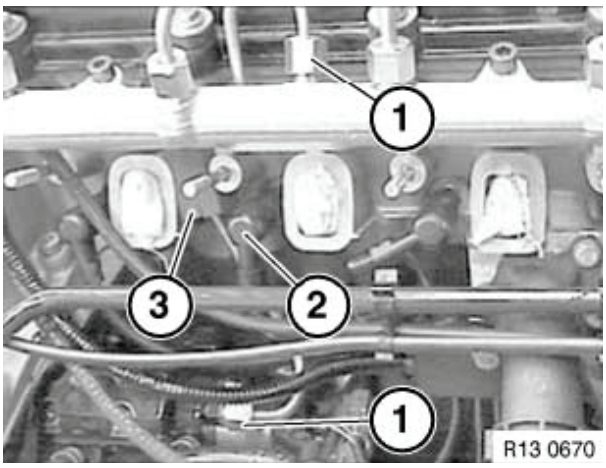


Figure 5-14

Note: **4BY2 Engines**: Note the position of the rubber mount **(Figure 5-14, (3))** for reassembly.

19. Remove glow plugs **(Figure 5-14, (2))**. *See Remove and Install Glow Plugs on page 5-19.*

20. *NOTICE: NEVER remove bolts retaining loop casting **(Figure 5-15)***. Remove timing case cover bolts **(Figure 5-16, (1))**.

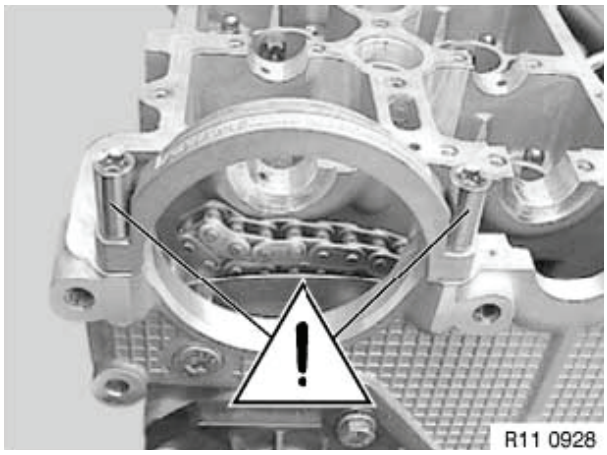


Figure 5-15

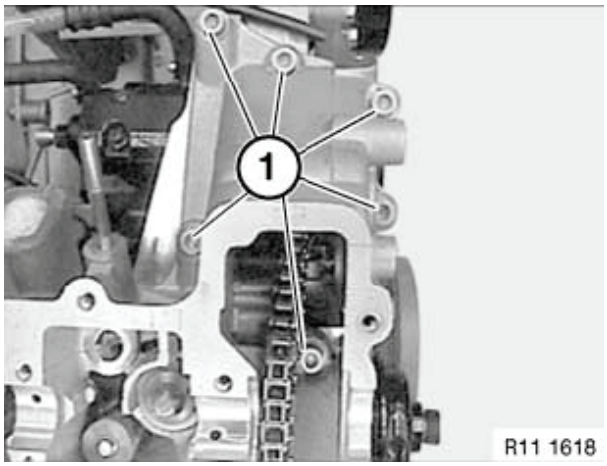


Figure 5-16

21. **4BY2 Engines:** Remove cylinder head bolts in reverse sequence, beginning with number 10 **(Figure 5-17)**.

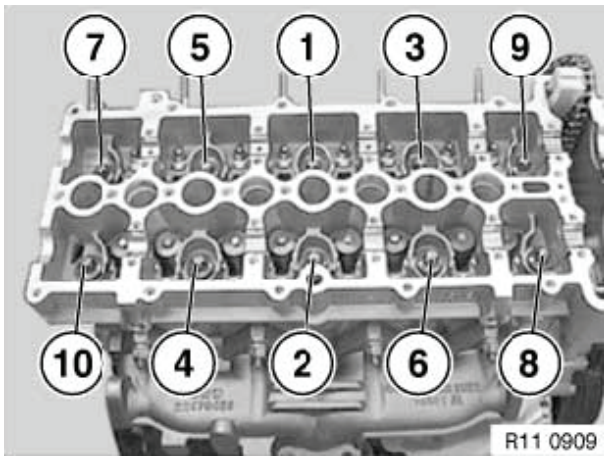


Figure 5-17

22. **6BY2 Engines:** Remove cylinder head bolts in reverse sequence, beginning with number 14 **(Figure 5-18)**.

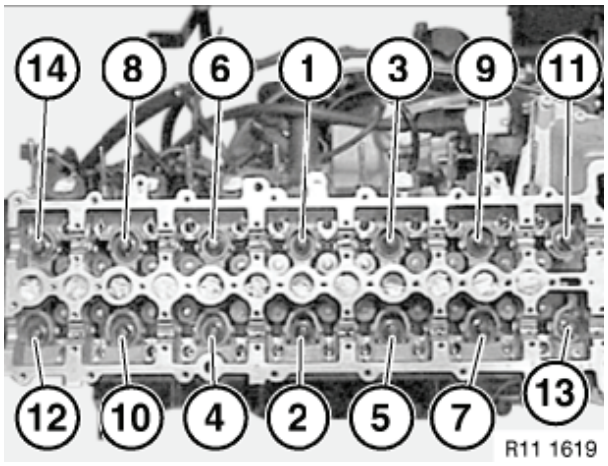


Figure 5-18

23. Remove cylinder head.
24. Remove the cylinder head gasket.

Disassemble Cylinder Head

1. Attach cylinder head to special tool OEM No. 11 9 000 **(Figure 5-19)**.

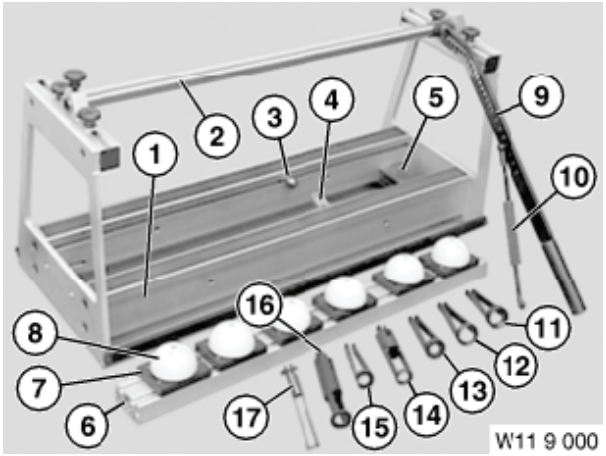


Figure 5-19

2. Put special tool OEM No. 11 9 008 with straight surface on combustion chamber side of cylinder head **(Figure 5-20)**.

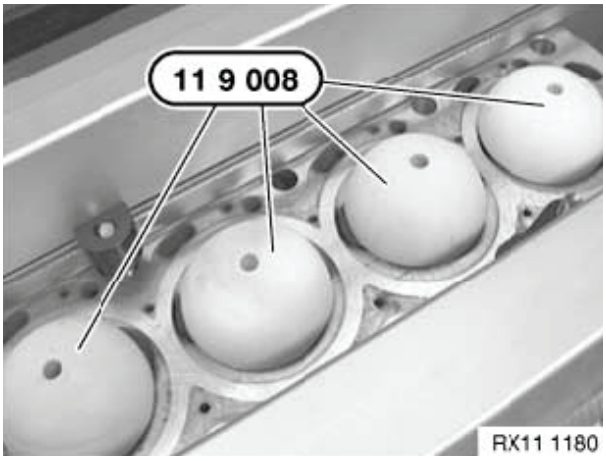


Figure 5-20

3. Insert special tool OEM No. 11 9 006 and lock with special tool OEM No. 11 9 005 in direction of the arrows **(Figure 5-21)**.

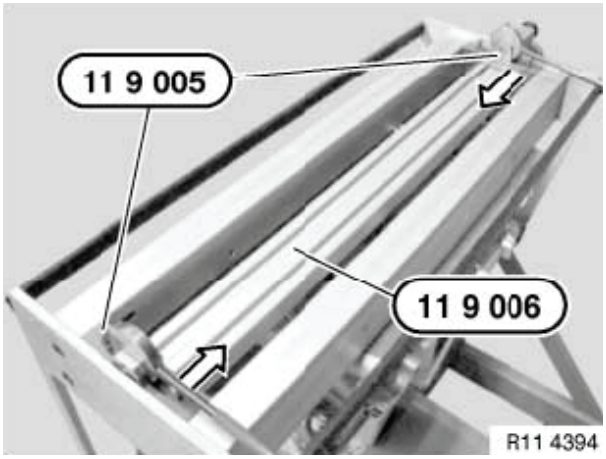


Figure 5-21

4. Lock special tool OEM No. 11 9 005 in direction of the arrows **(Figure 5-22)**. Rotate cylinder head 180° into service position.

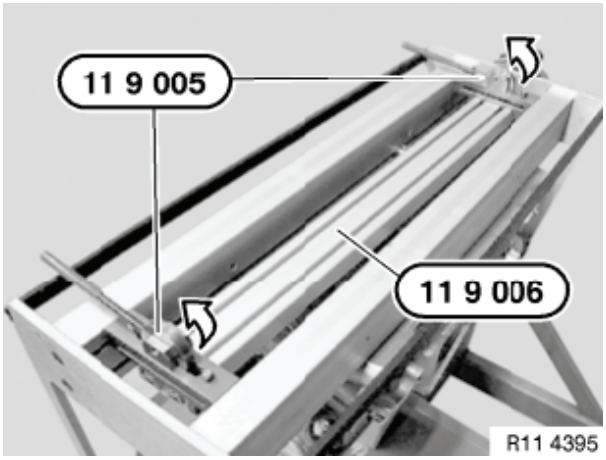


Figure 5-22

5. Secure cylinder head to special tool OEM No. 11 9 001 **(Figure 5-23)**.

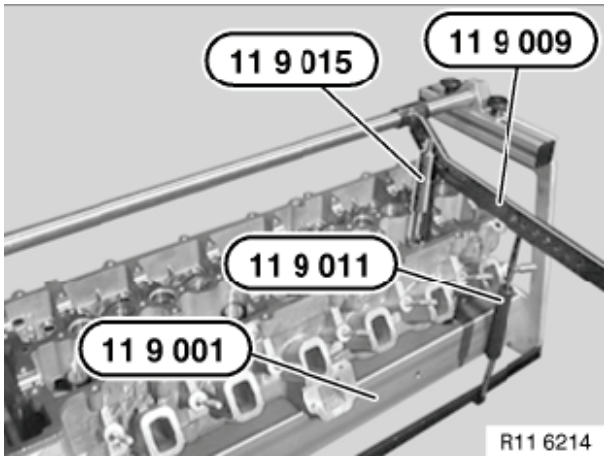


Figure 5-23

6. Install spring compressor OEM No. 11 9 015 on lever OEM No. 11 9 009.
7. Press down to compress valve spring and lock in place with special tool OEM No. 11 9 011.
8. *NOTICE: Mark all valve train components so they can be installed back in their original locations.*

   Remove valve keepers **(Figure 5-24)**.

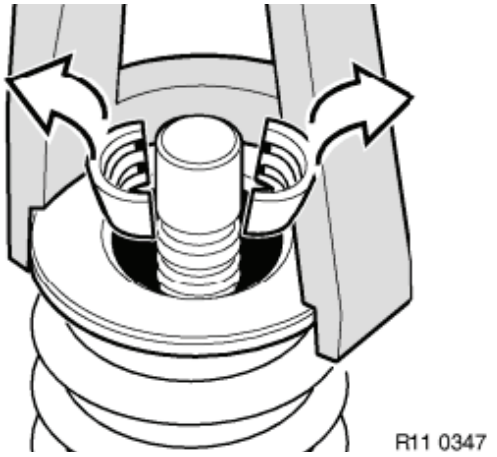


Figure 5-24

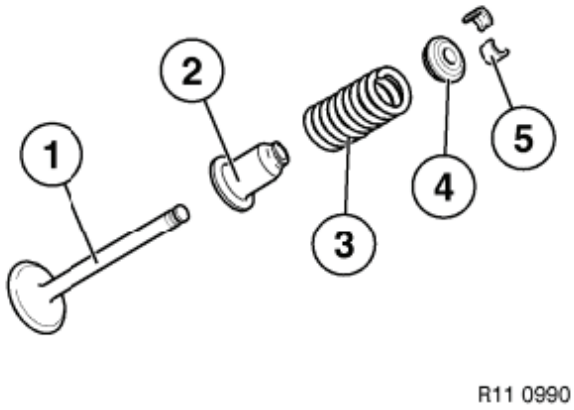


Figure 5-25

1 – Valve
2 – Valve Stem Seal
3 – Valve Spring
4 – Valve Spring Retainer
5 – Valve Keeper (2 used each valve)

9. Release tension on valve spring and remove valve spring retainer and valve spring.
10. Repeat for all cylinders.
11. Remove valve stem seals. *See Replace Valve Stem Seals on page 5-25.*

Clean Cylinder Head Components

Thoroughly clean all components using a non-metallic brush and an appropriate solvent. Each part must be free of carbon, metal filings and other debris.

Pressure Test the Cylinder Head

1. Remove and disassemble cylinder head. *See Disassemble Cylinder Head on page 5-22.*

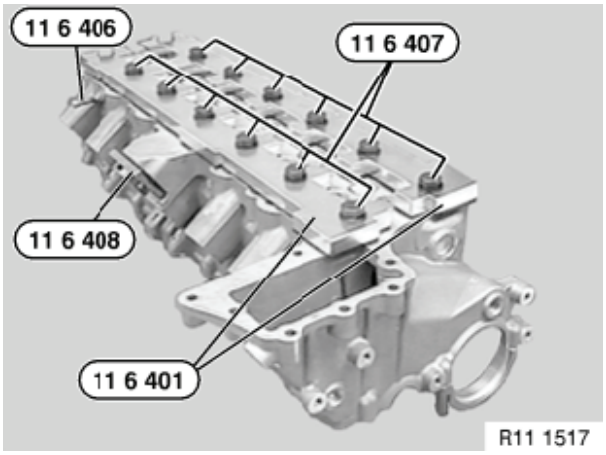


Figure 5-26

Note: Special tool OEM No. 11 6 407 consists of twelve screws for mounting special tools OEM No. 11 6 401 to the cylinder head. If OEM No. 11 6 407 is not available, use the old cylinder head bolts to secure special tool OEM No. 11 6 401.

2. Seal off all coolant openings using special tool OEM No. 11 6 400.

Note: OEM No. 11 6 400 consists of 11 6 401, 11 6 406, 11 6 407 and 11 6 408.

3. Connect air source to cylinder head and immerse in water bath. Apply pressure and adjust to 4.5 bar (65 psi) **(Figure 5-27)**.

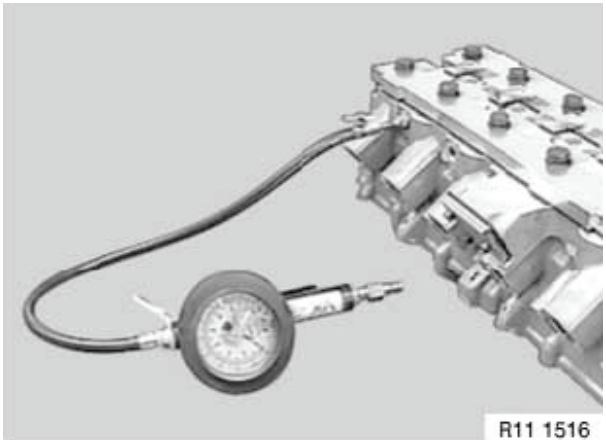


Figure 5-27

Note: Reduce surface tension of water used for test with a few drops of detergent.

4. Inspect cylinder head for discharge of bubbles indicating a crack in the casting.

Inspect Cylinder Head Components

Clean all gasket material, sealant and carbon from components. Use a suitable solvent and a soft-bristle brush to clean parts.

Visually inspect parts. Replace any parts that are obviously discolored, heavily pitted or otherwise damaged. Discard any part that does not meet its specified limit. *NOTICE: Any part which is found defective as a result of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.*

NOTICE: Mark all valve train components so they can be installed in their original locations.

Note: Record all measurements taken during inspection.

Inspection of Valve Guides

1. Insert a NEW valve so the end is flush with the valve spring end of the valve guide.
2. Install dial indicator OEM No. 00 2 510 or similar as shown **(Figure 5-28)**.

Figure 5-28

3. Move valve back and forth while reading dial indicator.

   Results: If measurement exceeds specification, the cylinder head and valves must be replaced.

Specifications

Inspection Item		Limit
Valve Guide Wear	Intake	0.5 mm (0.020 in.)
	Exhaust	

Replace Valve Stem Seals

1. Remove the valve spring. It is not necessary to remove valve.
2. Press special tool OEM No. 11 6 370 onto valve stem seal and turn **(Figure 5-29)**.

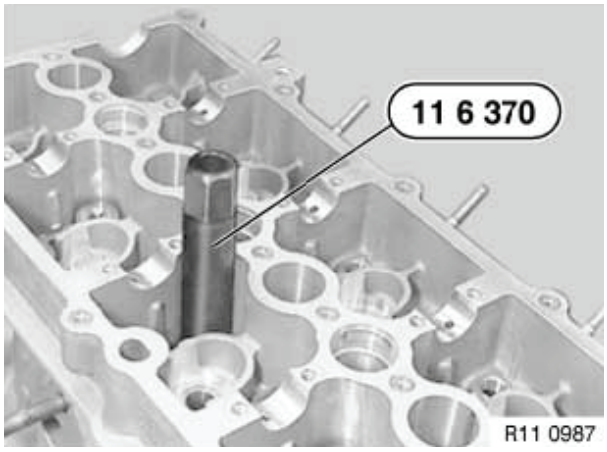


Figure 5-29

3. Remove special tool together with valve stem seal.
4. Lubricate valve stem and install special tool OEM No. 11 1 960.
5. Coat new valve stem seal **(Figure 5-30, (1))** with oil and install over tool. Remove special tool OEM No. 11 1 960.

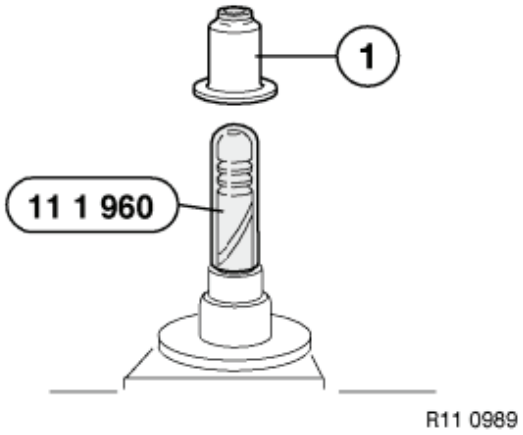


Figure 5-30

6. Press valve stem seal into place with special tool OEM No. 11 6 380 until it is seated **(Figure 5-31)**.

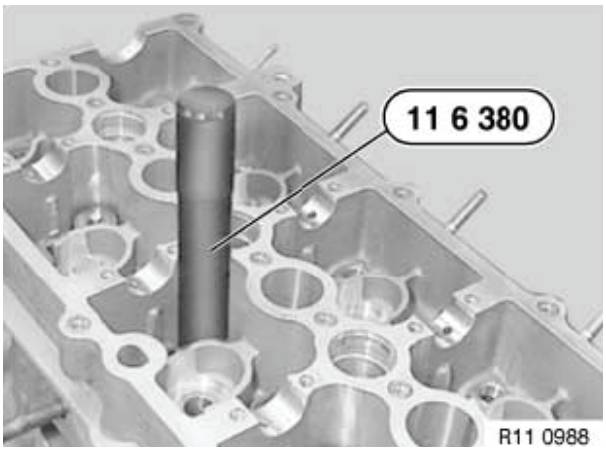


Figure 5-31

7. Install valve spring.

Assemble Cylinder Head

1. Liberally lubricate all moving parts with clean engine oil during assembly.
2. Install the valves in cylinder head.
3. Install new valve stem seals. *See Replace Valve Stem Seals on page 5-25.*
4. Secure cylinder head to special tool OEM No. 11 9 001 **(Figure 5-32)**.

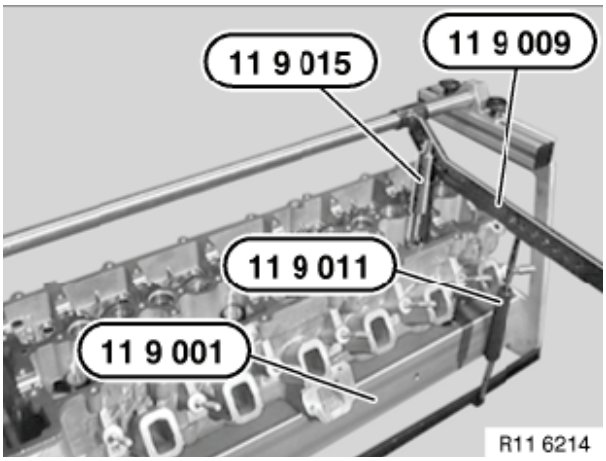


Figure 5-32

5. Install spring compressor OEM No. 11 9 015 on lever OEM No. 11 9 009 **(Figure 5-32)**.
6. Install valve spring and retainer.
7. Press down to compress valve spring and lock in place with special tool OEM No. 11 9 011 **(Figure 5-32)**.
8. Install valve keepers.
9. Allow the valve spring to expand against the keepers. Repeat with remaining valves.

Determine Cylinder Head Gasket Thickness

1. Thoroughly clean all old gasket material from the cylinder head gasket surface of the cylinder block.
2. Clean all carbon and deposits from measuring locations of each piston.
3. Place a dial indicator with measuring fixture OEM No. 00 2 530 on clean cylinder block **(Figure 5-33)**. Set the dial to zero.

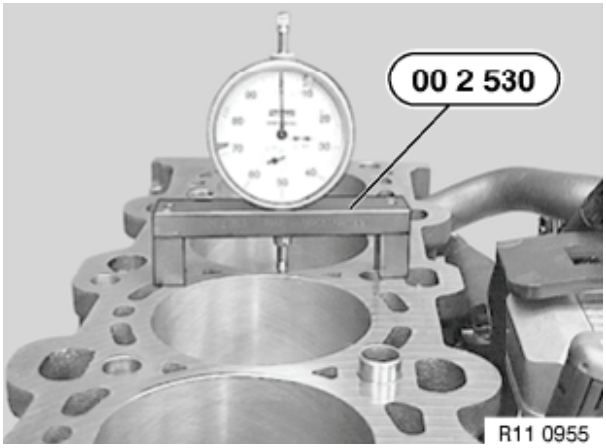


Figure 5-33

4. Rotate the crankshaft to bring piston to the top of its stroke.

5. Slide fixture and indicator over cleaned area of piston **(Figure 5-34, (1))**. Rotate the crankshaft to determine the highest point of piston travel and record the measurement. Repeat the procedure in a second area **(Figure 5-34, (2))**.

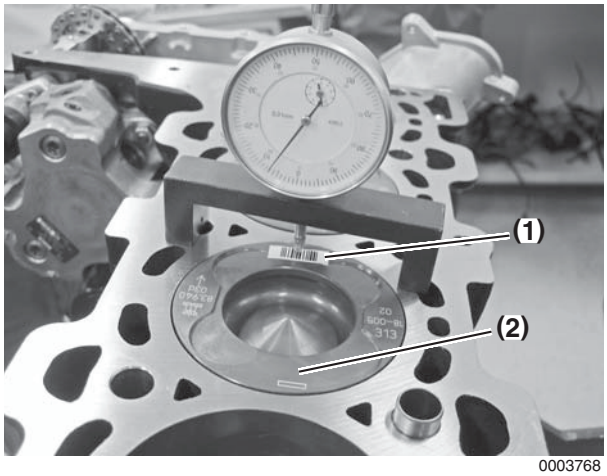


Figure 5-34

6. Measure all pistons in the same manner.
7. Select the lesser measurement for all pistons and use the following chart to choose the correct gasket. Gasket thickness is identified by the number of holes **(Figure 5-35, (arrow))**.

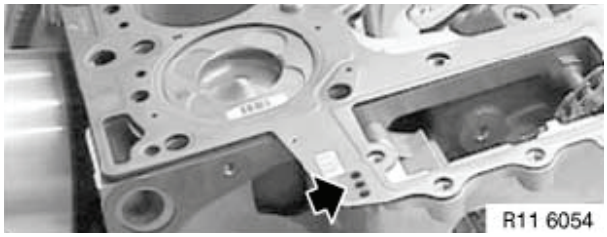


Figure 5-35

Cylinder Head Gasket Identification

Engine	Measured Distance	Gasket
4BY2 / 6BY2	0.72 to 0.83 mm (0.028 to 0.033 in.)	1-hole
	0.83 to 0.93 mm (0.033 to 0.037 in.)	2-hole
	0.93 to 1.04 mm (0.037 to 0.041 in.)	3-hole
	1.04 to 1.24 mm (0.041 to 0.049 in.)	0-hole

Install Cylinder Head

1. If the pistons, connecting rods or crankshaft were refurbished or replaced, check piston height to determine correct cylinder head gasket thickness. *See Determine Cylinder Head Gasket Thickness on page 5-26.* If those items remain unchanged, select a gasket that matches the one removed during disassembly.
2. Check condition and placement of alignment dowel sleeves **(Figure 5-36, (1))**.

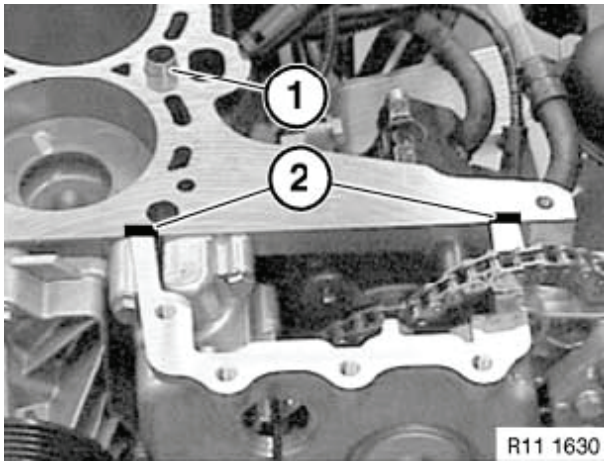


Figure 5-36

3. Ensure the gasket surfaces of the cylinder head and cylinder block are clean and dry. Transition areas **(Figure 5-36, (2))** must be absolutely clean of grease and oil. *NOTICE: Ensure the threaded bolt holes are clean and dry. If coolant or oil remains in the holes, there is a risk of cracking the cylinder block when the bolts are installed.*
4. Install a new cylinder head gasket having the correct number of identification holes as determined in step 1.
5. Install the cylinder head.

6. Lightly oil threads of new bolts and install new bolts. Tighten the bolts in stages, and in the sequence shown **(Figure 5-37)** and **(Figure 5-38)**. Use a torsion angle tool such as that shown **(Figure 5-39)**. *NOTICE: NEVER reuse cylinder head bolts. New bolts must be installed whenever they are removed. NEVER wash off bolt coating.*

4BY2 Engine

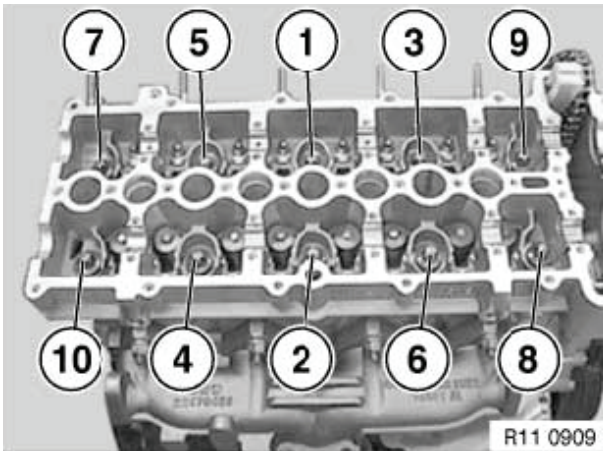


Figure 5-37

6BY2 Engine

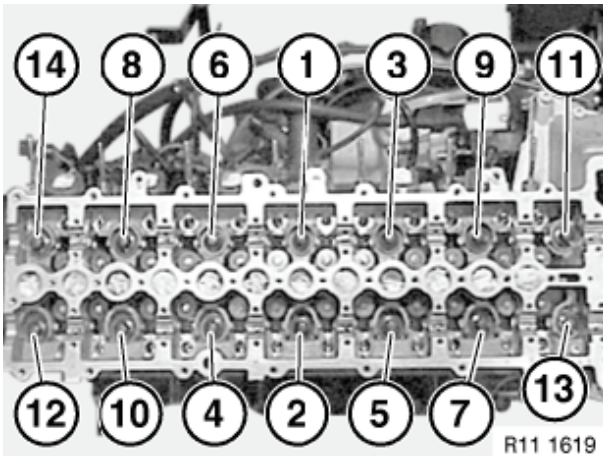


Figure 5-38

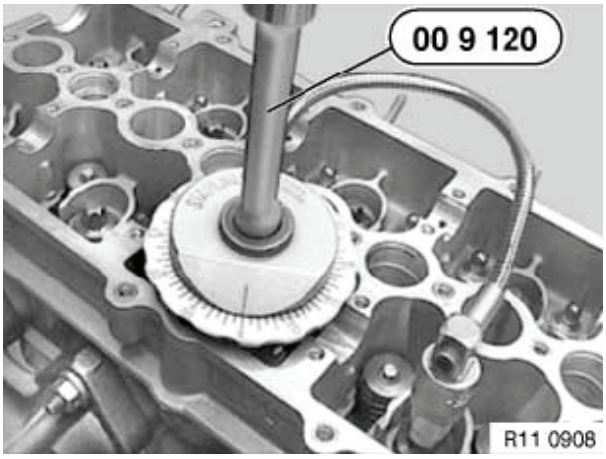


Figure 5-39

Cylinder Head Torque Specification

Item	Specification
First	Tighten all bolts to 80 N·m (59 ft-lb)
Second	Loosen all bolts at least 180°
Third	Tighten all bolts to 50 N·m (37 ft-lb)
Fourth	Tighten all bolts an additional 90°
Fifth	Tighten all bolts an additional 90°

7. Install the timing case cover screws **(Figure 5-40, (1))** and tighten.

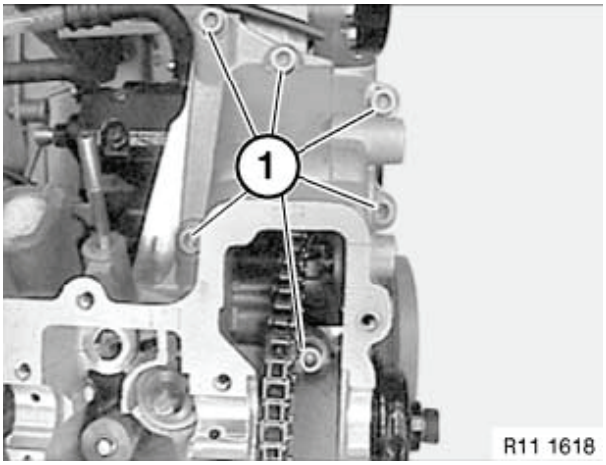


Figure 5-40

8. Install high-pressure pump-to-fuel rail line **(Figure 5-41, (1))**.

   4BY2 Engines: Install rubber mount **(Figure 5-41, (3))**.

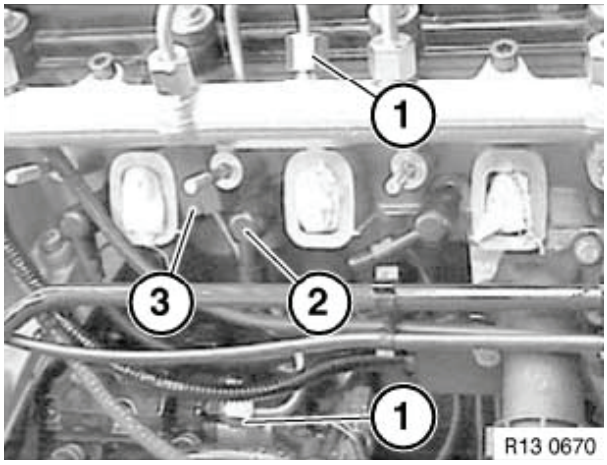


Figure 5-41

9. Install the glow plugs **(Figure 5-41, (2))**.
10. Install high-pressure fuel rail. *See Remove and Install Fuel Rail on page 6-20.*
11. Connect harness connector to temperature sensor **(Figure 5-42, (2))**.

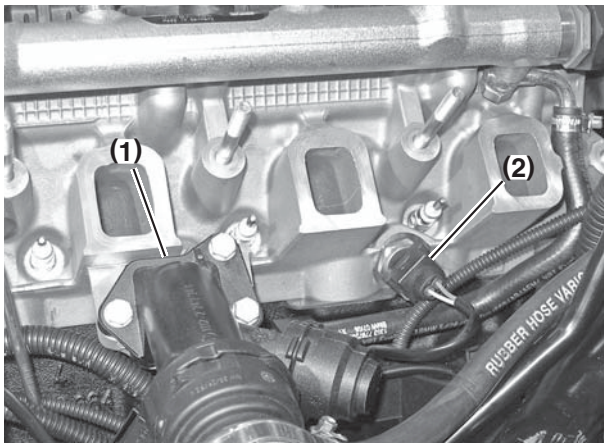


Figure 5-42

12. Install coolant branch fitting **(Figure 5-42, (1))** with a new seal and tighten bolts.
13. Connect oil cooler return pipe **(Figure 5-43, (2))** to thermostat housing.

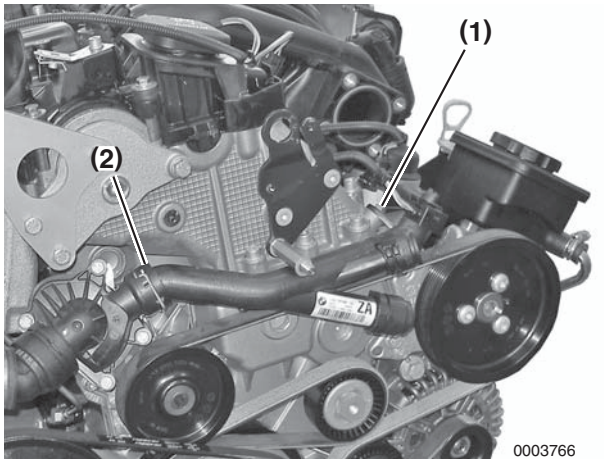


Figure 5-43

14. Install bolt **(Figure 5-43, (1))**.
15. Install fuel injectors. *See Install Fuel Injector on page 6-13.* Connect high-pressure lines using special tool OEM No. 13 5 020. *See Remove and Install High-Pressure Fuel Lines on page 6-14*.
16. Rotate crankshaft using the crankshaft dampener bolt until No. 1 cylinder is at TDC. Secure flywheel using flywheel holding tool OEM No. 11 5 180 **(Figure 5-44)**.

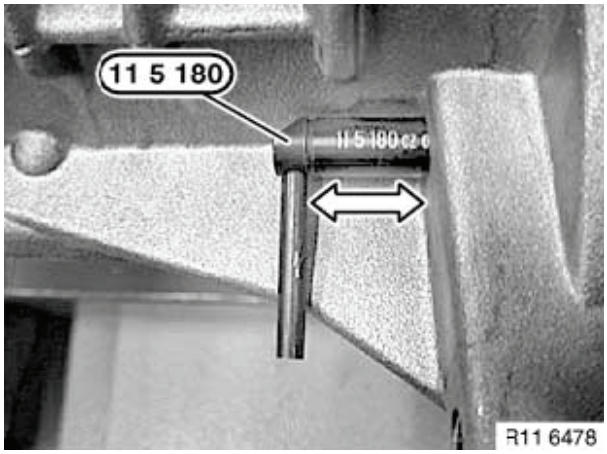


Figure 5-44

17. *NOTICE: NEVER mix used valve train components. When installing any valve train components, be sure to install them in their original positions.*

    Install all hydraulic rocker arm pivots and cam followers.

18. Install both camshafts. *See Install Camshafts on page 5-54.*
19. Install cylinder head cover. *See Remove and Install Cylinder Head Cover on page 5-17.*
20. Install exhaust manifold. *See Exhaust Manifold on page 5-69.*
21. Install front and rear heat exchanger brackets **(Figure 5-45, (3))**.

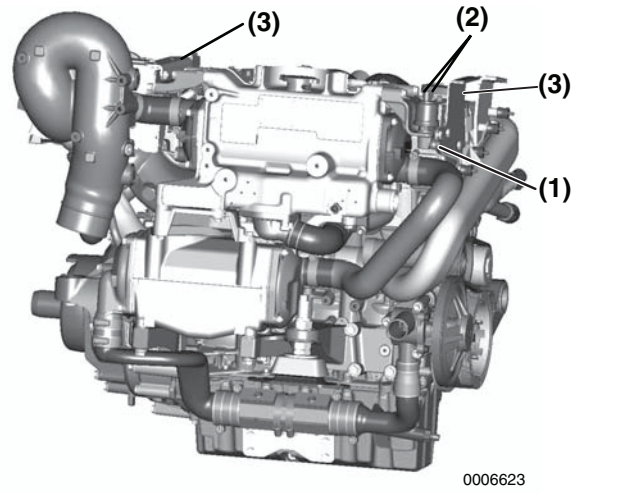


Figure 5-45

22. Install oil pressure sender line banjo bolt **(Figure 5-45, (1))** and new copper gaskets. Tighten securely.
23. Connect wires **(Figure 5-45, (2))** to oil pressure sender.
24. Install intake manifold. *See Intake Manifold on page 5-66.*
25. Install heat exchanger. *See Remove and Install Heat Exchanger on page 7-13.*
26. Install intake manifold.
27. Install turbocharger. *See Install Turbocharger on page 9-6.*
28. Fill engine with coolant.
29. Connect negative (-) battery cable.
30. Check engine oil level. Add more oil if necessary.
31. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
32. Start engine and check for leaks.

PISTONS AND CYLINDERS

Remove and Disassemble Piston and Connecting Rod

NOTICE: Keep the piston pin parts, piston assemblies and connecting rod assemblies together to be returned to the same position during the reassembly process. Label the parts using an appropriate method.

1. Remove cylinder head. *See Remove Cylinder Head on page 5-19*.
2. Remove oil sump and oil pump. *See Oil Pump on page 8-12*.
3. Remove the oil deflector **(Figure 5-46, (1))**.

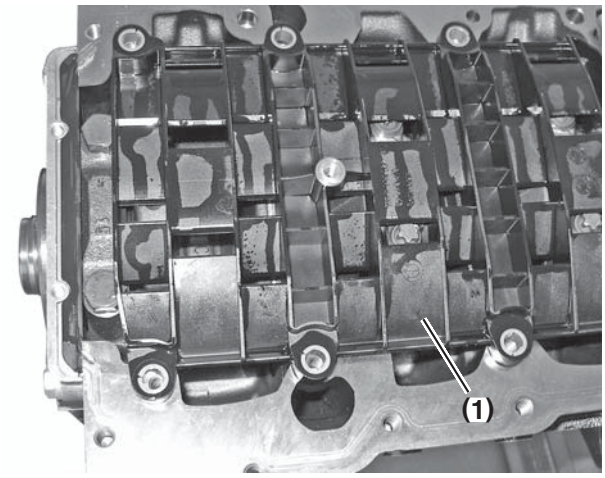


Figure 5-46

4. Remove the piston cooling nozzles from the cylinder block. *NOTICE: Use care not to damage the piston cooling nozzles. The oil spray must hit the piston precisely. If it does not, the piston will become too warm resulting in engine breakdown. NEVER straighten damaged nozzles. They must be replaced.*
5. Remove the ridge at the top of the cylinder if necessary.

   NOTICE: Engines with high operating hours may have a ridge near the top of the cylinders that will catch the piston rings and make it impossible to remove the pistons. Use a suitable ridge reamer to remove ridges and carbon prior to removing pistons.
6. Mark each piston and connecting rod before removing them. They must be installed in the same location and orientation as they were removed. *NOTICE: Pistons can fall from cylinder block if engine is inverted. Use care when removing the connecting rod caps.*
7. Remove the connecting rod cap bolts **(Figure 5-47)**.

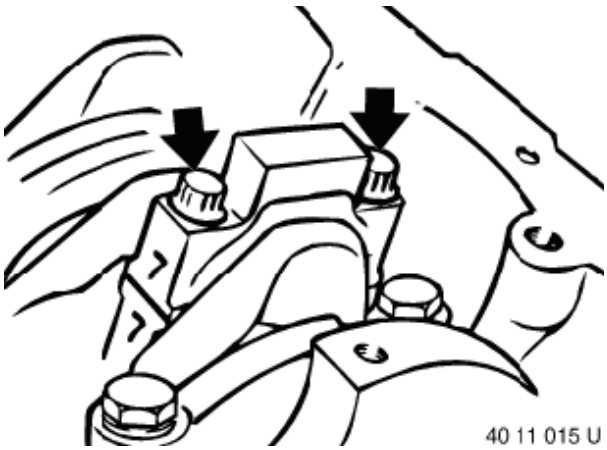


Figure 5-47

8. Remove the connecting rod cap and bearing inserts.
9. Check the bearing oil clearance as each piston and rod assembly is removed to help determine extent of wear. *See Measure Oil Clearance on page 5-59.*
10. Push the piston and connecting rod out of the cylinder. Use a wooden dowel against the connecting rod if necessary.

    NOTICE: NEVER allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

11. Remove the wrist pin retaining rings **(Figure 5-48)**.

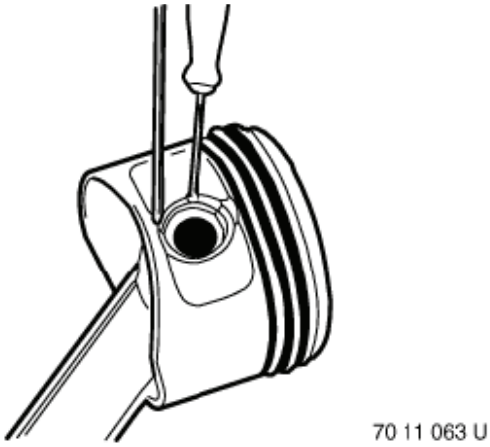


Figure 5-48

12. Push out the wrist pin. Keep piston and matched wrist pin together. *NOTICE: Pistons and wrist pins are matched. NEVER mix parts.*
13. Use a piston ring expander **(Figure 5-49)** to remove the piston rings, taking care not to scratch the surface of the piston.

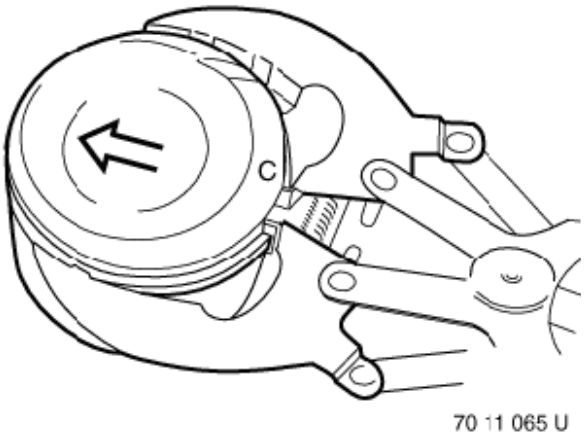


Figure 5-49

Inspect Pistons and Piston Rings

1. Insert new piston rings, one at a time, into the cylinder. Use a piston with the piston rings removed to slide the ring squarely into the cylinder bore. Measure the end gap of each piston ring **(Figure 5-50)**.

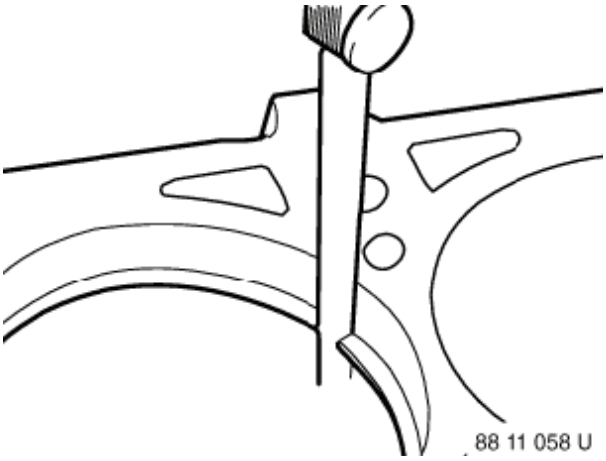


Figure 5-50

Note: Measure cylinder bore to ensure it is within specifications before measuring piston ring end gap. *See Inspect Cylinder Block on page 5-62*.

Specifications

Inspection Item		Standard	Limit
Top Piston Ring	Side Clearance	0.12 to 0.16 mm (0.005 to 0.006 in.)	-
	End Gap	0.20 to 0.35 mm (0.008 to 0.014 in.)	-
Second Piston Ring	Side Clearance	0.07 to 0.11 mm (0.003 to 0.004 in.)	-
	End Gap	0.30 to 0.45 mm (0.012 to 0.018 in.)	-
Oil Ring	Side Clearance	Cannot be measured	
	End Gap		
Piston-to-Cylinder	Clearance		0.15 mm (0.006 in.)

2. Clean piston ring grooves using a piston ring groove cleaning tool. Follow tool manufacturer's instructions for correct operation.

3. Wash pistons in an appropriate solvent using a soft-bristled brush.
4. Visually inspect each piston for cracks. Pay particular attention to the ring lands between the piston ring grooves.
5. Install a new piston ring. Use a feeler gauge to measure the side clearance between the ring and the piston **(Figure 5-51)**. Replace the piston if not within specification. Repeat with the second ring.

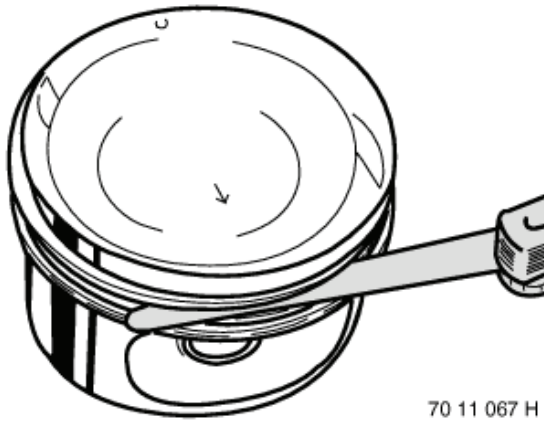


Figure 5-51

Note: The oil ring (third groove) cannot be measured.

6. Repeat steps for each of the cylinders and the piston rings for that specific cylinder.

Assemble Piston and Connecting Rod

1. Ensure the piston and rings are clean and the ring grooves are not damaged.
2. Oil the wrist pin bore and wrist pin before assembling.
3. Check the fit of the wrist pin in the connecting rod. The wrist pin should pass through the bushing with little force and not have any significant play **(Figure 5-52)**.

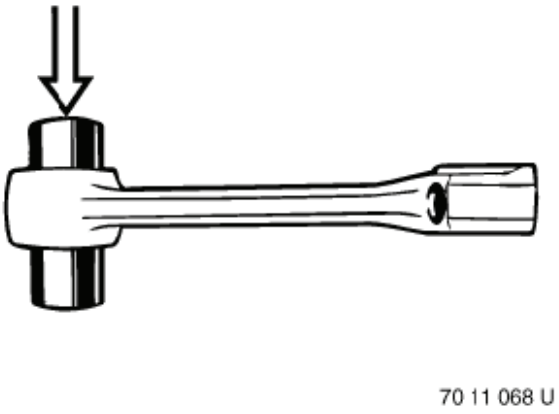


Figure 5-52

4. Install one retaining ring in the piston with the gap in the retaining ring opposite the recess.
5. Orient the piston and connecting rod as shown for assembly **(Figure 5-53)**. The arrow on top of the piston must point to the right when the connecting rod identification marks are visible.

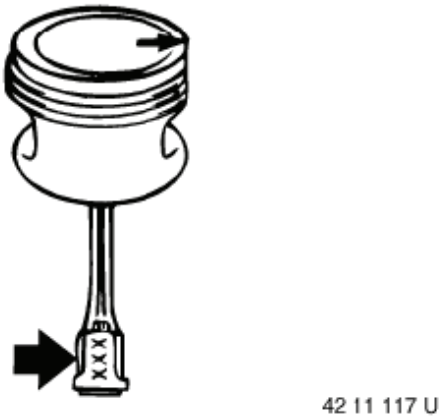


Figure 5-53

6. *NOTICE: Pistons and wrist pins are matched. NEVER mix parts.* Insert the wrist pin and install the second retaining ring.

Note: Install new piston rings with markings facing up **(Figure 5-54)**.

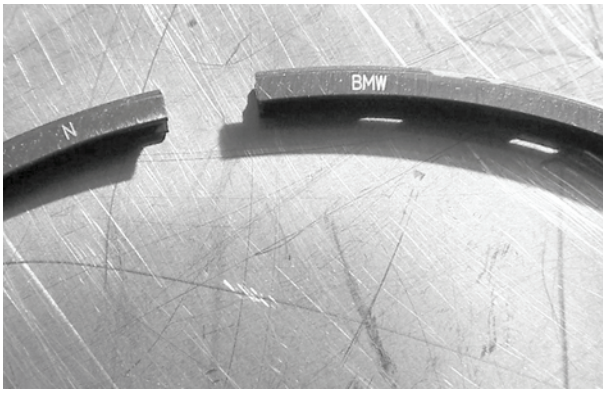


Figure 5-54

7. Install the piston rings using a piston ring expander tool. The oil ring **(Figure 5-55, (3))** has an expander spring underneath it **(Figure 5-55, (4))**. Install the expander spring end gap and oil ring end gap 180° apart. Stagger all exposed ring gaps 120° from each other with none in line with the wrist pin.

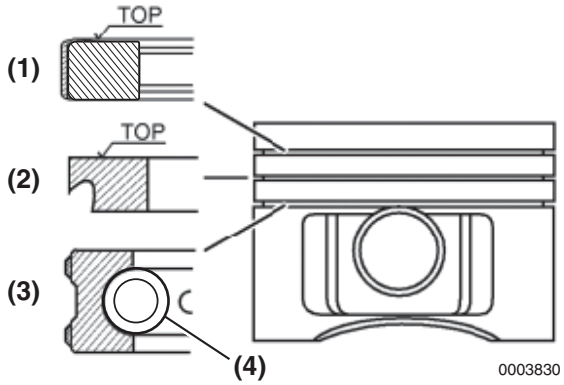


Figure 5-55

1 – Top Piston Ring
2 – Second Piston Ring
3 – Oil Ring
4 – Oil Ring Expander Spring

Install Piston and Connecting Rod

1. *NOTICE: ALL parts that are being reused MUST be installed in their original location and orientation.* Bearing inserts for the connecting rod and rod cap are different. Install bearing inserts having an “S” and blue dye **(Figure 5-57)** in connecting rod. Install bearing inserts having red dye **(Figure 5-56)** in rod cap.

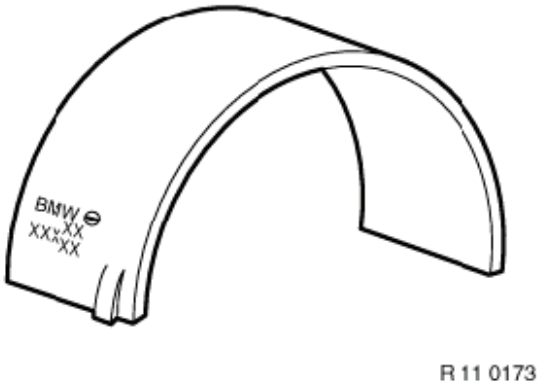


Figure 5-56

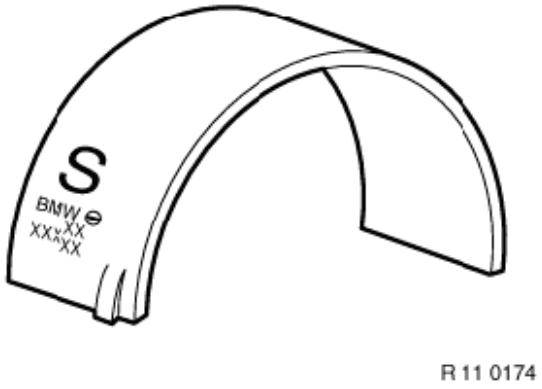


Figure 5-57

2. Install one blue-marked bearing insert in each connecting rod and one red-marked insert in each rod cap. *NOTICE: Ensure the bearing inserts, and connecting rod and cap mounting surfaces are absolutely clean and oil-free.*
3. Rotate the crankshaft so the journal for the piston being installed is near BDC.
4. Apply a light coat of clean engine oil to the bearing insert.

5. Install special tool OEM No. 11 6 330 on connecting rod **(Figure 5-58)**.

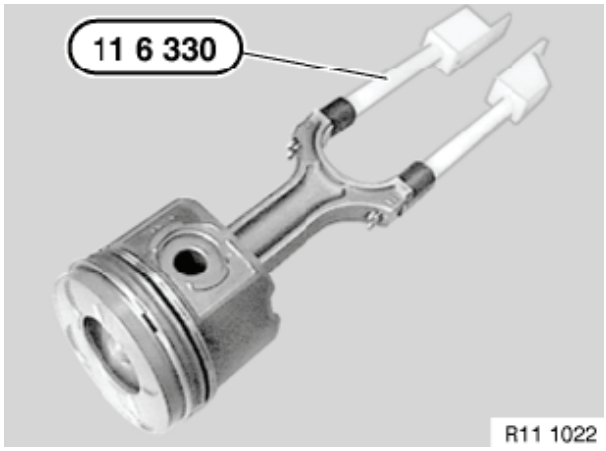


Figure 5-58

6. Lubricate the piston, piston rings, cylinder bore, and piston ring compressor with clean engine oil.
7. Position the piston rings so that the ring gaps are distributed evenly (approximately 120° apart) around the piston and **not** in line with the wrist pin. Install piston ring compressor **(Figure 5-59)**.

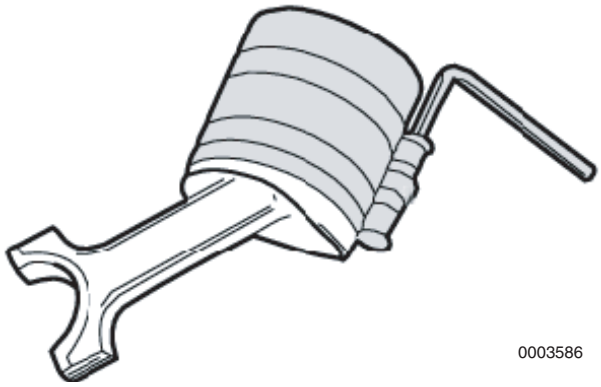


Figure 5-59

8. Carefully install the connecting rod and piston so that the arrow on the piston points toward the front end of the engine **(Figure 5-60)**. *NOTICE: NEVER force piston or drive piston into cylinder bore. Install using only finger pressure.*

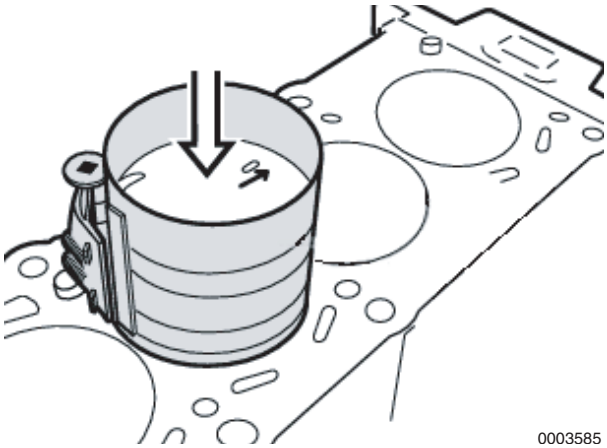


Figure 5-60

9. Remove special tool OEM No. 11 6 330 **(Figure 5-61)**.

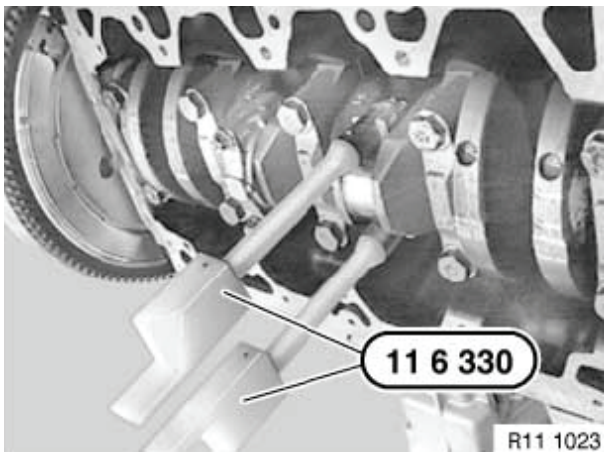


Figure 5-61

10. Check bearing oil clearance before proceeding. *See Measure Oil Clearance on page 5-59.*
11. Apply a light coat of clean engine oil to the bearing insert and crankshaft journal.

12. Install the connecting rod cap. Ensure the connecting rod and cap have the same marking number and that the marks are on the same side **(Figure 5-62)**.

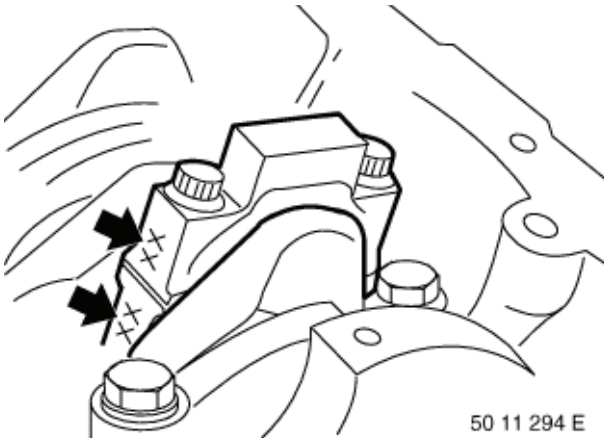


Figure 5-62

13. Lightly oil NEW bolts and install to an initial torque of 5 N·m (44 in.-lb) **(Figure 5-63)**. Torque-turn tighten to final specification of 20 N·m (177 in.-lb) plus 70°. *NOTICE: NEVER install used connecting rod cap bolts. ALWAYS install new bolts when installing connecting rod cap.*

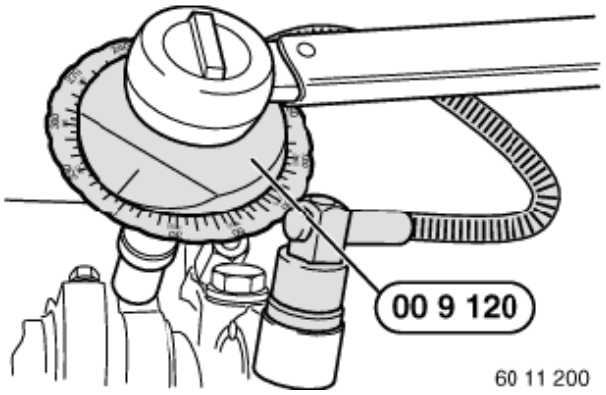


Figure 5-63

14. Check that the piston cooling nozzles are in perfect condition and fully open. If necessary, clean with compressed air. **WARNING!** ***Flying Object Hazard. ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.*** *NOTICE: Use care not to damage the piston cooling nozzles. The oil spray must hit the piston precisely. If it does not, the piston will become too warm, resulting in engine breakdown. NEVER straighten damaged nozzles. They must be replaced.*
15. Install the piston cooling nozzles and tighten the banjo bolts to 23 N·m (17 ft-lb).
16. Install oil deflector and tighten bolts to 10 N·m (89 in.-lb)
17. Install oil pump. *See Oil Pump on page 8-12.*
18. Install the oil sump. *See Remove and Install Oil Sump on page 8-11.*
19. Install the cylinder head. *See Install Cylinder Head on page 5-27.*

FLYWHEEL AND FLYWHEEL HOUSING

Remove and Install Flywheel Housing

1. Disconnect the negative (-) battery cable from the battery.
2. Remove the marine gear or stern drive (as equipped).
3. Remove two bolts **(Figure 5-64, (1) and Figure 5-65 (1))** and remove starter motor **(Figure 5-64, (2) and Figure 5-65 (2))**. *See Remove and Install Starter Motor on page 10-5.*

Stern Drive Engines

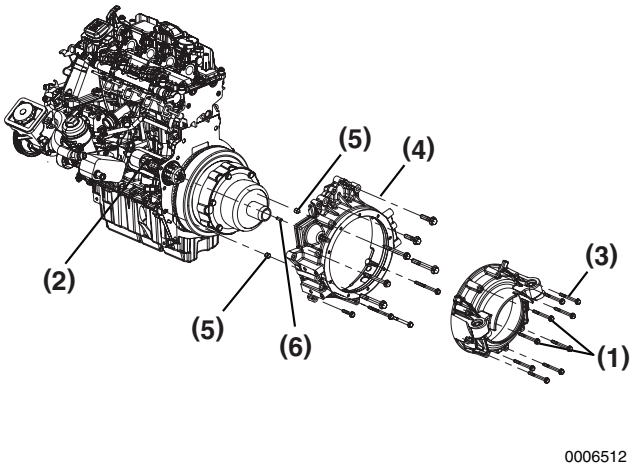


Figure 5-64

Marine Gear Engines

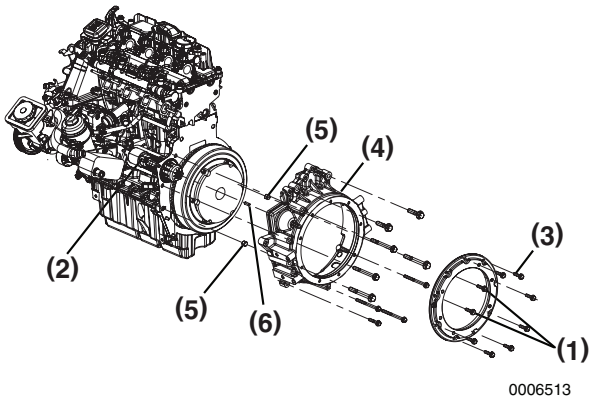


Figure 5-65

4. Remove bolts securing oil sump to flywheel housing.
5. Remove 11 bolts **(Figure 5-64, (3) and Figure 5-65 (3))**. Remove housing **(Figure 5-64, (4) and Figure 5-65 (4))**. Use care not to lose the two alignment sleeves **(Figure 5-64, (5) and Figure 5-65 (5))** and the dowel **(Figure 5-64, (6) and Figure 5-65 (6))**.
6. Clean mating surfaces. Install alignment sleeves and dowel in flywheel housing.
7. Install flywheel housing.
8. Install washers on the M10 x 130, M8 x 130 and M8 x 40 bolts.
9. Install 11 bolts and washers. Tighten in two stages to specifications.

Flywheel Housing Torque

Item	Initial Torque	Final Torque
M12 Bolt	15 N·m (133 in.-lb)	80 N·m (59 ft-lb)
M10 Bolt		46 N·m (34 ft-lb)
M8 Bolt		23 N·m (204 in.-lb)

10. Install the starter motor. *See Remove and Install Starter Motor on page 10-5.*
11. Connect battery negative (-) cable.

Remove and Install Drive Coupling

Engines with Marine Gear

Removal

1. Remove flywheel housing. *See Remove and Install Flywheel Housing on page 5-37*.
2. Install flywheel holding tool to prevent flywheel rotation.
3. Remove 12 bolts **(Figure 5-66, (1))**.

Marine Gear Engines

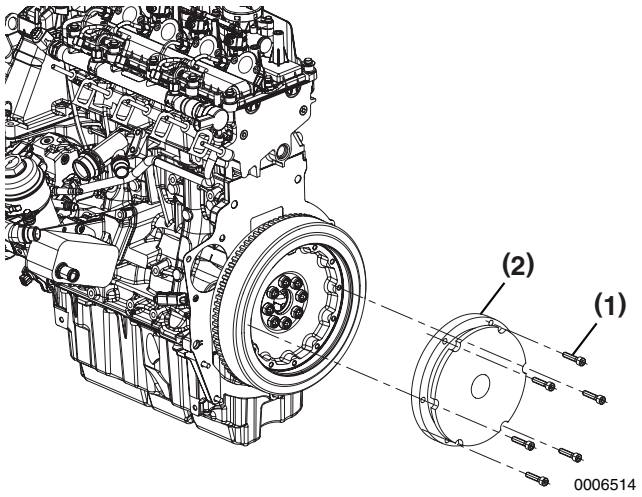


Figure 5-66

4. Remove coupler **(Figure 5-66, (2))**.

Installation

1. Install flywheel holding tool to prevent flywheel rotation.

   NOTICE: Ensure all mating surfaces are clean and dry.

2. Install coupler. Install bolts and washers. Tighten to specification.

Drive Coupling Torque

Item	Initial Torque	Final Torque
M10 Bolt	15 N·m (133 in.-lb)	46 N·m (34 ft-lb)
M8 Bolt		23 N·m (204 in.-lb)

3. Remove flywheel holding tool.
4. Install flywheel housing. *See Remove and Install Flywheel Housing on page 5-37*.

Engines with Stern Drive

Removal

1. Remove flywheel housing. *See Remove and Install Flywheel Housing on page 5-37*.
2. Install flywheel holding tool to prevent flywheel rotation.
3. Remove six bolts and washers **(Figure 5-67, (1))**.

Stern Drive Engines

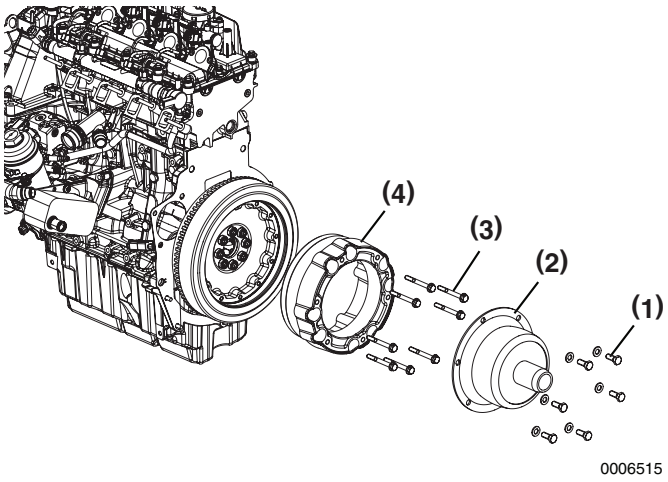


Figure 5-67

4. Remove coupler **(Figure 5-67, (2))**.
5. Remove eight bolts **(Figure 5-67, (3))** and remove coupler adapter **(Figure 5-67, (4))**.

Installation

1. Install flywheel holding tool to prevent flywheel rotation.

   NOTICE: Ensure all mating surfaces are clean and dry.

2. Install coupler adapter and tighten eight bolts to specification.
3. Install coupler. Install bolts and washers. Tighten to specification.

Drive Coupling Torque

Item	Initial Torque	Final Torque
M10 Bolt	15 N·m (133 in.-lb)	46 N·m (34 ft-lb)
M8 Bolt		23 N·m (204 in.-lb)

4. Remove flywheel holding tool.
5. Install flywheel housing. *See Remove and Install Flywheel Housing on page 5-37*.

Remove Flywheel

1. Remove the flywheel housing and drive coupling. *See Remove and Install Flywheel Housing on page 5-37* and *Remove and Install Drive Coupling on page 5-38.*
2. Remove bolts **(Figure 5-68, (1))** retaining the flywheel.

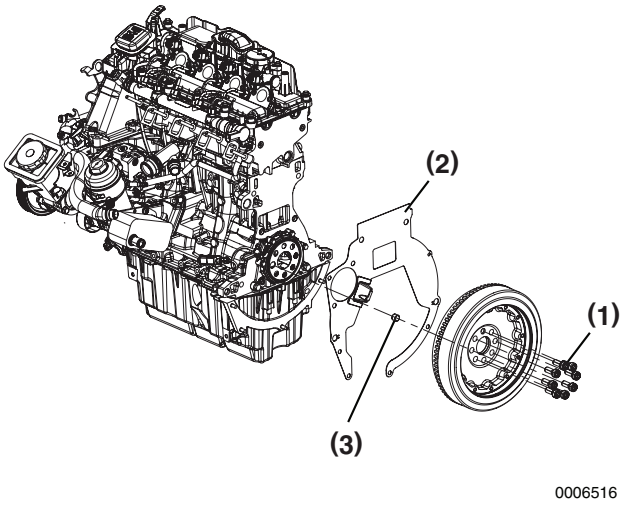


Figure 5-68

Note: Flywheel bolts are T-60 Torx head.

3. Remove flywheel. Inspect guide bushing **(Figure 5-68, (3))** in crankshaft and remove if damaged.
4. Remove torque plate **(Figure 5-68, (2))**.
5. Inspect the flywheel for damage. Install a new flywheel if the ring gear teeth are chipped, broken, or have become so worn that starter motor pinion will not engage properly.

Replace Rear Crankshaft Seal

1. Drain engine oil. *See Engine Oil Specifications on page 3-14*.
2. Remove flywheel. *See Remove Flywheel on page 5-39.*
3. Remove oil sump. *See Remove and Install Oil Sump on page 8-11*.
4. Remove bolt **(Figure 5-69, (2))** and crankshaft sensor **(Figure 5-69, (3))**. *See Replace Crankshaft Sensor on page 12-24*.

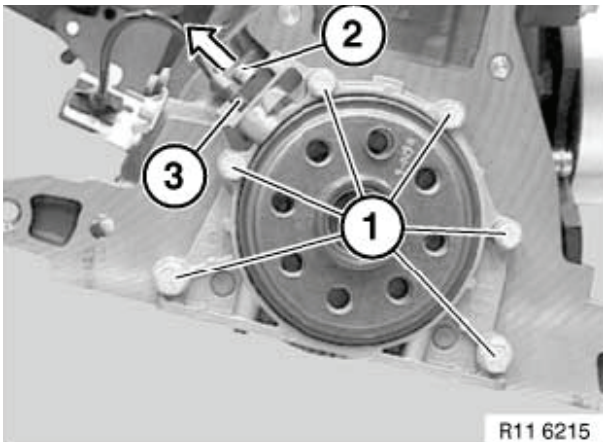


Figure 5-69

5. Remove bolts **(Figure 5-69, (1))** and remove rear crankshaft seal and housing as an assembly.

Note: The rear crankshaft seal and housing are available only as an assembly. The seal has a protective bushing **(Figure 5-70, (1))** installed and is to be used during installation. Use only the supplied bushing as an installation tool. Keep the bushing as a special tool for use in future service.

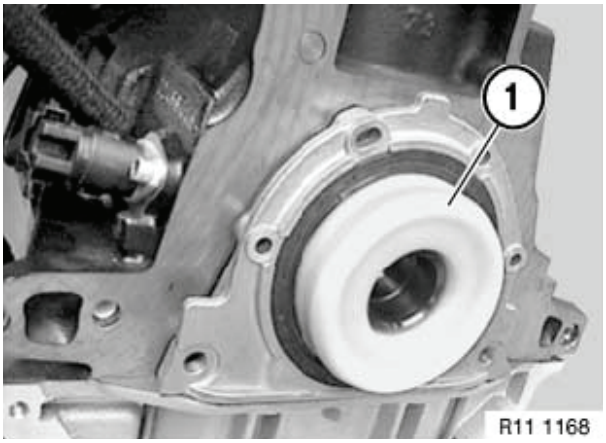


Figure 5-70

6. Lubricate the crankshaft outside diameter. Push the seal housing squarely onto the crankshaft **(Figure 5-70)**.
7. Install bolts and tighten securely.
8. Install oil sump. *See Remove and Install Oil Sump on page 8-11.*
9. Install crankshaft sensor. *See Replace Crankshaft Sensor on page 12-24.*
10. Install flywheel. *See Install Flywheel on page 5-41*.
11. Add engine oil to the correct oil level. *NOTICE: NEVER overfill engine with engine oil.*

Install Flywheel

1. If removed, install the guide bushing **(Figure 5-71, (3))** in the crankshaft.

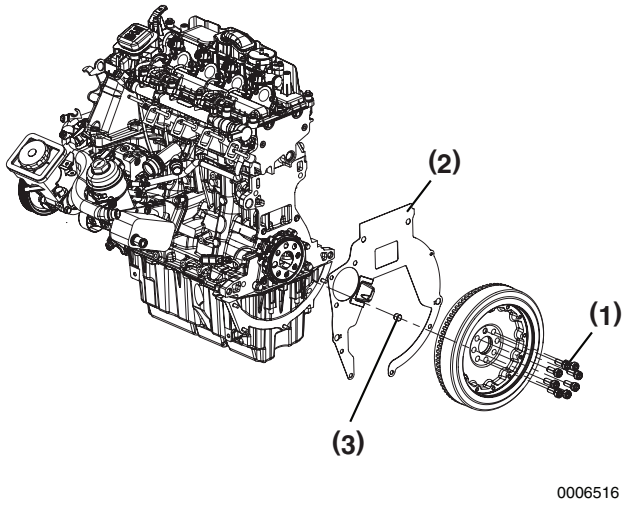


Figure 5-71

2. Install torque plate **(Figure 5-71, (2))**.
3. Install the flywheel on the crankshaft.

Note: Flywheel bolts are T-60 Torx head.

4. Apply medium strength thread lock and sealer to the threads of the flywheel bolts **(Figure 5-71, (1))**. Install bolts and tighten to initial torque specification. *NOTICE: NEVER reuse flywheel bolts. ALWAYS install new flywheel bolts.*

Flywheel Bolt Torque

Item	Initial Torque	Final Torque
Flywheel Bolt	15 N·m (133 in.-lb)	120 N·m (89 ft-lb)

5. Tighten flywheel bolts to final torque specification.
6. Install drive coupling. *See Remove and Install Drive Coupling on page 5-38*.
7. Install flywheel housing. *See Remove and Install Flywheel Housing on page 5-37*.

CAMSHAFT AND TIMING GEAR TRAIN

Components

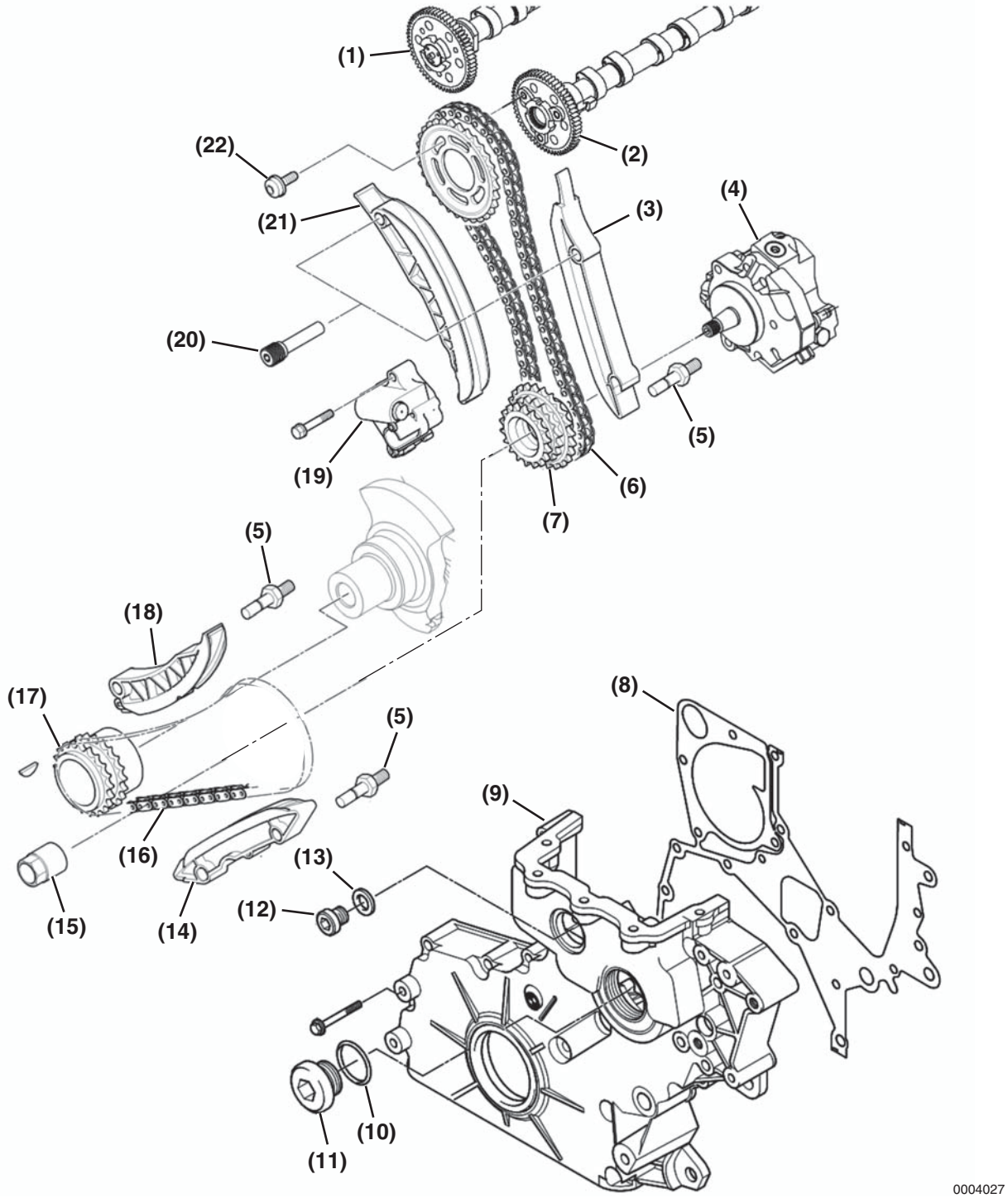


Figure 5-72

1 – Exhaust Camshaft
2 – Intake Camshaft
3 – Guide Rail
4 – High-Pressure Fuel Pump
5 – Guide Rail Pin
6 – Upper Timing Chain
7 – Sprocket
8 – Timing Case Cover Gasket
9 – Timing Case Cover
10 – O-Ring
11 – Access Plug
12 – Plug
13 – Seal
14 – Guide Rail
15 – Sprocket-to-High-Pressure Pump Nut
16 – Lower Timing Chain
17 – Crankshaft Sprocket
18 – Lower Chain Tensioner
19 – Hydraulic Tensioner
20 – Pivot Pin
21 – Upper Chain Tensioner
22 – Sprocket Retaining Screw

Check and Adjust Camshaft Timing

Check Camshaft Timing

1. Remove cylinder head cover. *See Remove and Install Cylinder Head Cover on page 5-17.*
2. Rotate the crankshaft in the normal running direction until No. 1 cylinder is at TDC of the power stroke. The front lobe of each camshaft **(Figure 5-73, (1))** will be facing the exhaust side.

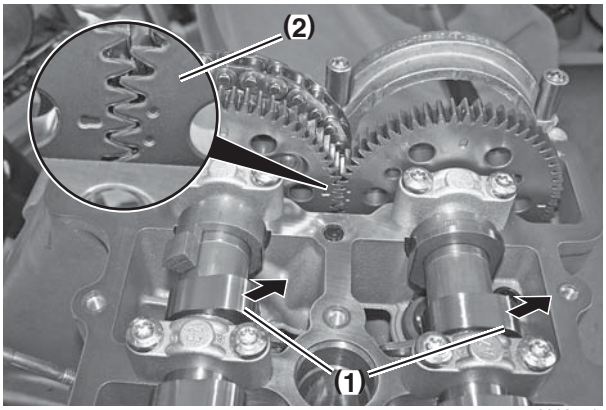


Figure 5-73

3. Verify position by checking that the camshaft timing marks on gears are aligned **(Figure 5-73, (2))**. The single mark on intake camshaft gear must fall between the two marks on the exhaust camshaft gear.
4. Secure crankshaft in TDC position with flywheel holding tool OEM No. 11 5 180 **(Figure 5-74)**. *NOTICE: NEVER rotate the crankshaft backward. If the crankshaft is turned past TDC, rotate two more turns (720°) to bring No. 1 piston back to TDC.*

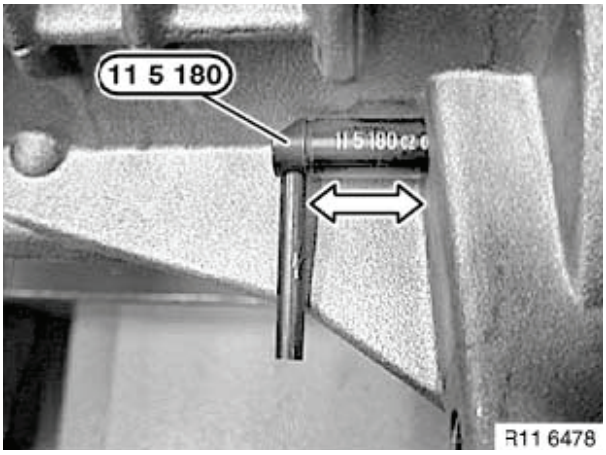


Figure 5-74

5. Install special tool OEM No. 11 6 321 **(Figure 5-75, (1))** on the flats of the intake camshaft **(Figure 5-75, (2))**. The tool must set firmly on the machined gasket surface **(Figure 5-75, (3))** on each side of the cylinder head. If it does not, the timing must be adjusted. *See Adjust Camshaft Timing on page 5-45.*

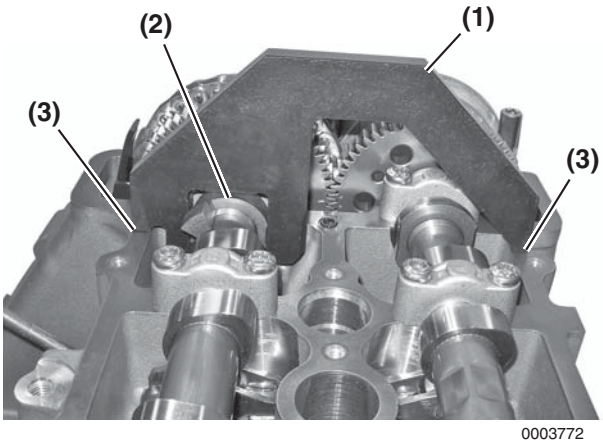


Figure 5-75

Note: Special tool shown on intake camshaft. Exhaust camshaft is checked in the same manner but has no adjustment. If camshaft gears are properly aligned, exhaust camshaft timing will be correct.

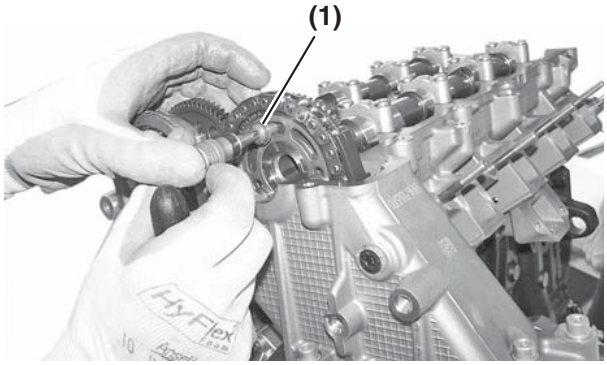
6. Remove special tools.
7. Install cylinder head cover.

Adjust Camshaft Timing

1. Rotate the crankshaft until No. 1 cylinder intake camshaft lobes are facing down. *NOTICE: NEVER remove the camshaft sprocket bolts.*

2. Loosen one bolt **(Figure 5-76, (1))**.

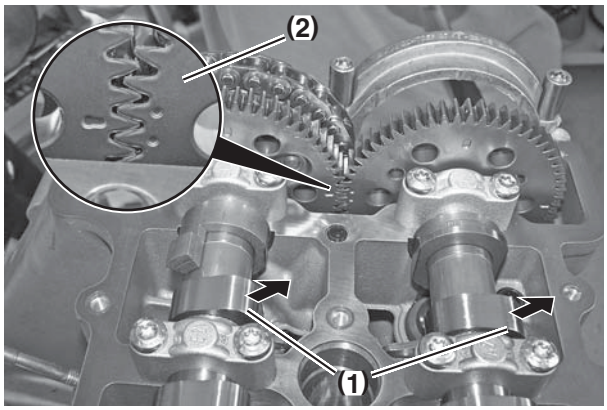
Note: One bolt must be loosened prior to rotating No. 1 piston to TDC position.



0003774

Figure 5-76

3. Rotate the crankshaft in the normal running direction until No. 1 cylinder is at TDC of the power stroke. The front lobe of each camshaft **(Figure 5-77, (1))** will be facing toward the exhaust side and the timing marks **(Figure 5-77, (2))** will meet.



0003771

Figure 5-77

4. Verify position by checking the camshaft timing marks **(Figure 5-77, (2))** on gears are aligned. The single mark on intake camshaft gear must fall between the two marks on the exhaust camshaft gear. *NOTICE: NEVER rotate the crankshaft backward. If the crankshaft is turned past TDC, rotate two more turns (720°) to bring No. 1 piston back to TDC.*
5. Secure crankshaft in TDC position with flywheel holding tool OEM No. 11 5 180 **(Figure 5-78)**.

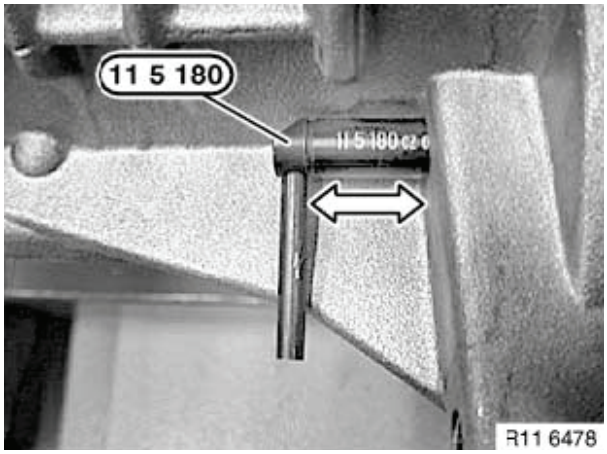
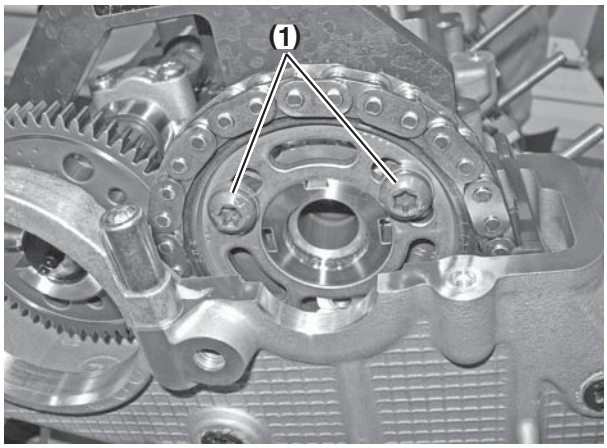


Figure 5-78

6. If camshaft is not in alignment, loosen two remaining bolts **(Figure 5-79, (1))** to adjust.



0003775

Figure 5-79

7. Install special tool OEM No. 11 6 321 **(Figure 5-80, (1))** on the flats of the intake camshaft and secure with special tool OEM No. 11 6 322 **(Figure 5-80, (2))**. Secure to cylinder head with two bolts.

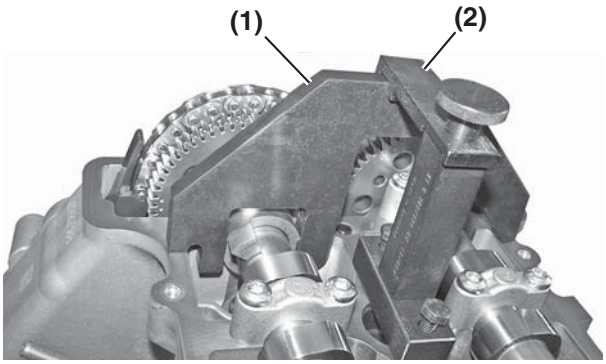


Figure 5-80

Note: Special tool shown on intake camshaft. Exhaust camshaft is checked in the same manner but has no adjustment. If camshaft gears are properly aligned, exhaust camshaft timing will be correct.

8. Tighten the two exposed sprocket retaining bolts to 15 N·m (133 in.-lb).
9. Remove special tools.
10. Rotate the crankshaft 360° to expose the remaining sprocket retaining bolt and tighten to 15 N·m (133 in.-lb).
11. Install cylinder head cover. *See Remove and Install Cylinder Head Cover on page 5-17.*

Remove and Install Vibration Damper - 4BY2

1. Disconnect battery negative (-) cable.
2. Remove alternator and seawater pump drive belts. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19.*
3. Remove starter motor. *See Remove and Install Starter Motor on page 10-5.*

Note: A shop-made flywheel holder can be fabricated using a piece of a used ring gear **(Figure 5-81)**.

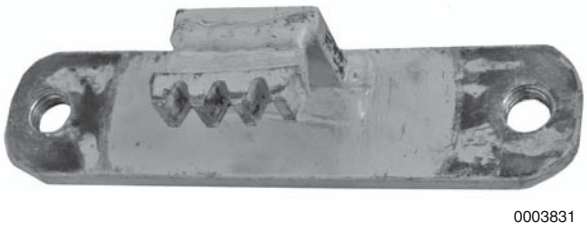


Figure 5-81

4. Install flywheel holder to prevent crankshaft from rotating **(Figure 5-82)**. Mount the tool using the starter mounting bolts.

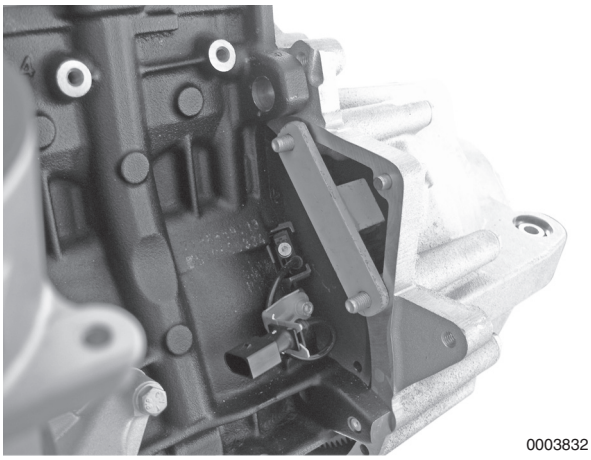


Figure 5-82

5. Remove the vibration damper bolt.
6. Remove flywheel holder and remove damper.
7. Place vibration damper on crankshaft and install new bolt and washer until vibration damper is snug.

8. Install special tool OEM No. 11 6 310 **(Figure 5-83, (1))** onto the vibration damper.

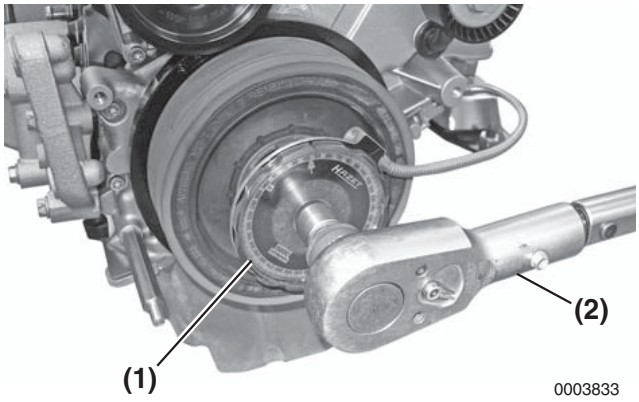


Figure 5-83

9. Tighten bolt to specification with an angled torque wrench **(Figure 5-83, (2))**.

Specifications

Vibration Damper Bolt Torque	Specification
Initial Torque	100 N·m (74 ft-lb)
Second Torque	Additional 60°
Third Torque	Additional 60°
Final Torque	Additional 30°

10. Install starter motor. *See Remove and Install Starter Motor on page 10-5.*
11. Install alternator and seawater pump belts. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19.*
12. Connect battery negative (-) cable.

Remove and Install Vibration Damper - 6BY2

1. Disconnect battery negative (-) cable.
2. Remove alternator and seawater pump drive belts. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19.*
3. Remove bolts **(Figure 5-84, (1))**.

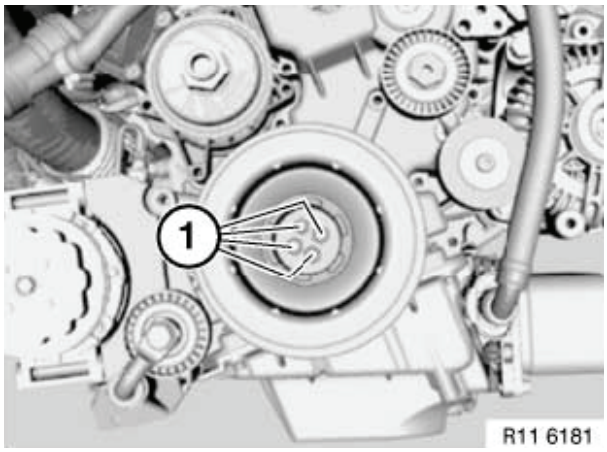


Figure 5-84

4. Remove the vibration damper.
5. Install vibration damper on crankshaft and install new bolts.
6. Torque-turn tighten bolts diagonally to specification.

Specifications

Vibration Damper Bolt Torque	Specification
Initial Torque	40 N·m (30 ft-lb)
Second Torque	Additional 60°
Third Torque	Additional 60°

7. Install alternator and seawater pump belts. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19.*
8. Connect battery negative (-) cable.

Remove Timing Case Cover

NOTICE: When working on the oil, coolant or fuel systems, you must protect the alternator from contamination. Cover alternator with suitable materials. Failure to comply may result in an alternator failure.

1. Disconnect battery negative (-) cable.
2. Drain engine coolant. *See Drain and Fill Closed Cooling System on page 7-10.*
3. Drain engine oil. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.
4. Remove alternator and seawater pump drive belts. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19.*
5. Remove oil sump. *See Remove and Install Oil Sump on page 8-11.*
6. Remove cylinder head. *See Remove Cylinder Head on page 5-19.*
7. Remove vibration dampener. *See Remove and Install Vibration Damper - 4BY2 on page 5-46* or *Remove and Install Vibration Damper - 6BY2 on page 5-47.*
8. Remove front crankshaft seal. *See Replace Front Crankshaft Seal on page 5-64.*
9. Remove alternator belt tensioner.
10. **4BY2:** Remove alternator. *See Remove and Install Alternator on page 11-5.*
11. Remove bolts securing cover and remove timing case cover **(Figure 5-85)**.

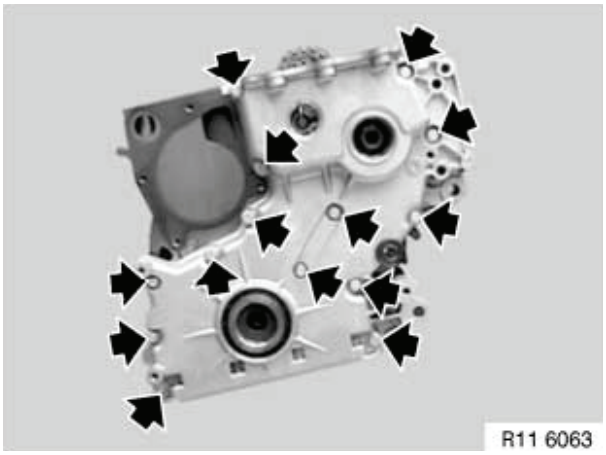


Figure 5-85

12. If the coolant pump has not been removed, cut the gasket at the three tabs **(Figure 5-86, (1))** and remove timing case cover portion of gasket.

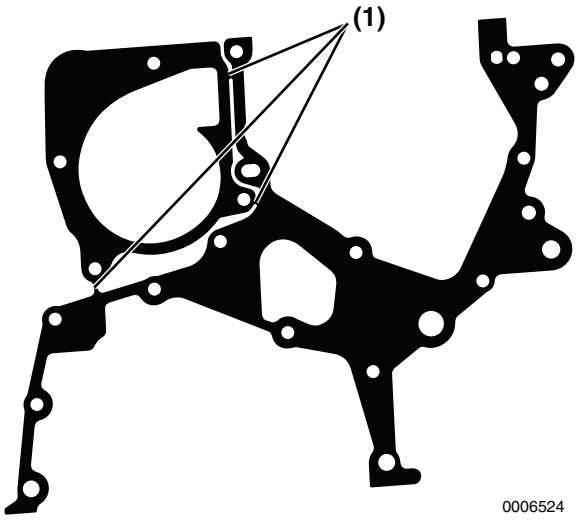


Figure 5-86

Remove and Install Timing Chain

1. Remove timing case cover. *See Remove Timing Case Cover on page 5-48*.
2. Compress chain tensioner rail **(Figure 5-87, (3))** and retain with special tool OEM No. 11 3 340 **(Figure 5-87, (1))**.

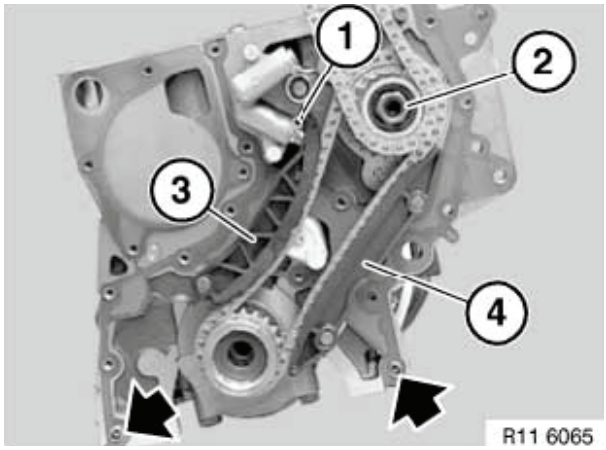


Figure 5-87

3. Remove tensioner rail **(Figure 5-87, (3))** and guide rail **(Figure 5-87, (4))**.
4. Remove nut **(Figure 5-87, (2))**.
5. Remove high-pressure pump sprocket using special tool OEM No. 13 5 191. *See Replace High-Pressure Fuel Pump on page 6-15*.
6. Remove sprockets and timing chains.
7. Install lower chain on sprockets and install as an assembly.
8. Install nut **(Figure 5-87, (2))** and tighten to 65 N·m (48 ft-lb).
9. Install tensioner rail and guide rail. Remove retainer **(Figure 5-87, (1))**.
10. Install timing case cover. *See Install Timing Case Cover on page 5-49*.

Install Timing Case Cover

Note: The front crankshaft seal must be installed with the timing case cover installed.

1. Thoroughly clean all old gasket material from mating surfaces.
2. Check condition and location of alignment dowel sleeves.

Note: Only a one-piece gasket is available for timing case cover and water pump. When repairing timing chain cover only, detach seal at marked points.

3. If coolant pump was not removed, cut gasket at three locations **(Figure 5-88, (1))**. Install gasket and apply a thin coat of Three Bond® 1207F (Yanmar part No. 977770-1207F) sealing agent to gasket at ends (arrow) on both sides.

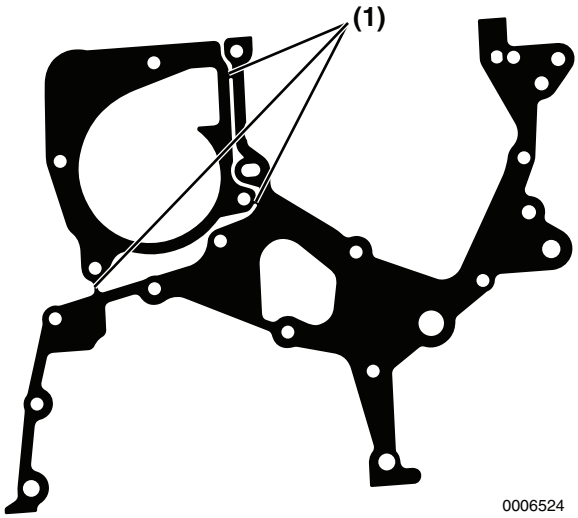


Figure 5-88

4. Install timing case cover.
5. Install all bolts and tighten to an initial torque of 5 N·m (44 in.-lb), then tighten in an alternating sequence to final torque specification of 14 N·m (124 in.-lb).
6. After all bolts have been tightened to final specification, check the torque and tighten again if necessary.
7. Install front crankshaft seal. *See Replace Front Crankshaft Seal on page 5-64.*
8. Install vibration dampener. *See Remove and Install Vibration Damper - 4BY2 on page 5-46 or Remove and Install Vibration Damper - 6BY2 on page 5-47.*
9. Install alternator belt tensioner.
10. Install cylinder head. *See Install Cylinder Head on page 5-27.*
11. Install oil sump. *See Remove and Install Oil Sump on page 8-11.*
12. **4BY2:** Install alternator. *See Remove and Install Alternator on page 11-5.*
13. Install alternator belt and belt guard. *See Remove and Install Alternator on page 11-5 and Replace Seawater Pump Belt on page 7-19.*
14. Add engine oil. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9.*
15. Fill engine with coolant. *See Drain and Fill Closed Cooling System on page 7-10.*
16. Connect battery negative (-) cable.

Remove and Install Timing Chain Tensioner

1. Remove timing case cover. *See Remove Timing Case Cover on page 5-48.*
2. Press both tensioner rails **(Figure 5-89, (1))** in direction of arrow. Insert special tool OEM No. 11 3 340 in designated openings in chain tensioner **(Figure 5-89, (2))**.

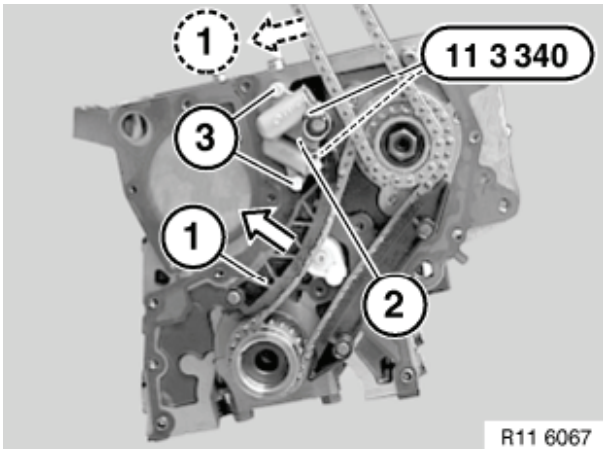


Figure 5-89

Note: Illustration shows upper tensioner rail removed and the tensioner with special tool installed.

3. Remove bolts **(Figure 5-89, (3))**.
4. Remove chain tensioner **(Figure 5-89, (2))**.
5. Installation is in the reverse of removal.

Remove Camshafts

NOTICE: Identify all parts and their location using an appropriate method. It is important that all parts are returned to the same position during the reassembly process.

1. Remove cylinder head cover. *See Remove and Install Cylinder Head Cover on page 5-17.*
2. Drain engine coolant.
3. Remove alternator drive belt. *See Remove and Install Alternator on page 11-5.*
4. Remove cover **(Figure 5-90, (1))** and bracket **(Figure 5-90, (2))**.

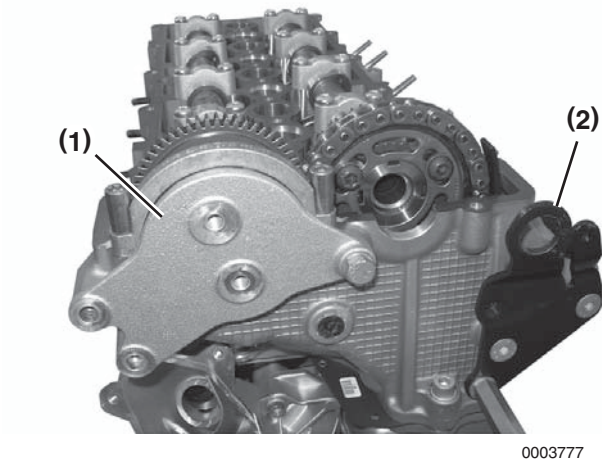


Figure 5-90

5. Rotate the crankshaft until No. 1 cylinder intake camshaft lobes are facing down.
6. Remove one bolt **(Figure 5-91, (1))**.

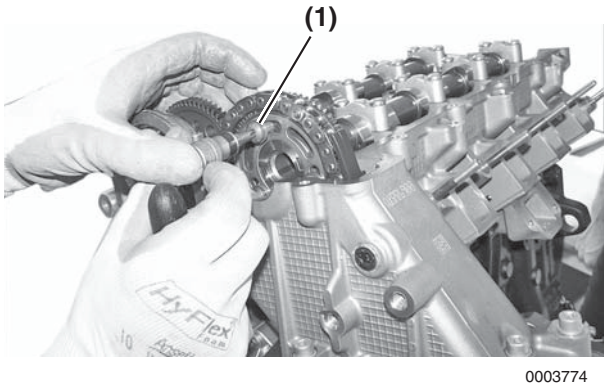


Figure 5-91

Note: One bolt must be removed prior to rotating No. 1 piston to TDC position.

7. Remove plug **(Figure 5-92)** from timing case cover.

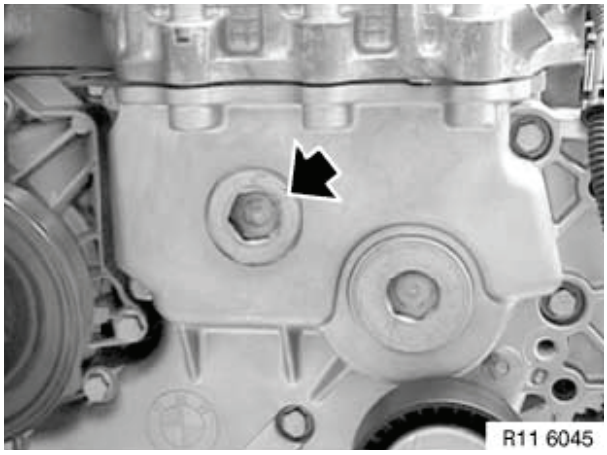


Figure 5-92

8. Rotate crankshaft counterclockwise 45°.

9. Use a wrench **(Figure 5-93, (2))** to turn exhaust camshaft **(Figure 5-93, (1))** in direction of arrow to compress the timing chain tensioner.

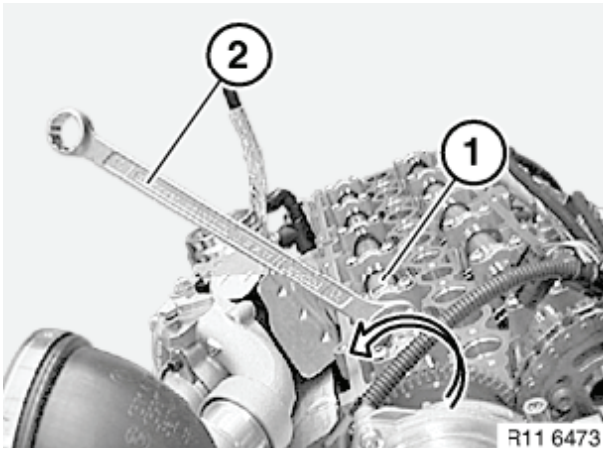


Figure 5-93

10. While holding the exhaust camshaft rotated, secure the tensioner in place using special tool OEM No. 11 3 340 **(Figure 5-94)**.

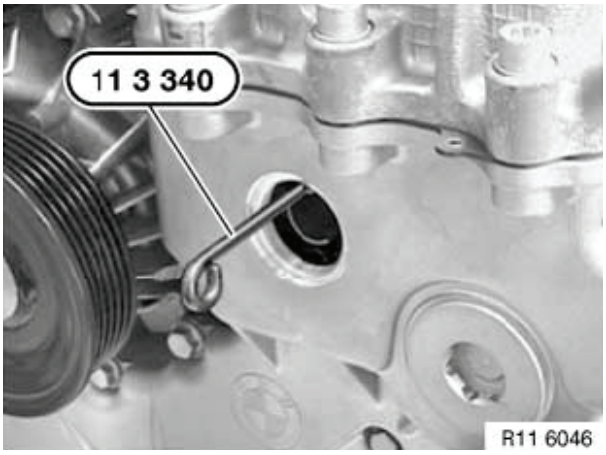


Figure 5-94

11. Rotate the crankshaft in the normal running direction until No. 1 cylinder is at TDC of the power stroke. The front lobe of each camshaft **(Figure 5-95, (1))** will be facing toward the exhaust side and the timing marks **(Figure 5-95, (2))** will meet.

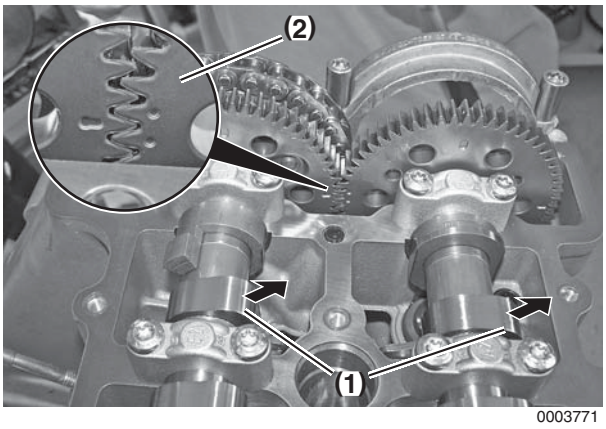


Figure 5-95

12. Verify position by checking that the camshaft timing marks **(Figure 5-95, (2))** on gears are aligned. The single mark on intake camshaft gear must fall between the two marks on the exhaust camshaft gear.
13. *NOTICE: NEVER rotate the crankshaft backward. If the crankshaft is turned past TDC, rotate two more turns (720°) to bring No. 1 piston back to TDC.* Secure crankshaft in TDC position with flywheel holding tool **(Figure 5-96)**.

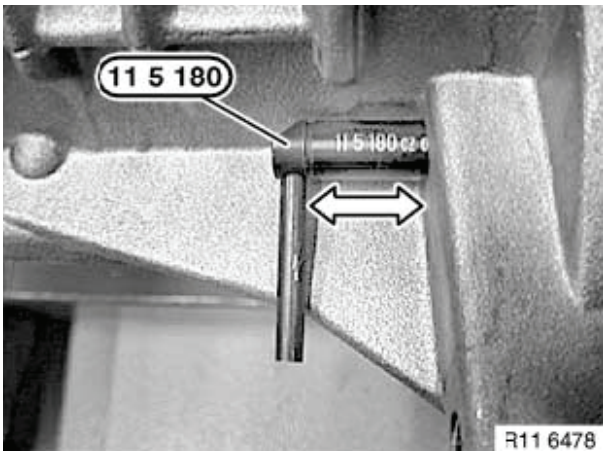


Figure 5-96

14. *NOTICE: NEVER remove the camshaft sprocket screws without first locking the chain tensioner in the released position.* Remove two remaining screws **(Figure 5-97, (1))**.

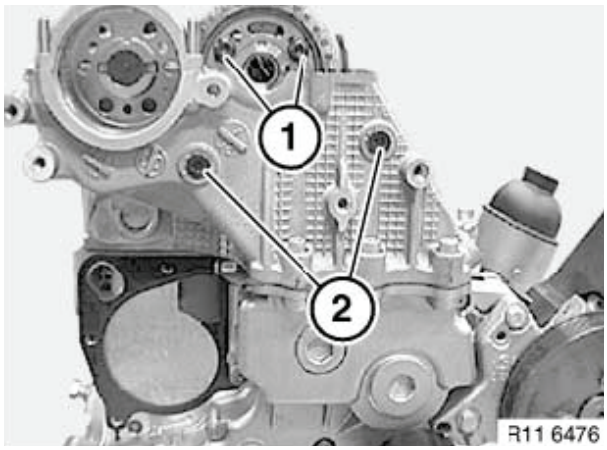


Figure 5-97

15. Remove two guide rail bearing pins **(Figure 5-97, (2))**.
16. Remove sprocket and chain from intake camshaft **(Figure 5-98, (1))**.

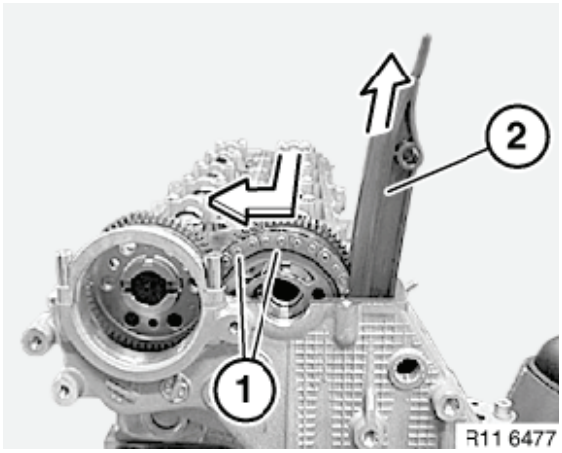


Figure 5-98

17. Release guide rails **(Figure 5-98, (2))** from mount and remove.
18. Remove camshaft sprocket **(Figure 5-99, (2))** from chain **(Figure 5-99, (1))** as shown by arrow.

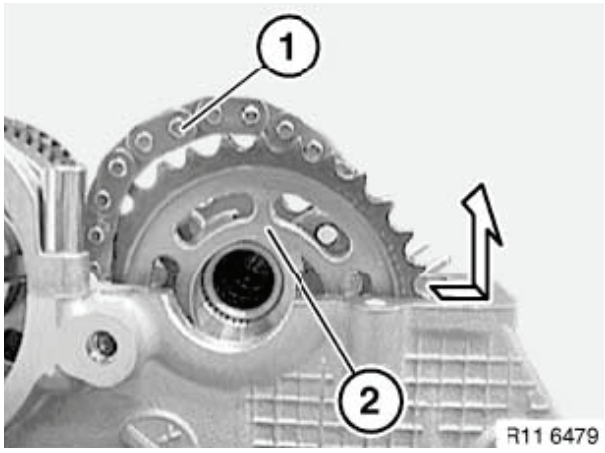


Figure 5-99

19. Evenly loosen all camshaft bearing cap bolts **(Figure 5-100, (1))** in 1/2-turn increments, working from each end towards the center.

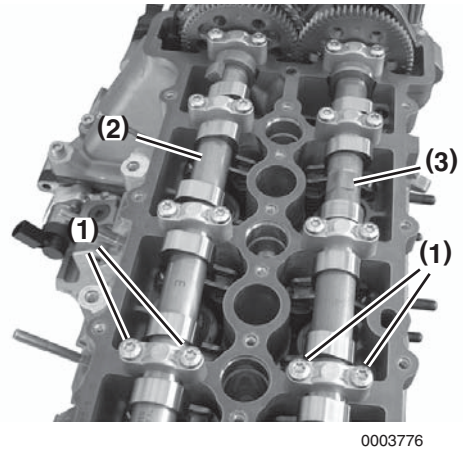


Figure 5-100

20. Remove all bearing caps. *NOTICE: Camshaft bearing caps are numbered and must be installed in their original locations.*
21. Remove the intake **(Figure 5-100, (2))** and exhaust **(Figure 5-100, (3))** camshafts.

22. Do not remove loop casting bolts. *NOTICE: NEVER remove bolts retaining loop casting* ***(Figure 5-101)***.

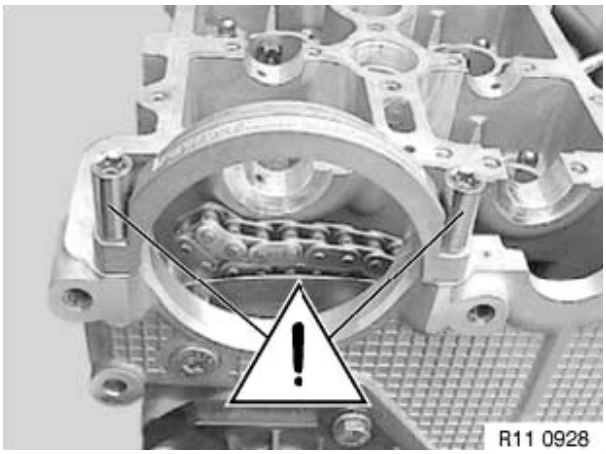


Figure 5-101

Install Camshafts

1. Lubricate all camshaft bearings, caps and journals with clean engine oil.
2. Identify the intake **(Figure 5-102, (E))** and exhaust **(Figure 5-102, (A))** camshafts.

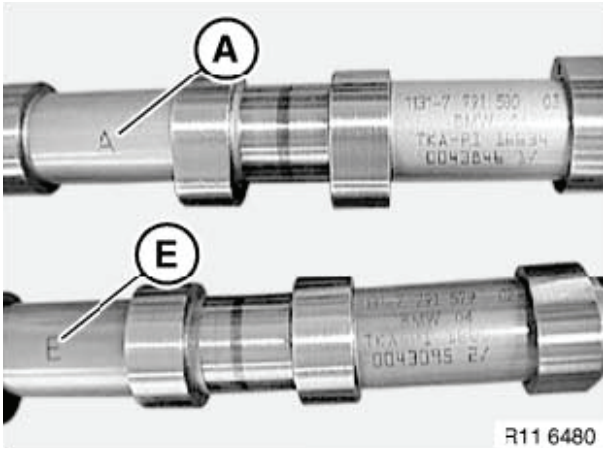


Figure 5-102

3. Install camshafts. Ensure the timing marks **(Figure 5-103, (1))** on the gears align as shown.

   When the timing marks are aligned, the lobes **(Figure 5-103, (2))** for cylinder No. 1 will face the exhaust side of the engine.

Note: The valves will hold the camshafts above the bearing seats until all bolts are tightened.

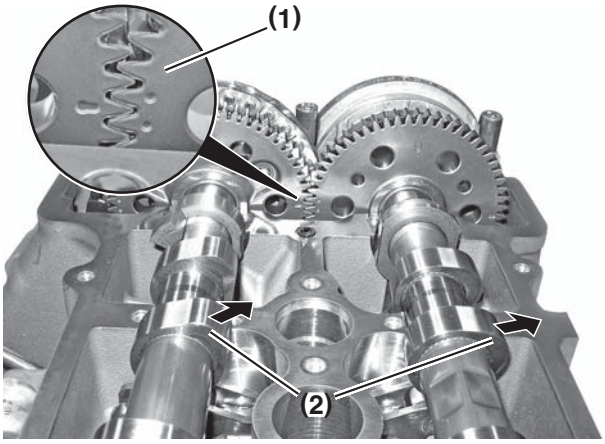


Figure 5-103

Note: Bearing caps are numbered beginning at the front **(Figure 5-104, (1))** of the engine. The numbered markings of all caps should face the exhaust side **(Figure 5-104, (2))**.

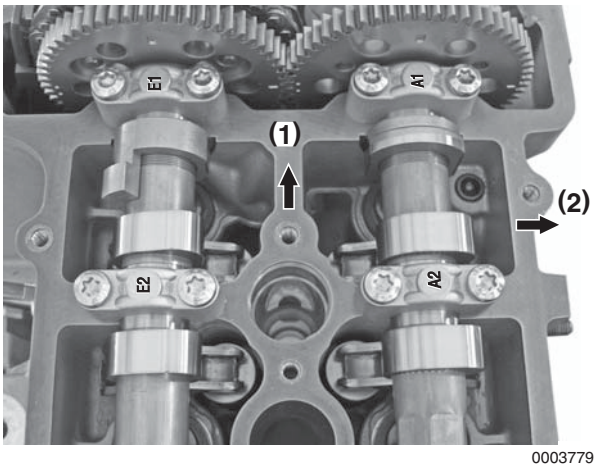


Figure 5-104

4. Install bearing caps in their proper locations.
   - Intake camshaft bearing caps are marked A1 - A7.
   - Exhaust camshaft bearing caps are marked E1 - E7.
5. Lightly oil the threads of all bolts and install finger-tight.
6. Tighten all bearing caps evenly in 1/2-turn increments, starting at the center and working toward each end, until all bearing caps are seated.
7. Tighten all bearing cap bolts to 10 N·m (89 in.-lb).
8. Install chain on sprocket and install sprocket on intake camshaft. Tighten bolts until snug.
9. Install guide rails.
10. Apply medium strength thread lock and sealer to the threads of the guide rail bearing pins. Install and tighten to 20 N·m (177 in.-lb).
11. Adjust camshaft timing. *See Adjust Camshaft Timing on page 5-45.*
12. Remove flywheel holding tool and install protective cap.
13. Remove chain tensioner locks.
14. Install alternator drive belt. *See Remove and Install Alternator on page 11-5.*
15. Fill engine with coolant. *See Drain and Fill Closed Cooling System on page 7-10*.
16. Install cylinder head cover. *See Remove and Install Cylinder Head Cover on page 5-17.*

CYLINDER BLOCK AND CRANKSHAFT

Components

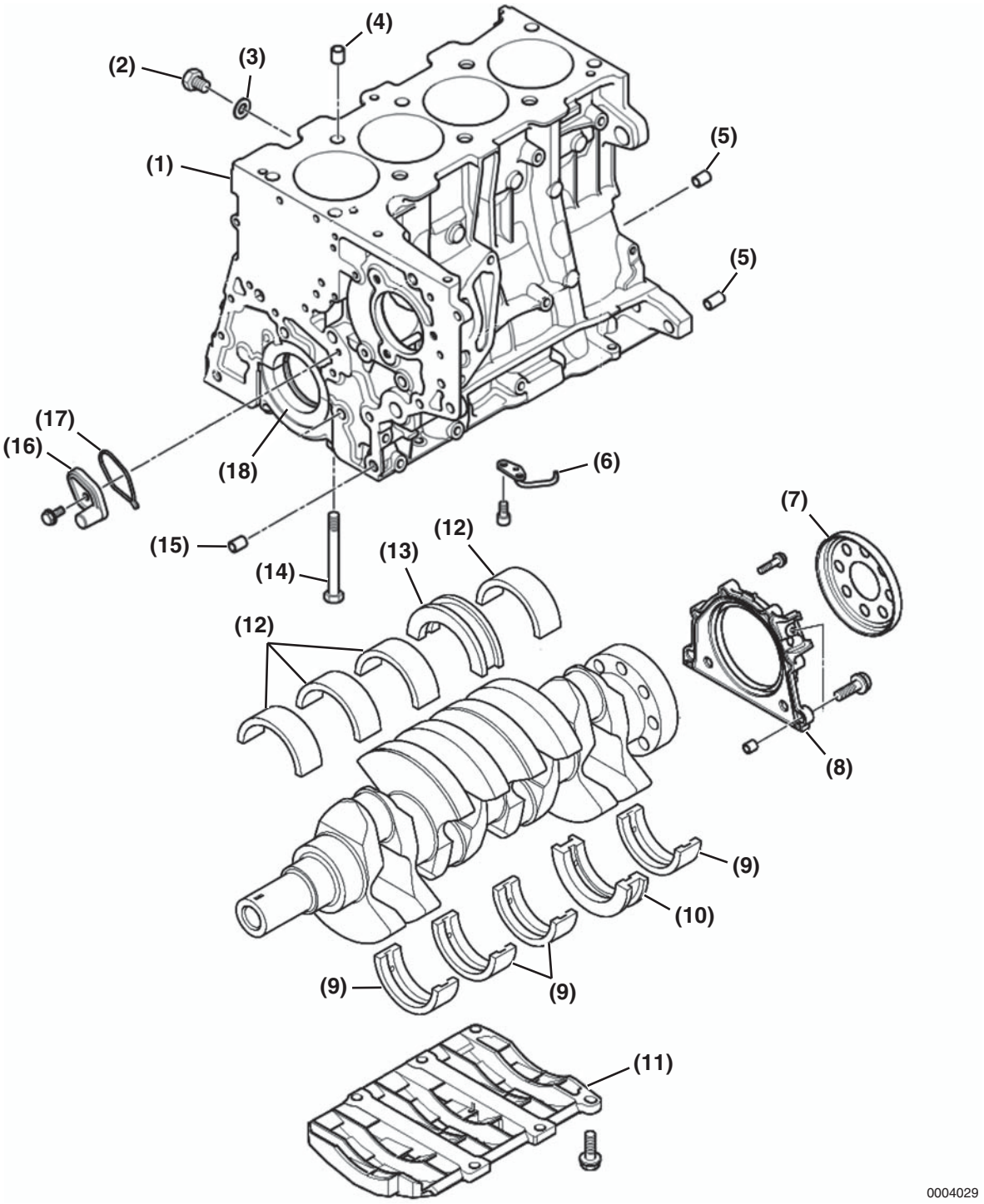


Figure 5-105

1 – Cylinder Block
2 – Coolant Drain Plug
3 – Seal
4 – Dowel Sleeve
5 – Dowel Sleeve
6 – Piston Cooling Jet
7 – Crankshaft Pulse Generator Wheel
8 – Rear Crankshaft Seal Assembly
9 – Lower Main Bearing Inserts
10 – Lower Main / Thrust Bearing Insert
11 – Oil Deflector
12 – Upper Main Bearing Inserts
13 – Upper Main / Thrust Bearing Insert
14 – Main Bearing Cap Bolt
15 – Dowel Sleeve
16 – Timing Chain Oiler
17 – Seal
18 – Main Bearing Cap

Note: Service procedures for 4BY2 and 6BY2 engines are similar, therefore graphics shown will be representative and might not match the engine being serviced.

Remove Crankshaft

1. Drain engine oil. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.
2. Remove flywheel housing. *See Remove and Install Flywheel Housing on page 5-37.*
3. Remove flywheel. *See Remove Flywheel on page 5-39.*
4. Remove rear crankshaft seal housing. *See Replace Rear Crankshaft Seal on page 5-40.*
5. Remove cylinder head. *See Remove Cylinder Head on page 5-19.*
6. Remove timing case cover. *See Remove Timing Case Cover on page 5-48.*
7. Remove timing chain. *See Remove and Install Timing Chain on page 5-49.*
8. Remove oil sump, oil suction pipe and strainer, and the oil pump. *See Oil Pump on page 8-12.*
9. Remove oil deflector **(Figure 5-106, (1))**.

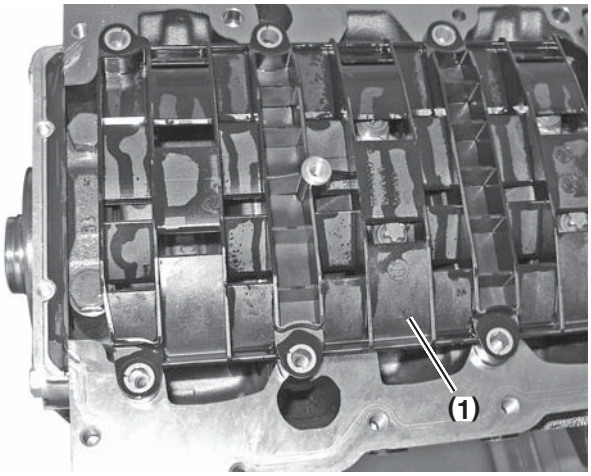


Figure 5-106

10. Remove pistons and connecting rods. *See Remove and Disassemble Piston and Connecting Rod on page 5-31.*
11. Before removing main bearing caps, measure crankshaft end play.
    - Mount a dial indicator on the cylinder block. Move the crankshaft in and out to measure end play **(Figure 5-107)**.

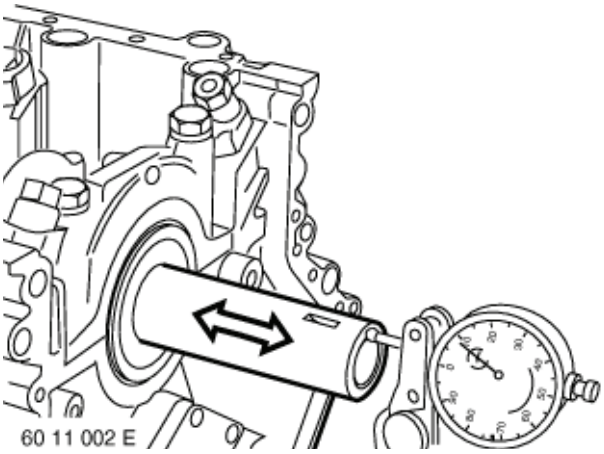


Figure 5-107

Specifications

Inspection Item	Specification
Crankshaft End Play	0.060 to 0.250 mm (0.0024 to 0.0098 in.)

12. Measure bearing oil clearance to help determine extent of wear. *See Measure Oil Clearance on page 5-59.*

Note: Main bearing caps 1 to 5 are marked on the exhaust side.

Note: All bearing caps must be installed in their original locations.

Note: **6BY2 Engines:** Main bearing caps No. 6 and 7 are not marked, but No. 6 is the location of the thrust bearing **(Figure 5-108)**.

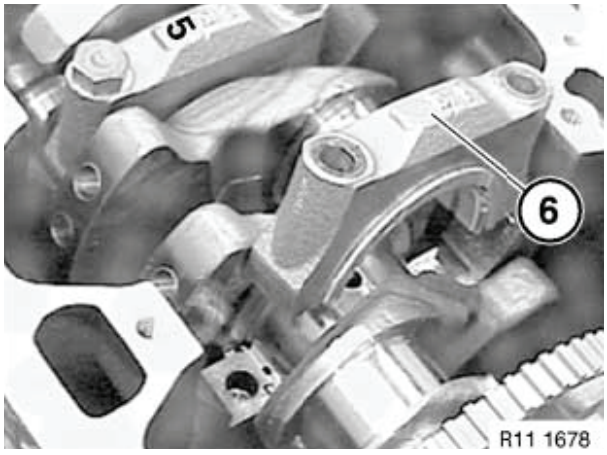


Figure 5-108

13. Remove the crankshaft bearing caps and main bearing inserts **(Figure 5-109)**.

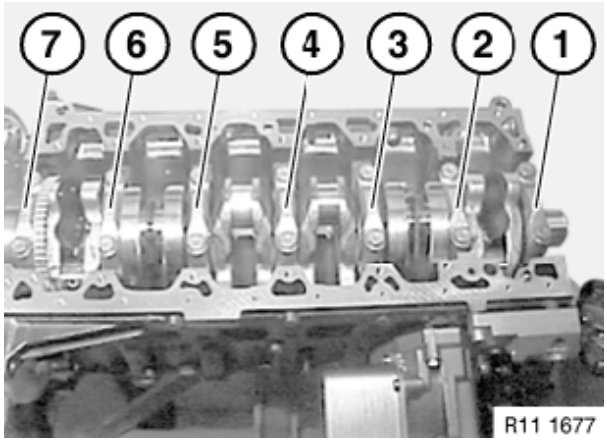


Figure 5-109

14. Remove crankshaft. Inspect and measure crankshaft journals as required.

Measure Oil Clearance

Oil clearance should be checked during disassembly to determine the extent of wear, and during reassembly to ensure long engine life. The same procedure is done for both connecting rods and main bearings.

1. Remove the bearing cap. Do not remove the bearing inserts at this time.
2. Wipe oil from the bearing insert and crankshaft journal surfaces.
3. Place a piece of PLASTIGAGE® **(Figure 5-110, (1))** along the full width of the bearing insert. *NOTICE: NEVER rotate crankshaft when using PLASTIGAGE. A false reading may result.*

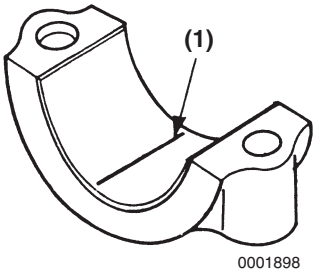


Figure 5-110

4. Install the bearing cap using the old bolts and tighten to specification. *See Special Torque Chart on page 5-8*.
5. Remove the bearing cap.

6. Compare the width of the flattened PLASTIGAGE to the graduation marks on the package **(Figure 5-111, (1))**. The mark that most closely matches the width of the flattened PLASTIGAGE will indicate the bearing oil clearance.

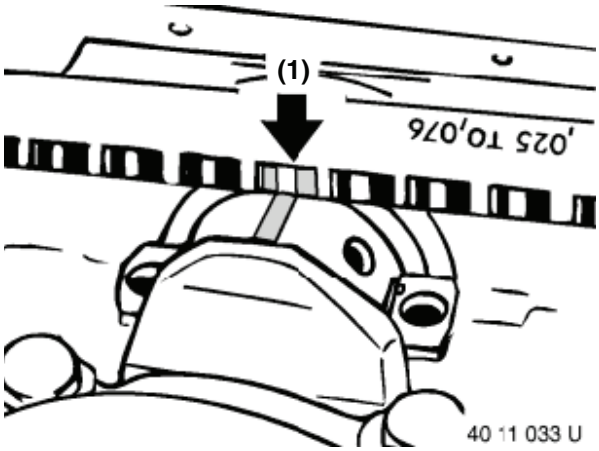


Figure 5-111

7. **Figure 5-112** and **Figure 5-113** show the relationship of each color coding compared to diameter. If necessary, install bearing inserts having a different color coding.

Main Bearings

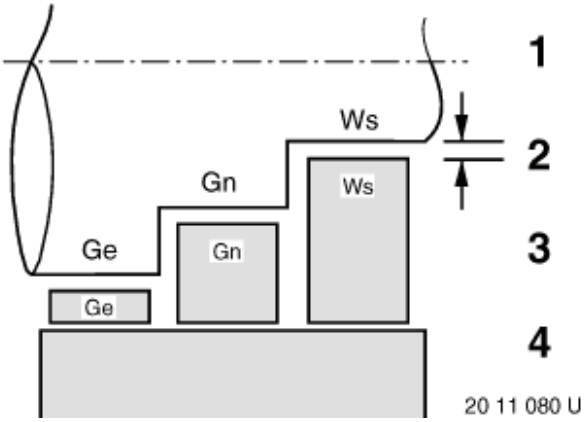


Figure 5-112

1 – Crankshaft
2 – Oil Clearance
3 – Bearing Inserts: Yellow, Green, White
4 – Bearing Cap

- Ge = Yellow
- Gn = Green
- Ws = White

Connecting Rod Bearings

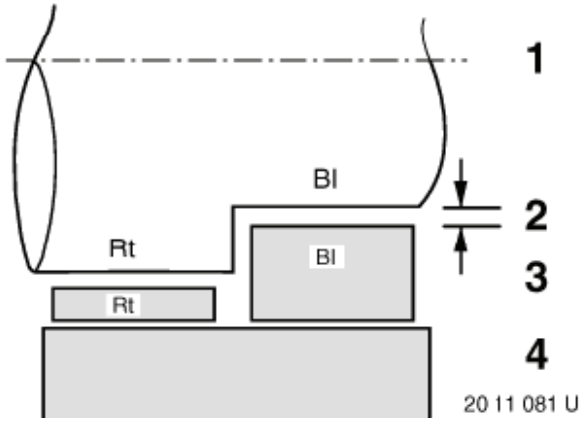


Figure 5-113

1 – Crankshaft
2 – Oil Clearance
3 – Bearing Inserts: Red or Blue
4 – Bearing Cap

- Rt = Red
- Bl = Blue

8. Repeat with the remaining bearings.

Inspect Crankshaft

1. Use the color check method or MAGNAFLUX® to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures are found.
2. Measure the outside diameter of each crankpin and main bearing journal. Take measurements at several places around each bearing surface. If not within specification, grind the journals and install undersize bearings, or replace the crankshaft.

Crankshaft Specifications

Main Bearing Journals	Specification
Standard Yellow	59.977 to 59.983 mm (2.3613 to 2.3615 in.)
Standard Green	59.970 to 59.976 mm (2.3610 to 2.3613 in.)
Standard White	59.964 to 59.969 mm (2.3608 to 2.3610 in.)
Undersize 1 (U 0.25) Yellow	59.727 to 59.733 mm (2.3514 to 2.3517 in.)
Undersize 1 (U 0.25) Green	59.720 to 59.726 mm (2.3512 to 2.3514 in.)
Undersize 1 (U 0.25) White	59.714 to 59.719 mm (2.3509 to 2.3511 in.)
Undersize 2 (U 0.50) Yellow	59.477 to 59.483 mm (2.3416 to 2.3418 in.)
Undersize 2 (U 0.50) Green	59.470 to 59.476 mm (2.3413 to 2.3416 in.)
Undersize 2 (U 0.50) White	59.464 to 59.469 mm (2.3411 to 2.3413 in.)
Crankshaft Bearing Clearance, Radial	0.019 to 0.052 mm (0.0007 to 0.0020 in.)

Connecting Rod Journals	Specification
Standard	45.00 -0.009 / -0.025 mm (1.7716 -0.0004 / -0.0010 in.)
Size 1	44.75 -0.009 / -0.025 mm (1.7618 -0.0004 / -0.0010 in.)
Size 2	44.50 -0.009 / -0.025 mm (1.7520 -0.0004 / -0.0010 in.)
Radial Bearing Play	0.015 - 0.050 mm (0.0006 - 0.0020 in.)

Thrust Bearing	Specification
Standard	25.00 +0.020 / +0.066 mm (0.9842 +0.0008 / +0.0026 in.)
Size 1	25.2 +0.020 / +0.066 mm (0.9921 +0.0008 / +0.0026 in.)
Size 2	25.4 +0.020 / +0.066 mm (1.000 +0.0008 / +0.0026 in.)
Crankshaft End Play	0.06 to 0.25 mm (0.0024 to 0.0098 in.)

Inspect Cylinder Block

1. Remove all main bearing inserts. Ensure the bearing seating surfaces are free of any debris.
2. Ensure that oil passages are clear and unobstructed.
3. Check for discoloration or evidence of cracks. If a fracture is suspected, use the color check method or the MAGNAFLUX method to determine if the cylinder block is fractured.
4. Measure cylinders for roundness, taper and inspect for evidence of scoring. Consider honing or replacing the cylinder block if the measurements are not within specification.
5. Take measurements at three places ***(Figure 5-114, (a, b, c))***, and in two directions ***(Figure 5-114, (d and e))*** in each cylinder.

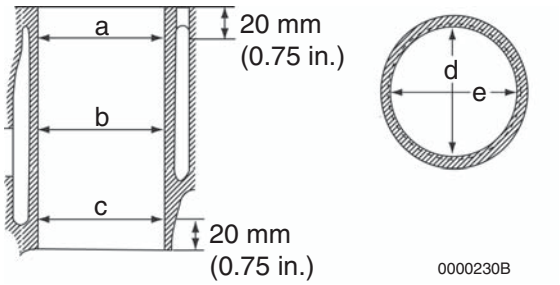


Figure 5-114

Cylinder Bore Specifications

Inspection Item*	Specification
Bore Diameter stage 0	84.007 ±0.007 mm (3.307352 ± 0.000276 in.)
Bore Diameter stage 1	84.257 ±0.007 mm (3.317195 ± 0.000276 in.)
Permitted out of round of cylinder bore	0.005 mm (0.000197 in.)
Permitted conicity of cylinder bore	0.01 mm (0.000393 in.)

* *Values are for new or reconditioned cylinders.*

Install Crankshaft

1. Select the correct bearing as follows:
   (a) Locate and record the grinding size of crankshaft **(Figure 5-115)**.

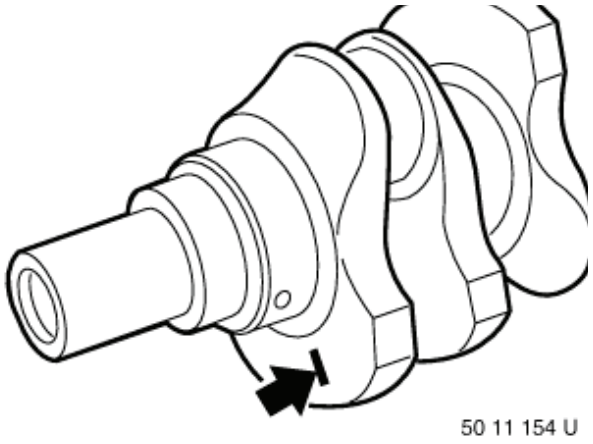


Figure 5-115

   (b) The crankshaft will be marked with yellow, green or white paint to determine the correct bearing shell to install in the bearing caps **(Figure 5-116)**.

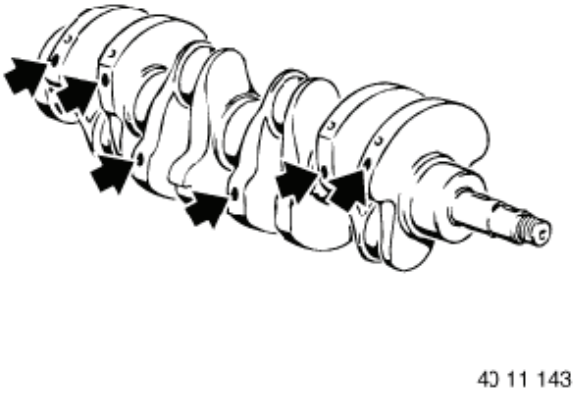


Figure 5-116

(c) Bearing shells are marked with yellow, green or white paint **(Figure 5-117)**. Select bearing shells with color that matches the paint on the crankshaft. *NOTICE: Ensure the bearing inserts and bearing mounting surfaces are absolutely clean and free of oil. Ensure all blind threaded holes are clean and free of oil or other fluid.*

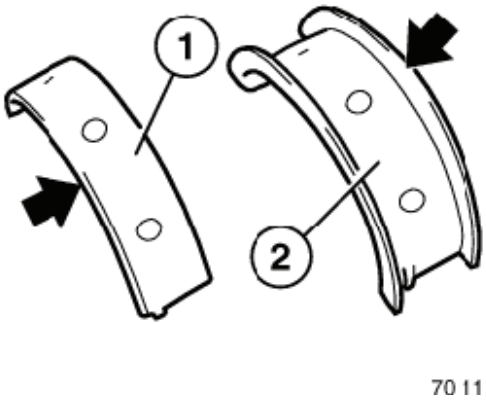


Figure 5-117

Note: Install thrust bearing insert (edges wrap around) in position 4 on 4BY2 and position 6 on 6BY2. Install insert half having an oil hole in the cylinder block **(Figure 5-118)**.

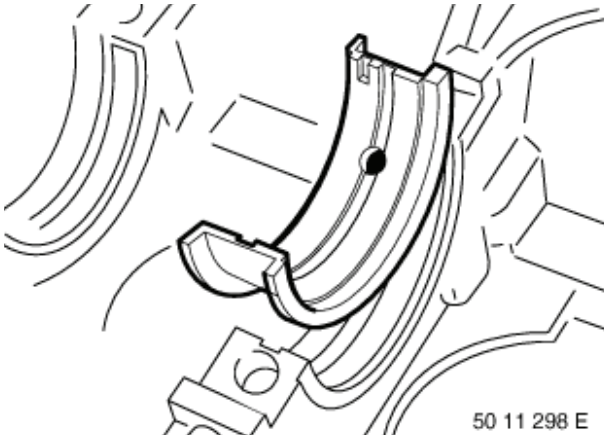


Figure 5-118

2. *NOTICE: Install ONLY bearing inserts with yellow identifying paint in the cylinder block main bearing bores.* Install yellow-painted main bearing inserts in the cylinder block and main bearing caps. Apply a generous amount of clean engine oil to the bearing inserts. Ensure all oil holes are properly aligned. Do not lubricate the crankshaft journals at this time.
3. Carefully lower the crankshaft into place. Do not rotate crankshaft.
4. Check bearing oil clearance before proceeding. *See Measure Oil Clearance on page 5-59*.
5. Apply clean engine oil to the crankshaft journals and main bearing inserts after oil clearance has been checked. *NOTICE: The main bearing caps are marked and must be installed in their original positions.*

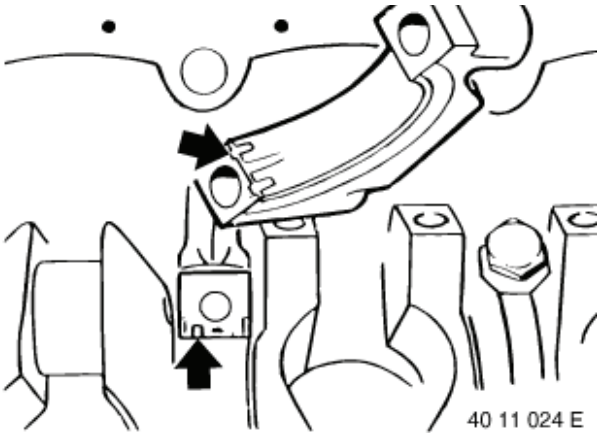


Figure 5-119

6. Install main bearing caps with the insert alignment tabs on the same side as those in the cylinder block. Lubricate threads on NEW bolts with clean engine oil and install. *NOTICE: NEVER reuse main bearing cap bolts. ALWAYS install new ones.*
7. Tighten bearing cap bolts to 22 N·m (16 ft-lb).
8. Loosen bolts of the thrust bearing retaining cap and tighten finger-tight.
9. Move each end of the crankshaft to center thrust bearing.

10. Torque-turn tighten all bolts to specification using torsion angle tool **(Figure 5-120)**. Turn crankshaft by hand to ensure there is no binding.

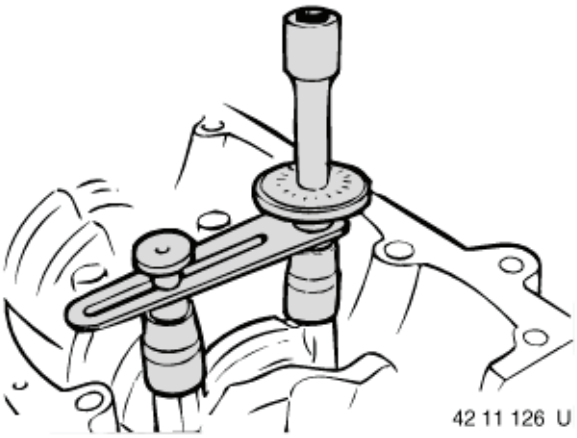


Figure 5-120

Main Bearing Bolt Torque

Item	Specification
Main Bearing Cap Bolts (torque-turn)	22 N·m (16 ft-lb) plus 90°

11. Check crankshaft end play after all bearing caps are installed.
12. Install pistons and connecting rods. Install piston cooling nozzles. *See Install Piston and Connecting Rod on page 5-34.*
13. Install oil deflector.
14. Install oil pump, oil suction pipe with strainer and the oil sump. *See Oil Pump on page 8-12*.
15. Install rear crankshaft seal housing. *See Replace Rear Crankshaft Seal on page 5-40*.
16. Install timing chain. *See Remove and Install Timing Chain on page 5-49*.
17. Install timing case cover using a new gasket. *See Install Timing Case Cover on page 5-49*.
18. Install vibration damper. *See Remove and Install Vibration Damper - 4BY2 on page 5-46* or *Remove and Install Vibration Damper - 6BY2 on page 5-47*.
19. Install flywheel. *See Install Flywheel on page 5-41*.
20. Install flywheel housing. *See Remove and Install Flywheel Housing on page 5-37*.
21. Install cylinder head. *See Install Cylinder Head on page 5-27.*
22. Add engine oil. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.

Replace Front Crankshaft Seal

1. Remove alternator belt and seawater pump belt. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19.*
2. Remove vibration damper. *See Remove and Install Vibration Damper - 4BY2 on page 5-46* or *Remove and Install Vibration Damper - 6BY2 on page 5-47.*

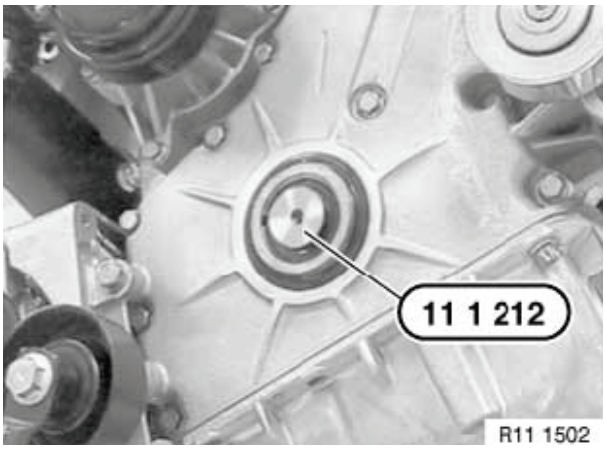


Figure 5-121

3. Install special tool OEM No. 11 1 212 to the end of crankshaft.

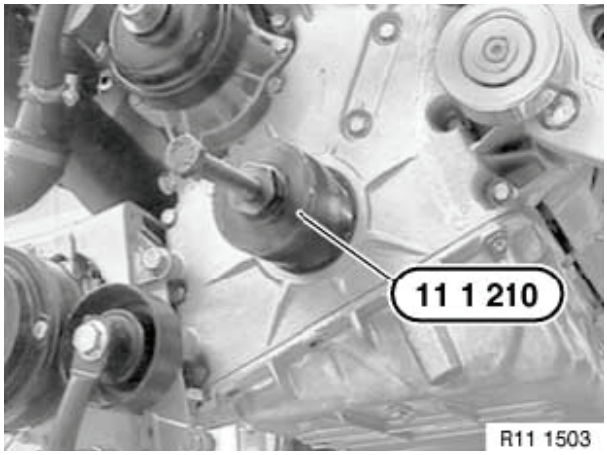


Figure 5-122

Note: Back the center screw out of the tool before attaching to seal.

4. Thread in special tool OEM No. 11 1 210 until it has firmly grasped the seal housing.
5. Turn center screw in to remove seal.
6. Wipe the sealing surface in the cover clean.

4BY2 Engines

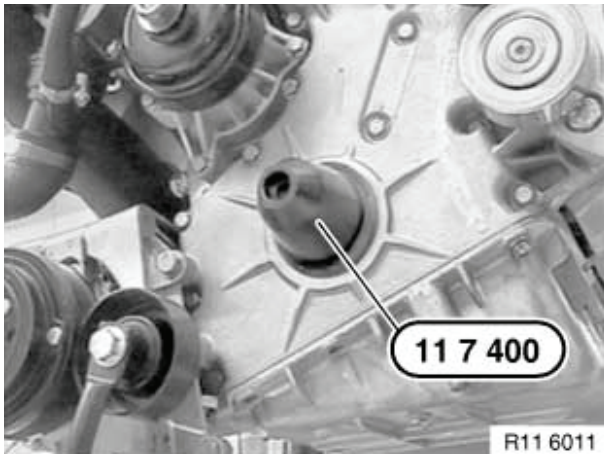


Figure 5-123

6BY2 Engines

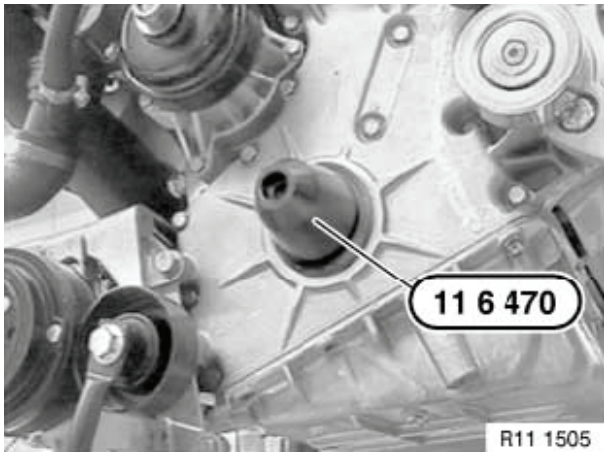


Figure 5-124

7. Install seal protector tool OEM No. 11 7 400 (4BY2) or 11 6 470 (6BY2) on end of crankshaft. Lubricate surface of tool with clean engine oil.
8. Slip seal over seal protector until it contacts case cover. Remove seal protector. *NOTICE: NEVER touch the sealing lip of the new seal with your fingers.*

9. Install center screw OEM No. 11 7 410 (4BY2) or 11 6 490 (6BY2) in end of crankshaft **(Figure 5-125 or Figure 5-126**).

4BY2 Engines

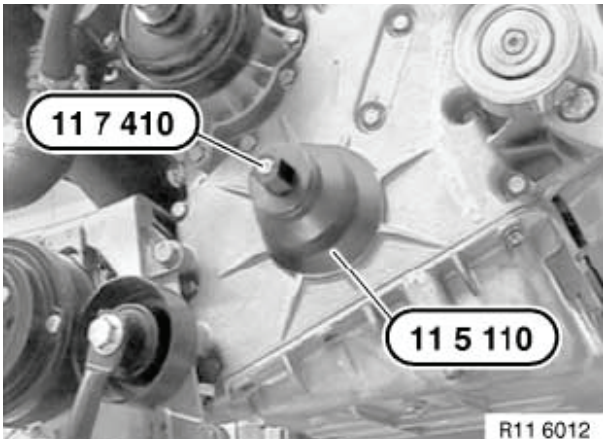


Figure 5-125

6BY2 Engines

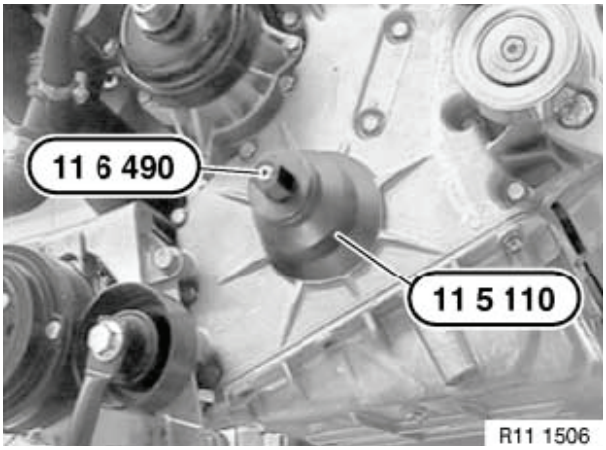


Figure 5-126

10. Place seal installer OEM No. 11 5 110 over center screw and install nut.
11. Tighten nut until seal is flush with timing case cover. Remove installer tool.
12. Install crankshaft damper. *See Remove and Install Vibration Damper - 4BY2 on page 5-46* and *See Remove and Install Vibration Damper - 6BY2 on page 5-47.*
13. Install belts. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19*.

INTAKE MANIFOLD

Remove

1. Remove injector harness connectors **(Figure 5-127, (1))** from all fuel injectors.

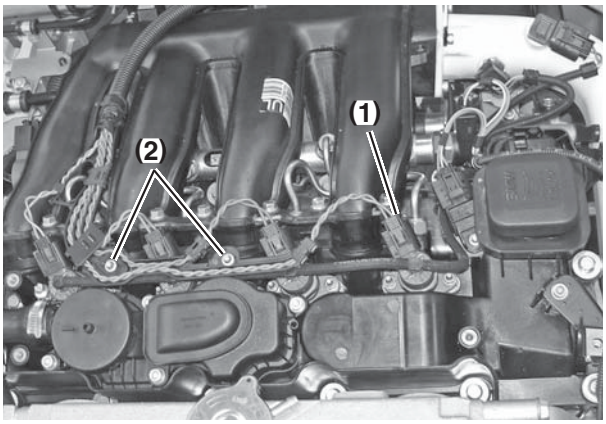


Figure 5-127

2. Remove screws **(Figure 5-127, (2))** and move injector harness out of the way.
3. Disconnect electrical connectors from charge air pressure sensor **(Figure 5-128, (1))** and charge air temperature sensor **(Figure 5-128, (2))**.

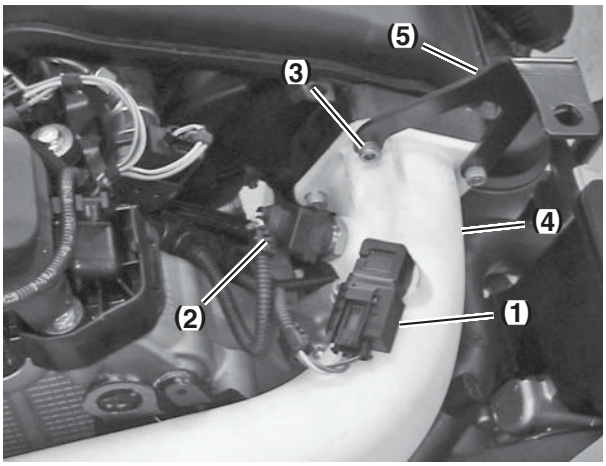


Figure 5-128

4. Remove four screws **(Figure 5-128, (3))**. Disconnect charge air pipe **(Figure 5-128, (4))** and bracket **(Figure 5-128, (5))**.

5. Disconnect inlet **(Figure 5-129, (1))** and outlet **(Figure 5-129, (2))** hoses from the fuel fine filter.

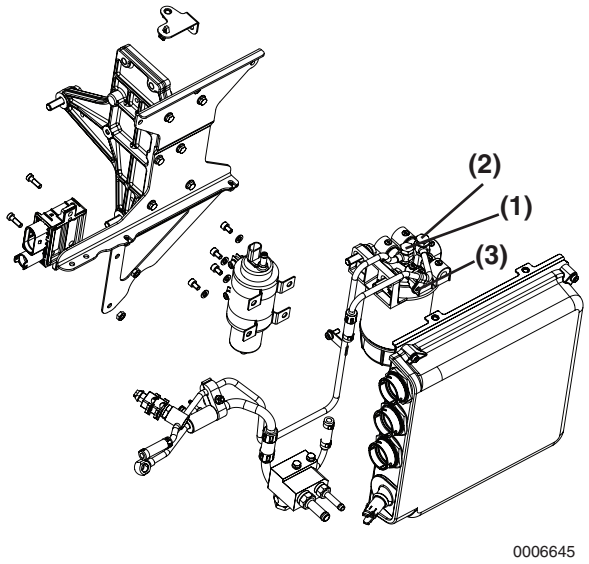


Figure 5-129

6. Remove clamp bolt **(Figure 5-129, (3))** to allow fuel inlet line **(Figure 5-129, (4))** to move.
7. Remove fuel fine filter from bracket.
8. Remove bolts **(Figure 5-130, (1))**.

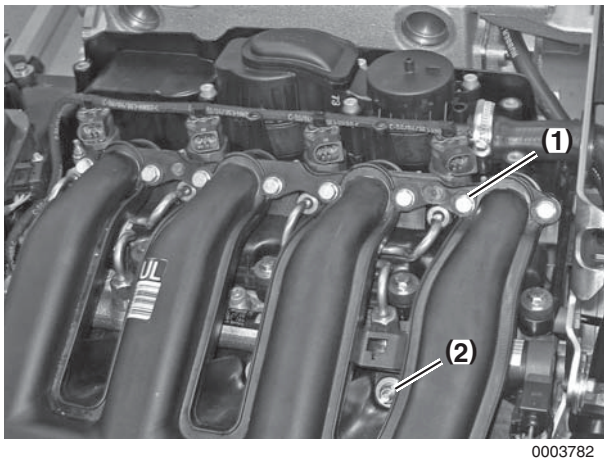


Figure 5-130

9. Remove nuts **(Figure 5-130, (2))**.
10. Remove intake manifold.

Install

1. Clean all sealing surfaces.
2. Install new sealing rings **(Figure 5-131, (1))**.

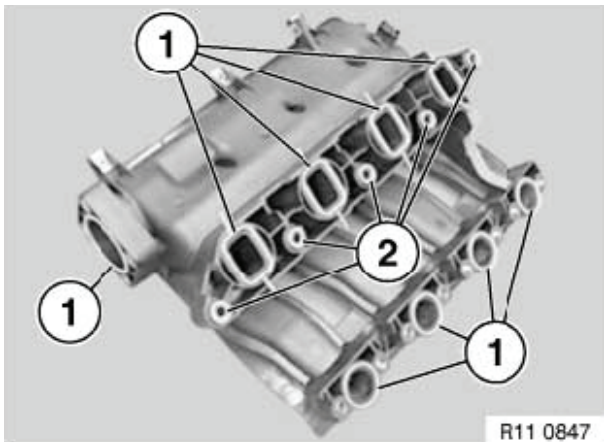


Figure 5-131

3. Check condition of rubber mounts **(Figure 5-131, (2))** and replace if damaged.
4. Install manifold on engine.
5. Install bolts and nuts. Tighten to 15 N·m (133 in.-lb).
6. Install fuel fine filter. Connect inlet **(Figure 5-132, (1))** and outlet **(Figure 5-132, (2))** hoses.

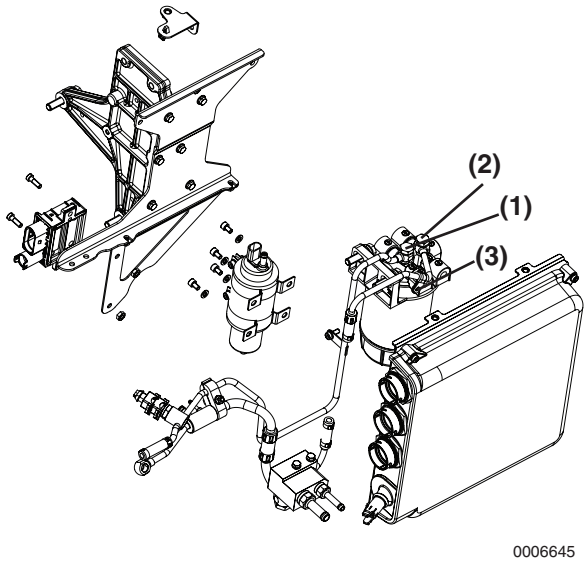


Figure 5-132

7. Secure inlet line clamp **(Figure 5-132, (3))**.

8. Ensure seal in charge air pipe is not damaged and is in place. Connect charge air pipe **(Figure 5-133, (4))** and bracket **(Figure 5-133, (5))**. Install four screws **(Figure 5-133, (3))** and tighten to 9.5 N·m (84 in.-lb)

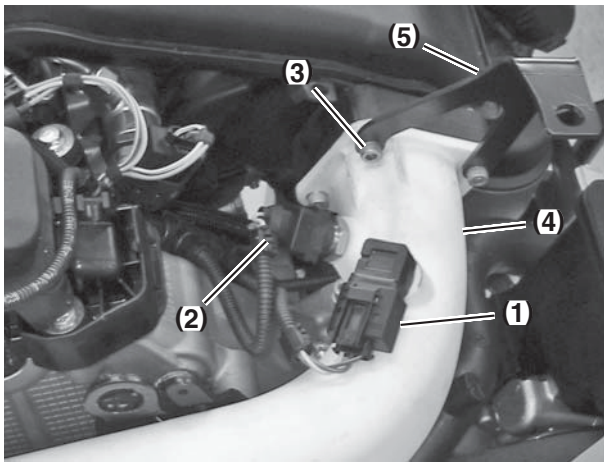


Figure 5-133

9. Connect electrical connectors to charge air pressure sensor **(Figure 5-133, (1))** and charge air temperature sensor **(Figure 5-133, (2))**.
10. Secure injector harness to intake manifold and connect to fuel injectors.
11. Bleed the fuel system. *See Bleed the Fuel System on page 6-22*.

EXHAUST MANIFOLD

Remove

1. Remove heat exchanger. *See Remove and Install Heat Exchanger on page 7-13.*
2. Remove turbocharger. *See Remove Turbocharger on page 9-6*.
3. Remove exhaust manifold nuts and exhaust manifold **(Figure 5-134, (1))**.

6BY2 Engine Shown

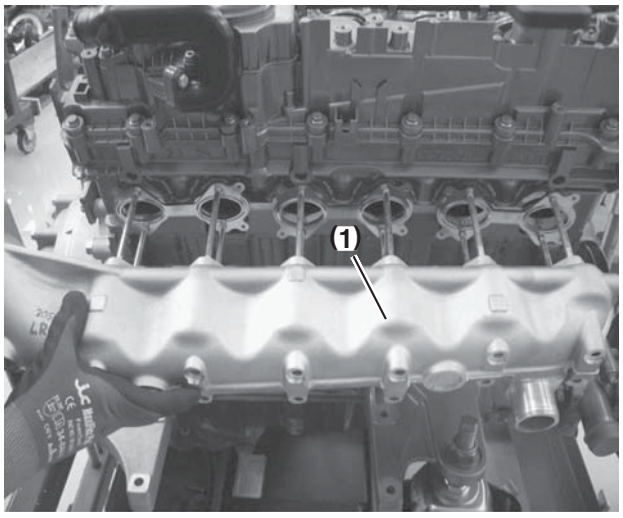


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Figure 5-134

Install

1. Clean mounting surfaces of all gasket material.
2. Apply a light coating of copper anti-seize to mounting studs.
3. Install new gaskets.
4. Install exhaust manifold with new nuts.
5. Tighten exhaust manifold nuts to the torque specification using a uniform cross pattern starting from the center out to each end.

Specifications

Item	Engine	Torque
Exhaust Manifold Nut Torque	4BY2	23 N·m (204 in.-lb)
	6BY2	

6. Install turbocharger. *See Install Turbocharger on page 9-6.*
7. Install heat exchanger. *See Remove and Install Heat Exchanger on page 7-13.*

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Section 6

FUEL SYSTEM

Page

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SAFETY PRECAUTIONS

Before servicing the fuel system, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures necessary to remove, install and repair fuel system components as used on the Yanmar 4BY2 and 6BY2 engines.

SPECIFICATIONS

Test and Adjustment Specifications

Test Item	Specification		Reference Page
High-Pressure Fuel Pump Pressure	Minimum at cranking	250 bar (3625 psi)	-
	Minimum at low idle	400 bar (5800 psi)	
	Maximum at 4000 rpm	1600 bar (23,200 psi)	
Fuel Feed Pump Pressure (Minimum)	All speeds	5.0 bar (72.5 psi)	*Measure Fuel Feed Pump Pressure on page 6-9*
Return Fuel Pressure (Maximum)	All speeds	200 mmAq (7.87 in.Aq)	*Test Return Fuel Pressure on page 6-10*
Fuel Supply Restriction (Maximum)	All speeds	0.1 bar (3 in.Aq)	-
Fuel Temperature	Maximum before speed reduction begins	80°C (176°F)	-

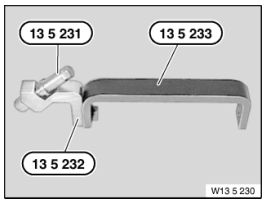
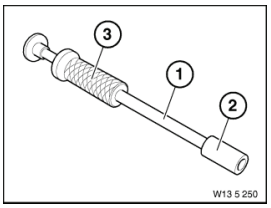
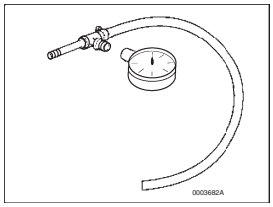
Note: Yanmar supplies a water separating pre-filter for mounting by the installer. The engine is also equipped with an on-engine fine filter.

Special Torque Chart

Component		Tightening Torque	Lubricating Oil Application (Thread Portion and Seat Surface)	Reference Page
Fuel Injector Retaining Nut		9 N·m (80 in.-lb)	Not Applied	*Install Fuel Injector on page 6-13*
High-Pressure Fuel Regulator Retaining Nut		80 N·m (59 ft-lb)		*Replace High-Pressure Fuel Regulator on page 12-25*
High-Pressure Fuel Sensor Retaining Nut		70 N·m (52 ft-lb)		*Replace High-Pressure Fuel Rail Pressure Sensor on page 12-26*
High-Pressure Pump Sprocket Nut Access Plug	M30 x 1.0	70 N·m (52 ft-lb)		*Replace High-Pressure Fuel Pump on page 6-15*
	M40 x 1.5	30 N·m (22 ft-lb)		
High-Pressure Pump Drive Sprocket Nut		65 N·m (48 ft-lb)		
High-Pressure Fuel Line Union Nut		23 N·m (204 in.-lb)		*Remove and Install High-Pressure Fuel Lines on page 6-14*
Return Fuel Banjo Bolt to Fuel Rail		25 N·m (221 in.-lb)		*Remove and Install Fuel Rail on page 6-20*

SPECIAL SERVICE TOOLS

Note: The tool numbers used in this section are either Yanmar or BMW part numbers. Yanmar part numbers are referred to as **Yanmar Part No.** and BMW part numbers are referred to as **OEM Part No.** Tools not having part numbers must be acquired locally.

No.	Tool Name	Applicable Model and Tool Size	Illustration
1	Diagnostic Tool	Obtain Locally	
2	Union Nut Wrench (For Removing and Installing High-Pressure Fuel Lines)	OEM Part No. 13 5 020	
3	Injector Removal Adapter (For Removing Fuel Injectors)	OEM Part No. 13 5 231, 13 5 232, and 13 5 233	
3	Slide Hammer (For Removing Fuel Injectors)	OEM Part No.13 5 250	
4	Fuel Pressure Gauge (For Measuring Fuel System Pressure)	Obtain Locally	

FUEL SYSTEM COMPONENTS

4BY2 Engines

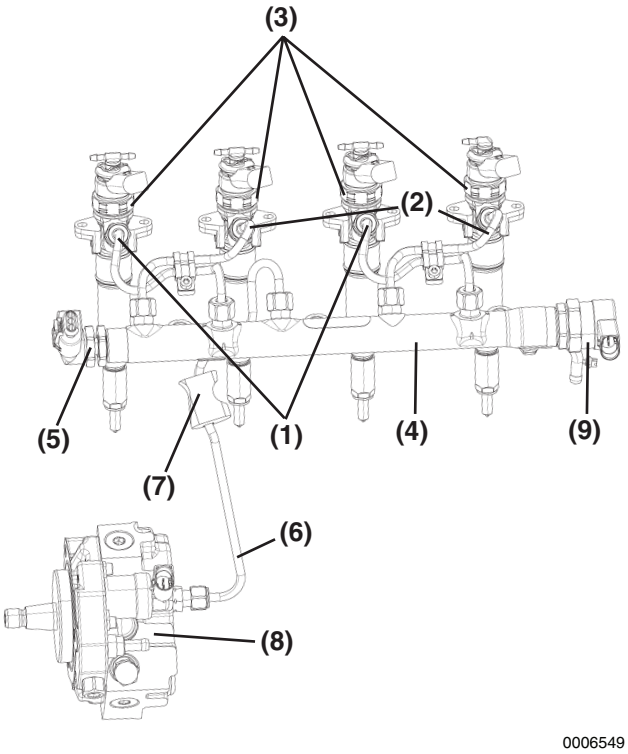


Figure 6-1

1 – High-Pressure Line, Cylinders No. 1 and 3
2 – High-Pressure Line, Cylinders No. 2 and 4
3 – Fuel Injectors
4 – High-Pressure Fuel Rail
5 – High-Pressure Fuel Rail Pressure Sensor
6 – High-Pressure Line from Pump
7 – Rubber Insulator
8 – High-Pressure Pump with Fuel Measuring Unit
9 – High-Pressure Fuel Regulator

6BY2 Engines

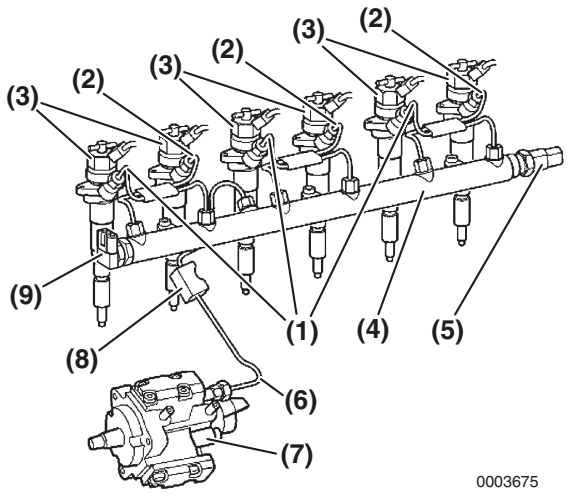


Figure 6-2

1 – High-Pressure Line, Cylinders No. 1, 3 and 5
2 – High-Pressure Line, Cylinders No. 2, 4 and 6
3 – Fuel Injectors
4 – High-Pressure Fuel Rail
5 – High-Pressure Fuel Regulator
6 – High-Pressure Line from Pump
7 – High-Pressure Pump with Fuel Measuring Unit
8 – Rubber Insulator
9 – High-Pressure Fuel Rail Pressure Sensor

FUEL FLOW DIAGRAM

4BY2

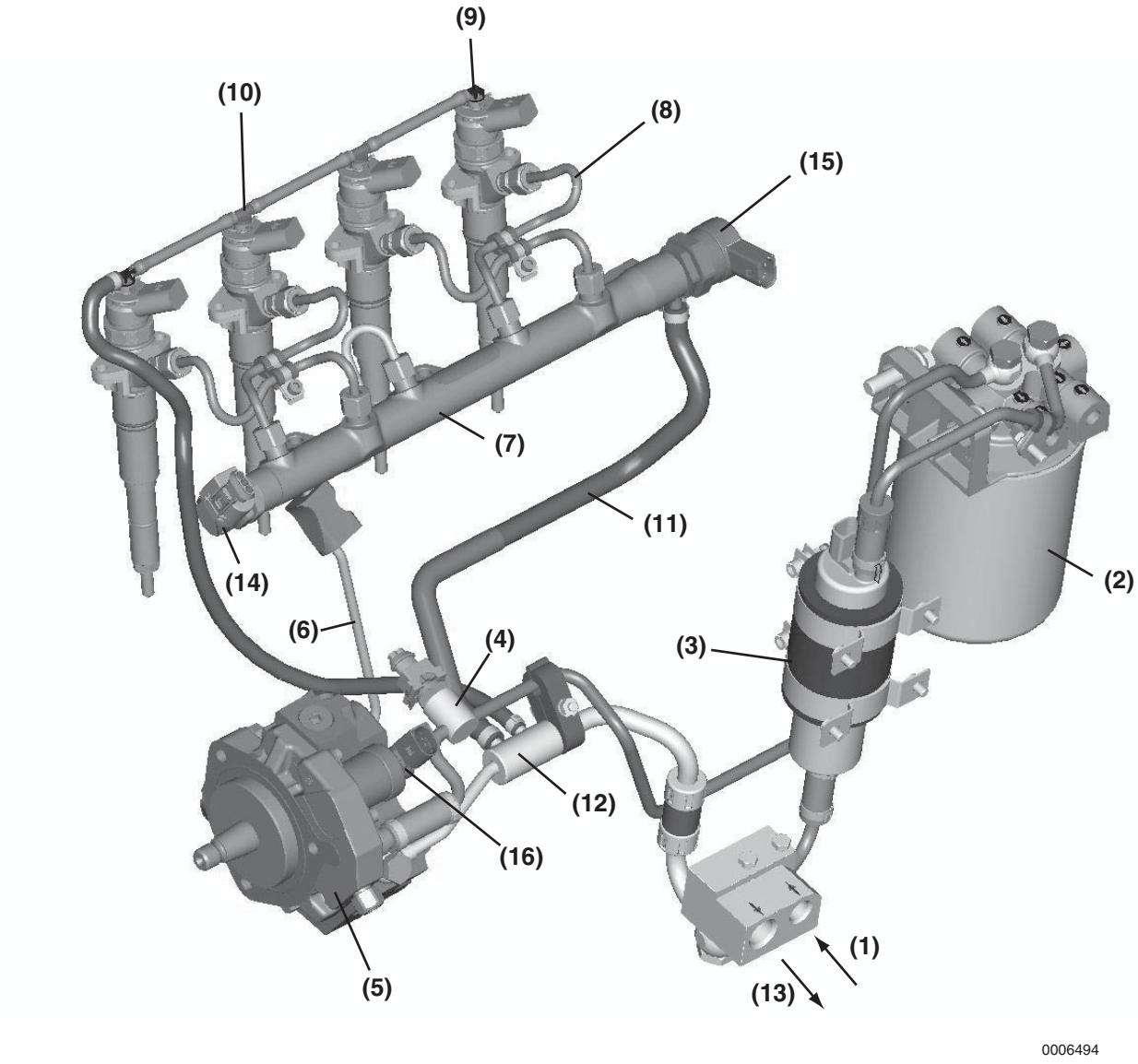


Figure 6-3

1 – Fuel Inlet from Tank
2 – Fuel Fine Filter
3 – Fuel Feed Pump
4 – Inlet Fuel Temperature Sensor
5 – High-Pressure Fuel Pump
6 – High-Pressure Fuel Supply Line
7 – High-Pressure Fuel Rail
8 – Fuel Injection Line
9 – Fuel Injector
10 – Fuel Injector Return Hose
11 – Common Rail Return Line
12 – Return Fuel Tee with Back Pressure Valve
13 – Return Fuel to Fuel Tank with Over Pressure Valve
14 – High-Pressure Fuel Rail Pressure Sensor
15 – High-Pressure Fuel Regulator (ECU-Controlled)
16 – Fuel Volume Regulator (ECU-Controlled)

6BY2

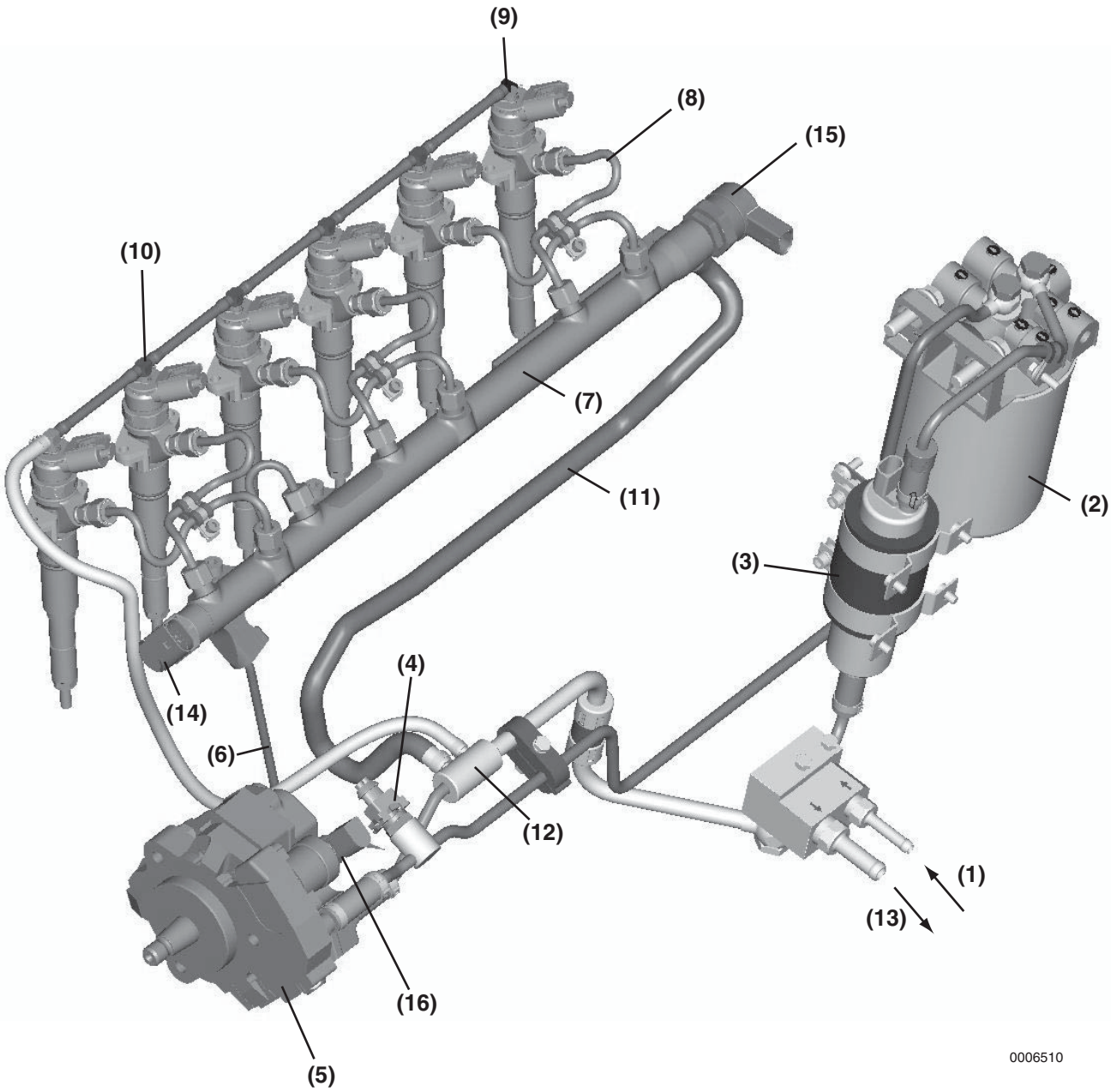


Figure 6-4

1 – Fuel Inlet from Tank
2 – Fuel Fine Filter
3 – Fuel Feed Pump
4 – Inlet Fuel Temperature Sensor
5 – High-Pressure Fuel Pump
6 – High-Pressure Fuel Supply Line
7 – High-Pressure Fuel Rail
8 – Fuel Injection Line
9 – Fuel Injector
10 – Fuel Injector Return Hose
11 – Common Rail Return Line
12 – Return Fuel Tee with Back Pressure Valve
13 – Return Fuel to Fuel Tank with Over Pressure Valve
14 – High-Pressure Fuel Rail Pressure Sensor
15 – High-Pressure Fuel Regulator (ECU-Controlled)
16 – Fuel Volume Regulator (ECU-Controlled)

TESTS AND ADJUSTMENTS

After completing work that involves opening the fuel system, do the following:

- Bleed the fuel system. *See Bleed the Fuel System on page 6-22*.
- Start engine and check for leaks. Allow engine to run until it is running smoothly.
- Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Measure Fuel Feed Pump Pressure

Procedure

1. Assemble a suitable fuel pressure gauge **(Figure 6-5, (1))** to a tee, and connect a short length of hose **(Figure 6-5, (3))** to one of the remaining two legs of the tee **(Figure 6-5, (2))**.

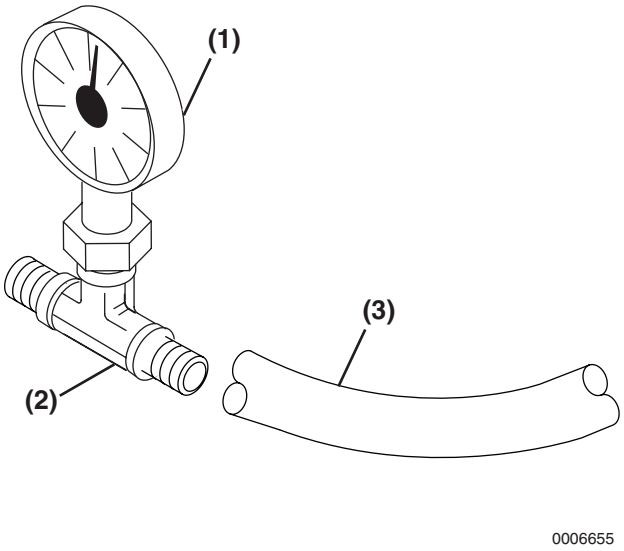


Figure 6-5

2. Disconnect the fuel line from the fuel feed pump outlet **(Figure 6-6, (1))**.

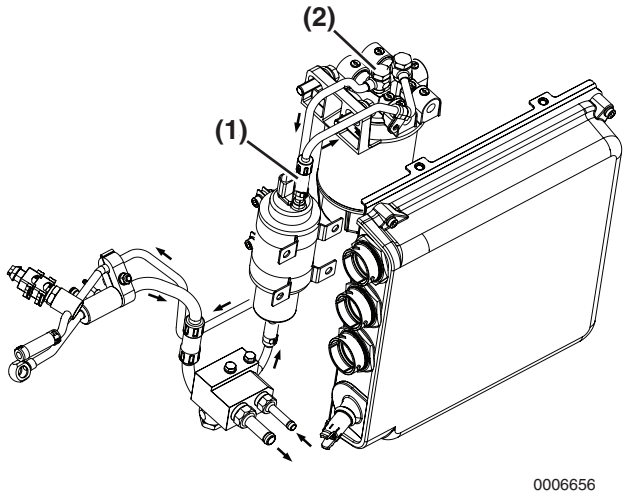


Figure 6-6

3. Connect fuel pressure gauge assembly between disconnected ends. Install and tighten hose clamps.
4. Start engine and set speed to low idle. Read and record pressure.
5. Operate engine at full load. Read and record pressure.
6. Repeat the procedure on the fuel outlet side of the fuel fine filter **(Figure 6-6, (2))**.

Specification

Inspection Item	RPM	Specification
Fuel Feed Pump Pressure (Minimum)	All	5.0 bar (73.0 psi)

Results

- If pressure reading is not within specification, inspect fuel filter / water separator, fuel fine filter and fuel feed pump.
- Measure vacuum / restriction before the electric pump. Connect a suitable fuel vacuum gauge assembly **(Figure 6-7, (1))** inline between the fuel tank and fuel feed pump, to measure vacuum. This value should not exceed 1000 mmAq (40 in.Aq). If it exceeds the specification, correct restriction from the fuel tank to the engine.

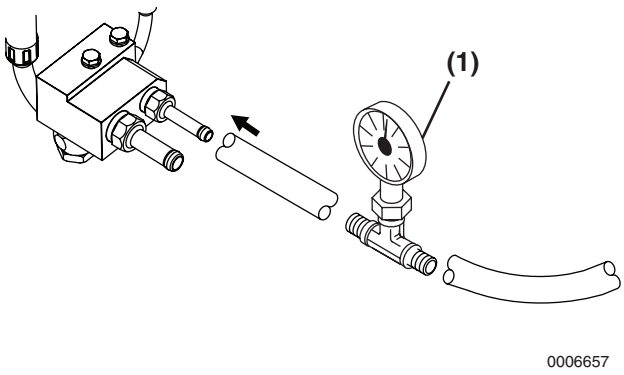


Figure 6-7

Note: If fuel feed pump pressure is significantly less than 5.0 bar (73.0 psi) and inlet restriction and return line pressure are within specifications, replace the electric fuel feed pump.

Test Return Fuel Pressure

Note: This test is dependent on the fuel supply. Test the low-pressure fuel system prior to performing this test. *See Measure Fuel Feed Pump Pressure on page 6-9*.

1. Assemble a tee, hose and 0 to 100 kPa (0 to 15 psi) pressure gauge.
2. Disconnect the hose from the fuel return line **(Figure 6-8, (1))**.

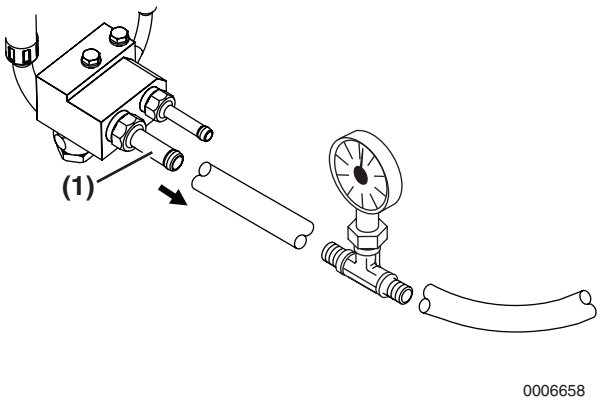


Figure 6-8

3. Connect test gauge assembly between disconnected ends. Install and tighten hose clamps.
4. Start engine and allow speed to stabilize at normal low idle.
5. Read and record pressure.

Specification

Inspection Item	RPM	Pressure
Return Fuel Pressure	All speeds	200 mmAq (7.9 in.Aq)

Results

If test pressure reading is not within specifications, find and correct the return fuel restriction.

REPAIR

After completing work that involves opening the fuel system, do the following:

- Bleed the system. *See Bleed the Fuel System on page 6-22*.
- Start engine and check for leaks. Allow engine to run until it is running smoothly.
- Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Remove Fuel Injector

NOTICE: When working on the oil, coolant or fuel systems, you must protect the alternator from contamination. Cover alternator with suitable materials. Failure to comply may result in an alternator failure.

1. Disconnect the battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Remove intake manifold. *See Intake Manifold on page 5-66.*
4. Remove return fuel line from fuel injector. *See Replace Injector Return Fuel Line on page 6-21.*
5. If removing only one fuel injector, remove the clamp **(Figure 6-9, (1))** joining the fuel injector lines to each other. *NOTICE: Immediately cap or plug all openings to prevent contamination of system.*

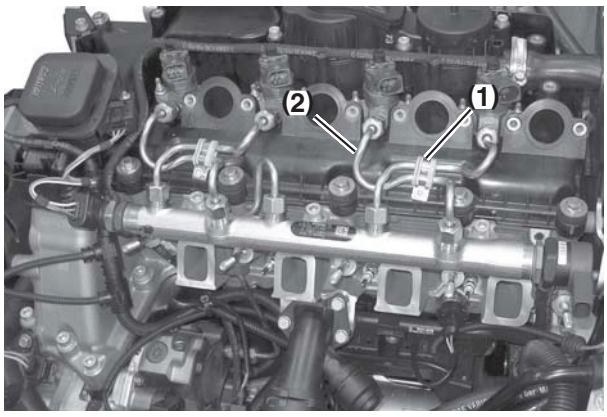


Figure 6-9

6. Remove high-pressure fuel line **(Figure 6-9, (2))** from injector and fuel rail. *See Remove and Install High-Pressure Fuel Lines on page 6-14*.
7. Remove two nuts retaining fuel injector flange. Remove fuel injector and flange **(Figure 6-10)**. *NOTICE: NEVER disassemble the fuel injector. Replace the entire unit as necessary.*

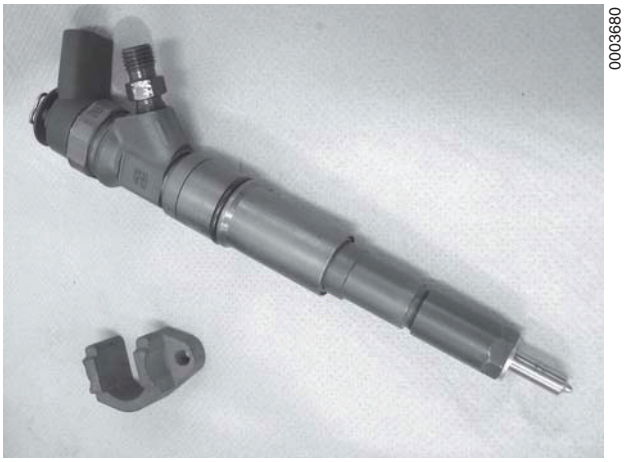


Figure 6-10

8. If the injector is stuck, assemble special tools OEM No. 13 5 250, 13 5 231 and 13 5 232 and fasten to injector high-pressure fuel line connection. Remove using slide hammer **(Figure 6-11)**.

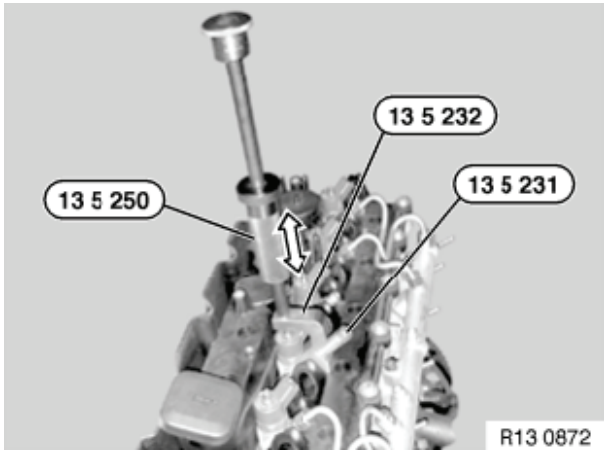


Figure 6-11

9. If injector gasket did not come out with injector, remove it from the bottom of the injector seat.

Clean Fuel Injector Cavities

1. Remove fuel injector. *See Remove Fuel Injector on page 6-11.*
2. Ensure the injector seal has been removed from the bottom of the injector cavity **(Figure 6-12, (1))**.

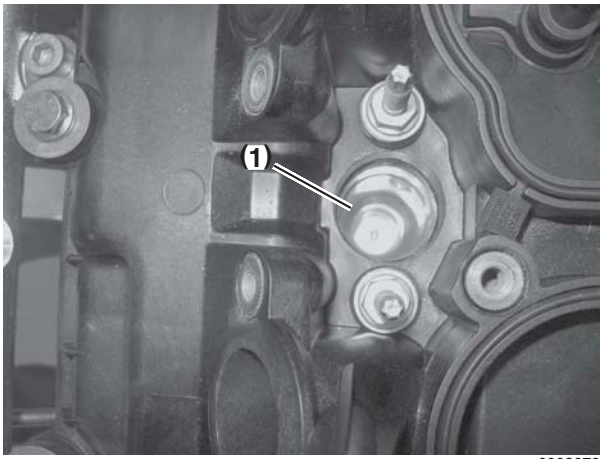


Figure 6-12

3. Thread the tip (special tool OEM No. 13 5 215) **(Figure 6-13, (1))** onto the end of special tool OEM No. 13 5 214 **(Figure 6-13, (2))**.

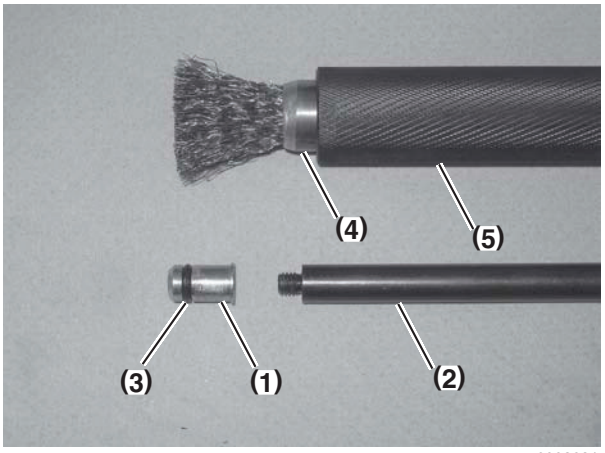


Figure 6-13

4. Ensure O-ring **(Figure 6-13, (3))** is in place and insert the tip into hole at bottom of injector cavity.
5. Remove tool OEM No. 13 5 214 from injector cavity, leaving the tip in hole at bottom of cavity.
6. Push brush **(Figure 6-13, (4))** into guide sleeve (special tool OEM No. 13 5 210) **(Figure 6-13, (5))**.
7. Insert brush and sleeve into injector cavity until it touches the bottom **(Figure 6-14)**.

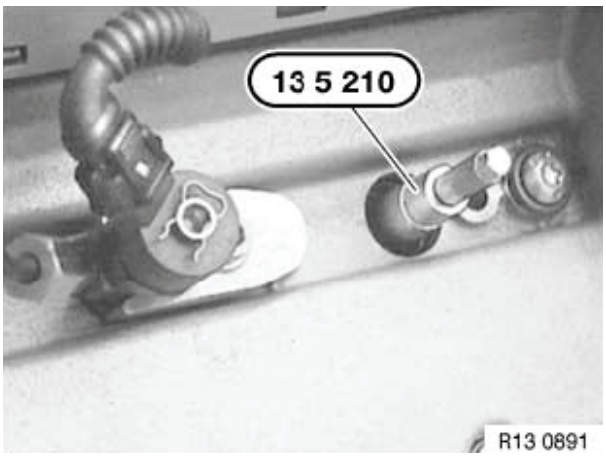


Figure 6-14

8. Use a socket wrench to turn tool while applying light pressure **(Figure 6-15)**.

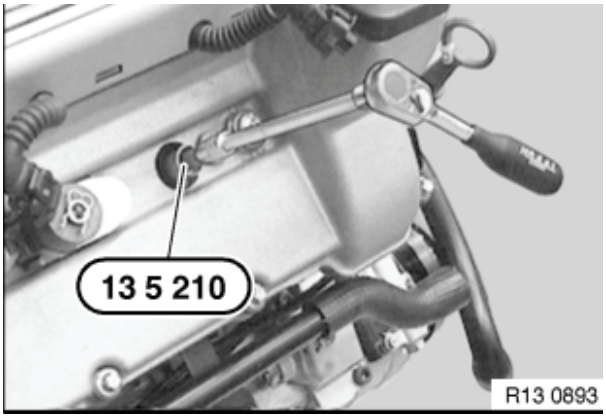


Figure 6-15

9. Clean sides of cavity by sliding tool in and out **(Figure 6-16)**.

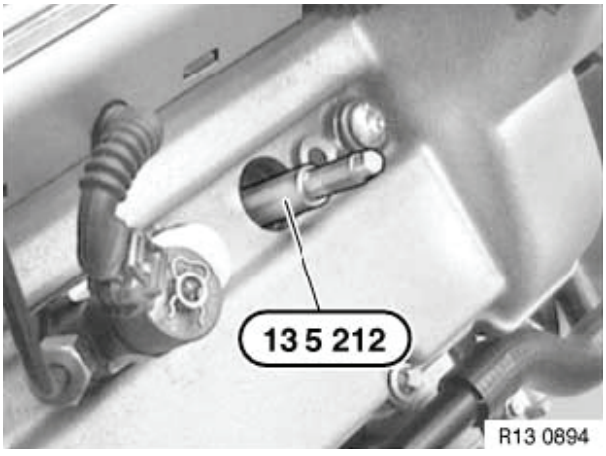


Figure 6-16

10. Use compressed air to blow debris out of cavity while covering cavity with cloth to catch debris. **WARNING!** ***Flying Object Hazard. ALWAYS wear eye protection when servicing the engine and when using compressed air or high-pressure water. Dust, flying debris, compressed air, pressurized water or steam may injure your eyes.***
11. Inspect to ensure sealing surface is clean. Repeat cleaning if necessary.
12. Use special tool OEM No. 13 5 214 to remove tip (special tool OEM No. 13 5 215) from bottom of injector cavity. *See Install Fuel Injector on page 6-13.*
13. Install fuel injector and high-pressure line. *See Install Fuel Injector on page 6-13*.
14. Run engine and check for fuel leaks.

Install Fuel Injector

1. Make sure that the old gasket is not at the bottom of the injector seat. Clean the sealing surfaces of the injector seat. *See Clean Fuel Injector Cavities on page 6-12*.
2. Inspect the O-ring and replace as necessary. Lubricate the O-ring with petroleum jelly. *NOTICE: ALWAYS install new copper gasket when installing an injector. Make sure all sealing surfaces are clean.*
3. Install new gasket **(Figure 6-17, (1))** on tip of injector **(Figure 6-17, (2))**.

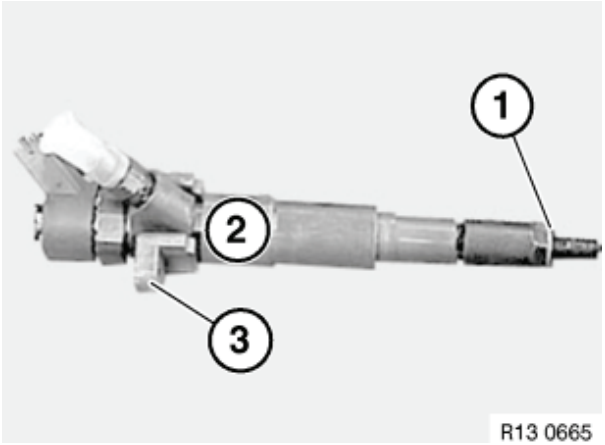


Figure 6-17

4. Place the retainer **(Figure 6-17, (3))** on the injector as shown.

Note: If installing used fuel injectors, clean the stem and nozzle prior to installation.

5. Install the injector and retainer as an assembly.
6. Install the two nuts **(Figure 6-18, (1))** and tighten in steps, first to 3.5 N·m (31 in.-lb) then to 8 N·m (71 in.-lb).

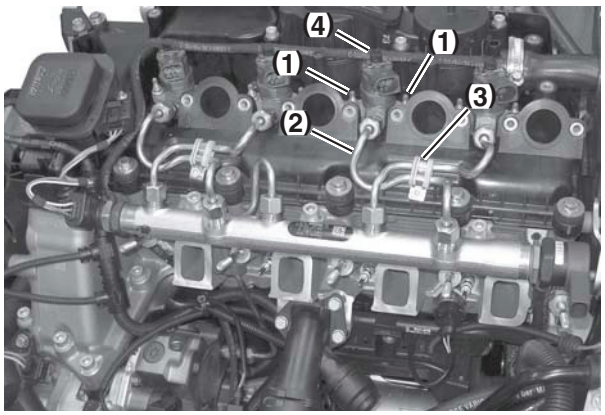


Figure 6-18

7. Install the high-pressure fuel line **(Figure 6-18, (2))**. *See Remove and Install High-Pressure Fuel Lines on page 6-14.*
8. If removed, install clamp **(Figure 6-18, (3))**.
9. Install injector return fuel lines **(Figure 6-18, (4))**. *See Replace Injector Return Fuel Line on page 6-21.*
10. Install intake manifold. *See Intake Manifold on page 5-66.*
11. Open all fuel supply valves.
12. Connect the battery negative (-) cable.
13. Fill and bleed fuel system. *See Bleed the Fuel System on page 6-22*.
14. Start the engine and check for fuel leaks. Allow the engine to run until it is running smoothly. **WARNING!** ***Piercing Hazard. NEVER check for a fuel leak with your hands. ALWAYS use a piece of wood or cardboard.***
15. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Remove and Install High-Pressure Fuel Lines

NOTICE: When working on the oil, coolant or fuel systems you must protect the alternator from contamination. Cover alternator with suitable materials. Failure to comply may result in an alternator failure.

Note: The procedures for high-pressure injection lines or high-pressure line from high-pressure fuel pump are essentially the same. Differences are called out within the steps.

1. Disconnect the battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Remove intake manifold and cover intake ports to prevent foreign objects from entering engine. *See Intake Manifold on page 5-66.*
4. If removing only one line, remove the clamp joining the fuel injector lines to each other.
5. Loosen union nuts on high-pressure fuel line(s) using special tool OEM No. 13 5 020 (or similar) **(Figure 6-19, (1))**.

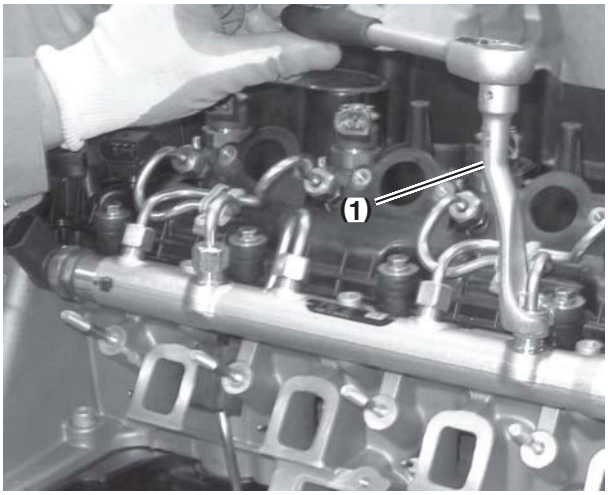


Figure 6-19

Note: Identify lines to ease installation.

6. If removing high-pressure line between high-pressure pump and fuel rail **(Figure 6-20, (1))**, disconnect glow plug connector (if equipped) **(Figure 6-20, (2))**. **4BY2 Engines:** Rubber mount **(Figure 6-20, (3))** will be removed with the line.

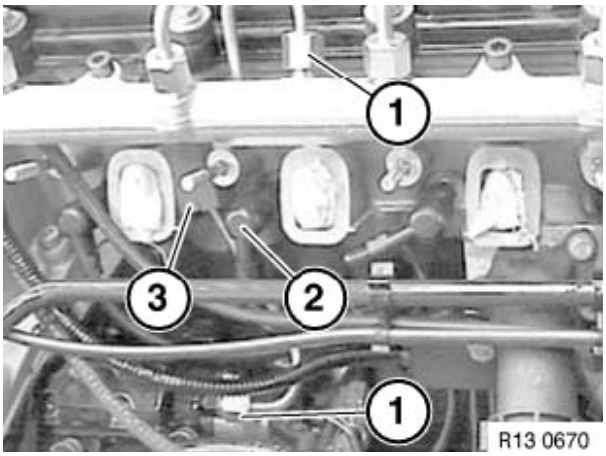


Figure 6-20

7. Remove high-pressure fuel line(s). *NOTICE: Immediately cap or plug all openings to prevent contamination of system.*
8. Install line(s) and start all union nuts before tightening any. Hand-tighten all union nuts. *NOTICE: Use care not to mix new high-pressure fuel injection lines.*
   - Injection lines having an even numbered last digit are used on even-numbered cylinders.
   - Injection lines having an odd numbered last digit are used on odd-numbered cylinders. Start both union nuts on high-pressure line before tightening either one.

Note: ALWAYS use special tool OEM No. 13 5 020 (or similar) when loosening or tightening high-pressure fuel line union nuts.

9. Tighten union nuts to 23 N·m (204 in.-lb).
10. Install intake manifold. *See Intake Manifold on page 5-66.*
11. Open all fuel supply valves.
12. Connect the battery negative (-) cable.
13. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
14. Start engine and check for fuel leaks.

Replace the Fuel Feed Pump

1. Disconnect the battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Disconnect electrical connector **(Figure 6-21, (1))**.

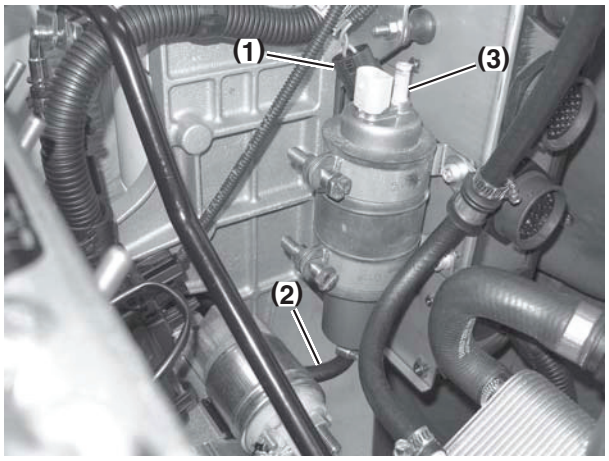


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Figure 6-21

4. Remove supply line **(Figure 6-21, (2))** and pressure line **(Figure 6-21, (3))** from fuel feed pump. *NOTICE: Install caps or plugs on all open fittings to prevent contamination of the fuel system.*
5. Remove four bolts and remove pump from electrical bracket.
6. Transfer fuel pump mounts to new pump.
7. Install fuel feed pump.
8. Connect the supply and pressure lines.
9. Connect the electrical wiring connector.
10. Open all fuel supply valves.
11. Connect the battery negative (-) cable.
12. Bleed fuel system. *See Bleed the Fuel System on page 6-22*.
13. Start the engine and check for leaks.
14. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace High-Pressure Fuel Pump

Removal

NOTICE: When working on the oil, coolant or fuel systems you must protect the alternator from contamination. Cover alternator with suitable materials.

1. Disconnect the battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Remove intake manifold. *See Intake Manifold on page 5-66.*
4. Remove alternator drive belt. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19.*
5. Disconnect electrical connector **(Figure 6-22, (1))** from fuel volume regulator.

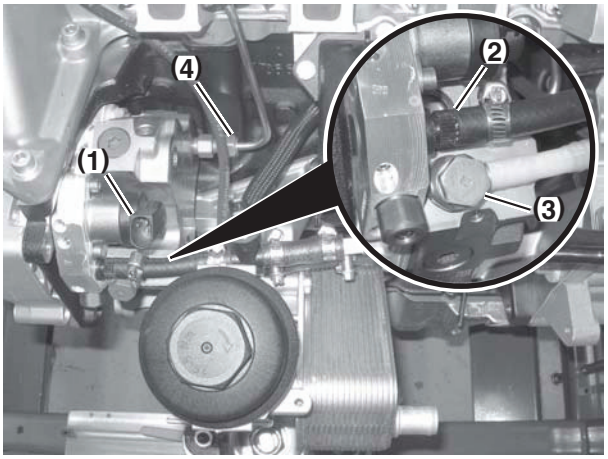

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Figure 6-22

6. Disconnect fuel supply line **(Figure 6-22, (2))**. *NOTICE: Immediately cap or plug all openings to prevent contamination of system.*
7. Remove banjo bolt **(Figure 6-22, (3))** and disconnect fuel return line.
8. Remove high-pressure line **(Figure 6-22, (4))** between pump and fuel rail using special tool OEM No. 13 5 020.

9. Remove plug **(Figure 6-23, (1))**.

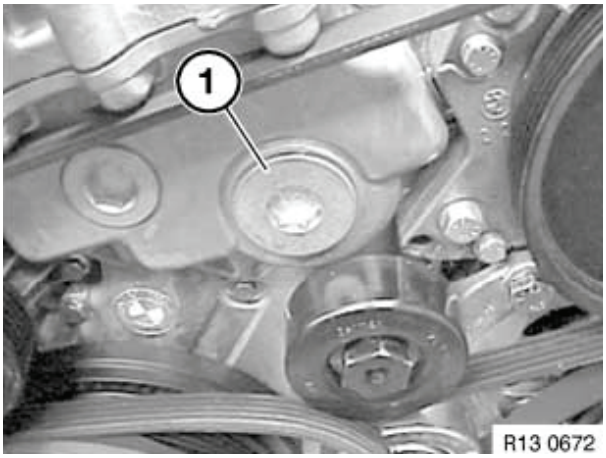

Figure 6-23

10. Hold crankshaft to prevent turning and remove nut **(Figure 6-24, (1))**.

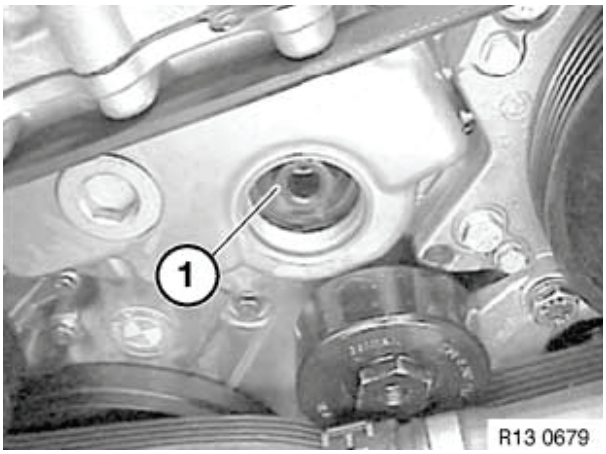

Figure 6-24

11. Thread special tool OEM No. 13 5 192 into timing case cover **(Figure 6-25)**.

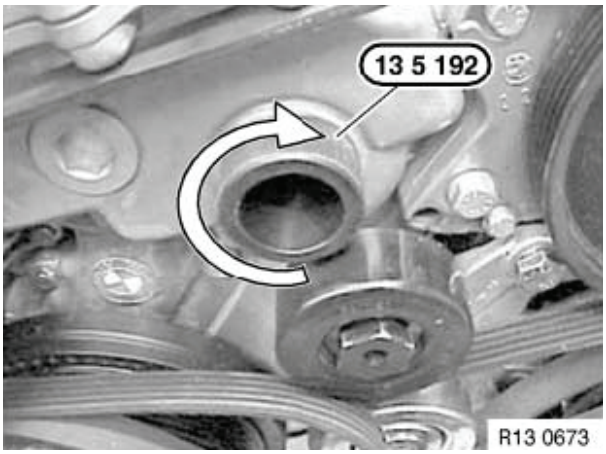

Figure 6-25

12. Thread special tool OEM No. 13 5 191 without jack screw **(Figure 6-26, (1))** into sprocket by hand until firmly seated.

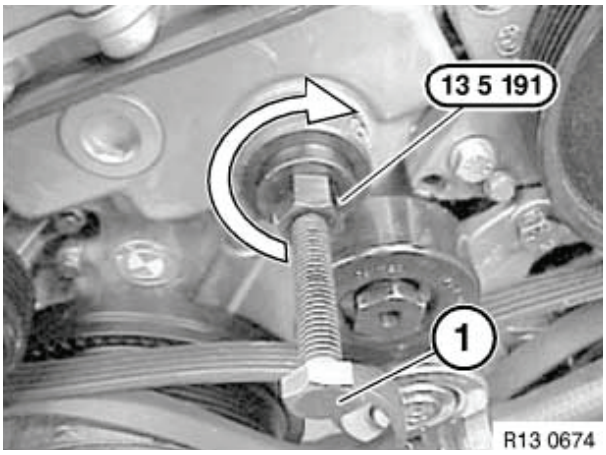

Figure 6-26

13. Thread jack screw **(Figure 6-26, (1))** into special tool until firmly in contact with end of pump shaft.
14. Remove three nuts **(Figure 6-27, (1))**.

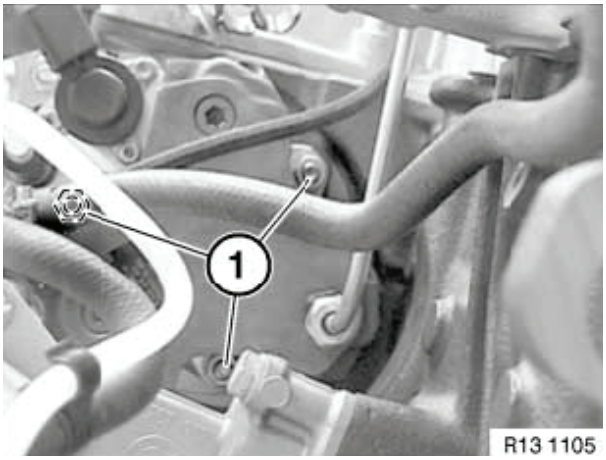

Figure 6-27

15. Tighten jack screw **(Figure 6-28, (1))** until high-pressure pump is released from sprocket. Remove high-pressure pump from engine.
NOTICE: NEVER remove special tools until high-pressure pump is installed. If the special tools are removed, the drive sprocket will no longer be held in the correct position for reassembly.

Figure 6-28

Installation

1. Remove jack screw **(Figure 6-29, (1))** but leave sleeve **(Figure 6-29, (2))** (special tool OEM No. 13 5 192) installed.

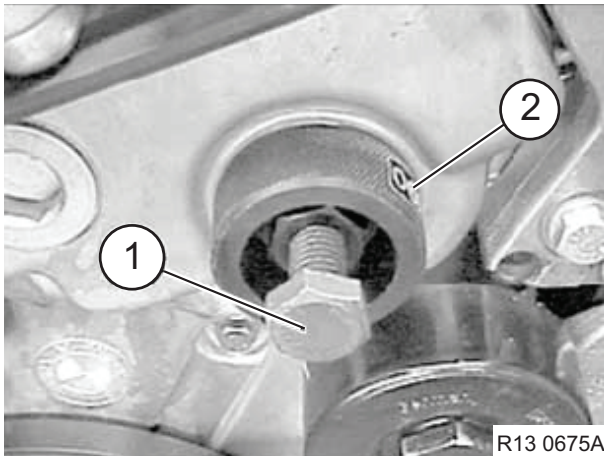

Figure 6-29

2. Ensure gasket surfaces of the engine block and high-pressure pump are clean. Install new gasket **(Figure 6-30, (1))**.

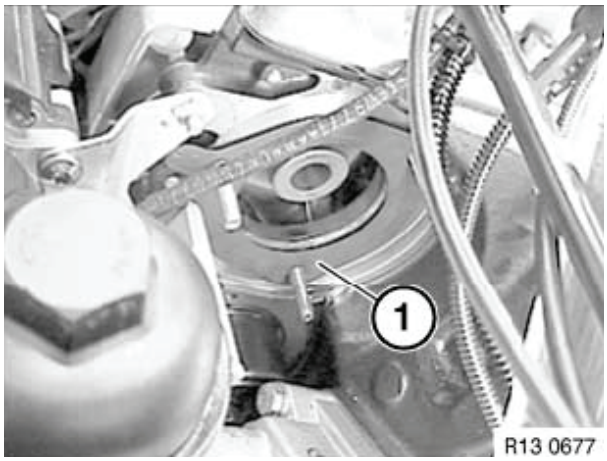

Figure 6-30

3. Install high-pressure fuel pump and install three nuts **(Figure 6-31, (1))**.

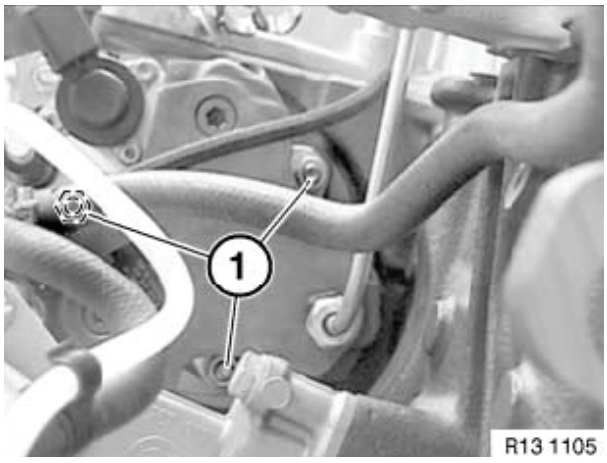

Figure 6-31

Note: The pump shaft may have a keyway cut into it but no key is used in this application.

4. Remove special tool OEM No. 13 5 192 from timing case cover **(Figure 6-32)**.

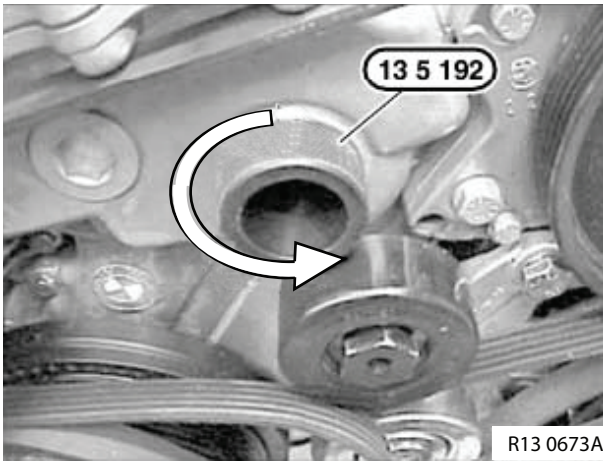

Figure 6-32

5. Remove special tool OEM No. 13 5 191 and install nut **(Figure 6-33, (1))**. Tighten nut to 65 N·m (48 ft-lb).

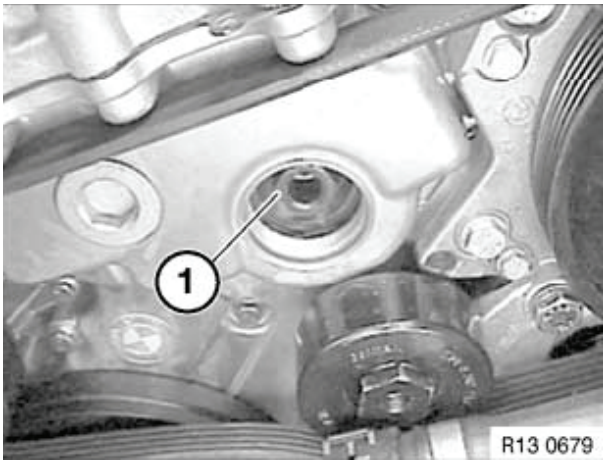

Figure 6-33

6. Install new O-ring on plug **(Figure 6-34, (1))**. Apply a light coat of oil to O-ring and install plug. Tighten to:
   - M30 x 1.0: 70 N·m (52 ft-lb)
   - M40 x 1.5: 30 N·m (22 ft-lb)

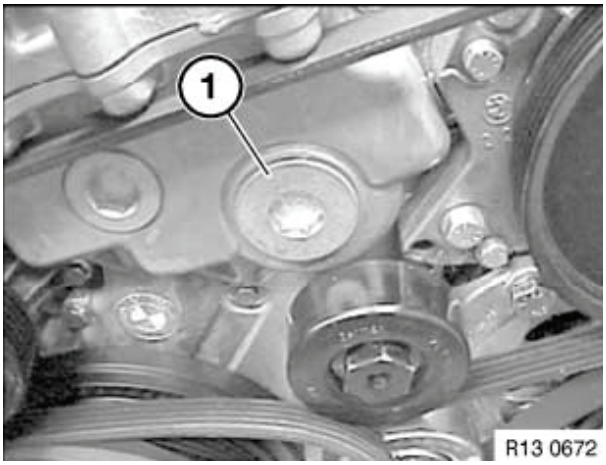

Figure 6-34

7. *NOTICE: Start both union nuts on high-pressure line before tightening either one.* Install high-pressure line and tighten union nuts **(Figure 6-35, (4))** using special tool OEM No. 13 5 020 to 23 N·m (204 in.-lb). *See Remove and Install High-Pressure Fuel Lines on page 6-14.*

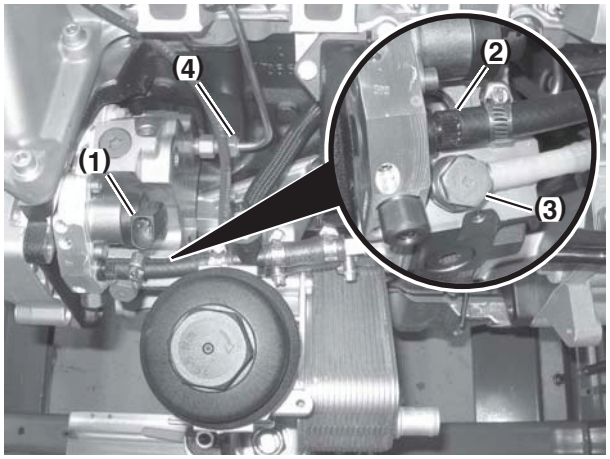

Figure 6-35

8. Connect fuel return line and banjo bolt **(Figure 6-35, (3))** with new seal washers.
9. Connect fuel supply line **(Figure 6-35, (2))**.

10. Connect electrical connector to fuel volume regulator **(Figure 6-35, (1))**.
11. Install alternator drive belt. *See Remove and Install Alternator on page 11-5.*
12. Install intake manifold. *See Intake Manifold on page 5-66.*
13. Open all fuel supply valves.
14. Connect the battery negative (-) cable.
15. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
16. Start the engine and check for leaks.
17. Check and delete any trouble codes that are registered in the ECU after the work has been completed. *See Trouble Codes on page 13-10.*

Replace Fuel Filters

Replace Fuel Fine Filter

CAUTION! *Remove any insulation material that has come into contact with fuel.*

1. Disconnect the battery negative (-) cable.
2. Close the fuel tank cock.
3. Unscrew and remove filter cartridge **(Figure 6-36, (1))**.

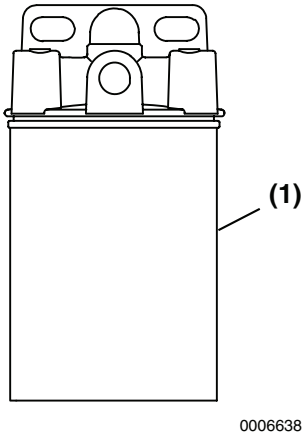

Figure 6-36

4. Replace rubber seal.
5. Replace filter. *NOTICE: When replacing fuel filters, always pre-fill them with fresh, clean fuel to improve the system ability to be bled.*
6. Hand-tighten cartridge to filter.
7. Connect the battery negative (-) cable.
8. Bleed the fuel system and check for leaks. *See Bleed the Fuel System on page 6-22.*

Replace the Fuel Filter / Water Separator

Note: Yanmar supplies a water separating pre-filter separate from the engine. Location and type of filter may vary.

1. Disconnect the battery negative (-) cable.
2. Close the fuel tank cock.
3. Loosen the drain plug **(Figure 6-37, (4))** on the bottom of the fuel filter / water separator and drain off any water or sediment.
4. Disconnect water sensor connector **(Figure 6-37, (1))**.
5. Turn the filter bowl **(Figure 6-37, (5))** counterclockwise to remove.

6. Remove the old filter element **(Figure 6-37, (3))**.

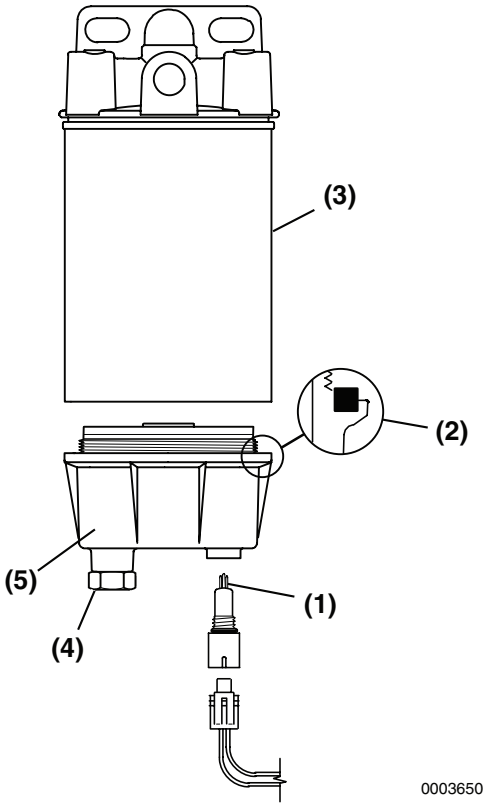

Figure 6-37

7. Clean the filter bowl. Inspect the water sensor probe **(Figure 6-37, (1))** for damage. Inspect the bowl seal **(Figure 6-37, (2))**. *NOTICE: When replacing fuel filters, always pre-fill them with fresh, clean fuel to improve the system's ability to be bled.*
8. Lubricate the seal at the top of the new filter element **(Figure 6-37, (3))** and install.
9. Lubricate the filter bowl seal **(Figure 6-37, (2))** and install the filter bowl. Turn clockwise by hand to tighten.
10. Ensure drain plug **(Figure 6-37, (4))** is securely tightened.
11. Connect water sensor connector **(Figure 6-37, (1))**.
12. Open the fuel cock.
13. Connect the battery negative (-) cable.
14. Bleed fuel system and check for leaks. *See Bleed the Fuel System on page 6-22.*

Remove and Install Fuel Rail

1. Disconnect the battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Remove intake manifold. *See Intake Manifold on page 5-66*.
4. Use special socket **(Figure 6-38, (2))** to loosen clamp **(Figure 6-38, (1))**. Remove the hose.

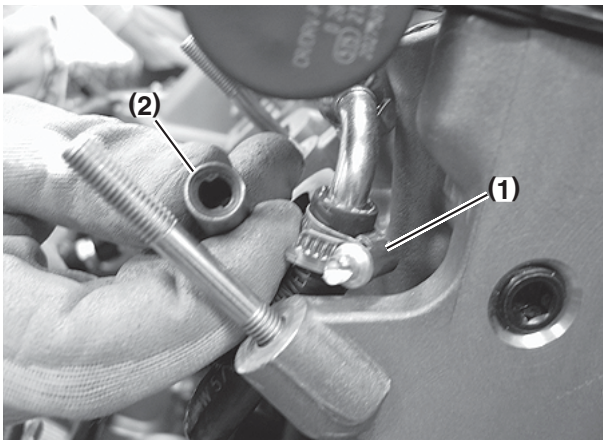

Figure 6-38

5. Remove all high-pressure fuel lines **(Figure 6-39, (1))**. *See Remove and Install High-Pressure Fuel Lines on page 6-14.*

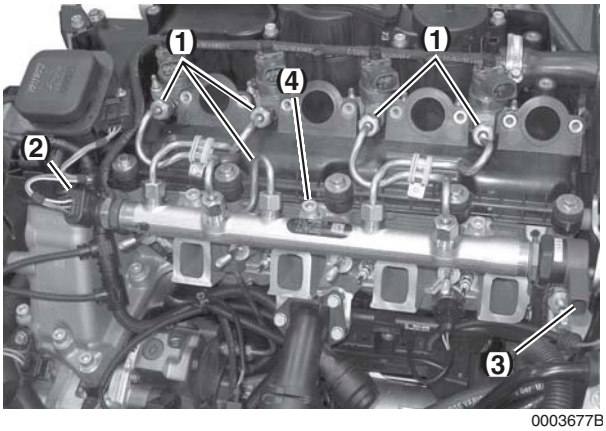

Figure 6-39

6. Disconnect electrical connectors from fuel pressure sensor **(Figure 6-39, (2))** and fuel pressure regulator **(Figure 6-39, (3))**.
7. Remove bolts **(Figure 6-39, (4))** and remove fuel rail from engine.

8. If removed, install fuel return hose fitting with new seal washers. Tighten banjo bolt to 25 N·m (221 in.-lb).
9. Install fuel rail on engine. Install and tighten bolts.
10. Connect return hose and tighten clamp using special socket.
11. Connect electrical connectors to fuel pressure sensor and fuel pressure regulator.
12. Install high-pressure lines. *See Remove and Install High-Pressure Fuel Lines on page 6-14.*
13. Install intake manifold. *See Intake Manifold on page 5-66.*
14. Open all fuel supply valves.
15. Connect the battery negative (-) cable.
16. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
17. Start engine and check for fuel leaks.

Replace Injector Return Fuel Line

1. Disconnect the battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Remove intake manifold. *See Intake Manifold on page 5-66. NOTICE: When working on the oil, coolant or fuel systems, you must protect the alternator against contamination. Cover alternator with suitable materials.*
4. Push clip **(Figure 6-40, (1))** in direction of arrow and remove fitting **(Figure 6-40, (2))** from fuel injector top. Repeat with all fuel injectors.

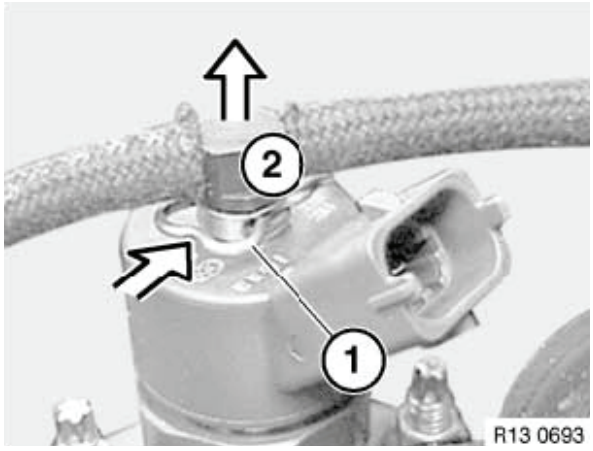

Figure 6-40

5. Disconnect return fuel hose **(Figure 6-41, (1))** from fuel tee. *NOTICE: NEVER disassemble fuel return line assembly. No individual parts are available and it must be replaced as a complete assembly.*

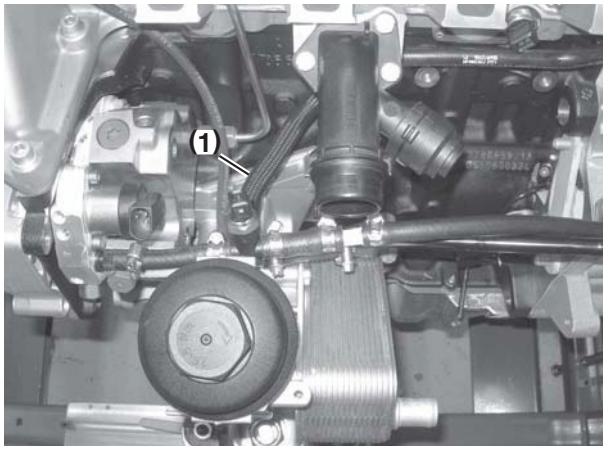

Figure 6-41

6. Inspect O-ring **(Figure 6-42, (1))** on each fitting. If any O-ring is damaged, the entire return fuel line **(Figure 6-42, (2))** must be replaced as an assembly.

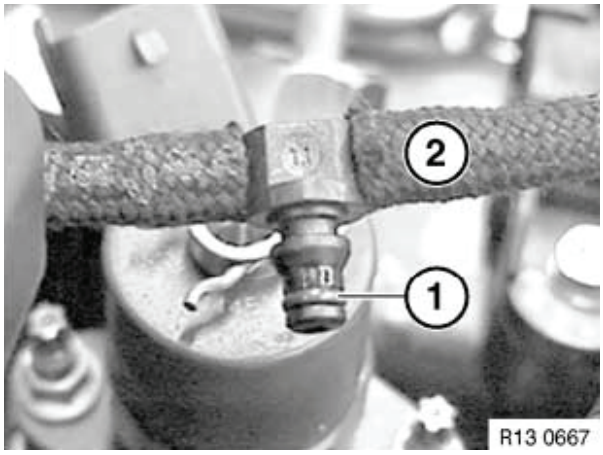

Figure 6-42

7. Assembly is in the reverse order from disassembly.
8. Open all fuel supply valves.

9. Connect the battery negative (-) cable.
10. Bleed the fuel system. *See Bleed the Fuel System on page 6-22.*
11. Start engine and check for fuel leaks.
    WARNING! ***Piercing Hazard. NEVER check for fuel leaks with your hand. ALWAYS use a piece of wood or cardboard.***

Bleed the Fuel System

The fuel system needs to be bled under the following conditions:

- Before starting the engine for the first time.
- After running out of fuel and fuel has been added to the fuel tank.
- After fuel system maintenance such as changing a fuel filter, draining the fuel filter / water separator or replacing a fuel system component.

The fuel feed pump is ECU-controlled and will operate for only 10 seconds when the key switch is turned to ON and the engine is not running or being started. For this reason, the key switch must be repeatedly turned to ON then to OFF to sufficiently bleed the fuel system.

1. Turn the key switch to ON and leave on for 10 seconds.
2. Turn key switch to OFF for 5 seconds, then turn key switch to ON for 10 seconds.
3. Repeat steps 1 and 2 five more times.

Note: The engine may run rough and misfire for a few seconds when first started until any remaining air is purged from the fuel system.

4. Attempt to start the engine. If the engine does not start within a reasonable time, repeat steps 1 and 2 until the engine starts and runs.

Section 7

COOLING SYSTEM

Page

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SAFETY PRECAUTIONS

Before servicing the cooling system, read the following safety information and review the *Safety Section on page 2-1*.

⚠ WARNING

Fire Hazard

Coolant may be flammable under certain conditions. NEVER allow coolant to come into contact with hot surfaces or insulation material.

NOTICE

Only use the engine coolant specified. Other engine coolants may affect warranty coverage, cause an internal buildup of rust and scale, and / or shorten engine life.

Prevent dirt and debris from contaminating the engine coolant. Carefully clean the radiator cap and the surrounding area before you remove the cap.

NEVER mix different types of engine coolants. This may adversely affect the properties of the engine coolant.

INTRODUCTION

This section of the *Service Manual* describes the procedures necessary to service the 4BY2 and 6BY2 marine engine cooling systems.

SPECIFICATIONS

Test and Adjustment Specifications

Note: All pressure specifications are with engine at normal operating temperature.

Test Item	Model	Specification			Reference Page
Cooling System Test Pressure	All	1.4 bar (20 psi)			*Pressure Test Cooling System and Filler Cap on page 7-7*
Filler Cap Test Pressure	All	1.4 bar (20 psi)			
Thermostat		Marking	Begins Opening	Fully Open	*Test Thermostat on page 7-8*
	All	88°C	88°C (190°F)	96°C (205°F)	

Repair Specifications

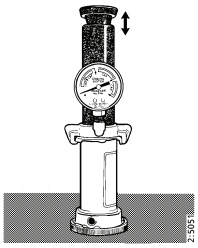
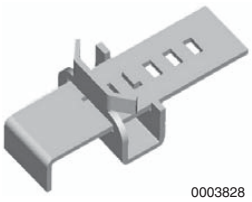
Coolant Capacity (Approximate)	4BY2	10.0 L (10.6 qt)
	6BY2	13.0 L (13.7 qt)

Special Torque Chart

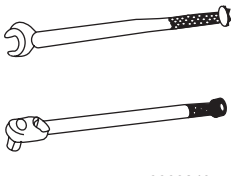
Component	Torque	Lubricating Oil Application	Reference Page
Charge Air Cooler Bolt	46 N·m (34 ft-lb)	Not Applied	*Remove and Install Charge Air Cooler on page 7-12*
Anode	25 N·m (18 ft-lb)	Not Applied	*Check and Replace Anodes on page 7-9*

SPECIAL SERVICE TOOLS

Note: The tool numbers used in this section are either Yanmar or BMW part numbers. Yanmar part numbers are referred to as **Yanmar Part No.** and BMW part numbers are referred to as **OEM Part No.** Tools not having part numbers must be obtained locally.

No.	Tool Name	Applicable Model and Tool Size	Illustration
1	Cooling System Tester (For pressure-testing the cooling system and filler cap)	Obtain locally	
2	Belt Tool (For removing and installing seawater pump belt)	-	

MEASURING INSTRUMENTS

No.	Instrument Name	Application	Illustration
1	Torque Wrench	For tightening nuts and bolts to the specified torque	

COOLING FLOW DIAGRAM

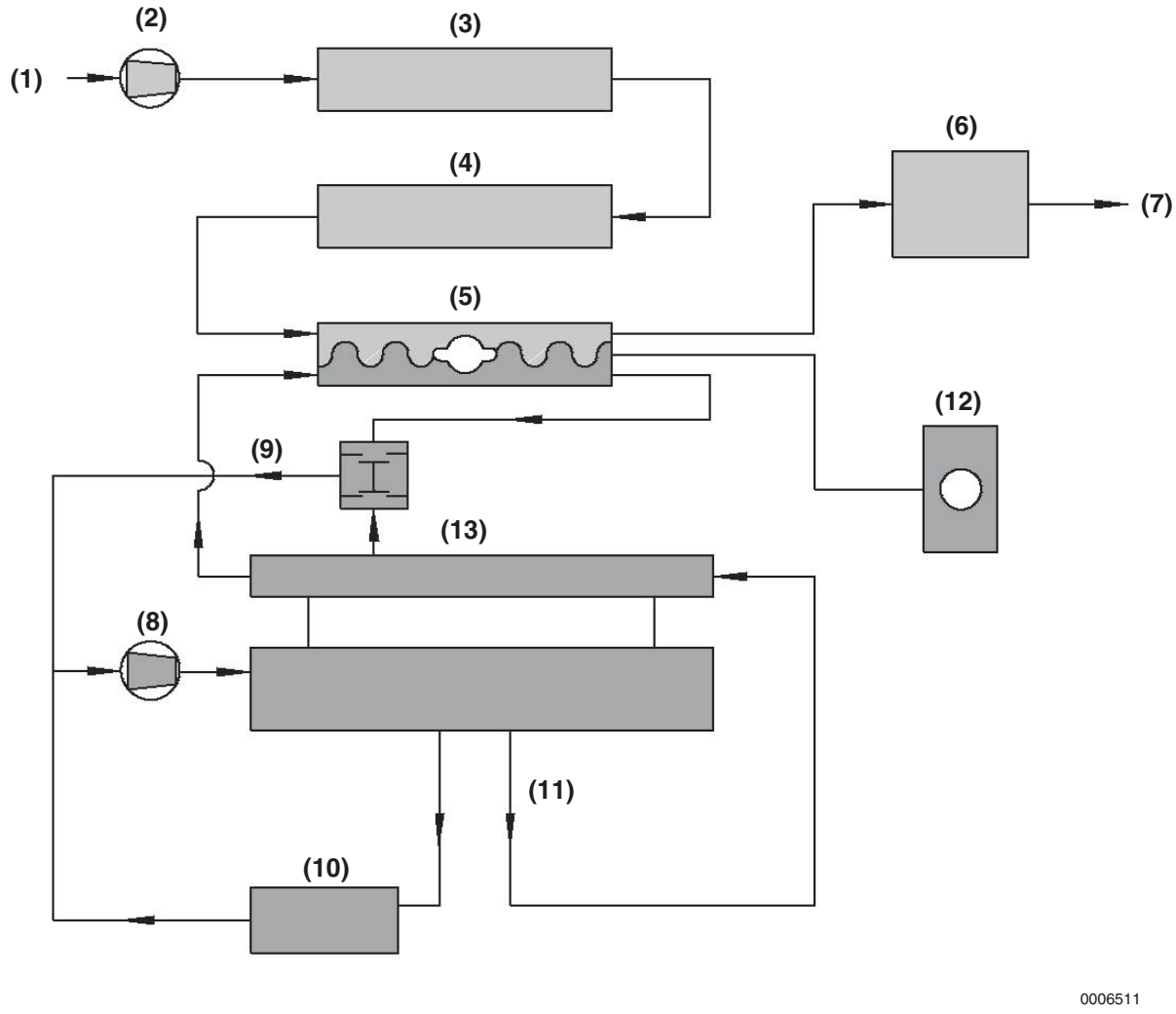


Figure 7-1

Note: Typical 4BY2 engine shown. 6BY2 is similar.

1 – Seawater Supply
2 – Seawater Pump
3 – Hydraulic Oil Cooler
4 – Charge Air Cooler
5 – Engine Heat Exchanger
6 – Exhaust Seawater Mixing Elbow
7 – Exhaust / Seawater Exit
8 – Engine Coolant Pump
9 – Thermostat
10 – Engine Oil Cooler
11 – Engine Coolant Passages
12 – Coolant Recovery Tank
13 – Water Cooled Exhaust Manifold

TESTS AND ADJUSTMENTS

Pressure Test Cooling System and Filler Cap

Cooling System

Use a cooling system tester with connections compatible with the Yanmar BY2 series cooling system.

1. Remove the filler cap from the heat exchanger. **WARNING!** ***Burn Hazard. NEVER remove the coolant filler cap if the engine is hot. Steam and hot engine coolant will escape and seriously burn you. Allow the engine to cool before attempting to remove the filler cap.***
2. Check that the lugs and sealing flange on the filler pipe are undamaged and free from anything that might prevent a good seal.
3. Install the tester and adapter in place of the filler cap.
4. Pump until pressure is 1.45 bar (21 psi) **(Figure 7-2)**.

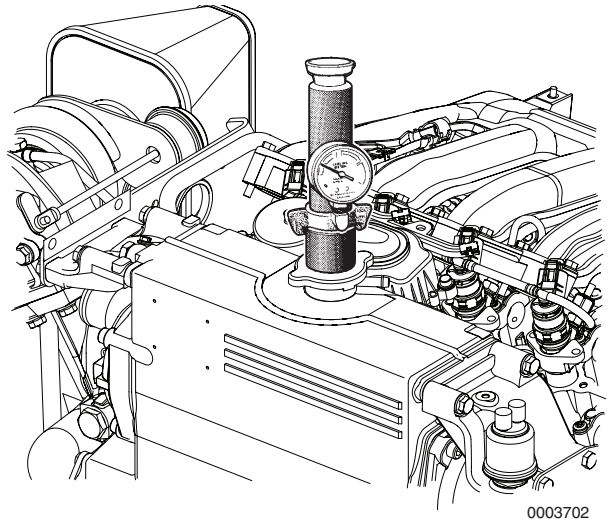


Figure 7-2

5. Pressure should hold steady. If the pressure drops, there is leakage in the system. Start by checking all hoses and pipe connections.

Filler Cap

1. Connect the cap to the cooling system tester using the adapter for the cap.
2. Pump until the cap opens **(Figure 7-3)**.

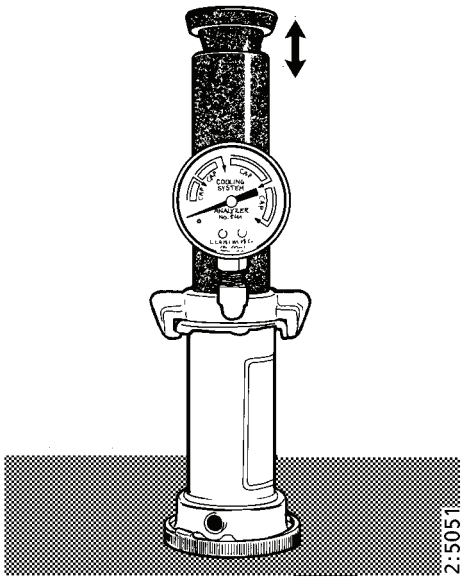


Figure 7-3

3. The tester needle should stop at approximately 1.45 bar (21 psi).

Test Thermostat

1. The design temperature for the thermostat is stamped into the thermostat body. Find and record this number.
2. Immerse the thermostat into a container of water. Suspend it so that it does not come into contact with the walls or bottom of the container.
3. Slowly heat the water and monitor the temperature with a thermometer. Stir the water.
4. Check that the thermostat begins to open at the specified temperature, and that it is fully open at the temperature given in the specifications.

If the test results are not within specification, replace the thermostat.

Specifications

Item	Marking	Starts Opening	Fully Open
Thermostat Opening	88°C	88°C (190°F)	96°C (205°F)

REPAIR

Drain and Refill Seawater Cooling System

Note: If water fails to drain from any open drain cock or port, remove the cock completely and probe the opening with a small piece of wire to loosen debris.

1. Open the lower seawater drain cock **(Figure 7-4, (1))** located in the piping between the seawater pump and hydraulic oil cooler. Allow to drain.

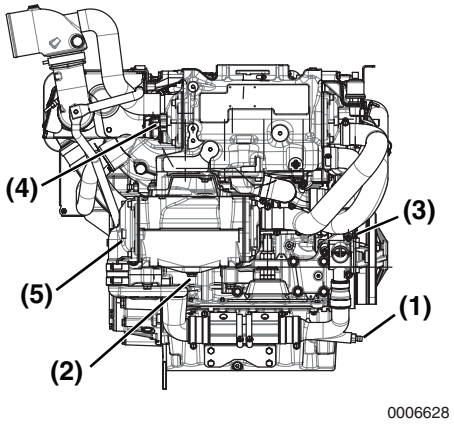


Figure 7-4

2. Open the drain cock **(Figure 7-4, (2))** on the bottom of the charge air cooler.
3. Loosen the seawater pump cover **(Figure 7-4, (3))** to allow water to drain. *See Seawater Pump on page 7-18.*
4. When water has drained, install cover and tighten bolts. *NOTICE: Be sure O-ring is in place in the groove of housing.*
5. Remove anodes from the engine heat exchanger **(Figure 7-4, (4))** and charge air cooler **(Figure 7-4, (5))** and allow water to drain from housings.

6. **Engines having the optional high-rise exhaust elbow:** Open drain cock **(Figure 7-5, (1))** and allow water to drain. Remove and inspect anode **(Figure 7-5, (2))**. *NOTICE: NEVER use thread sealer or thread sealing tape when installing anodes. Anodes must make good metal-to-metal contact to perform properly.*

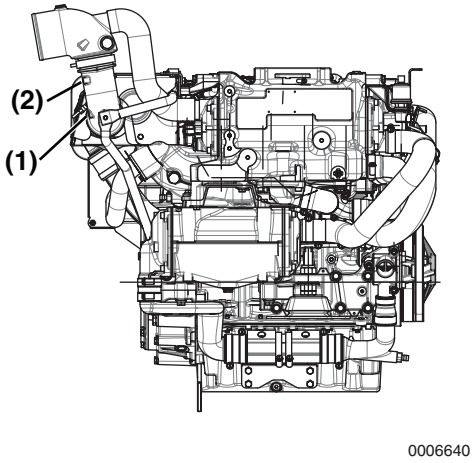


Figure 7-5

7. Inspect condition of anodes and replace as necessary. *See Check and Replace Anodes on page 7-9*.
8. Close all drain cocks.

Check and Replace Anodes

There are anodes in the seawater cooling system and they should be inspected and replaced periodically. *See Periodic Maintenance Schedule on page 4-5* for the recommended frequency.

Anodes are located in the heat exchanger **(Figure 7-6, (2))** and the charge air cooler **(Figure 7-6, (1))**.

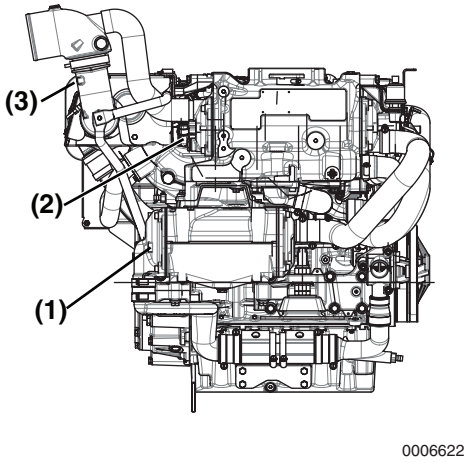


Figure 7-6

An anode is also located in the optional high-rise elbow **(Figure 7-6, (3))**.

1. Drain cooling system. *See Drain and Refill Seawater Cooling System on page 7-8*.
2. Remove each anode and inspect for corrosion. Any anode having less than half its original size remaining should be replaced.
3. Install each anode using a new copper gasket. Tighten to 25 N·m (18 ft-lb). *NOTICE: NEVER use thread sealer or thread sealing tape when installing anodes. Anodes must make good metal-to-metal contact to perform properly.*
4. Start engine and check for water leaks.

Drain and Fill Closed Cooling System

1. Disconnect battery negative (-) cable.
2. Remove coolant filler cap from heat exchanger.

   WARNING! ***Burn Hazard. NEVER remove the coolant filler cap if the engine is hot. Steam and hot engine coolant will escape and seriously burn you. Allow the engine to cool before attempting to remove the filler cap.***

3. Remove the heat exchanger to access the cylinder block drain plug behind it. *See Remove and Install Heat Exchanger on page 7-13.*

Note: The charge air cooler has been removed for clarity of photo **(Figure 7-7)**.

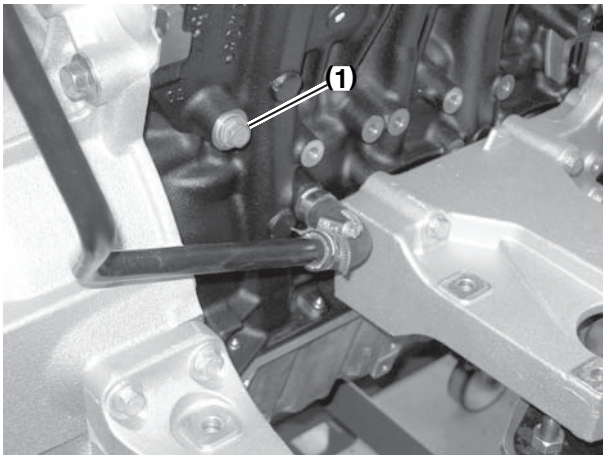


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Figure 7-7

4. Remove drain plug **(Figure 7-7, (1))** from the engine block. Allow coolant to drain into a container of appropriate size.
5. Install cylinder block drain plug and a new gasket.
6. Install heat exchanger. *See Remove and Install Heat Exchanger on page 7-13*. Ensure the drain cock **(Figure 7-8, (2))** on the heat exchanger is closed.

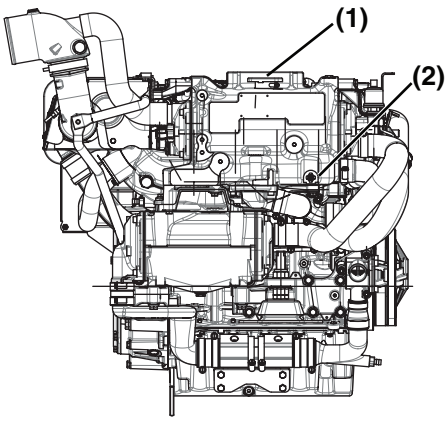

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Figure 7-8

7. If not already done, remove the filler cap **(Figure 7-8, (1))** from the heat exchanger.
8. Inspect the cap gasket and flange on the filler neck for damage. Replace if necessary.
9. Check the rubber hose connecting the coolant recovery tank to the heat exchanger. Be sure the hose is securely connected and there is no damage.
10. *NOTICE: NEVER pour coolant into a hot engine. Allow engine to cool.* Pour coolant mix slowly into the heat exchanger to prevent the formation of air pockets. Fill until the heat exchanger is completely full.
11. Install the filler cap and tighten firmly.
12. Remove the coolant recovery tank cap and fill with coolant mix to approximately 50 mm (2 in.) below the full line. Replace cap. Never fill to the full line.
13. After filling an empty cooling system, test-run the engine for approximately 5 minutes and recheck the engine coolant level at the coolant recovery tank again.

Disconnect and Connect Quick-Connect Fittings

Disconnect

1. Pry metal clip **(Figure 7-9, (1))** until it clicks into position shown.

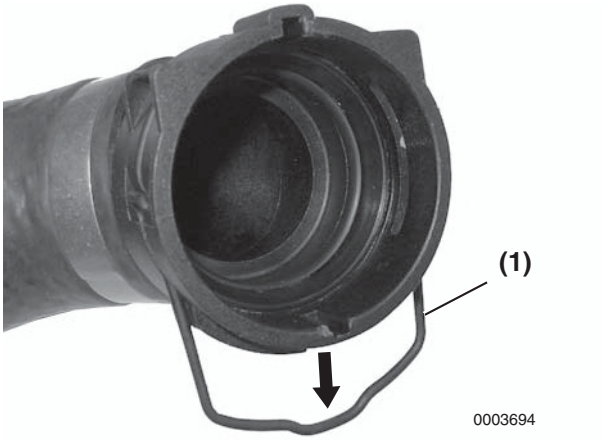


Figure 7-9

2. Disconnect fitting joint.

Connect

1. Push metal clip against the fitting into the latched position.
2. Ensure the O-ring is in place and in good condition.
3. Align the two fittings and push together until the clip makes an audible click.
4. Check to be sure the connection is securely latched by attempting to pull apart.

Remove and Install Hydraulic Oil Cooler

1. Drain cooling system. *See Drain and Refill Seawater Cooling System on page 7-8*.
2. Loosen clamps and remove seawater pipe **(Figure 7-10, (1))**.

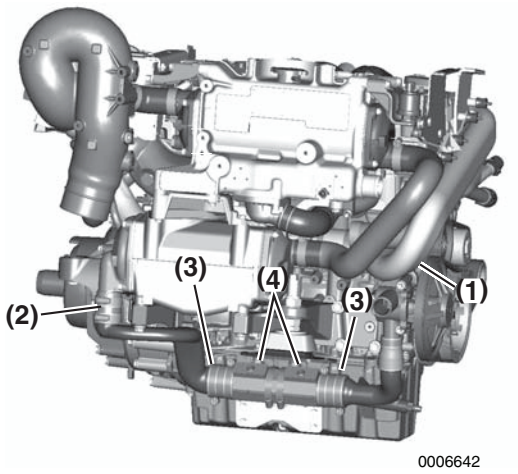


Figure 7-10

3. Loosen clamps and remove seawater pipe **(Figure 7-10, (2))**.
4. Remove hydraulic lines from ports **(Figure 7-10, (3))**. Allow fluid to drain into an appropriate container. Dispose of waste properly.
5. Loosen clamps **(Figure 7-10, (4))** completely and remove hydraulic oil cooler.
6. Inspect cooler for damage or blockage.
7. Install cooler and tighten clamps **(Figure 7-10, (4))**.
8. Install hydraulic lines. Ensure copper washers are in place.
9. Install seawater pipes **(Figure 7-10, (1 and 2))**. Tighten clamps securely.
10. Add power steering fluid or marine gear oil as appropriate.
11. Start engine and check for water or hydraulic leaks.
12. Check level of power steering fluid or marine gear oil and add more if necessary.

Inspect and Clean Hydraulic Oil Cooler

1. Drain cooling system. *See Drain and Refill Seawater Cooling System on page 7-8*.
2. Loosen clamps **(Figure 7-11, (1))** and remove seawater pipe **(Figure 7-11, (2))**.

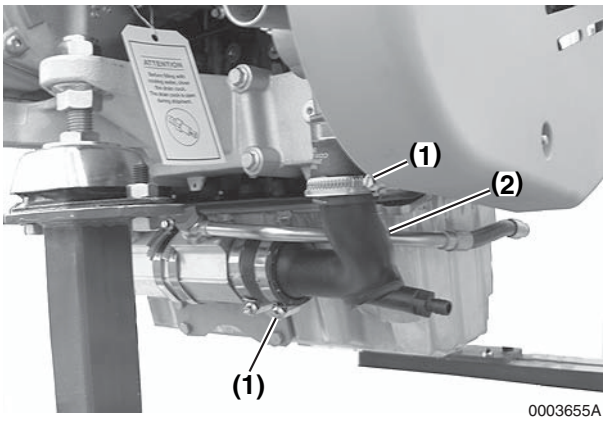


Figure 7-11

3. Remove any loose debris from inside cooler.
4. Visually inspect cooling tubes for evidence of debris, corrosion or damage. *NOTICE: If the cooling tubes are plugged, remove cooler and thoroughly backflush with water. NEVER clean using a wooden dowel or wire brush. Damage or inability to clean sufficiently will require repair by a radiator shop or replacement of oil cooler.*
5. Install seawater pipe **(Figure 7-11, (2))** and tighten clamps **(Figure 7-11, (1))**.
6. Start engine and check for water leaks.

Remove and Install Charge Air Cooler

1. Drain seawater system. *See Drain and Refill Seawater Cooling System on page 7-8*.
2. Disconnect seawater pipe between hydraulic oil cooler and charge air cooler **(Figure 7-12, (1))**.

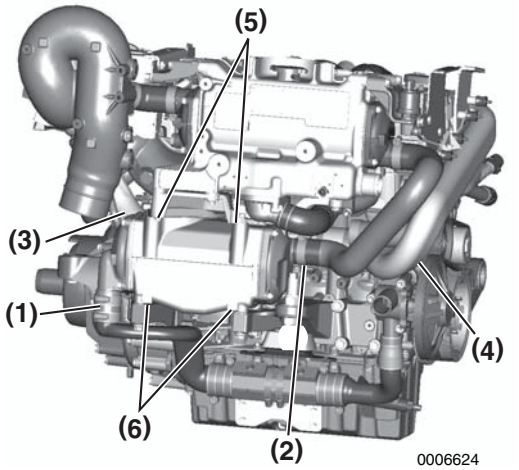


Figure 7-12

3. Disconnect seawater pipe between charge air cooler and heat exchanger **(Figure 7-12, (2))**.
4. Disconnect pipe between charge air cooler and turbocharger **(Figure 7-12, (3))**.
5. Remove pipe between charge air cooler and intake manifold **(Figure 7-12, (4))**.
6. Remove two bolts **(Figure 7-12, (5))** that attach heat exchanger to charge air cooler.
7. Remove four lower bolts **(Figure 7-12, (6))** that attach charge air cooler. Remove charge air cooler assembly from engine.
8. Disassemble and repair as necessary. *See Disassemble and Assemble Charge Air Cooler on page 7-13.*
9. Install charge air cooler and start all bolts.
10. Tighten mounting bolts to 46 N·m (34 ft-lb).
11. Install pipe between intake manifold and charge air cooler.
12. Install and secure air inlet pipe between turbocharger and charge air cooler.

13. Connect seawater pipe between heat exchanger and charge air cooler.
14. Connect seawater pipe between charge air cooler and hydraulic oil cooler.
15. Start the engine and check for coolant leaks. Check the level of the coolant and fill as necessary.

Disassemble and Assemble Charge Air Cooler

1. Remove charge air cooler from engine. *See Remove and Install Charge Air Cooler on page 7-12.*
2. Remove outlet cover **(Figure 7-13, (4))** and spacer **(Figure 7-13, (5))**.

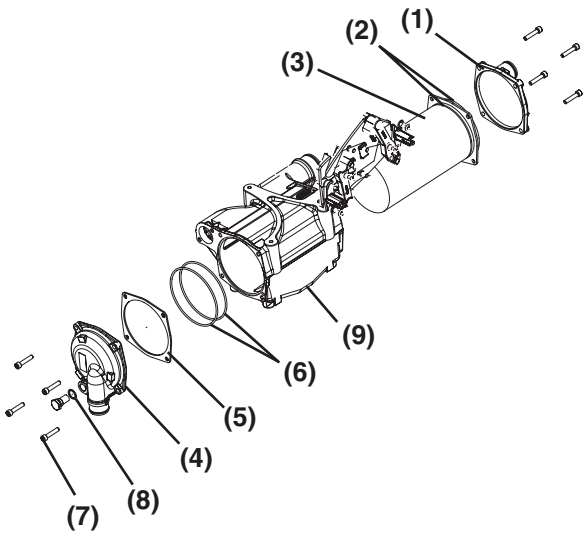


Figure 7-13

3. Remove inlet cover **(Figure 7-13, (1))**.
4. Pull core **(Figure 7-13, (3))** from housing.
5. Remove O-rings **(Figure 7-13, (2 and 6)).**
6. Remove anode **(Figure 7-13, (7))** and copper gasket **(Figure 7-13, (8))**.
7. *NOTICE: NEVER use caustic soda to clean the components.* Use paraffin-based engine detergent to clean the cooler element. Thoroughly flush and rinse all components.
8. If any internal deposits remain in the tubes, consult a local radiator repair shop.

Note: ALWAYS install new O-rings.

9. Install new O-rings **(Figure 7-13, (2))** on cooler core.
10. Install cooler core **(Figure 7-13, (3))** and inlet cover **(Figure 7-13, (1))**.
11. Install one O-ring **(Figure 7-13, (6))** between core and housing **(Figure 7-13, (9))**.
12. Install spacer **(Figure 7-13, (5))**, remaining O-ring **(Figure 7-13, (6))** and outlet cover **(Figure 7-13, (4))**.
13. Install new anode **(Figure 7-13, (7))** and copper gasket **(Figure 7-13, (8))**. *See Check and Replace Anodes on page 7-9.*
14. Install charge air cooler. *See Remove and Install Charge Air Cooler on page 7-12.*

Remove and Install Heat Exchanger

1. Drain coolant from the engine and heat exchanger. *See Drain and Fill Closed Cooling System on page 7-10*.
2. Drain the seawater system. *See Drain and Refill Seawater Cooling System on page 7-8*.
3. Disconnect seawater hoses **(Figure 7-14, (1 and 2))** from heat exchanger.

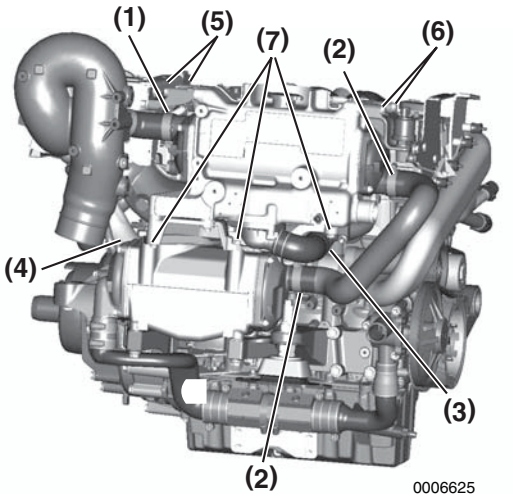
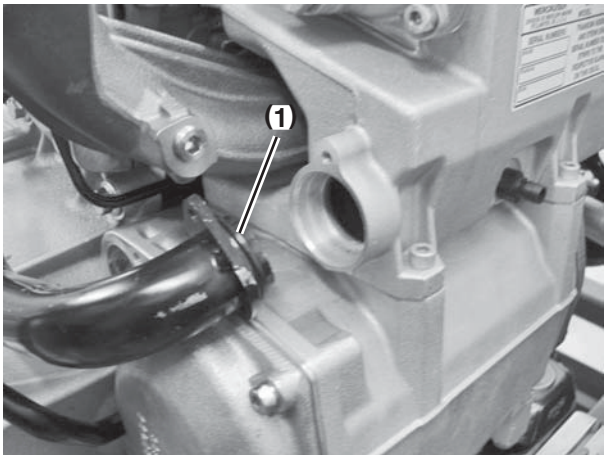


Figure 7-14

4. Disconnect coolant hose **(Figure 7-14, (3))** and pipe **(Figure 7-14, (4))** from heat exchanger.
5. Remove upper mounting bracket bolts **(Figure 7-14, (5 and 6))**.
6. Remove three lower bolts **(Figure 7-14, (7))**.
7. Remove the heat exchanger.

8. Disassemble, inspect and clean heat exchanger as necessary. *See Disassemble and Assemble Heat Exchanger on page 7-14.*
9. Install the heat exchanger assembly on the engine. Install and tighten bolts **(Figure 7-14, (5, 6 and 7))**.
10. Install two new O-rings on coolant pipe **(Figure 7-15, (1))** and connect to heat exchanger.



0003695

Figure 7-15

11. Connect remaining seawater and coolant hoses to heat exchanger.
12. Fill the system with coolant. *See Drain and Fill Closed Cooling System on page 7-10.*
13. Start the engine and check for coolant leaks. Check coolant level and fill as necessary.

Disassemble and Assemble Heat Exchanger

1. Remove heat exchanger from engine. *See Remove and Install Heat Exchanger on page 7-13.*
2. Remove outlet cover **(Figure 7-16, (1))** and spacer **(Figure 7-16, (2))**.

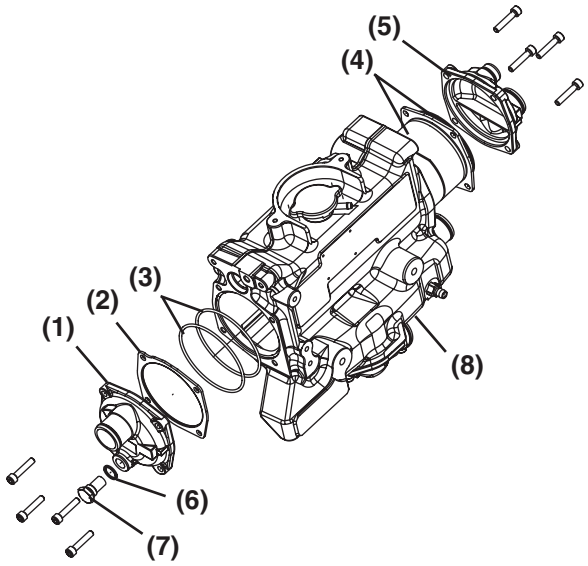


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Figure 7-16

3. Remove inlet cover **(Figure 7-16, (5))**.
4. Pull core from housing.
5. Remove O-rings **(Figure 7-16, (3 and 4))**.
6. Remove anode **(Figure 7-16, (7))** and copper gasket **(Figure 7-16, (6))**.
7. *NOTICE: NEVER use caustic soda to clean the components.* Use paraffin-based engine detergent to clean the cooler element. Thoroughly flush and rinse all components.
8. If any internal deposits remain in the tubes, consult a local radiator repair shop.

Note: ALWAYS install new O-rings.

9. Install new O-rings **(Figure 7-16, (4))** on cooler core.
10. Install cooler core and inlet cover **(Figure 7-16, (5))**.
11. Install one O-ring **(Figure 7-16, (3))** between core and housing **(Figure 7-16, (8))**.

12. Install spacer **(Figure 7-16, (2))**, remaining O-ring **(Figure 7-16, (3))** and outlet cover **(Figure 7-16, (1))**.
13. Install new anode **(Figure 7-16, (7))** and copper gasket **(Figure 7-16, (6))**. *See Check and Replace Anodes on page 7-9.*
14. Install heat exchanger. *See Remove and Install Heat Exchanger on page 7-13.*

Remove and Install Coolant Pump

1. Allow the engine to cool and drain the coolant from the engine block. *See Drain and Fill Closed Cooling System on page 7-10.*
   WARNING! *Coolant Hazard. ALWAYS wear eye protection and rubber gloves when you handle Long Life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.*
2. Remove belt guard.
3. Remove seawater pump belt and alternator belt. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19*.
4. Disconnect the coolant hoses from the coolant pump cover.
5. Remove coolant pump cover bolts and coolant pump cover from coolant pump housing **(Figure 7-17, (2))**.

Note: Coolant pump cover is shown removed for clarity **Figure 7-17**.

6. Remove the four coolant pump bolts **(Figure 7-17, (1))** and remove the coolant pump.

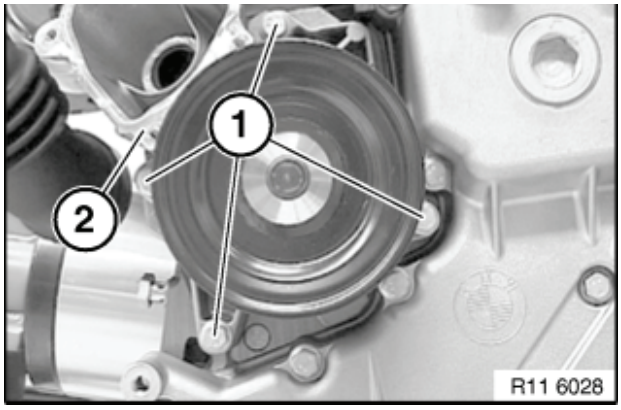

Figure 7-17

7. Cut the coolant pump gasket at the three tabs **(Figure 7-18, (1))** then remove and clean any residual gasket material from the engine block and coolant pump.

   NOTICE: Avoid damaging the sealing surface of the cylinder block and coolant pump when removing the gasket.

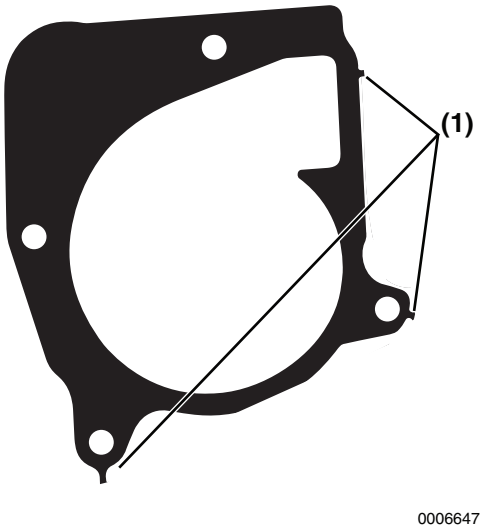

Figure 7-18

8. Cut the coolant pump gasket at the three tabs **(Figure 7-19, (1))** to separate it from the new timing chain cover gasket. Check gasket fit before proceeding.

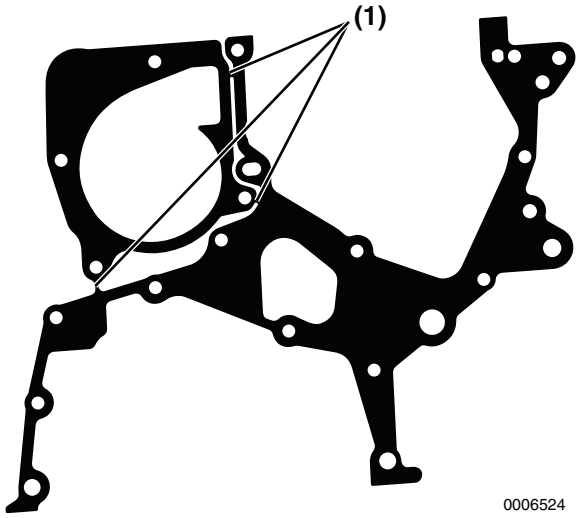

Figure 7-19

9. Hold the new gasket in place and install the coolant pump and tighten the four bolts. Tighten mounting bolts to 23 N·m (203 in.-lb)
10. Install and tighten the coolant pump cover and bolts using a new gasket seal. Tighten mounting bolts to 9.5 N·m (84 in.-lb)
11. Connect the coolant hoses to the coolant pump cover.
12. Install the seawater pump belt and the alternator belt. *See Remove and Install Alternator on page 11-5* and *Replace Seawater Pump Belt on page 7-19*.
13. Install the belt guard.
14. Fill engine block with coolant. *See Drain and Fill Closed Cooling System on page 7-10.*
15. Start the engine and check for coolant leaks. Check the level of the coolant and fill as necessary.

Remove and Install Thermostat

Removal

1. Allow the engine to cool and drain the coolant from the engine block. *See Drain and Fill Closed Cooling System on page 7-10.*
   WARNING! *Coolant Hazard. ALWAYS wear eye protection and rubber gloves when you handle Long Life engine coolant. If contact with the eyes or skin should occur, flush eyes and wash immediately with clean water.*
2. Remove air pipe and coolant hoses as necessary to allow access to the thermostat housing assembly **(Figure 7-20, (1))**.

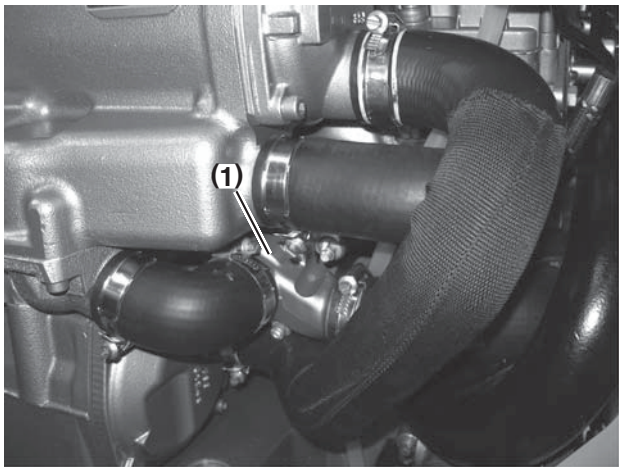

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Figure 7-20

3. Remove coolant hose **(Figure 7-21, (1))** connecting thermostat housing to heat exchanger.
4. Remove coolant hose **(Figure 7-21, (2))** connecting thermostat housing to the coolant pump. To release the clips on the coolant hose see, *Disconnect and Connect Quick-Connect Fittings on page 7-11*.

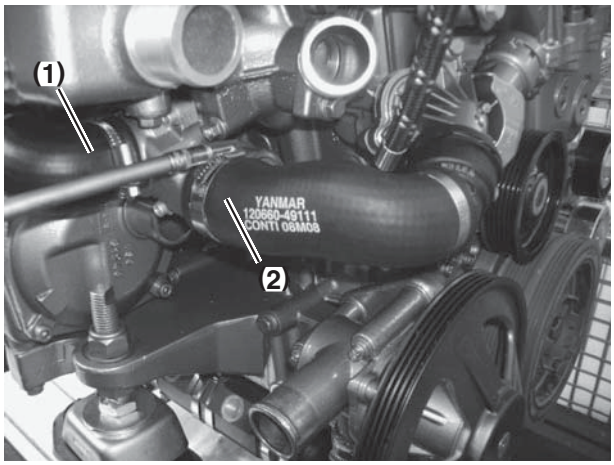

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Figure 7-21

Note: Coolant hoses shown removed for clarity **Figure 7-21** and **Figure 7-22**.

5. Remove the three thermostat housing bolts **(Figure 7-22, (1))** and remove the thermostat housing assembly.

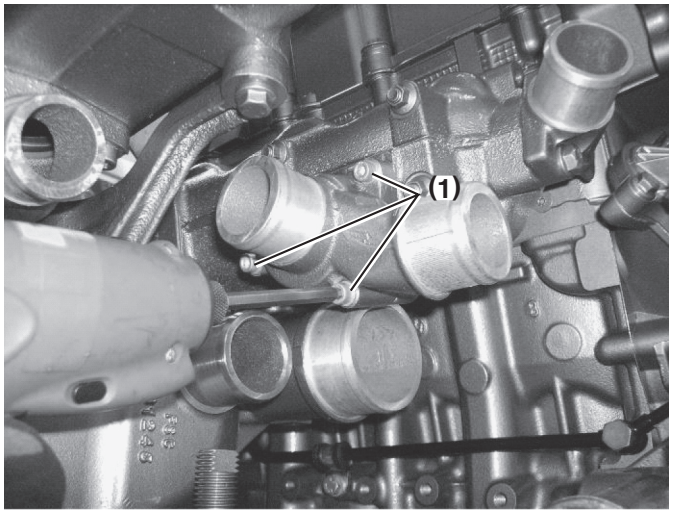

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Figure 7-22

6. Test thermostat as required. *See Test Thermostat on page 7-8.* Replace as needed.

Note: When replacing the thermostat or housing, replace as an assembly. The thermostat and housing are serviced as a single assembly.

Installation

1. Clean the thermostat housing and mounting surfaces **Figure 7-21**.

   NOTICE: Avoid damaging the sealing surface of the thermostat housing and exhaust manifold during cleaning.

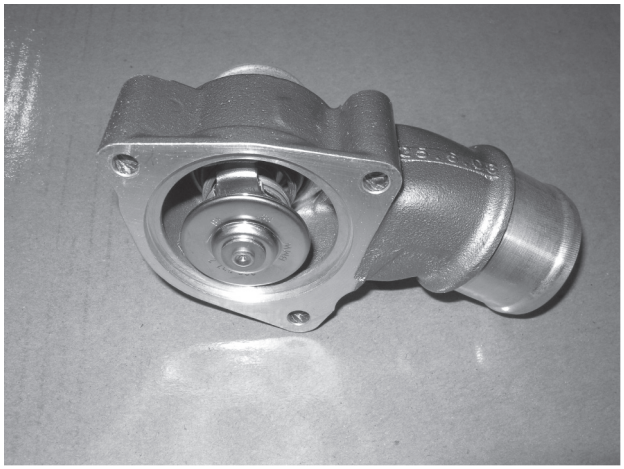

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Figure 7-23

2. Using a new thermostat housing seal, install and tighten the thermostat housing assembly. Tighten mounting bolts to 9.5 N·m (84 in.-lb).
3. Install and tighten the coolant hose connecting the thermostat housing to the coolant pump. To connect the clips on the coolant hose see, *Disconnect and Connect Quick-Connect Fittings on page 7-11*.
4. Install and tighten the coolant hose connecting the thermostat housing to heat exchanger.
5. Install and tighten all air pipe and coolant hoses removed during disassembly.
6. Fill the system with coolant. *See Drain and Fill Closed Cooling System on page 7-10*.
7. Start the engine and check for coolant leaks. Check the level of the coolant and add more as necessary.

Seawater Pump

Inspect and Replace Impeller

1. Drain the seawater circuit by loosening the drain cock **(Figure 7-24, (1))** in the outlet pipe.

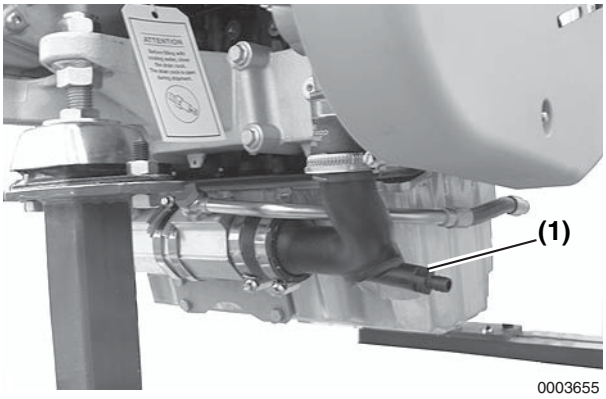

Figure 7-24

2. Remove the seawater pump belt. *See Replace Seawater Pump Belt on page 7-19.*
3. Remove four screws and remove the water pump cover, belt pulley and shaft as an assembly **(Figure 7-25, (1))**.

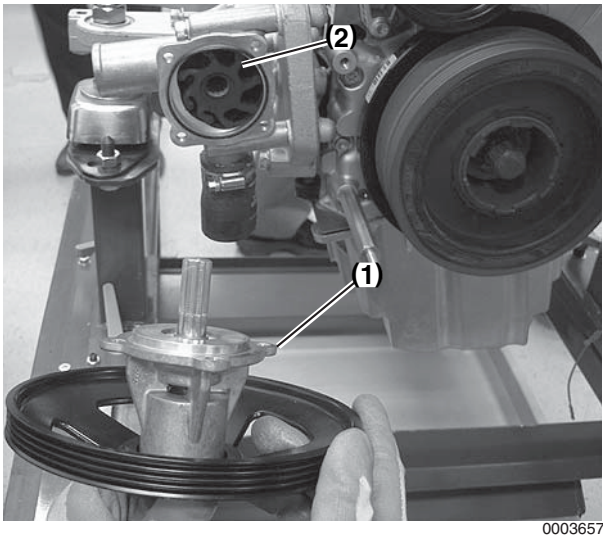

Figure 7-25

4. Remove the impeller **(Figure 7-25, (2))** from the housing.
5. Inspect the impeller for cracks, broken vanes, or excessive wear. Replace as necessary.
6. Inspect the housing and cover for excessive wear.

Note: When installing the new impeller, rotate the impeller clockwise to bend the vanes in the direction of rotation **(Figure 7-26)**.

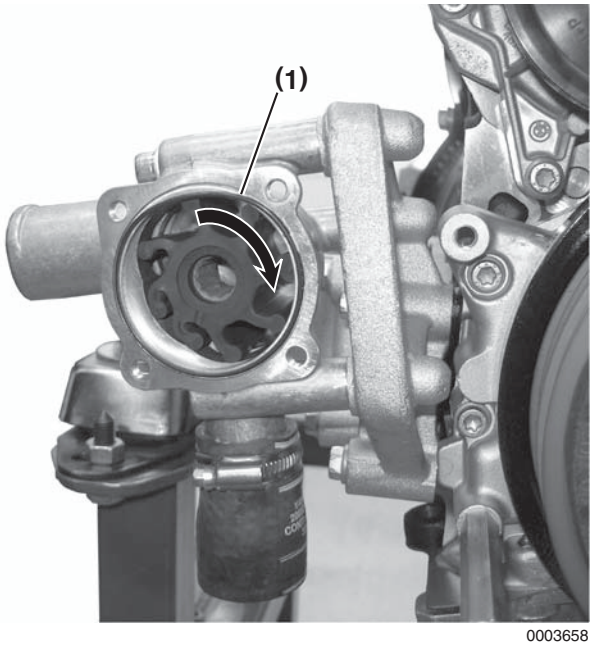

Figure 7-26

7. Install a new O-ring **(Figure 7-26, (1))** and hold it in the groove using petroleum jelly.
8. Install the shaft, cover and pulley assembly. Install and tighten four screws.
9. Install the seawater pump belt. *See Replace Seawater Pump Belt on page 7-19.*

Remove and Install Seawater Pump

1. Disconnect battery negative (-) cable.
2. Remove seawater pump belt. *See Replace Seawater Pump Belt on page 7-19.*
3. Disconnect seawater supply hose from seawater pump.
4. Disconnect seawater pump-to-hydraulic oil cooler pipe **(Figure 7-27, (1))**.

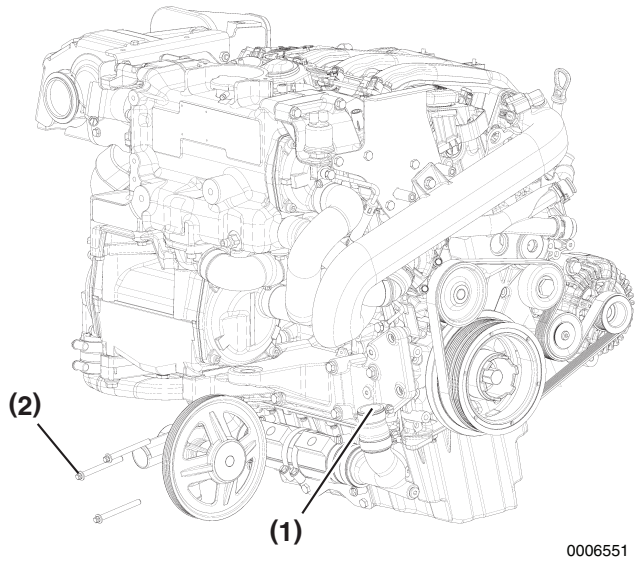

Figure 7-27

5. Remove three bolts **(Figure 7-27, (2))** and remove seawater pump.
6. Repair as necessary.
7. Installation is in the reverse of removal.
8. Install seawater pump belt. *See Replace Seawater Pump Belt on page 7-19.*
9. Connect battery negative (-) cable.

Replace Seawater Pump Belt

1. Disconnect battery negative (-) cable from the battery.
2. Remove belt guard.
3. Check belt tension. If belt is loose, it must be replaced.
4. Cut seawater belt to remove.
5. Install new belt on crankshaft pulley and around seawater pump pulley as far as possible.
6. Install belt removal tool **(Figure 7-28, (1))** between seawater pump pulley and belt.

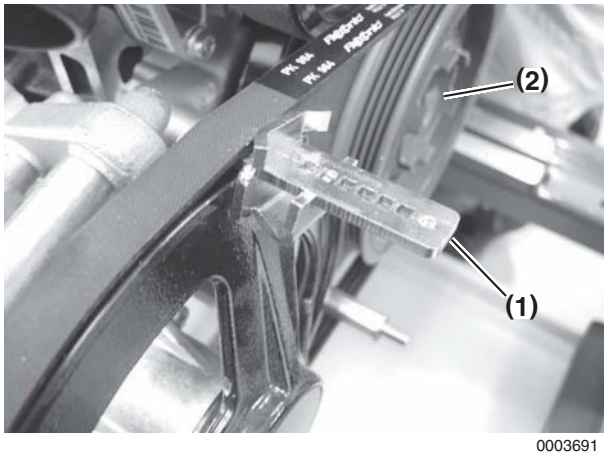

Figure 7-28

7. **CAUTION!** ***Pinch Hazard. ALWAYS use care not to catch finger between belt and pulley while installing belt.*** Roll the belt onto the pulley by rotating crankshaft using a socket and breaker bar on the crankshaft pulley bolt **(Figure 7-28, (2))**. Lift end of tool while rotating. *NOTICE: Ensure belt is correctly engaged in all grooves of both pulleys.*
8. Install belt guard.
9. Connect battery negative (-) cable. Start engine and verify pump operation.

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Section 8

LUBRICATION

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SAFETY PRECAUTIONS

Before servicing the BY2 marine engine lubrication system, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* describes the procedures necessary to service the 4BY2 and 6BY2 lubrication systems.

SPECIFICATIONS

Test and Adjustment Specifications

Note: All pressure specifications are with engine at normal operating temperature.

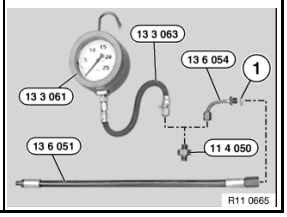
Test Item	Model	Test RPM	Specification
Oil Pressure	4BY2	Idle	0.8 bar (12 psi)
		4000 rpm	3.8 to 6.0 bar (55 to 87 psi)
	6BY2	Idle	0.7 bar (10 psi)
		4000 rpm	3.8 to 6.0 bar (55 to 87 psi)

Special Torque Chart

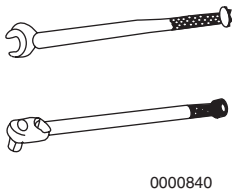
Component	Tightening Torque	Lubricating Oil Application	Reference Page
Oil Filter Cap	25 N·m (221 in.-lb)	Not Applied	*Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*
Oil Sump Bolt	20 N·m (177 in.-lb)	Not Applied	*Remove and Install Oil Sump on page 8-11*
Oil Sump Drain Plug	25 N·m (221 in.-lb)	Not Applied	
Oil Pickup Bolts	10 N·m (89 in.-lb)	Not Applied	*Install Oil Pump on page 8-12*

SPECIAL SERVICE TOOLS

Note: The tool numbers used in this section are either Yanmar or BMW part numbers. Yanmar part numbers are referred to as **Yanmar Part No.** and BMW part numbers are referred to as **OEM Part No.** Tools not having part numbers must be obtained locally.

No.	Tool Name	Part Number	Illustration
1	Oil Pressure Test Gauge Kit	OEM Part No. 13 6 054, 13 6 051, 13 3 063 and 13 3 061	

MEASURING INSTRUMENTS

No.	Instrument Name	Application	Illustration
1	Torque Wrench	For tightening nuts and bolts to the specified torque	

TESTS AND ADJUSTMENTS

Engine Oil Flow

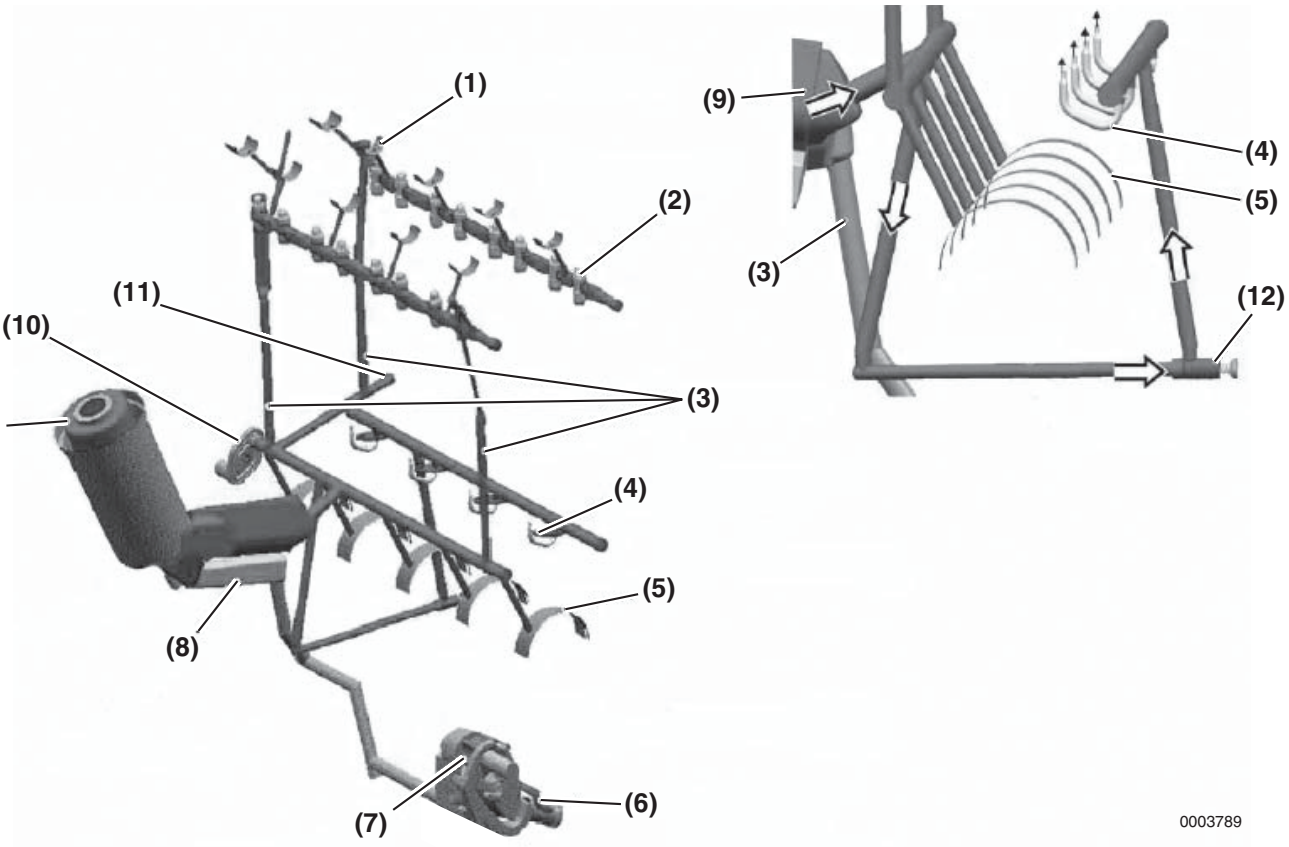


Figure 8-1

1 – Camshaft Bearings
2 – Hydraulic Valve Adjuster
3 – Oil Galleys
4 – Piston Cooling Jet
5 – Crankshaft Bearings
6 – Oil Galley for Pressure Regulator Valve
7 – Oil Pump
8 – Oil Return
9 – Oil Filter
10 – Timing Chain Lubrication Nozzle
11 – Port to Turbocharger Lubrication Line and Oil Pressure Sensor Line
12 – Piston Cooling Oil Pressure Regulator

Check Engine Oil Pressure

Perform an engine oil pressure check if there is any indication of low oil pressure.

1. Check oil level. Add oil if necessary.
2. Start the engine and allow it to warm to normal operating temperature.
3. Stop the engine.
4. Disconnect wires **(Figure 8-2, (1))**.

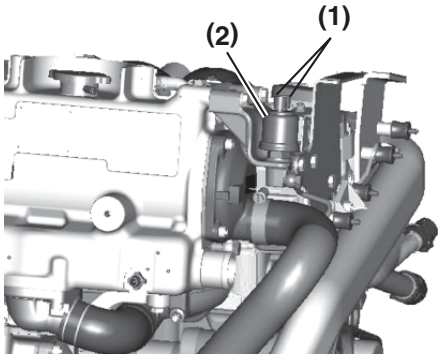


Figure 8-2

5. Remove the oil pressure sensor **(Figure 8-2, (2))**.
6. Install special tool OEM No. 11 4 050 with O-ring **(Figure 8-3, (1))** in oil pressure sensor port.

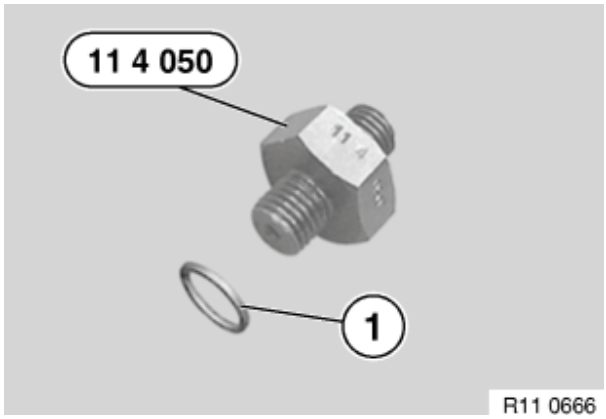


Figure 8-3

Note: Special tools OEM No. 13 6 054 and 13 6 051, and O-ring **(Figure 8-4, (1))** are used with a DIS Tester.

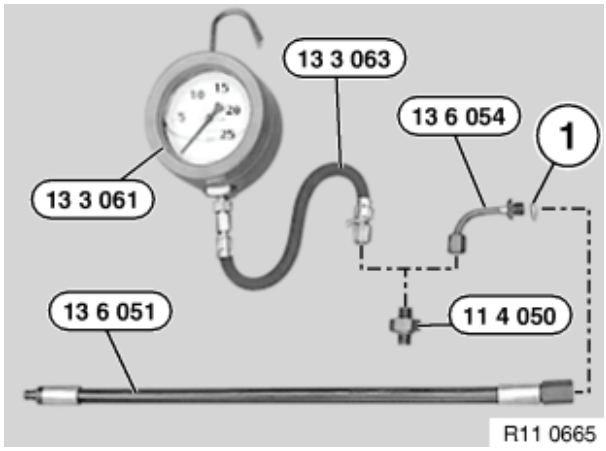


Figure 8-4

7. Connect test pressure gauge **(Figure 8-4)** special tool OEM No. 13 3 063 and 13 3 061.
8. Start the engine and read the pressure gauge at the listed engine speeds.

Results:

- If the mechanical oil pressure test gauge indicates good oil pressure, replace the faulty oil pressure sensor or faulty oil pressure gauge.
- If the mechanical oil pressure test gauge indicates low oil pressure, troubleshoot the lubrication system to locate the cause of the low oil pressure. Repair as necessary.

Specifications

Inspection Item		Test RPM	Specification
Engine Oil Pressure	4BY2	Idle	0.8 bar (12 psi)
		4000 rpm	3.8 to 6.0 bar (55 to 87 psi)
	6BY2	Idle	0.7 bar (10 psi)
		4000 rpm	3.8 to 6.0 bar (55 to 87 psi)

REPAIR

Engine Lubrication System Components

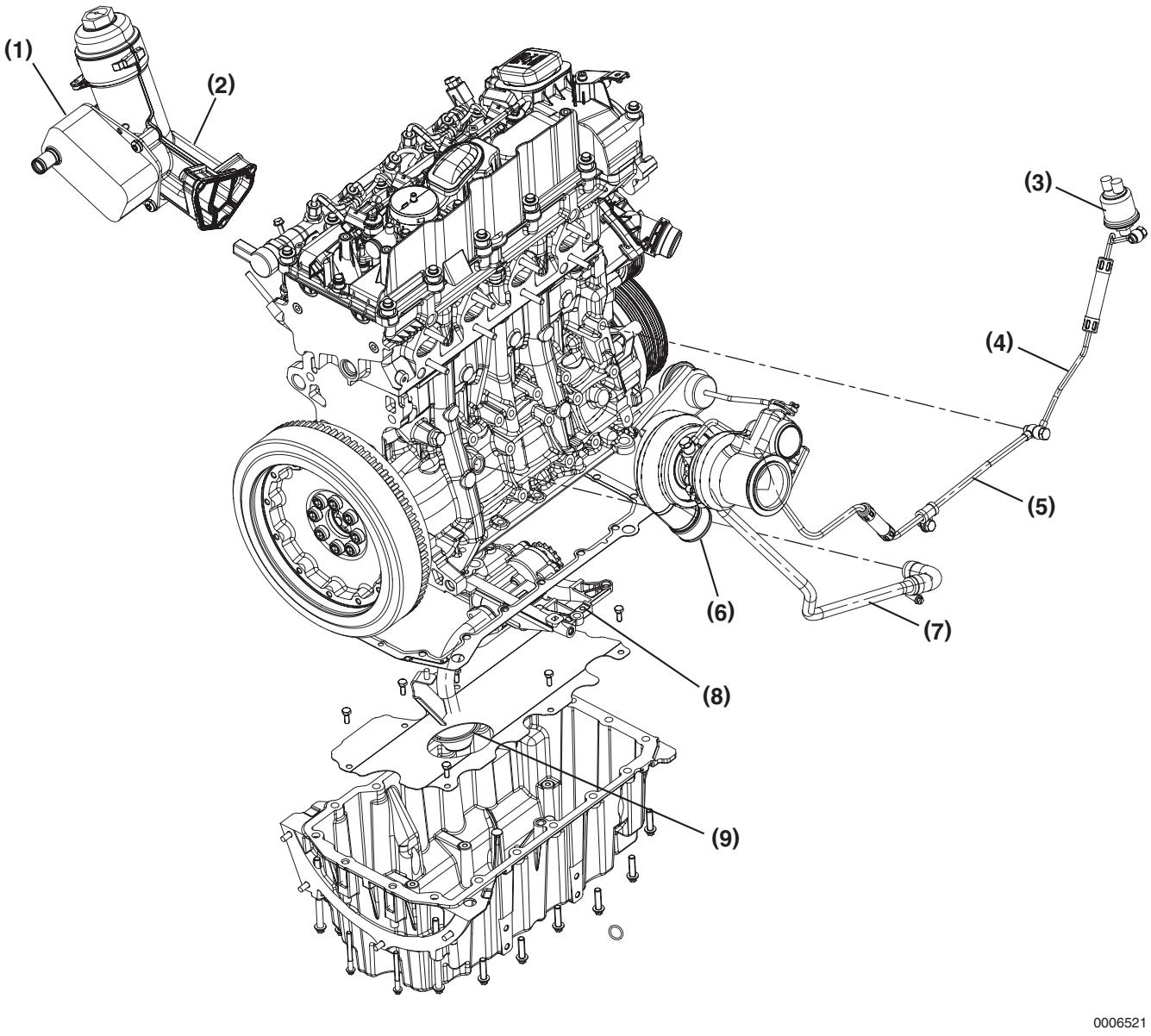


Figure 8-5

1 – Engine Oil Cooler
2 – Oil Filter Housing
3 – Oil Pressure Sensor
4 – Oil Pressure Sensor Line
5 – Turbocharger Lubrication Supply Line
6 – Turbocharger
7 – Turbocharger Lubrication Return Line
8 – Oil Pump
9 – Oil Pickup and Screen

Change Engine Oil and Replace Engine Oil Filter Element

The engine oil on a new engine becomes contaminated from the initial break-in of internal parts. It is very important that the initial oil replacement is performed as scheduled.

It is easiest and most effective to drain the engine oil after operation while the engine is still warm. **WARNING!** ***Burn Hazard. ALWAYS stay clear of the hot engine oil to avoid being burned.***

1. Turn engine off.
2. Remove engine cover.
3. *NOTICE: NEVER use an adjustable wrench or other open-end tool as there is a risk of damaging the filter cover.* Loosen the engine oil filter cap **(Figure 8-6, (2))** 1 - 2 turns with a socket wrench.

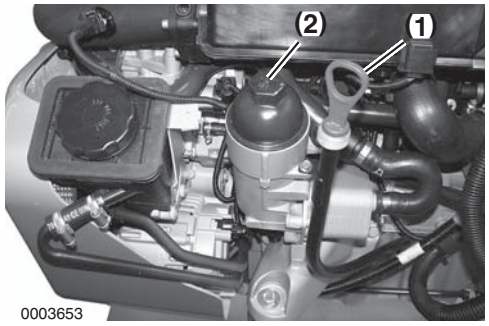


Figure 8-6

4. Remove the engine oil dipstick **(Figure 8-6, (1))**. Attach an oil drain pump and pump out the oil. Dispose of waste properly.
5. Remove the engine oil filter cap **(Figure 8-6, (2))**and filter assembly.
6. Remove the filter element from stem.
7. Replace the three O-rings **(Figure 8-7, (1))** on the stem.

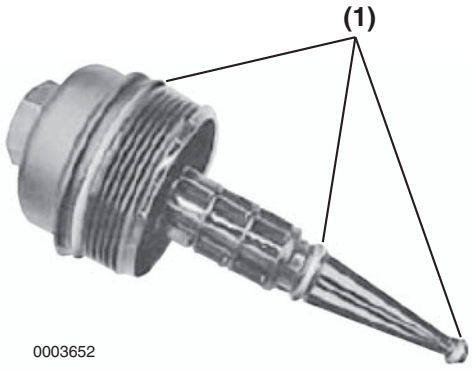


Figure 8-7

8. Install a new filter element. Ensure the filter fits snugly in the filter cap.
9. Install the cap and filter assembly. Tighten cap by hand until the seal touches the housing.
10. Tighten to 25 N·m (225 in.-lb).
11. Fill with new engine oil. *See Engine Oil Specifications on page 3-14. NOTICE: NEVER overfill the engine with oil.*
12. Perform a trial run and check for oil leaks.
13. Approximately 10 minutes after stopping the engine, remove the oil dipstick and check the oil level. Add oil if the level is too low.

Remove and Install Oil Cooler

1. *NOTICE: When working on the oil, coolant or fuel systems you must protect the alternator from contamination. Cover alternator with suitable materials.*

   Drain engine coolant. *See Drain and Fill Closed Cooling System on page 7-10.*

2. Remove oil filter element. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9.*

3. Remove coolant pipe retaining bolt **(Figure 8-8, (1))**.

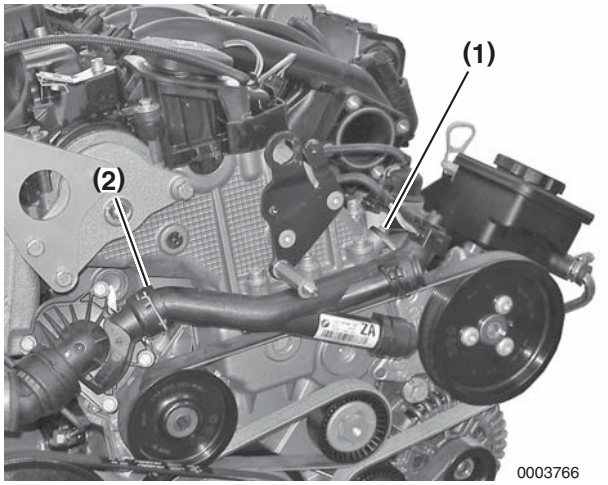


Figure 8-8

4. Disconnect coolant pipe **(Figure 8-8, (2))** from thermostat housing.
5. Disconnect coolant pipe hose **(Figure 8-9, (1))** from oil cooler **(Figure 8-9, (3))**.

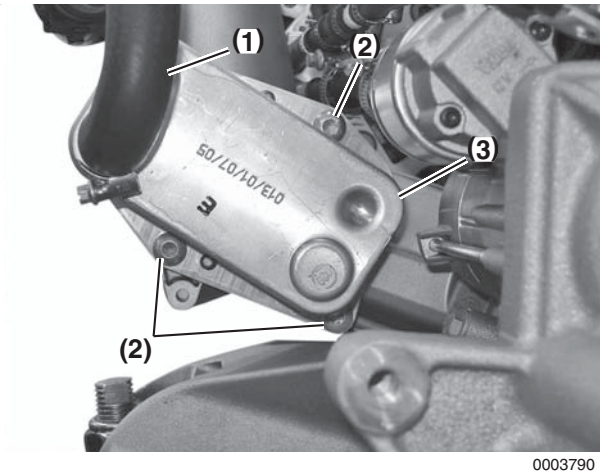


Figure 8-9

6. Remove three screws **(Figure 8-9, (2))** and remove oil cooler **(Figure 8-9, (3))**.
7. Inspect ports for evidence of blockage or corrosion **(Figure 8-10)**. Clean or replace oil cooler as necessary.

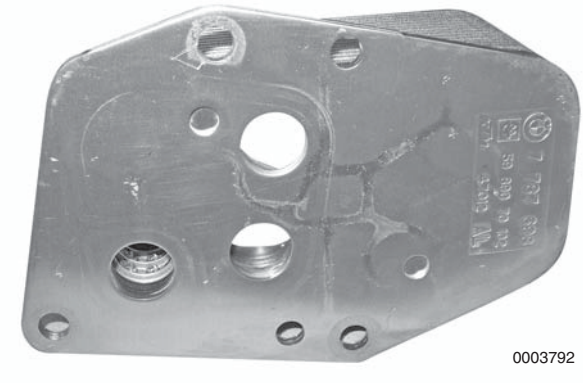


Figure 8-10

8. Thoroughly clean sealing surfaces.
9. Install a new seal **(Figure 8-11, (1))** in the oil filter housing.

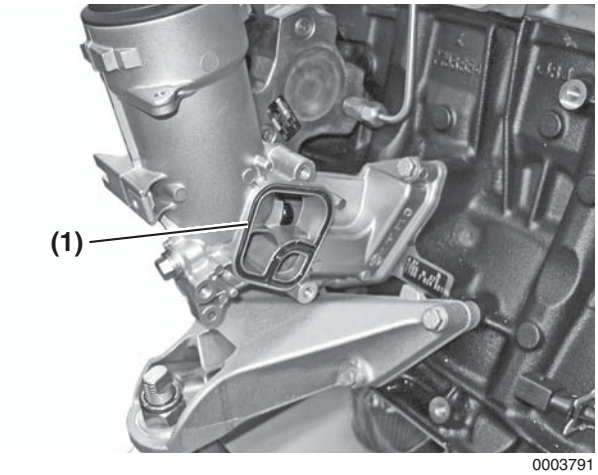


Figure 8-11

10. Install oil cooler onto oil filter housing.
11. Install and connect coolant pipe. Secure to cylinder head with screw.
12. Install new oil filter element and tighten cap to 25 N·m (225 in.-lb).
13. Fill the engine with coolant.
14. Run engine and check for oil or water leaks.

Remove and Install Oil Filter Housing

1. Drain engine oil. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.
2. Drain engine coolant. *See Drain and Fill Closed Cooling System on page 7-10.*
3. Remove oil filter cartridge. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9.*
4. Remove coolant pipe retaining bolt **(Figure 8-12, (1))**.

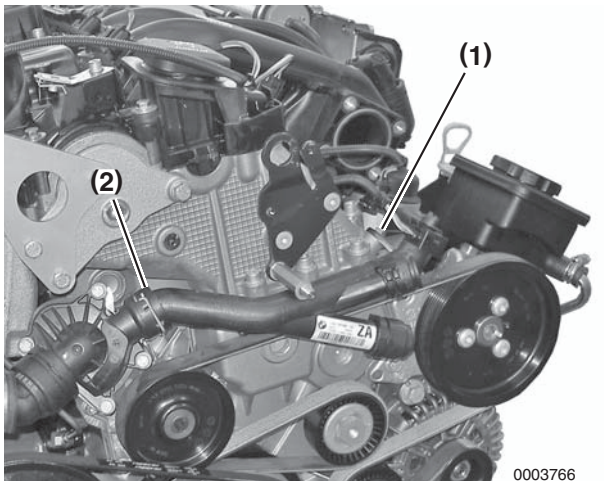


Figure 8-12

5. Disconnect coolant pipe **(Figure 8-12, (2))** from thermostat housing.
6. Disconnect coolant pipe hose **(Figure 8-13, (1))** from oil cooler **(Figure 8-13, (2))**.

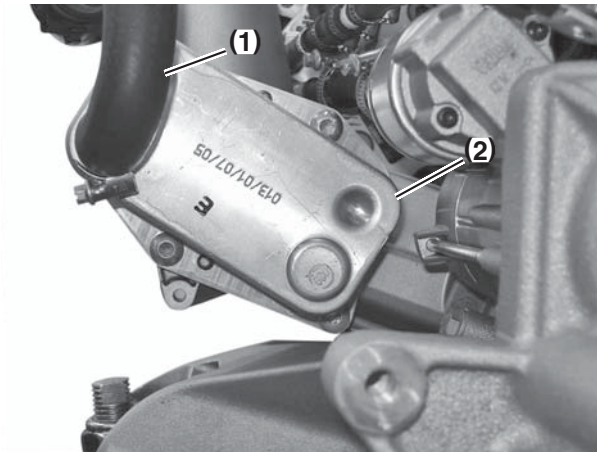


Figure 8-13

7. Remove coolant pipe **(Figure 8-14, (1))** from engine.

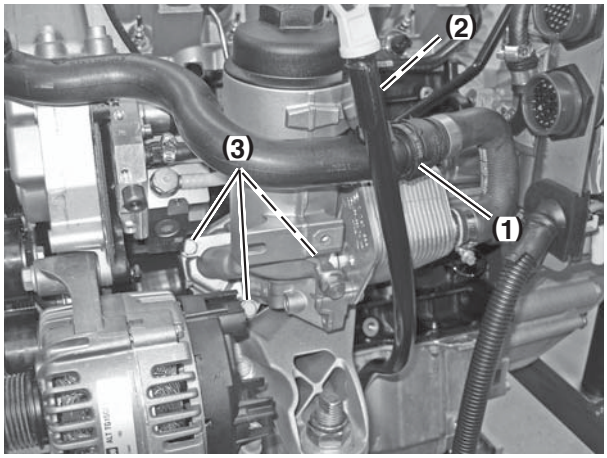


Figure 8-14

8. Remove bolt **(Figure 8-14, (2))** securing dipstick tube to oil filter housing.
9. Remove three bolts **(Figure 8-14, (3))** and remove oil filter housing from engine.
10. Install a new seal and install oil filter housing.
11. Connect the coolant pipe and secure the dipstick tube.
12. Add coolant. *See Drain and Fill Closed Cooling System on page 7-10*.
13. Install the filter cover and filter. Tighten to 25 N·m (221 in.-lb).
14. Add engine oil. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.
15. Start the engine and inspect for leaks.

Remove and Install Oil Sump

1. Drain engine oil. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.
2. Remove bolt securing oil dipstick tube to oil filter housing. Remove oil dipstick tube from oil pan.

3. Remove bolts **(Figure 8-15, (1))** that secure oil sump to the flywheel housing.

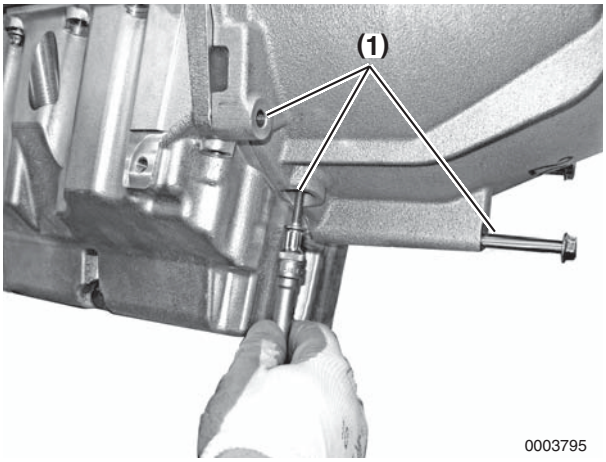


Figure 8-15

4. Remove bolts **(Figure 8-16, (1))** securing oil sump to cylinder block.

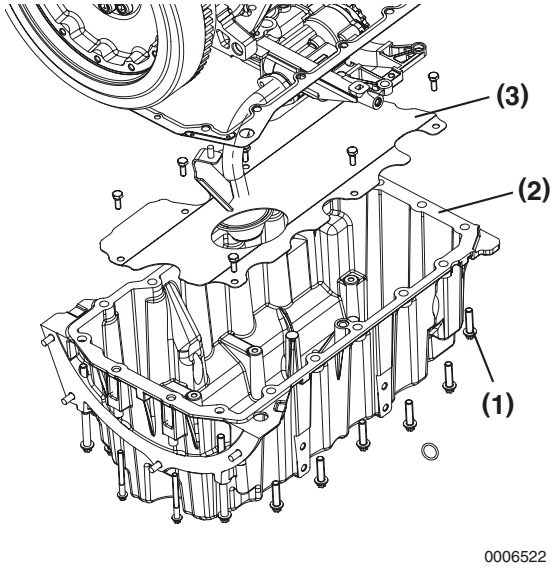


Figure 8-16

5. Remove oil sump **(Figure 8-16, (2))** and gasket **(Figure 8-16, (3))**.
6. Clean gasket surfaces of old gasket material.
7. Install oil sump with a new gasket.
8. Tighten oil sump bolts beginning at the center and working alternately toward each end. Tighten bolts to 20 N·m (177 in.-lb).
9. Connect oil dipstick tube to oil filter housing.
10. If removed, install oil drain plug and tighten to 25 N·m (221 in.-lb).
11. Fill engine with clean engine oil.
12. Run engine and check for leaks.
13. Check oil level and add more as necessary.

Oil Pump

The oil pump contains no serviceable parts. If the oil pump is damaged, it must be replaced as an assembly.

Remove Oil Pump

1. Drain oil from oil sump.
2. Remove oil sump. *See Remove and Install Oil Sump on page 8-11.*
3. Remove bolts **(Figure 8-17, (1 and 2))**. Remove oil strainer assembly and suction pipe.

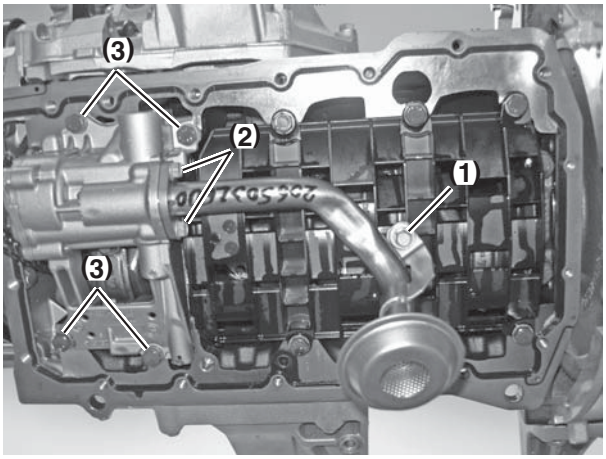


Figure 8-17

4. Remove bolts securing oil pump **(Figure 8-17, (3))**. Remove oil pump from engine.

Install Oil Pump

1. Install oil pump assembly. Ensure drive chain is properly engaged on the sprocket.
2. Secure oil pickup to oil deflector and oil pump with new gasket. Tighten bolts to 10 N·m (89 in.-lb).
3. Install oil sump. *See Remove and Install Oil Sump on page 8-11.*
4. Fill crankcase to proper level with new engine oil.

Section 9

TURBOCHARGER

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SAFETY PRECAUTIONS

Before servicing the turbocharger, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* describes the removal, inspection and installation of turbochargers used on 4BY2 and 6BY2 engines.

SPECIFICATIONS

Test and Adjustment Specifications

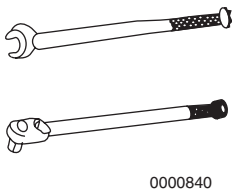
Test Item	Engine	Limit		Reference Page
Turbocharger Boost Pressure	4BY2-150	Minimum - 1600 mbar (23.2 psi)	Maximum - 1750 mbar (25.4 psi)	*Measure Charge Pressure on page 9-5*
	4BY2-180	Minimum - 1650 mbar (23.9 psi)	Maximum - 1800 mbar (26.1 psi)	
	6BY2-220	Minimum - 1950 mbar (28.3 psi)	Maximum - 2150 mbar (31.2 psi)	
	6BY2-260	Minimum - 2000 mbar (29.0 psi)	Maximum - 2200 mbar (31.9 psi)	

Special Torque Chart

Component		Size	Comments	Specification
Turbocharger to Exhaust Manifold	4BY2 6BY2	-	Apply copper anti-seize to threads	23 N·m (204 in.-lb)
Turbocharger Oil Supply Line	4BY2 6BY2	M10	Replace banjo bolt and sealing rings	22 N·m (195 in.-lb)
Turbocharger Oil Return to Crankcase	4BY2 6BY2	-	Hose clamp	3 N·m (27 in.-lb)

SPECIAL SERVICE TOOLS

Note: The tool numbers used in this section are either Yanmar or BMW part numbers. Yanmar part numbers are referred to as **Yanmar Part No.** and BMW part numbers are referred to as **OEM Part No.** Tools not having part numbers must be obtained locally.

No.	Instrument Name	Application	Illustration
1	Torque Wrench	For tightening nuts and bolts to the specified torque	 0000840

SEALANTS AND COMPOUNDS

Sealant Name	Use
Copper Anti-Seize	Exhaust Manifold - Turbocharger to Exhaust Manifold bolts

TESTS AND ADJUSTMENTS

Measure Charge Pressure

The turbocharger charge pressure can be measured using a console digital display.

Low charge pressure can be due to compressor wheel or turbine wheel damage, control rod wear or dirt in the compressor housing.

1. Remove charge air temperature sensor **(Figure 9-1, (1))** from charge air intake pipe.

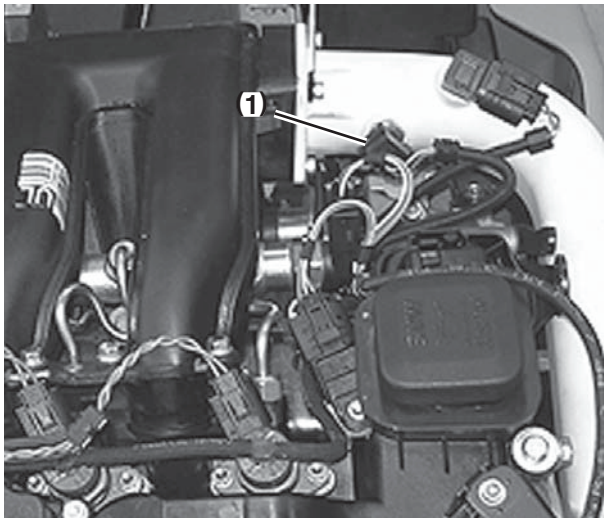


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Figure 9-1

2. Install an M12 x 1.5 adapter and connect a mechanical gauge to the charge air temperature sensor port.
3. Operate the engine under normal load conditions at wide open throttle (4000 rpm) and take a reading after at least 30 seconds of constant operation.

Results:

If the reading is not within specification, adjust the control rod (4BY2) or replace the turbocharger.

Specifications

		Limit	
Inspection Item	**Engine**	**Minimum**	**Maximum**
Turbocharger Boost Pressure	4BY2-150	1600 mbar (23.2 psi)	1750 mbar (25.4 psi)
	4BY2-180	1650 mbar (23.9 psi)	1800 mbar (26.1 psi)
	6BY2-220	1950 mbar (28.3 psi)	2150 mbar (31.2 psi)
	6BY2-260	2000 mbar (29.0 psi)	2200 mbar (31.9 psi)

REPAIR

Remove Turbocharger

NOTICE: Observe strict cleanliness procedures at all times when working on the turbocharger. Never leave connections for oil inlets or outlets unprotected. Foreign bodies in the bearing housing will lead to turbocharger breakdown.

NOTICE: NEVER change the length of the wastegate control rod without doing it in coordination with a charge pressure test. (See Measure Charge Pressure on page 9-5.) Doing so will cause incorrect boost pressure resulting in poor performance or engine damage, and can void all warranty.

1. Remove air filter **(Figure 9-2, (5))**.

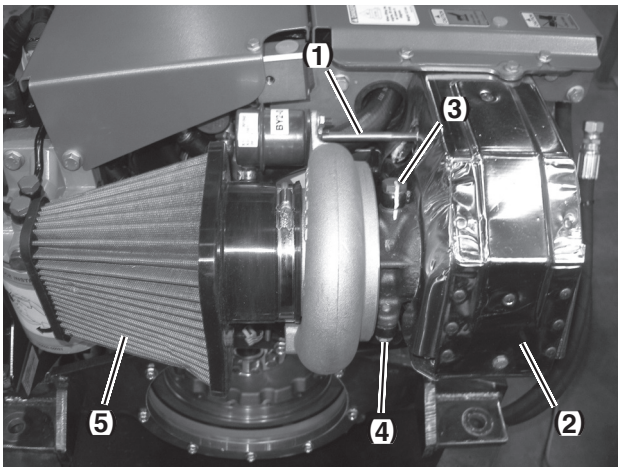

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Figure 9-2

2. Disconnect wastegate control rod **(Figure 9-2, (1))**.
3. Remove the insulating cover **(Figure 9-2, (2))**.
4. Disconnect the lubrication supply line **(Figure 9-2, (3))** and return line **(Figure 9-2, (4))** from the turbocharger.
5. Loosen and remove turbocharger-to-exhaust mixing elbow clamps and pull elbow away from turbocharger.
6. Disconnect charge air pipe **(Figure 9-3, (1))** from turbocharger.

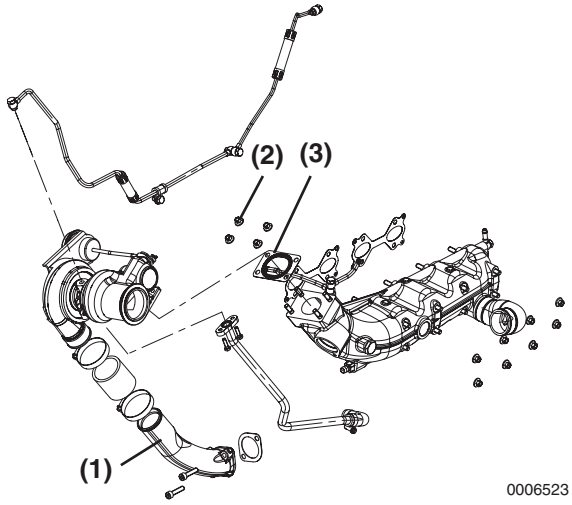

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Figure 9-3

7. Remove four bolts **(Figure 9-3, (2))** and remove turbocharger from exhaust manifold.
8. Remove gasket **(Figure 9-3, (3))**.

Install Turbocharger

NOTICE: NEVER change the length of the wastegate control rod without doing it in coordination with a charge pressure test. (See Measure Charge Pressure on page 9-5.) Doing so will cause incorrect boost pressure resulting in poor performance or engine damage, and can void all warranty.

Note: When installing the turbocharger, replace all gaskets with new ones. Change the engine oil and replace the engine oil filter. *See Change Engine Oil and Replace Engine Oil Filter Element on page 8-9*.

1. Clean mounting surfaces of all gasket material.

2. Apply a light coating of copper anti-seize to turbocharger bolts **(Figure 9-4, (2))**.

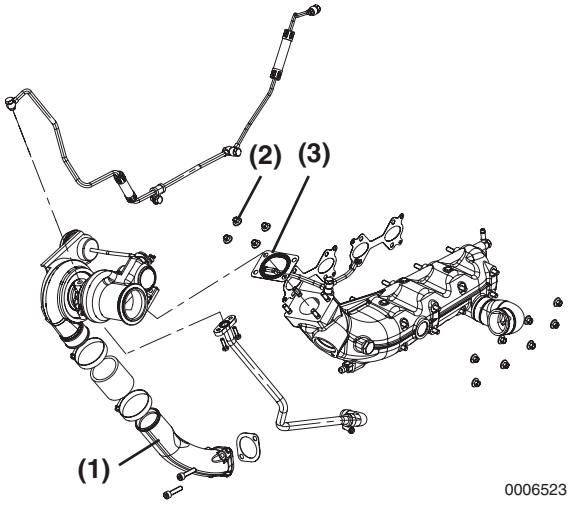

Figure 9-4

3. Install turbocharger to exhaust manifold with a new gasket **(Figure 9-4, (3))**. Tighten bolts to 23 N·m (204 in.-lb).
4. Connect charge air pipe **(Figure 9-4, (1))** and tighten clamps securely.
5. Install new gaskets and connect lubrication return line **(Figure 9-5, (4))** and supply line **(Figure 9-5, (3))**.

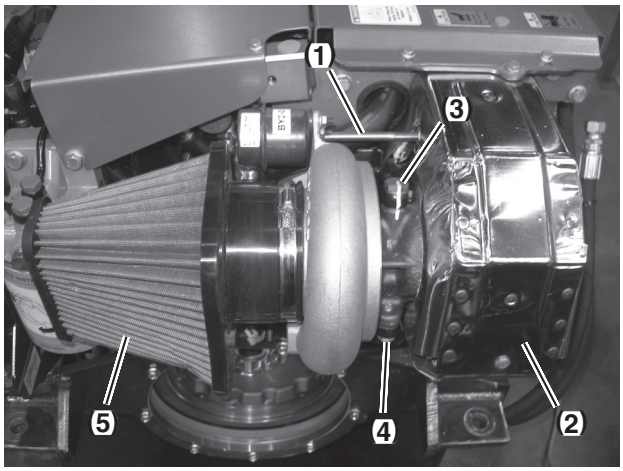

Figure 9-5

6. Install insulating cover **(Figure 9-5, (2))** and connect wastegate control rod **(Figure 9-5, (1))**.
7. Install air filter **(Figure 9-5, (5))**.
8. Connect exhaust mixing elbow to turbocharger and tighten clamps securely.
9. Start engine and check for oil leaks.

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Section 10

STARTER MOTOR

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SAFETY PRECAUTIONS

Before servicing the starter motor, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* covers servicing of the starter motor on 4BY2 and 6BY2 engines.

STARTER MOTOR SPECIFICATIONS

General Specifications

Item	Bosch (4BY2)	Denso (6BY2)
Nominal Power	2.0 kW	2.0 kW
Nominal Voltage	12V	12V
Test Voltage	13 ± 0.26V	13 ± 0.26V
Maximum Operating Temperature	120°C (248°F)	120°C (248°F)
Rotation	Clockwise	Clockwise
Weight	3.5 kg (7.7 lb)	3.5 kg (7.7 lb)

Special Torque Chart

Item	Specification
Battery Positive (+) Cable	15 N·m (133 in.-lb)
Solenoid Primary Wire	8 N·m (71 in.-lb)

STARTER MOTOR TROUBLESHOOTING

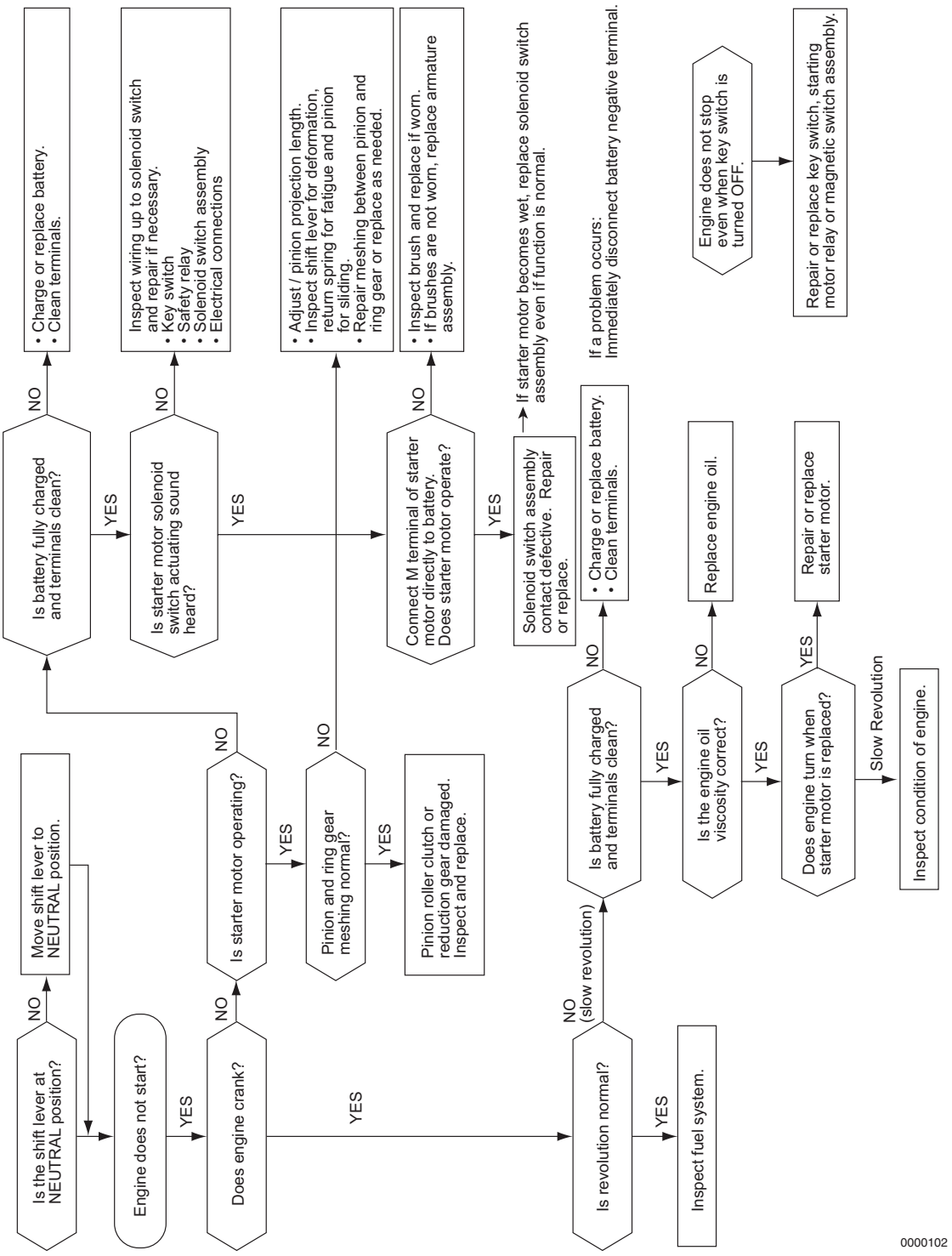

Figure 10-1

REMOVE AND INSTALL STARTER MOTOR

1. Disconnect the battery negative (-) cable and turn the battery master switch to OFF (if equipped).
2. Remove intake manifold. *See Intake Manifold on page 5-66*.
3. Disconnect positive (+) cable **(Figure 10-2, (1))** and primary wire **(Figure 10-2, (2))**.

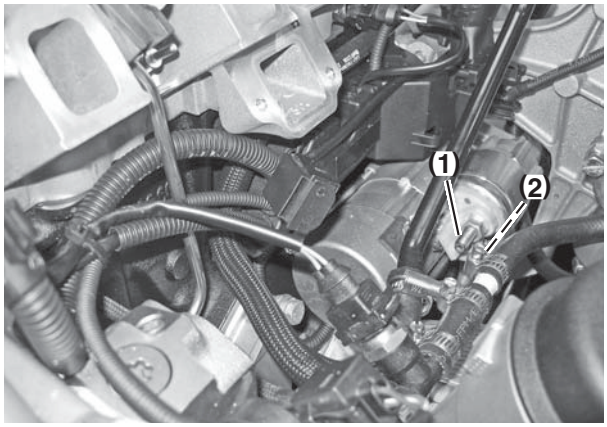

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Figure 10-2

4. Remove bolts **(Figure 10-3, (1))** securing the starter motor to the flywheel housing.

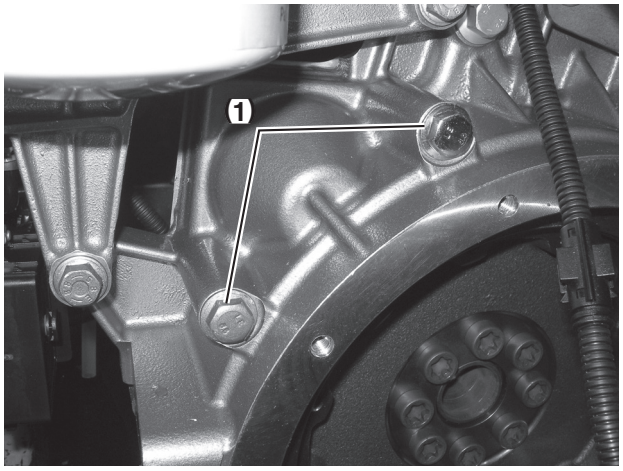

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Figure 10-3

5. Carefully remove the starter motor. *NOTICE: Check the starter pinion for damage. If the starter pinion is damaged, the flywheel ring gear must also be checked for damage.*
6. Clean the starter mounting area of the flywheel housing.
7. Install the starter motor.
8. Clean the cable connections.
9. Connect the positive (+) cable and primary wire to the appropriate terminals of the starter.
10. Install intake manifold. *See Intake Manifold on page 5-66*.
11. Connect the battery negative (-) cable and return the master switch (if equipped) to the ON position.
12. Operate starter to verify operation.

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Section 11

ALTERNATOR

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SAFETY PRECAUTIONS

Before you begin servicing the alternator, read the following safety information and review the *Safety Section on page 2-1*.

⚠ WARNING

Electrical Hazard

ALWAYS turn off the battery switch (if equipped) or disconnect the negative battery cable before servicing the electrical system.

ALWAYS check the electrical harnesses for cracks, abrasions, and damaged or corroded connectors. ALWAYS keep the connectors and terminals clean.

NOTICE

NEVER operate the engine if the alternator is producing unusual sounds. Damage to the alternator will result.

NEVER remove the positive (+) battery cable from alternator terminal B while the engine is operating. Damage to the alternator will result.

NEVER turn the battery switch OFF while the engine is operating. Damage to the alternator will result.

NEVER use a high-pressure wash directly on the alternator. Water will damage the alternator and result in inadequate charging.

INTRODUCTION

This section of the *Service Manual* describes servicing of the 4BY2 and 6BY2 charging systems.

SPECIFICATIONS

General Specifications

Item	Specification
Manufacturer	Valeo
Model	TG15 150A KSR-DF
Nominal Voltage	12V
Nominal Output	150A

Special Torque Chart

Item	Specification
Alternator Mounting Bolts	38 N·m (28 ft-lb)
Positive Cable Nut	13 N·m (115 in.lb)

REPAIR

Replace Alternator Belt

1. Disconnect battery negative (-) cable from the battery.
2. Remove belt guard.
3. Remove seawater pump belt. *See Replace Seawater Pump Belt on page 7-19*.

Note: **Figure 11-1(A)** shows belt routing for stern drive equipped models.
Figure 11-1(B) shows belt routing for marine gear equipped models.

Belt Routing

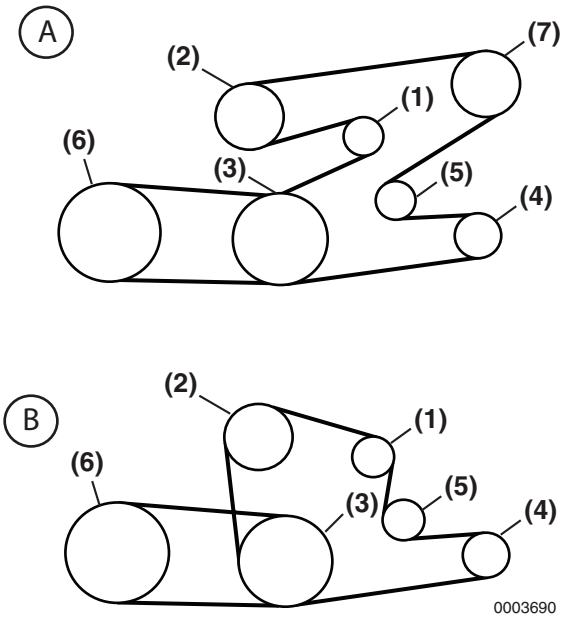

Figure 11-1

1 – Belt Tensioner
2 – Coolant Pump
3 – Crankshaft
4 – Alternator
5 – Fixed Idler
6 – Seawater Pump
7 – Power Steering Pump (Stern Drive Only)

4. Use a socket and breaker bar to rotate the belt tensioner and relieve belt tension. Remove belt. *NOTICE: If belt is to be reused, note direction of travel and install in same direction of travel.*
5. Installation is the reverse of removal. **CAUTION!** ***Pinch Hazard. ALWAYS use care not to pinch a finger between belt and pulley while installing belt. Failure to comply may result in minor or moderate injury.*** *NOTICE: Ensure belt correctly engages all grooves of each pulley. Failure to do so will lead to premature belt failure.*

Remove and Install Alternator

1. Disconnect battery negative (-) cable from the battery.
2. Remove belt guard.
3. Remove alternator belt. *See Replace Alternator Belt on page 11-5.*
4. Disconnect positive (+) cable **(Figure 11-2, (1))** from alternator.

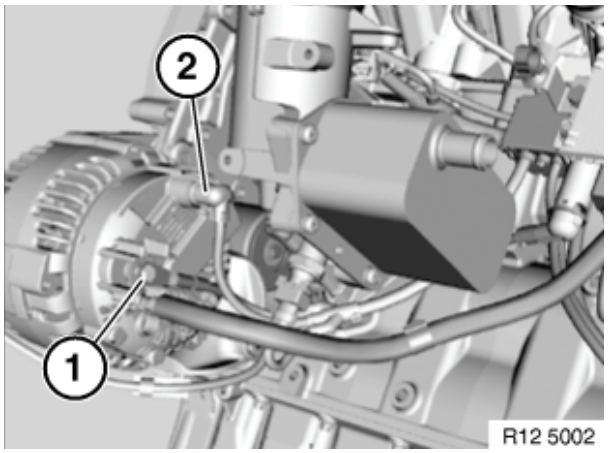

Figure 11-2

5. Disconnect connector **(Figure 11-2, (2))** from alternator.

6. Pry off protective cap **(Figure 11-3, (1))** and remove the bolt that secures idler pulley **(Figure 11-3, (2))**.

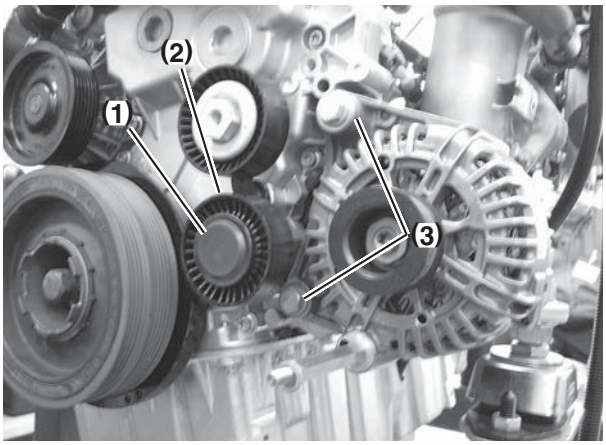

Figure 11-3

7. Remove two bolts **(Figure 11-3, (3))** and remove alternator from engine.
8. Install alternator and tighten mounting bolts to 38 N·m (28 ft-lb).
9. Install idler pulley and install protective cap.
10. Connect cables to alternator. Tighten positive cable nut to 13 N·m (115 in.-lb).
11. Install alternator belt. *See Replace Alternator Belt on page 11-5.*
12. Install belt guard.
13. Connect battery negative (-) cable to the battery.

Remove and Install Alternator Belt Tensioner

1. Disconnect battery negative (-) cable from the battery.
2. Remove belt guard.
3. Remove alternator belt. *See Replace Alternator Belt on page 11-5.*
4. Remove intake manifold. *See Intake Manifold on page 5-66.*
5. Remove alternator. *See Remove and Install Alternator on page 11-5*.
6. Remove bolt **(Figure 11-4, (1))** securing idler pulley **(Figure 11-4, (2))**. Remove idler pulley.

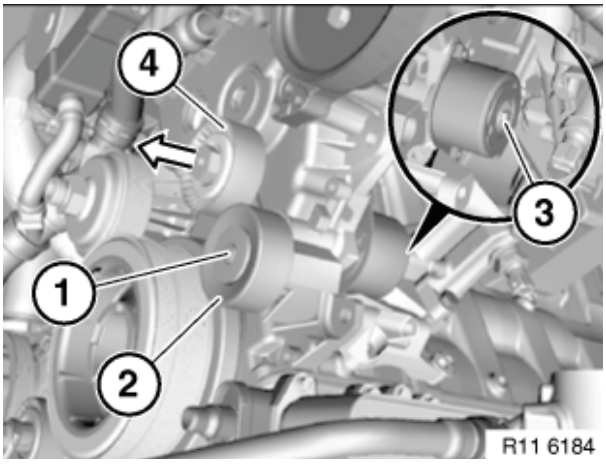

Figure 11-4

Note: Bolt **(Figure 11-4, (3))** must be removed and installed with the belt tensioner spring assembly.

7. Loosen bolt **(Figure 11-4, (3))** securing tensioning pulley and arm to belt tensioner spring assembly.
8. Remove arm and pulley **(Figure 11-4, (4))** in direction of arrow.
9. Remove bolts. Remove tensioner spring assembly **(Figure 11-5, (1))** in direction of arrow.

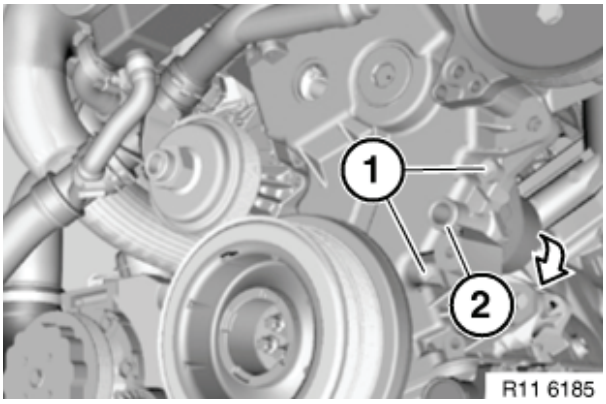

Figure 11-5

10. Installation is done in reverse of removal. Install new seal **(Figure 11-5, (2))**.

Section 12

ELECTRICAL AND ECU

SAFETY PRECAUTIONS

Before servicing the electrical components, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* describes the operation of and procedures to test and replace the components of the electrical system and engine control unit (ECU) as used on the Yanmar 4BY2 and 6BY2 marine engines.

SPECIFICATIONS

Special Torque Chart

Item	Specification
High-Pressure Fuel Control Valve Retaining Nut	80 N·m (59 ft-lb)
High-Pressure Fuel Sensor Retaining Nut	70 N·m (52 ft-lb)
Fuel Volume Regulator Screws	6.6 N·m (58 in.-lb)

FUNCTION DESCRIPTION - ENGINE MANAGEMENT SYSTEM

Component Locations

4BY2

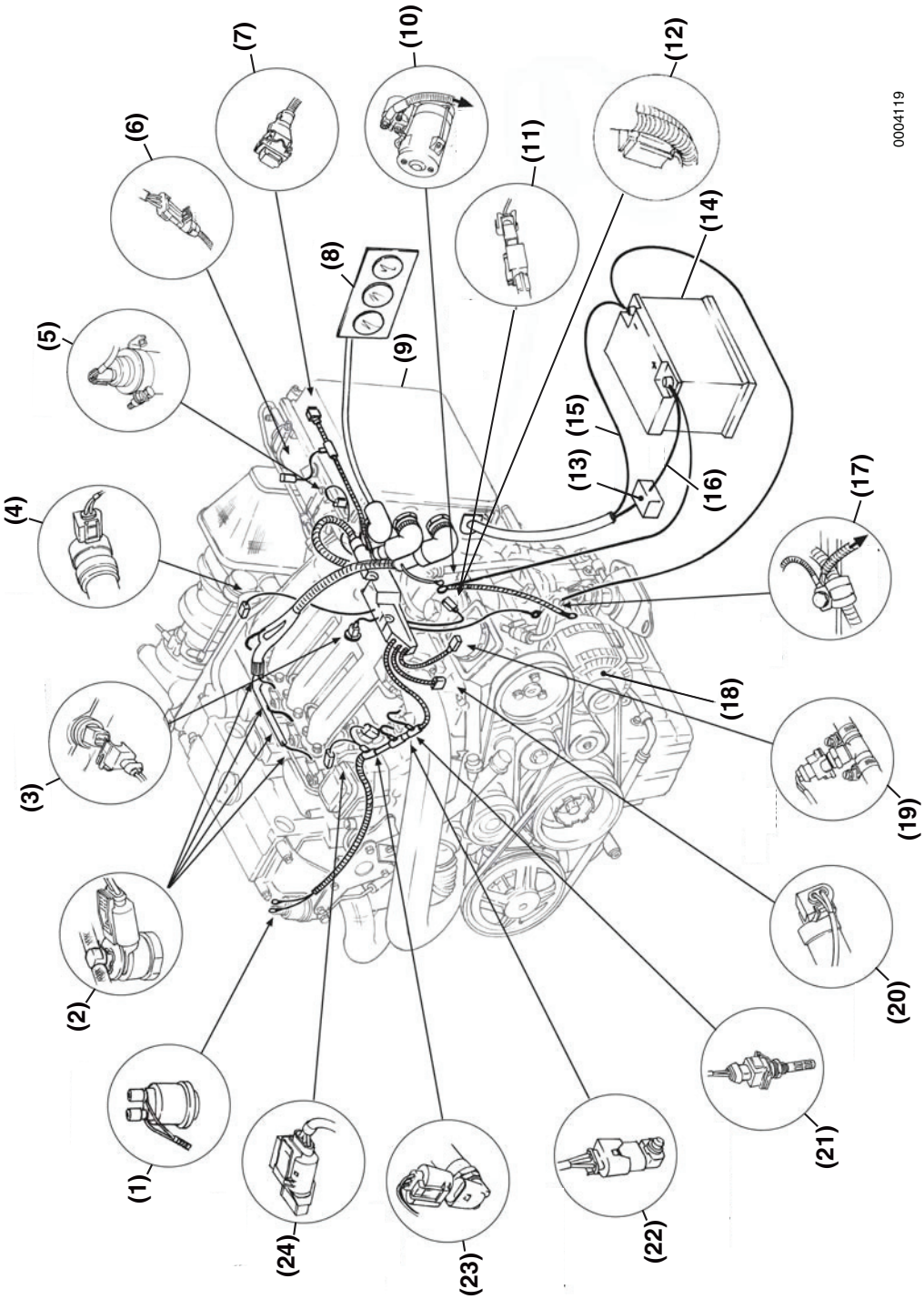

Figure 12-1

1 – Oil Pressure Sensor
2 – Fuel Injectors
3 – Engine Coolant Temperature Sensor
4 – High-Pressure Fuel Regulator
5 – Low-Pressure Fuel Pump
6 – Water-in-Fuel Sensor
7 – Neutral Start Switch Connector
8 – Instrument Panel
9 – Electrical Panel (Fuses, Relays, ECU)
10 – Starter Motor
11 – Crankshaft Speed Sensor
12 – Glow Plug Harness Connector
13 – Circuit Breaker (Boatbuilder Installed Option)
14 – Battery
15 – Battery Negative (-) Cable (Black)
16 – Battery Positive (+) Cable (Red)
17 – Battery Ground Connection
18 – Alternator
19 – Fuel Temperature Sensor
20 – Fuel Volume Regulator
21 – Charge Air Temperature Sensor
22 – Charge Air Pressure Sensor
23 – High-Pressure Fuel Rail Pressure Sensor
24 – Camshaft Speed Sensor

6BY2

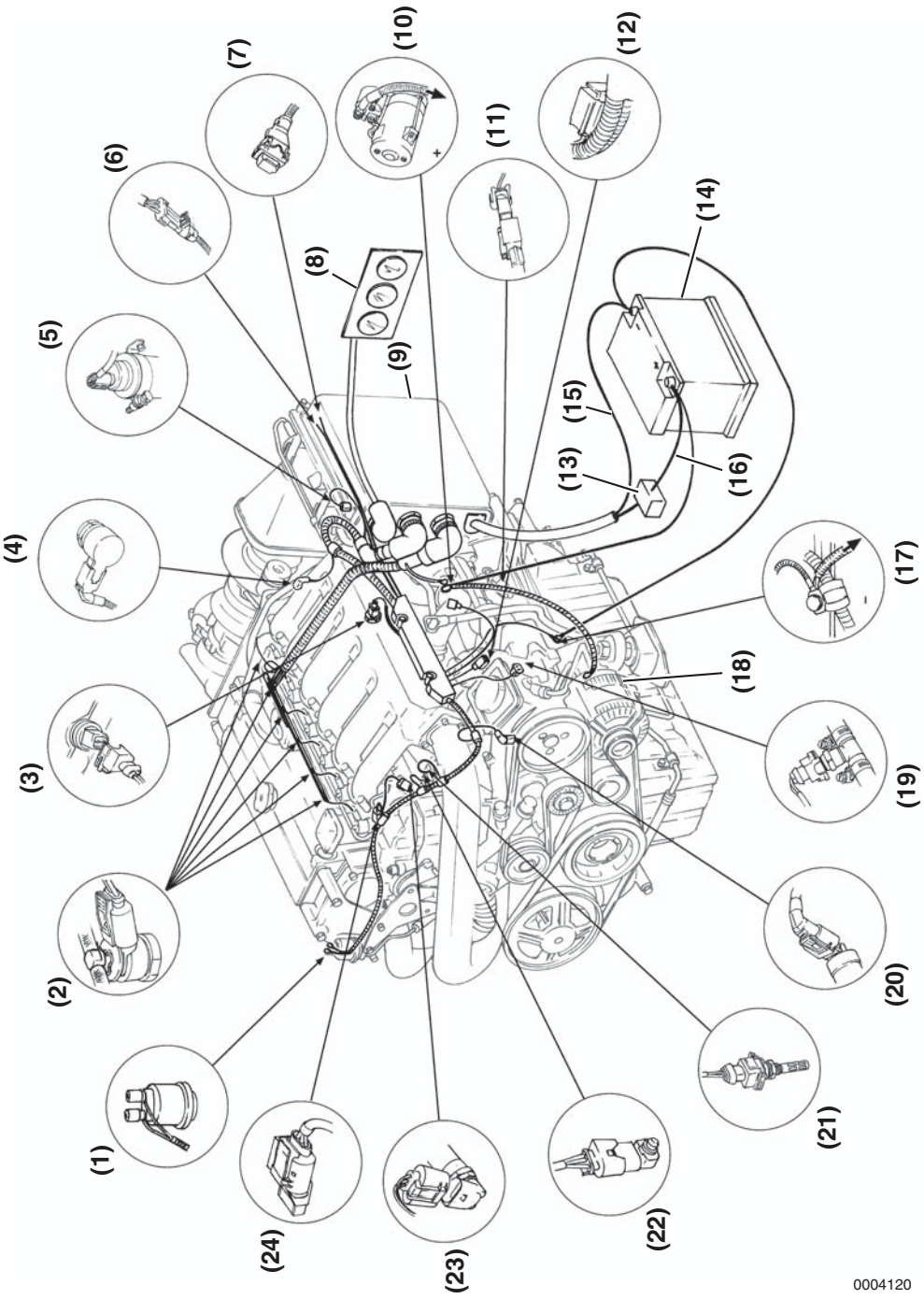

Figure 12-2

1 – Oil Pressure Sensor
2 – Fuel Injectors
3 – Engine Coolant Temperature Sensor
4 – High Pressure Fuel Regulator
5 – Low-Pressure Fuel Pump
6 – Water-in-Fuel Sensor
7 – Neutral Start Switch Connector
8 – Instrument Panel
9 – Electrical Panel (Fuses, Relays, ECU)
10 – Starter Motor
11 – Crankshaft Speed Sensor
12 – Glow Plug Harness Connector
13 – Circuit Breaker (Boatbuilder Installed Option)
14 – Battery
15 – Battery Negative (-) Cable (Black)
16 – Battery Positive (+) Cable (Red)
17 – Battery Ground Connection
18 – Alternator
19 – Fuel Temperature Sensor
20 – Fuel Volume Regulator
21 – Charge Air Temperature Sensor
22 – Charge Air Pressure Sensor
23 – High-Pressure Fuel Rail Pressure Sensor
24 – Camshaft Speed Sensor

Electrical Panel Components

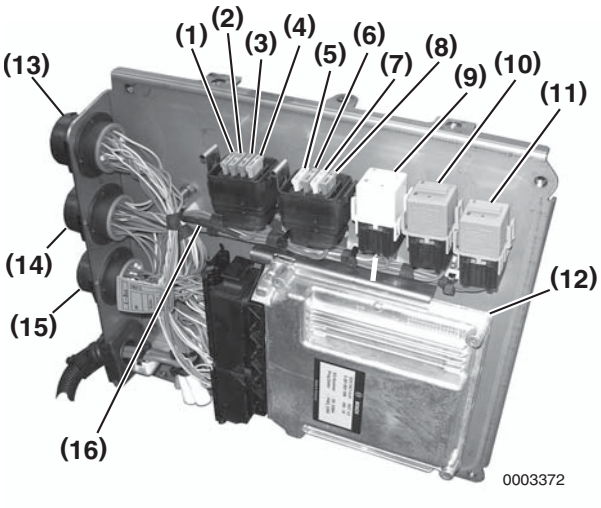

Figure 12-3

1 – **Fuse F1 (3 A) - Switched B+ to CAN**
2 – **Fuse F2 (10 A) - B+ to Key Switch**
3 – **Fuse F3 (15 A) - Fuel Supply Pump**
4 – **Fuse F4 (30 A) - Switched B+ to ECU**
5 – **Fuse F5 (20 A) - Power to Sensors and Actuators**
6 – **Fuse F6 (10 A) - Auxiliary Power**
7 – **Jumper Fuse F7 (3 A) - Single / Port Selection, default is single / port (fuse in). Remove fuse for starboard configuration.**
8 – **Jumper Fuse F8 (3 A) - CAN / Analog Throttle Selection, default is analog (fuse out). Insert 3 A fuse to configure for CAN.**
9 – **K1 - Starter Relay**
10 – **K3 - Fuel Supply Pump Relay**
11 – **K2 - Main Power Relay**
12 – **ECU**
13 – **Connector X1 - Communication to Helm Display**
14 – **Connector X21/1 - Engine Wiring Harness**
15 – **Connector X22/1 - Fuel Injector Wiring Harness**
16 – **Blocking Diode V1**

NOTICE: The electrical panel cables must be connected directly to the battery, and must have a circuit breaker installed in the B+ (red) lead.

Electrical Panel Connector (X1) Connections

The ECU is connected to other components and systems via connector X1 **(Figure 12-4)**. The graphic and table show the pin locations and assignments.

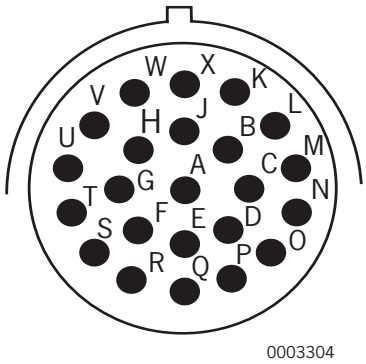

Figure 12-4

Connector X1 Pin Assignments

Connector	Pin	Name	Assignment	Detail	Max Current
X1	A	KL31	Battery Ground Terminal	Common ground	20 A
X1	B	KL30	Battery Positive Terminal	Common power supply for engine controller, injection system, and fuel pump	10 A
X1	C	KL50	Start Signal from Key Switch	Input signal to engine controller	1 A
X1	D	KL15	Ignition Power Input	Input signal to controller	1 A
X1	E	K-Line	Diagnostic Serial I / O		0.1 A
X1	F	Error Indicator	Check Engine Indicator	Input signal for CAN hub	0.5 A
X1	G	Instrument Power	Fused Battery Power	Power for accessories	5 A
X1	H	Warning Indicator			0.5 A
X1	J	GEAR	Switch to Ground	Start-in-gear protection	50 mA
X1	K	FWG2	Throttle Position Second Channel	Analog throttle safety channel	5 mA
X1	L	FWG1 +5V	Throttle Supply f. Main Channel		5 mA
X1	M	FWG1 GND	Throttle Return f. Main Channel		5 mA
X1	N	FWG1	Throttle Position Main Channel	Analog throttle main channel	5 mA
X1	O	FWG2 +5V	Throttle Supply f. Second Channel		5 mA
X1	P	FWG2 GND	Throttle Return f. Second Channel		5 mA
X1	Q		Oil Pressure Switch	For Classic System	
X1	R	CAN+	CAN Power Supply	Delayed power-off; diode	3 A
X1	S	CAN_H	CAN High	EDC data line	50 mA
X1	T	CAN_L	CAN Low	Not terminated	50 mA
X1	U	CAN-	Shield		
X1	V	Oil Pressure Gauge	Resistive Oil Sensor to Ground	Input signal for CAN hub	0.5 A
X1	W	Water-in-Fuel Sensor	Ground Signal if Water is in Fuel	Input signal for CAN hub	0.1 A
X1	X		Not used		

Engine Control Unit (ECU) Assignments

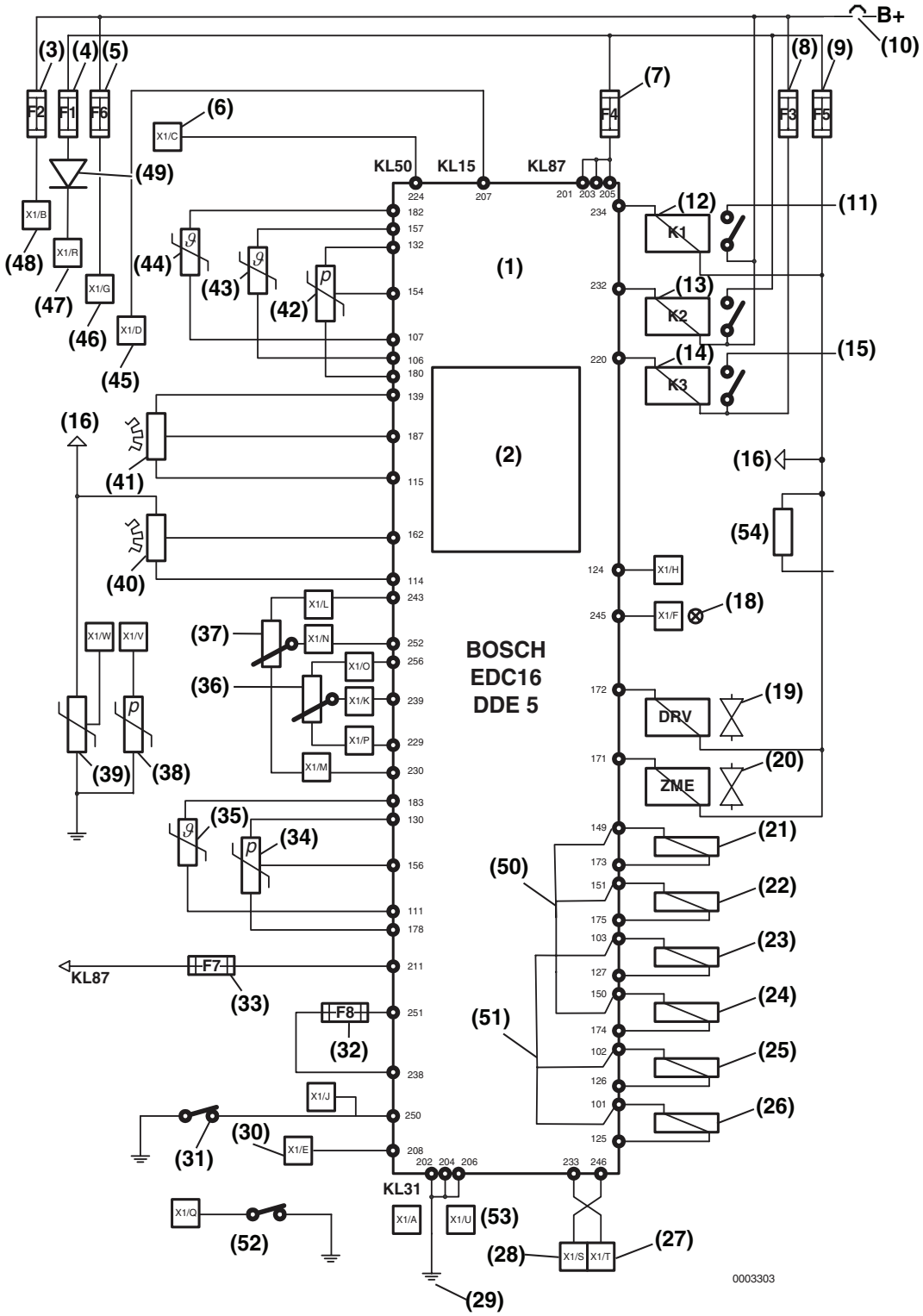

Figure 12-5

1 – Engine Control Unit (ECU)
2 – Internal ECU Sensors (operating voltage and ambient air pressure)
3 – Fuse (F2) 10 A[1] - Start
4 – Fuse (F1) 3 A - CAN Switched Power
5 – Fuse (F6) 10 A - Auxiliary Power
6 – Start Signal from Key Switch
7 – Fuse (F4) 30 A - ECU Switched Power
8 – Fuse (F3) 15 A - Fuel Supply Pump
9 – Fuse (F5) 20 A - Fuel Pressure Regulator, Water-in-Fuel, Camshaft Sensor, and Fuel Volume Regulator
10 – Circuit Breaker (Boatbuilder Installed)
11 – Power to Starter Solenoid Primary Terminal
12 – Starter Relay K1
13 – Main Power Relay K2
14 – Fuel Supply Pump Relay K3
15 – Power to Fuel Supply Pump
16 – B+ to Water-in-Fuel Sensor
17 – Not Used
18 – Check Engine Indicator Output
19 – High-Pressure Fuel Regulator
20 – Fuel Volume Control (high-pressure pump)
21 – Fuel Injector No. 4 (4BY2) or No. 6 (6BY2)
22 – Fuel Injector No. 2 (4BY2) or No. 2 (6BY2)
23 – Fuel Injector No. 3 (4BY2) or No. 5 (6BY2)
24 – Fuel Injector No. 1 (4BY2) or No. 3 (6BY2)
25 – Fuel Injector No. 1 (6BY2)
26 – Fuel Injector No. 4 (6BY2)
27 – CAN Signal - Low
28 – CAN Signal - High
29 – Panel, ECU, and CAN Ground
30 – K-Line
31 – Neutral Start Switch (NC in neutral)
32 – Jumper Fuse (F8) 3 A - CAN / Analog Throttle Selection, default is analog (fuse out). Insert 3 A fuse to configure for CAN.
33 – Jumper Fuse (F7) 3 A - Single / Port Selection, default is single / port (fuse in). Remove fuse for starboard configuration.
34 – High-Pressure Fuel Rail Pressure Sensor
35 – Fuel Temperature Sensor
36 – Subthrottle Sensor 2
37 – Subthrottle Sensor 1
38 – Oil Pressure Sensor
39 – Water-in-Fuel Sensor
40 – Camshaft Speed Sensor
41 – Crankshaft Speed Sensor
42 – Charge Air Pressure Sensor
43 – Charge Air Temperature Sensor
44 – Engine Coolant Temperature Sensor
45 – Ignition Power Input from Key Switch (terminal X1-D)
46 – Auxiliary Power Output (terminal X1-G)
47 – NMEA + Power Supply (X7-R)
48 – Battery Power to Key Switch (terminal X1-B)
49 – CAN Signal Blocking Diode
50 – High Bench 1
51 – High Bench 2
52 – Oil Pressure Switch (X1-Q)
53 – NMEA Ground Supply
54 – Power Resistor for Generator

[1] *NEVER connect any additional devices to F2. F6 may be used however, it is not switched.*

Figure 12-5 shows a general schematic diagram of all ECU input and output assignments.

The ECU is supplied by Bosch and has a hardware specification of EDC 16. The base ECU software is Bosch DDE 5. The engine control software is application specific version NSW 400, which is a torque-based software structure. It is NMEA 2000 implemented and provides diagnostics through OBD protocol.

The ECU monitors data from the various sensors and controls such functions as low-pressure fuel pump operation, fuel injection pressure, fuel injection system volume, and the timing and volume of fuel injected by the Bosch electronic fuel injectors. Throttle control is fly-by-wire, meaning it is controlled by electric signals from the helm. The throttle control is either analog or digital depending on the level of control options installed.

The ECU also uses sensor inputs to monitor engine condition and will generate a trouble code if a system or sensor indicates a problem. In most cases, a Check Engine light will be displayed. The engine may or may not run normally depending on the fault. If an engine coolant overheat is detected, for instance, the ECU will reduce the engine power output and the coolant overheat indicator will illuminate. If an audible alarm is installed, it too will sound.

Not all inputs are monitored by the ECU. Low oil pressure and water in fuel are two examples. Either of these conditions will result in a warning indicator and possible audible alarm. Low oil pressure will also be indicated by the oil gauge at the helm.

COMPONENT TESTS

NOTICE: When using a common automotive test lamp to test relays and their circuits, contact with terminal 85 ***(Figure 12-6, (2))*** *will cause the relay to engage. This will result in starter engagement or fuel pump operation.*

Relays

Relays control power to the starter, fuel feed pump and main system power.

The winding ground circuit (terminal 85) of all relays is controlled by the ECU.

Start Relay (K1)

12 V is supplied by fuse F5 to winding terminal 86. When the start signal from the key switch is seen at ECU terminal 224, the winding ground circuit (terminal 85) is completed at ECU terminal 234 (assuming neutral is sensed at ECU terminal 250) and current passes through terminals 87 and 30 to energize the starter motor.

Results of Failed Relay

Failure of the relay results in inability to start engine

If this relay is defective, no P-codes will be generated.

Note: Viewed from bottom of connector.

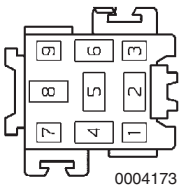

Figure 12-6

1 – Pin 2 - terminal 87 (not used)
2 – Pin 4 - terminal 85
3 – Pin 5 - terminal 87
4 – Pin 6 - terminal 30
5 – Pin 8 - terminal 86

Main Relay (K2)

12 V is supplied directly to terminal 30 **(Figure 12-7, (4)**. An internal connection connects one end of the winding to terminal 30. When the key switch is turned ON, a 12 V signal is sent to ECU terminal 27. The ECU then completes the winding ground circuit (terminal 85) through ECU terminal 232.

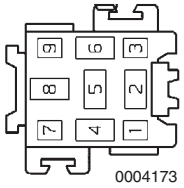

Figure 12-7

1 – Pin 2 - terminal 87
2 – Pin 4 - terminal 85
3 – Pin 5 - terminal 87
4 – Pin 6 - terminal 30

Results of Failed Relay

Failure of the relay results in loss of power to all systems.

If this relay is defective, the following P-codes may be generated.

- P0689 - short circuit to ground
- P0690 - short circuit to B+

Note: Viewed from bottom of connector.

Fuel Pump Relay (K3)

12 V is supplied by fuse F3 to terminal 30 **(Figure 12-8, (4)**. An internal connection connects one end of the winding to terminal 30. When the key switch is turned to ON, a 12 V signal is sent to ECU terminal 87. The ECU then completes the winding ground circuit (terminal 85) through ECU terminal 220.

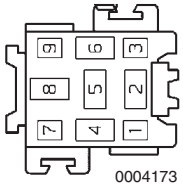

Figure 12-8

1 – Pin 2 - terminal 87
2 – Pin 4 - terminal 85
3 – Pin 5 - terminal 87 (not used)
4 – Pin 6 - terminal 30

Results of Failed Relay

Failure of the relay results in fuel supply pump will not operate.

If this relay is defective, the following P-codes may be generated.

- P0230 - power interruption - defective fuse (F3) or relay or connections
- P0231 - regulation short circuit to Ground
- P0232 - regulation short circuit to B+

Note: Viewed from bottom of connector.

Oil Pressure Sensor

This sensor measures the engine oil pressure and sends the signal to the helm gauge. It is a pressure sensitive variable resistor. It is mounted in the front heat exchanger bracket and is connected to the engine block via a pressure line.

The sensor output is not used by the ECU.

Results of Failed Sensor

Failure of the sensor results in loss of engine oil pressure monitoring.

If this sensor is defective, no P-codes will be generated.

Test Values

- Resistance at 0 bar (0 psi): 10 +3 to -5 ohm
- Resistance at 2 bar (29 psi): 52 ±4 ohm
- Resistance at 4 bar (58 psi): 88 ±4 ohm
- Resistance at 6 bar (87 psi): 124 ±5 ohm

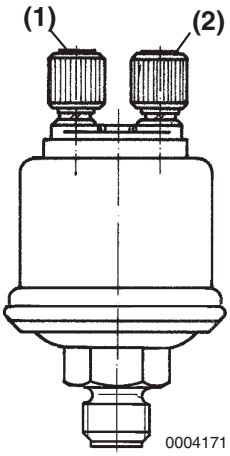

Figure 12-9

1 – Engine Harness
2 – Engine Harness

Note: Polarity of wire connections is not important. Either wire can be connected to either terminal.

Fuel Injector

The fuel injectors are continuously supplied with high-pressure fuel and are electronically triggered by the ECU. The ECU controls the frequency, duration and timing of injection.

Results of Failed Injector

If an injector-related failure occurs, the following P-codes may be generated:

- P2049 - Short circuit on high side to ground or B+
  - 4BY2 - engine will stop
  - 6BY2 - engine may continue to run
- P2052 - Short circuit on high side to ground or B+
  - Engine may continue to run
- P0261, P0264, P0267, P0270, P0273, P0276 - short circuit to B+
- P0201, P0202, P0203, P0204, P0205, P0206, - no connection / short to ground

Note: A minimum of two injectors must function for the 4BY2 to run. A minimum of three injectors must function for the 6BY2 to run.

Test Values

Resistance at 20°C (68°F): 0.4 ohm

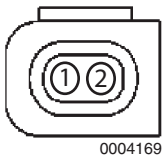

Figure 12-10

1 – Pin 1 - Low Side
2 – Pin 2 - High Side

Engine Coolant Temperature Sensor

This sensor measures the temperature of the engine coolant. It is an NTC (negative temperature coefficient) type sensor. It is mounted in the cylinder head.

The sensor output is used by the ECU for:

- Calculation of the injection rate
- Regulating glow plug on-time
- Regulating engine low idle speed
- Regulating fuel rail pressure

Results of Failed Sensor

Failure of the sensor results in destruction of the sensor if short circuit to B+.

If this sensor is defective, the following P-codes may be generated:

- P0117 - short circuit to B+
- P0118 - No connection / short to ground

Test Values

- Resistance at 20°C (68°F): 2.5 to 3.0 k-ohm
- Resistance at 50°C (122°F): 0.7 to 0.9 k-ohm
- Resistance at 100°C (212°F): 0.12 to 0.17 k-ohm

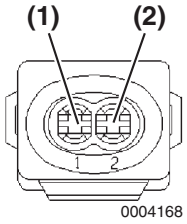

Figure 12-11

1 – Pin 1 - Out (ECU pin 182)
2 – Pin 2 - Ground (ECU pin 17)

High-Pressure Fuel Regulator

This regulator valve controls the fuel pressure in the fuel rail. The ECU uses values supplied by several sensors and sends corresponding signals to control fuel pressure. It is mounted on the rear of the fuel rail.

Results of Failed Valve

Failure of the valve results in:

- Limitation of the injection rate (*See Engine Faults and Torque Limitations on page 13-3.*)
- Engine may fail to start

NOTICE: If a fault code is generated, check the fuel supply and delivery first.

If this valve is defective, the following P-codes may be generated:

- P0088 - fuel rail pressure out of range
- P0087 - fuel rail pressure out of range
- P0089 - fuel rail pressure out of range
- P0090 - not connected / valve failure
- P0091 - short circuit to ground / valve failure
- P0092 - short circuit to B+ / valve failure

Test Values

- Resistance at 20°C (68°F): 4.0 ohm
- At 1800 bar (26 107 psi) (relative): 4.5 V

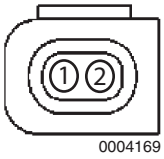

Figure 12-12

1 – Pin 1 - 12V (Fuse F5)
2 – Pin 2 - Out (ECU pin 172)

Water-in-Fuel Sensor

This sensor monitors fuel for the presence of water and sends the signal to the helm display. If water is present, the resistance between the probes drops below the threshold of 47 k-ohms and results in a warning at the helm. It is mounted on the bottom of the fuel filter / water separator.

The sensor output is not used by the ECU.

Results of Failed Sensor

Failure of the sensor results in loss of water-in-fuel monitoring

If this sensor is defective, no P-codes will be generated.

Test Values

- No test values are available for this device

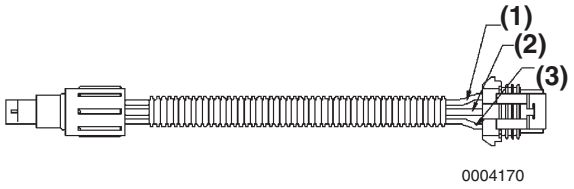

Figure 12-13

1 – Pin A - Black Wire
2 – Pin B - Red Wire
3 – Pin C - Yellow Wire

Crankshaft Speed Sensor

This sensor measures the speed of the crankshaft. This value is compared with the camshaft speed by the ECU. It is mounted on the rear crankshaft seal housing at the rear of the engine. The ECU supplies 5V and ground.

The sensor signal is used by the ECU for:

- The calculation of the actual rotations of the engine
- The check of the starting conditions
- The calculation of the injection rate at the starting procedure
- The control of the injection start
- The calculation of the limitation of the injection rate
- The calculation if an external regulation of the injection rate is necessary
- The control of the glow plugs
- The control of the injection rate
- The control of the rail pressure
- The control at idle speed

Results of Failed Sensor

Failure of the sensor results in:

- Inability to start the engine. Engine cannot run without this sensor.

If this sensor is defective, the following P-codes may be generated:

- P0344 - disagreement between camshaft speed sensor and crankshaft speed sensor
- P2617 - no connection / short circuit

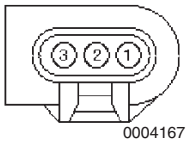

Figure 12-14

1 – Pin 1 - 5V (ECU pin 139)
2 – Pin 2 - F_out (ECU pin 187)
3 – Pin 3 - Ground (ECU pin 115)

Glow Plug / Control Unit

The System

The glow plug control system consists of the following components:

- ECU
- Electronic glow plug control unit
- Glow plugs
- Bit-serial data (BSD) interface and electrical cables

The following information is important to understand the glow plug control:

- Glow plugs are designed for operating voltage between 5.3 and 7.8 volts
- Glow plugs are fast-start type
- Glow plug regulation is pulse-width modulated
- The electronic glow plug control unit replaces the more commonly used relay
- The implementation of a function for emergency cases
- Each circuit can be individually diagnosed

Function

The glow plug control unit communicates with the ECU via the bit-serial data interface. The heating output is calculated by the ECU according to the coolant temperature and the system voltage. Engine speed and injection rate affect the rate at which the glow plugs are switched on and off.

Preheating

When the coolant temperature is above 25°C (77°F), the unit will operate for 0.5 seconds. As temperatures decrease below 25°C (77°F), the on-time will increase up to a maximum of 2.7 seconds, depending on temperature.

If the key switch is turned to ON but the engine is not started immediately, the controller will continue to implement the glowing process for 10 seconds.

Post-Heating

Once the engine is started and the coolant temperature increases above 30°C (86°F), post heating will occur to improve idle and reduce emissions.

Results of Component Failure

Component failure results in:

- P0671 - cylinder 1 glow plug circuit - not connected / short circuit
- P0672 - cylinder 2 glow plug circuit - not connected / short circuit
- P0673 - cylinder 3 glow plug circuit - not connected / short circuit
- P0674 - cylinder 4 glow plug circuit - not connected / short circuit
- P0675 - cylinder 5 glow plug circuit - not connected / short circuit
- P0676 - cylinder 6 glow plug circuit - not connected / short circuit
- P0670 - Glow control unit - component failure / short circuit / over-current
- P0380 - Glow control relay actuator - not connected / short circuit

Test Values

Glow plug resistance at 20°C (68°F): 0.5 ohm

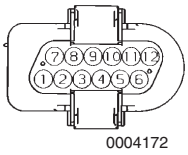

Figure 12-15

1 – Pin 1 - Glow plug No. 1
2 – Pin 2 - Glow plug No. 2
3 – Pin 3 - Glow plug No. 3
4 – Pin 4 - Glow plug No. 4
5 – Pin 5 - Glow plug No. 5
6 – Pin 6 - Glow plug No. 6
7 – Pin 12 - Signal of measured value (ECU pin 168)
8 – Pin 6 - Ground (ECU pin 170)
9 – Pin 5 - 12V (Fuse F5)

Connector X3

The control signals travel via connector X3. If the glow control unit is not installed, connector X3 must be protected by a cover.

Fuel Temperature Sensor

This sensor measures the temperature of the fuel being supplied to the high-pressure fuel pump. It is an NTC (negative temperature coefficient) type sensor. It is mounted in the fuel line just upstream from the high-pressure fuel pump.

The sensor output is used by the ECU for:

- Protecting the engine from overheating
- Calculation of the injection rate
- Calculation of the rate of the fuel pump

Results of Failed Sensor

Failure of the sensor results in:

- Limitation of the injection rate (*See Engine Faults and Torque Limitations on page 13-3.*)
- Destruction of the sensor if short circuit to B+

If this sensor is defective, the following P-codes may be generated:

- P0182 - short circuit to B+
- P0183 - No connection / short to ground

Test Values

- Resistance at -20°C (-4°F): 20 to 24 k-ohm
- Resistance at 0°C (32°F): 16.5 to 8 k-ohm
- Resistance at 20°C (68°F): 2.4 to 3.2 k-ohm
- Resistance at 120°C (248°F): 0.5 to 0.6 k-ohm

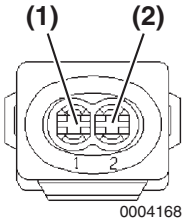

Figure 12-16

1 – Pin 1 - Ground (ECU pin 111)
2 – Pin 2 - Out (ECU pin 183)

Fuel Volume Regulator

This component controls fuel volume in the fuel injection system. The ECU uses values supplied by several sensors and sends corresponding signals to control fuel pressure. It is mounted on the rear of the high-pressure fuel pump.

Results of Failed Regulator

Failure of the regulator results in:

- Limitation of the injection rate (*See Engine Faults and Torque Limitations on page 13-3.*)
- All high-pressure fuel system control is provided by the fuel rail pressure control valve.

  NOTICE: If a fault code is generated, check the fuel supply and delivery first.

If this regulator is defective, the following P-codes may be generated:

- P0001 - not connected
- P0003 - short circuit to ground
- P0004 - short circuit to B+
- P0088 - fuel rail pressure out of range

- P0087 - fuel rail pressure out of range
- P0089 - fuel rail pressure out of range
- P0090 - fuel rail pressure out of range

Test Values

Resistance at 20°C (68°F): 3.0 ohm

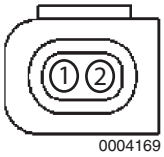

Figure 12-17

1 – Pin 1 - 12V (Fuse F5)
2 – Pin 2 - Out (ECU pin 171)

Charge Air Temperature Sensor

This sensor measures the temperature of the compressed air coming from the turbocharger. It is mounted on the charge air pipe.

Results of Failed Sensor

Failure of the sensor results in:

- Limitation of the injection rate (*See Engine Faults and Torque Limitations on page 13-3.*)
- Reduction in rated power
- Destruction of the sensor if short circuit to B+

If this sensor is defective, the following P-codes may be generated:

- P0112 - Charge air temperature over 125°C (257°F)
- P0113 - Charge air temperature under -20°C (-4°F)

Test Values

- Resistance at -20°C (-4°F): 40 to 48 k-ohm
- Resistance at 0°C (32°F): 14.5 to 16.5 k-ohm
- Resistance at 20°C (68°F): 6.0 to 6.5 k-ohm
- Resistance at 120°C (248°F): 0.18 to 0.22 k-ohm

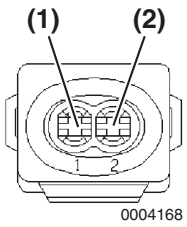

Figure 12-18

1 – Pin 1 - Out (ECU pin 157)
2 – Pin 2 - Ground (ECU pin 16)

Charge Air Pressure Sensor

This sensor measures the charge air pressure as absolute value (charge air pressure + atmospheric pressure). It is mounted on the charge air pipe and is sealed by an O-ring.

Results of Failed Sensor

Failure of the sensor results in limitation of the injection rate (*See Engine Faults and Torque Limitations on page 13-3.*)

If this sensor is defective, the following P-codes may be generated:

- P0238 - Boost pressure at 4 bar (58 psi) (absolute)
- P0237 - Boost pressure under 0.5 bar (7.3 psi) (absolute)
- P0236 - plausibility check fail

Test Values

Note: Pressure is kPa (absolute)

- Relation to supply voltage:
  Vout = (2/875 x pressure value - 1/70) x supply voltage

Examples:

- At 5V supply voltage and atmospheric pressure (98 kPa), Vout is approximately 1.04 V
- At 5V supply voltage and 200 kPa (absolute), Vout is approximately 2.21 V

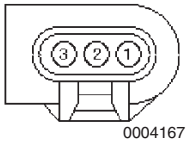

Figure 12-19

1 – Pin 1 - 5V (ECU pin 139)
2 – Pin 2 - Ground (ECU pin 180)
3 – Pin 3 - Out (ECU pin 154)

High-Pressure Fuel Rail Pressure Sensor

This sensor measures the fuel pressure in the fuel rail. The values are used by the ECU for fuel quantity regulation and fuel pressure regulation. It is mounted on the front of the fuel rail. The ECU supplies 5V and ground.

Results of Failed Sensor

Failure of the sensor results in:

- Default value in the ECU
- Limitation of the injection rate (*See Engine Faults and Torque Limitations on page 13-3*.)

  NOTICE: If a fault code is generated, check the fuel supply and delivery first.

If this sensor is defective, the following P-codes may be generated:

- P0088 - fuel rail pressure out of range
- P0087 - fuel rail pressure out of range
- P0089 - fuel rail pressure out of range
- P0090 - fuel rail pressure out of range
- P0193 - no connection / short circuit B+
- P0192 - short circuit to ground

Test Values

- At 0 bar (0 psi) (relative): 0.5 V
- At 1800 bar (26107 psi) (relative): 4.5 V

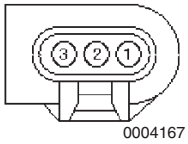

Figure 12-20

1 – Pin 1 - Ground (ECU pin 178)
2 – Pin 2 - Out (ECU pin 156)
3 – Pin 3 - 5V (ECU pin 130)

Camshaft Speed Sensor

This sensor measures the speed of the camshaft. This value is compared with the crankshaft speed by the ECU. It is mounted on the cylinder head cover near the front of the engine.

Results of Failed Sensor

Failure of the sensor results in:

- Difficulty starting and reduction in power (*See Engine Faults and Torque Limitations on page 13-3*.)

If this sensor is defective, the following P-codes may be generated:

- P0344 - disagreement between camshaft speed sensor and crankshaft speed sensor
- P2614 - no connection / short circuit

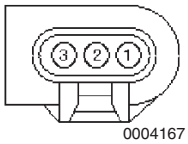

Figure 12-21

1 – Pin 1 - 12V (Fuse F5)
2 – Pin 2 - F_out (ECU pin 187)
3 – Pin 3 - Ground (ECU pin 115)

Throttle Position Sensor

This sensor is located in the remote control head. It communicates with the ECU with varying signals based on throttle position. The ECU then calculates the position of the throttle lever in percent, and adjusts fuel injection to adjust engine speed. The ECU supplies 5V and ground connections.

Results of Failed Sensor

Failure of the sensor results in:

- One failed sensor - limitation of the injection rate (*See Engine Faults and Torque Limitations on page 13-3.*)
- Two failed sensors - engine low idle will increase

If this sensor is defective, the following P-codes may be generated:

- Sensor 1+2 (PWG):
  - P0122 - both throttle signals are missing / short circuit to ground
  - P0222 - both throttle signals are missing / short circuit to ground
- Sensor 1 only (PWG):
  - P0123 - throttle signal 1 short circuit to B+
  - P0122 - throttle signal 1 is missing / short circuit to ground
- Sensor 2 only (PGS):
  - P0223 - throttle signal 2 short circuit to B+
  - P0222 - throttle signal 2 is missing / short circuit to ground

Test Values

- At 0 bar (0 psi) (relative) - 0.5 V
- At 1800 bar (26 107 psi) (relative) - 4.5 V

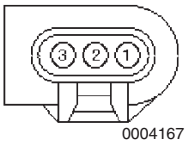

Figure 12-22

1 – Pin 1 - Ground (ECU pin 178)
2 – Pin 2 - Out (ECU pin 156)
3 – Pin 3 - 5V (ECU pin 130)

Voltage Set-Point Values

Sensor	Low Idle	High Idle
PWG 1	0.70 to 0.80	3.65 to 4.10
PWG 2	0.31 to 0.43	1.83 to 2.04

REPAIR

Replace Engine Control Unit (ECU)

NOTICE: The ECU may be damaged if it is powered when you unplug it. Turn the key switch to OFF and disconnect the battery before disconnecting the ECU from the electrical harness.

1. Disconnect the electrical panel power cables from the battery, negative (-) cable first.
2. Remove the electrical panel cover.
3. Disconnect two electrical connectors **(Figure 12-23, (1))** from ECU.

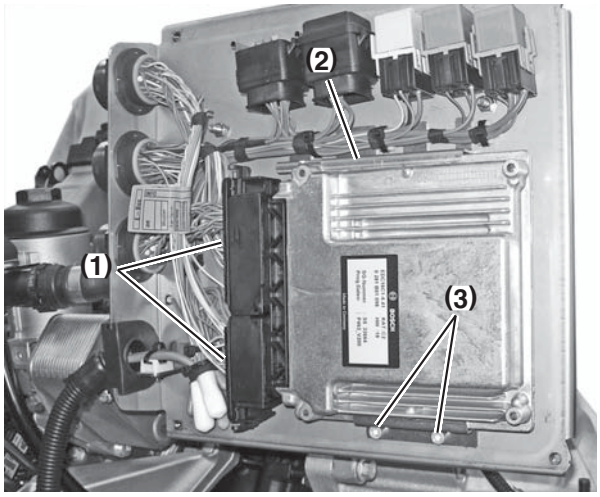

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Figure 12-23

4. Remove screws securing the upper ECU retainer **(Figure 12-23, (2))**.
5. Loosen the lower attaching screws **(Figure 12-23, (3))** and remove the ECU.
6. Install the new control unit and tighten the screws.
7. Connect the electrical connectors to the ECU.
8. Connect the electrical panel power cables to the battery.
9. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace Coolant Temperature Sensor

1. Drain engine coolant. *See Drain and Fill Closed Cooling System on page 7-10*.
2. Remove intake manifold. *See Intake Manifold on page 5-66*.
3. Remove electrical connector **(Figure 12-24, (1))** from sensor.

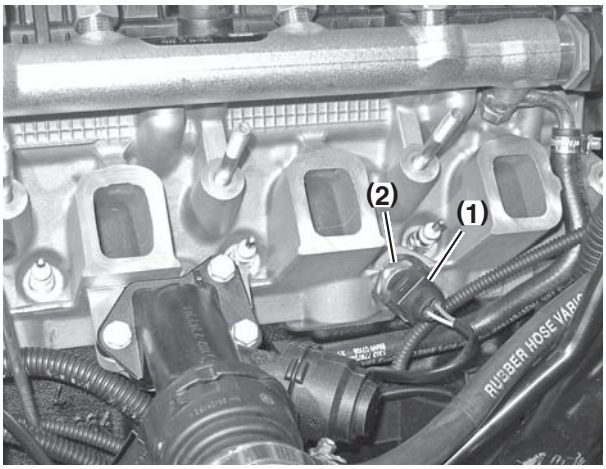

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Figure 12-24

4. Remove sensor **(Figure 12-24, (2))** from cylinder head.
5. Installation is in reverse of removal.
6. Tighten sensor to 13.4 N·m (119 in.-lb).
7. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace Charge Air Pressure Sensor

1. Disconnect battery negative (-) cable.
2. Disconnect electrical connector **(Figure 12-25, (1))**.

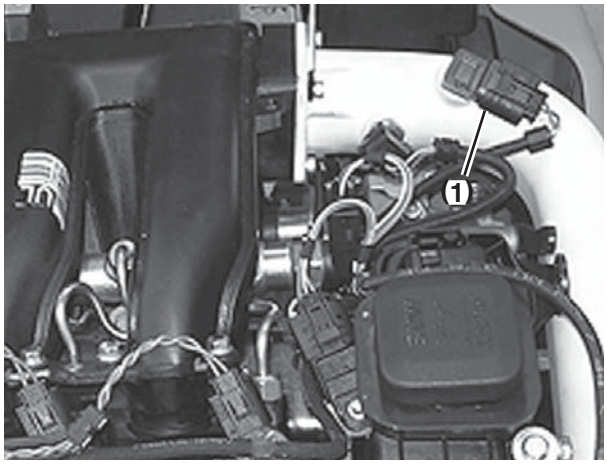


Figure 12-25

3. Pull sensor out of charge air pipe.
4. Install new sealing ring **(Figure 12-26, (1))** before installing sensor **(Figure 12-26, (2))**.

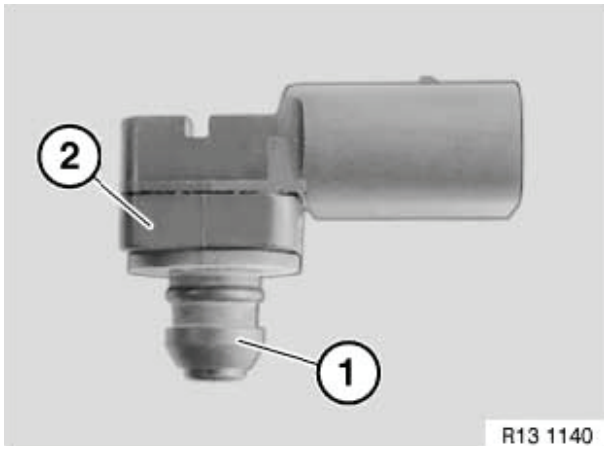


Figure 12-26

5. Install sensor and connect electrical connector.
6. Connect battery negative (-) cable.
7. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace Charge Air Temperature Sensor

1. Disconnect battery negative (-) cable.
2. Disconnect electrical connector **(Figure 12-27, (1))**.

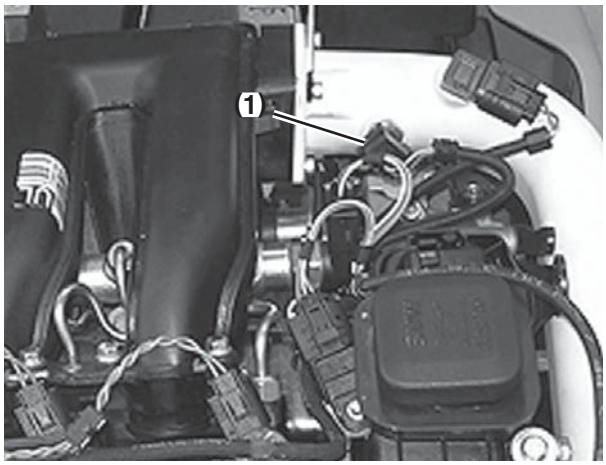


Figure 12-27

3. Remove sensor from charge air pipe.
4. Replace sealing ring before installing sensor.
5. Install sensor and tighten to 7 N·m (62 in.-lb.). Connect electrical connector.
6. Connect battery negative (-) cable.
7. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace Crankshaft Sensor

1. Disconnect battery negative (-) cable.
2. Remove starter motor. *See Remove and Install Starter Motor on page 10-5.*
3. Disconnect harness connector from crankshaft sensor connector **(Figure 12-28, (1))**.

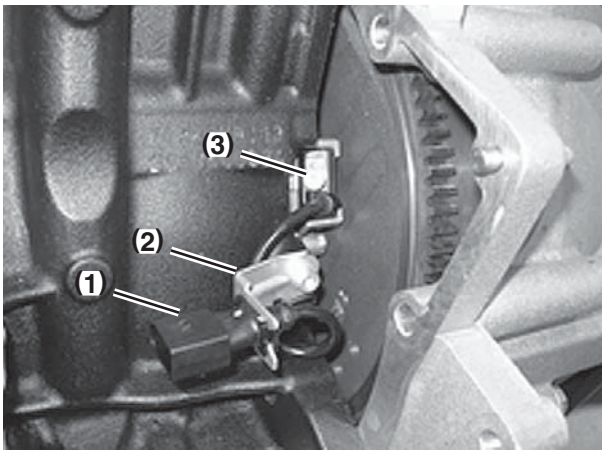


Figure 12-28

4. Remove connector from mounting bracket **(Figure 12-28, (2))**.
5. Remove screw **(Figure 12-28, (3))** and remove sensor from engine.
6. Install sensor and tighten screw **(Figure 12-28, (3))** to 9.5 N·m (84 in.-lb).
7. Install connector in bracket and connect engine harness.
8. Install starter motor. *See Remove and Install Starter Motor on page 10-5*.
9. Connect battery negative (-) cable.
10. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace Camshaft Sensor

1. Disconnect harness connector **(Figure 12-29, (1))**.

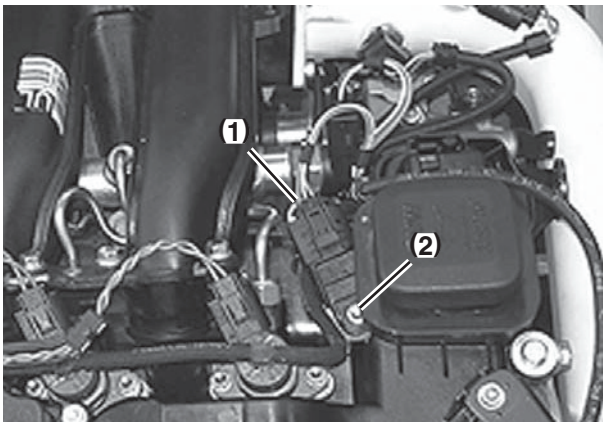


Figure 12-29

2. Remove screw **(Figure 12-29, (2))** and remove camshaft sensor.
3. Check condition of seal **(Figure 12-30, (1))** and replace if necessary.

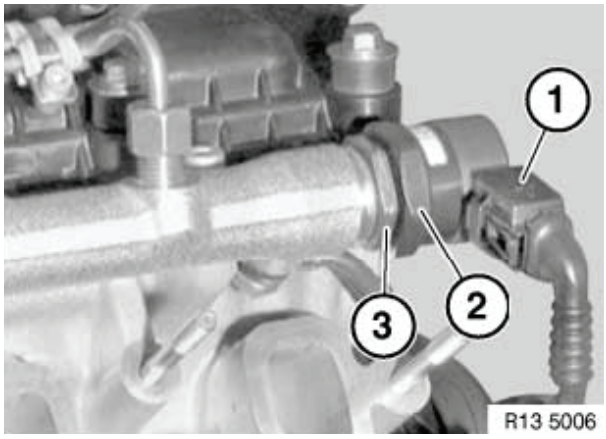
Figure 12-30

4. Install sensor and tighten screw to 2.3 N·m (20 in.-lb).
5. Connect harness connector.
6. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace High-Pressure Fuel Regulator

NOTICE: When working on the oil, coolant or fuel systems, you must protect the alternator from contamination. Cover alternator with suitable materials. Failure to comply may result in an alternator failure.

1. Disconnect battery negative (-) cable.
2. Shut off all valves in the fuel supply system. *NOTICE: Immediately cap or plug all openings to prevent contamination of system.*
3. Remove intake manifold and cover open ports in cylinder head to prevent foreign objects from entering engine. *See Intake Manifold on page 5-66*.
4. Disconnect electrical connector **(Figure 12-31, (1))**.



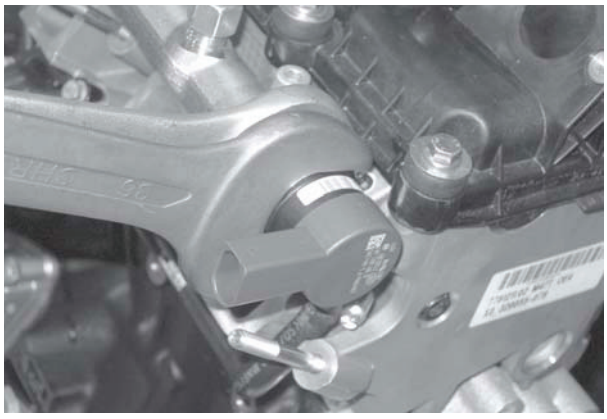


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Figure 12-31

5. Hold sensor hex **(Figure 12-31, (2))** with wrench and loosen retaining nut **(Figure 12-31, (3))**.
6. Remove regulator from fuel rail.
7. Install new regulator in fuel rail. Ensure orientation is correct. *NOTICE: The high-pressure fuel regulator can be installed ONLY once. When installing a new regulator, ensure it is correctly positioned before tightening to specification.*
8. Hold hex of regulator and tighten retaining nut to 82.5 N·m (61 ft-lb).
9. Connect electrical connector.
10. Install intake manifold. *See Intake Manifold on page 5-66*.
11. Open all fuel supply valves.
12. Connect battery negative (-) cable.
13. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
14. Start engine and check for fuel leaks.
15. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace High-Pressure Fuel Rail Pressure Sensor

NOTICE: When working on the oil, coolant or fuel systems, you must protect the alternator from contamination. Cover alternator with suitable materials. Failure to comply may result in an alternator failure.

1. Disconnect battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Disconnect electrical connector from sensor **(Figure 12-32, (1))**.

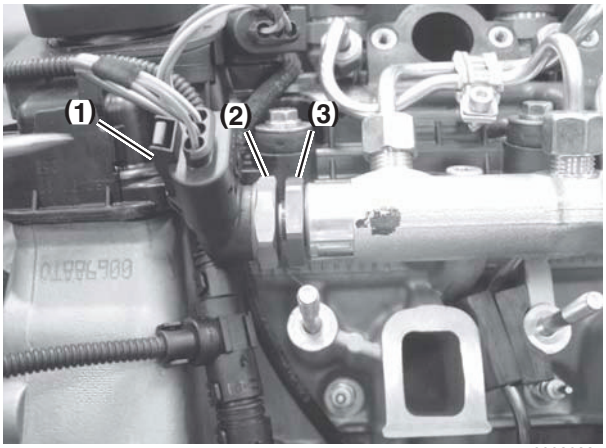

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Figure 12-32

4. Hold sensor hex **(Figure 12-32, (2))** with wrench and loosen retaining nut **(Figure 12-32, (3))**.
5. Remove sensor from fuel rail.
6. Inspect threads of sensor. Replace sensor if damage is evident.
7. Inspect the O-ring and replace if necessary.
8. Apply a light coating of petroleum jelly to O-ring.
9. Install sensor in fuel rail. Ensure orientation is correct. *NOTICE: The high-pressure fuel sensor can be installed a maximum of ten times. After ten installations, a new sensor must be installed.*
10. Hold hex of sensor and tighten retaining nut to 70 N·m (52 ft-lb).
11. Connect electrical connector to sensor.
12. Open all fuel supply valves.
13. Connect battery negative (-) cable.
14. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
15. Start engine and check for fuel leaks.
16. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace Fuel Temperature Sensor

1. Disconnect the battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Remove intake manifold. *See Intake Manifold on page 5-66*.
4. Disconnect electrical connector from sensor **(Figure 12-33, (1))**.

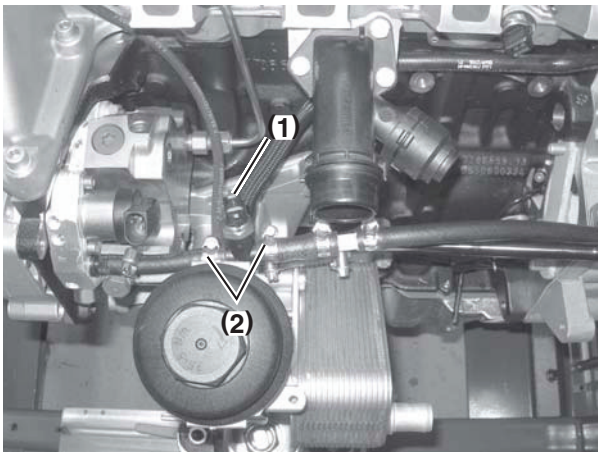

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Figure 12-33

5. Loosen hose clamps **(Figure 12-33, (2))** and remove hoses from sensor.
6. Installation is in the reverse of removal.
7. Install intake manifold. *See Intake Manifold on page 5-66.*
8. Open all fuel supply valves.
9. Connect the battery negative (-) cable.
10. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
11. Start engine and check for fuel leaks.

Replace Fuel Volume Regulator

NOTICE: When working on the oil, coolant or fuel systems, you must protect the alternator from contamination. Cover alternator with suitable materials. Failure to comply may result in an alternator failure.

1. Disconnect battery negative (-) cable.
2. Shut off all valves in the fuel supply system.
3. Remove intake manifold and cover intake ports to prevent foreign objects from entering engine. *See Intake Manifold on page 5-66.*
4. Thoroughly clean high-pressure fuel pump.
5. Disconnect electrical connector **(Figure 12-34, (1))**. *NOTICE: Immediately cap or plug all openings to prevent contamination of system*

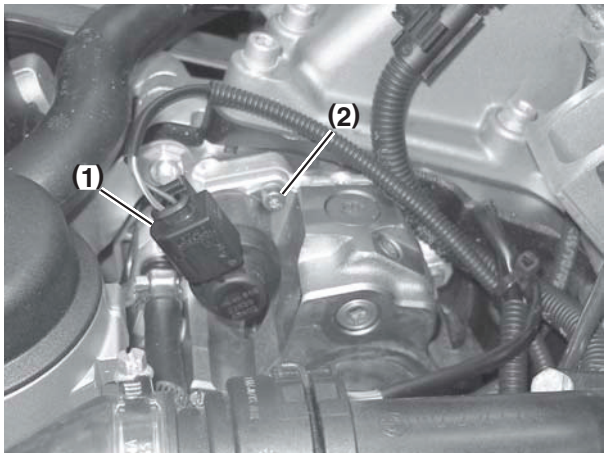

Figure 12-34

6. Remove three screws **(Figure 12-34, (2))**.
7. Remove fuel volume regulator.
8. Installation is done in the reverse of removal. Tighten screws to 6.6 N·m (58 in.-lb).
9. Open all fuel supply valves.
10. Connect battery negative (-) cable.
11. Bleed fuel system. *See Bleed the Fuel System on page 6-22.*
12. Start engine and check for fuel leaks.
13. Check and delete any trouble codes that are registered in the ECU after the work has been completed.

Replace Oil Pressure Sensor

1. Disconnect wires **(Figure 12-35, (1))**.

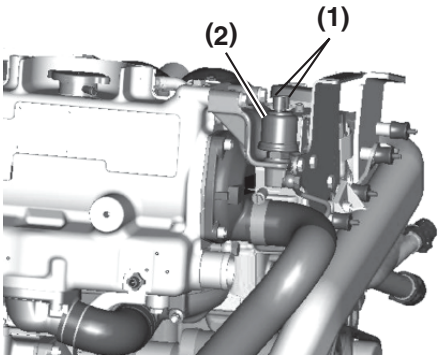

Figure 12-35

2. Remove oil pressure sensor **(Figure 12-35, (2))** from heat exchanger bracket.
3. Install new O-ring on oil pressure sensor stem.
4. Install and tighten oil pressure sensor to 23 N·m (204 in.-lb).

Note: Polarity of wire connections is not important. Either wire can be connected to either terminal.

5. Connect wires.

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Section 13

TROUBLESHOOTING

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SAFETY PRECAUTIONS

Before servicing the engine, review the *Safety Section on page 2-1*.

INTRODUCTION

This section of the *Service Manual* contains information and diagnostic troubleshooting charts to accurately diagnose engine, starter or alternator problems.

ENGINE FAULTS AND TORQUE LIMITATIONS

Torque Limitation for Failed Sensors Mode

This limitation occurs only if a fault is active. It will be displayed on the display-alarm and a P-Code will be saved in the system. The alarm consists of an audible alarm, a warning light and a check engine light on the digital display. The codes can be read with a diagnostic tester. A substitute torque map is activated and torque reduction occurs. This fault occurs if there is an electrical problem in the respective sensor or actuator.

The following failures activate this mode:

- Coolant temperature sensor
- Camshaft sensor
- Boost pressure sensor
- Rail pressure system
- Throttle signal missing
- Sensor supply voltage
- Metering unit failure
- Fuel injector failure
- Rail pressure governor deviation

Torque Limitation for Smoke Limitation Mode

In the case of this limitation, there are two possible situations:

If an electronic fault occurs, it will be displayed on the display-alarm and a P-Code is saved in the system. These codes can be read with a diagnostic tester. A substitute map is activated and torque reduction occurs as in *Torque Limitation for Failed Sensors Mode* on this page.

However, if the boost pressure is too low or the intake air temperature is too high, this limitation is activated for the prevention of black smoke and torque reduction also occurs. In this case there is not an alarm on the display and no P-Code appears.

The following failures activate this mode:

- Intake air temperature too high
- Boost pressure too low
- Air intake system damage (e.g., hole in intake air pipe)

Torque Reduction Chart Based on Boost Pressures

Using the boost pressure on the display, it can be determined if the engine is in this mode and approximately where in the map it is. The present relative boost pressure is displayed on the instrument display.

Note: Relative boost pressure = absolute boost pressure - 1000 mbar

Engine speed [rpm]	4000 rpm		2000 rpm	
Torque	Torque [N·m]	Boost pressure abs (mbar)	Torque [N·m]	Boost pressure abs (mbar)
Engine	**4BY2-150**			
100% (normal operation)	265	1600	295	700
90%	240	700	265	400
80%	215	600	240	250
70%	185	300	205	100
60%	160	150	180	0
50%	135	0	15	0

Engine	4BY2-180			
100% (normal operation)	315	1700	315	900
90%	285	1050	285	500
80%	250	900	250	350
70%	220	600	220	200
60%	190	300	190	50
50%	160	100	160	0

Engine	6BY2-220			
100% (normal operation)	390	2000	450	1100
90%	350	1400	405	700
80%	315	1100	360	500
70%	275	800	315	350
60%	235	500	270	150
50%	195	250	225	0

Engine	6BY2-260			
100% (normal operation)	450	2000	450	1100
90%	405	1700	405	700
80%	360	1400	360	500
70%	315	1150	315	300
60%	270	700	270	100
50%	225	400	225	0

Torque Reduction Chart Based on Intake Air Temperature

The intake air temperature will limit the torque at 3000 rpm if the air temperature is increasing.

Engine speed	2000 rpm		2000 rpm	
Torque	Torque [N·m]	Intake air temperature [°C]	Torque [N·m]	Intake air temperature [°C]
Engine	4BY2-150		4BY2-180	
100% (normal operation)	295	30-50	315	30-50
90%	265	60-90	285	60-90
80%	240	100-130	250	100-130

Engine	6BY2-220		6BY2-260	
100% (normal operation)	450	30-50	450	30-50
90%	405	60-90	405	60-90
80%	360	100-130	360	100-130

Torque Limitation for Overheat Protection Mode

In the case of this mode, there are two possible situations:

If an electronic fault occurs, it will be displayed on the display-alarm and a P-Code is saved in the system. These codes can be read with a diagnostic tester. A substitute value (fixed value until fault disappears) is activated (coolant temp=110, fuel temp=90) and a torque reduction occurs. In this case, the coolant temperature is also limited by the torque limit which is described in *Torque Limitation for Failed Sensors Mode on page 13-3*. The substitute value of the fuel temperature is fixed at 90°C (194°F)and that sets a limitation of approximately 75% from the maximum torque **(Figure 13-1)**.

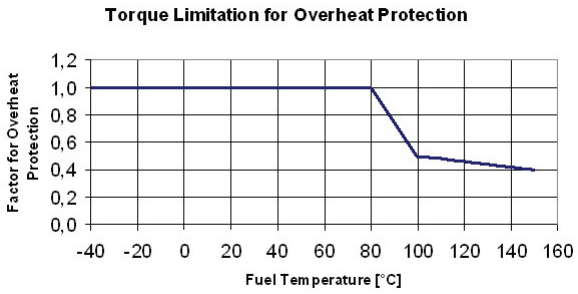

Figure 13-1

If the coolant temperature is over 108°C (226°F), an audible alarm sounds and engine overheat is displayed on the instrument panel display. At 120°C (248°F) the torque limitation is 30% **(Figure 13-2)**. If the fuel temperature is too high (over 90°C [194°F]), this limitation is also active for the overheat prevention as shown in **Figure 13-1**. From 100 to 140°C (212 to 284°F) the torque limit is about 40% of the maximum torque. In this case, there is not an alarm on the instrument panel display. In both cases, no P-Code appears.

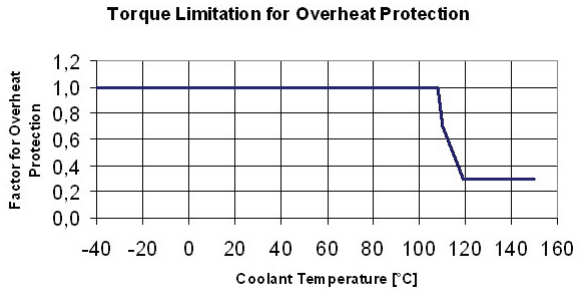

Figure 13-2

TROUBLESHOOTING CHART

Starting Trouble

Problem / Symptom	Cause	Action
Engine Will Not Crank	Discharged battery	Charge / replace battery
	Blown fuse	Replace fuse
	Defective starter motor	Replace starter motor
	Loose wiring connections	Tighten connections
	Electrical panel power circuit breaker tripped	Reset circuit breaker
Engine Cranks but Will Not Start	No fuel to engine	Check fuel level in tank
		Ensure all valves are on
	No fuel to cylinders	Clean or replace fuel filter / water separator
		Replace clogged fine filter
		Bleed fuel system
		Blown fuse - F3, F4, F5
		ECU / software problem
	Low ambient temperature	Install block heater
	Oil viscosity too high	Replace with correct viscosity oil for operating conditions

Exhaust Color

Problem / Symptom	Cause	Action
White Smoke	Cold engine	Allow engine to warm to operating temperature
		Defective thermostat
	Incorrect fuel	Replace fuel with correct type
	Defective (leaking) fuel injector	Test / replace fuel injector
	Injection timing is incorrect	ECU / software problem
White Smoke with Water Vapor	Leaking cylinder head gasket	Replace
	Leaking charge air cooler	Repair as necessary
	Cracked cylinder head	
	Cracked cylinder	
Blue Smoke	Worn piston rings / cylinders	Repair as necessary
	Oil leak in turbocharger (oil present in intake manifold)	
	Damaged piston cooling nozzles	

Problem / Symptom	Cause	Action
Black Smoke Under Load	Clogged air filter	Replace air filter
	Incorrect valve timing	Check / correct camshaft installation
	Defective (leaking) fuel injector	Test / replace fuel injector
	Low charge air pressure	Replace air filter
		Damaged turbocharger
	Excessive exhaust backpressure	Correct as necessary
	Plugged intake port(s)	Repair as necessary

Vibration - Drive Disengaged

Problem / Symptom	Cause	Action
Rough at All Engine Speeds	Air in fuel system	Bleed fuel system
	Faulty fuel injector	Replace as necessary
	Leaking cylinder head gasket	Replace
	Damaged intake or exhaust valves	Repair as necessary
	Incorrect injection pressure	Check / replace fuel pressure regulator
		Check / replace high-pressure fuel pump
Vibration Increases with Engine Speed (Stern Drive Models)	Worn or damaged universal joints	Replace universal joints

Vibration - Drive Engaged

Problem / Symptom	Cause	Action
Rough at All Speeds	Engine and propeller shaft misaligned	Check and adjust
	Leaking cylinder head gasket	Replace
	Bent propeller shaft	Replace as necessary
Rough at Higher Speeds	Bent propeller	Replace as necessary
	Slipping clutch / clutch dog	Repair as necessary
	Incorrect injection pressure	Check / replace fuel pressure regulator
		Check / replace high-pressure fuel pump

Engine Knocks

Problem / Symptom	Cause	Action
Excess Fuel Injected	Defective fuel injector	Check / replace fuel injector
	High fuel injection pressure	Check / replace fuel pressure regulator / sensor
Noise Changes with Engine Load	Incorrect or poor quality fuel	Drain and refill tank
	Worn crankshaft / bearings	Repair as necessary
	Broken piston / rings	Repair as necessary

Low Power Output

Problem / Symptom	Cause	Action
Miscellaneous	Clogged intake air filter	Replace
	Leaking cylinder head gasket	Replace
	Damaged turbocharger	Replace
	Incorrect propeller	Replace
	Excessive exhaust backpressure	Remove obstruction
Fuel	Plugged fuel filter(s)	Replace as necessary
	Faulty fuel supply pump	Replace
Low Fuel Injection Pressure	Defective fuel pressure regulator / sensor	Check / replace
	Worn high-pressure fuel pump	Check / replace
	Injection timing is incorrect	ECU / software problem
Low RPM at Wide Open Throttle	Propeller pitch too great	Replace
	Engine overheated	Reduce load / repair cooling system
	Damaged turbocharger	Replace

Engine Overheat

Problem / Symptom	Cause	Action
Instrument Shows High Temperature	Clogged seawater inlet	Clean
	Low coolant level	Fill with coolant / inspect for leak
	Clogged seawater filter (if equipped)	Clean
	Clogged hydraulic cooler	Clean
	Seawater pump worn or damaged	Repair / replace as necessary
	Defective sensor / instrument	Repair as necessary
	Defective thermostat	Replace
	Damaged closed coolant pump	Replace
	Combustion gas leakage (causes loss of coolant)	Repair as necessary
	Seawater pump belt slips or pump pulley loose on pump shaft	Repair as necessary
	Clogged heat exchanger	Clean

Engine Runs Cold

Problem / Symptom	Cause	Action
Instrument Shows Low Temperature	Defective sensor / instrument	Repair as necessary
	Defective thermostat	Replace
	Cabin heater / boiler too large	Replace with smaller unit or remove

Coolant Loss

Problem / Symptom	Cause	Action
Repeated Low Coolant Level	Defective cylinder head gasket (external leakage)	Replace
	External leakage at connection	Repair as necessary
Coolant Forced Out of Coolant Recovery Tank	Turbocharging pressure enters cooling system via leaking charge air cooler	Repair / replace as necessary
	Defective cylinder head gasket (internal leakage)	Replace
White Smoke when Engine is Hot Indicates Water Vapor	Crack in cylinder head (not cracks between valve seats)	Repair as necessary
	Cracked cylinder wall	Repair as necessary
	Leaking cylinder head gasket	Replace

Helm Panel Display

Problem / Symptom	Cause	Action
No Display	Harness connector loose	Repair as necessary
	Defective diode V1	Replace

TROUBLE CODES

Working Procedure

Try to form a comprehensive view of the problem. Start by asking the operator the following:

- Symptoms
- Conditions in which the fault occurs
- How often the fault occurs
- If the trouble codes have been erased

Then, extract all the stored trouble codes.

Compare them and try to conclude the probable cause of the fault before taking any other measures. The trouble codes are stored in the order they were registered.

Diagnostic Trouble Codes

Some conditions will produce an alarm but do not generate a trouble code. An example is engine overheat (over 108°C [226°F]) caused by an obstructed seawater inlet. The overheat alarm will sound and the engine torque will be reduced to protect the engine, but no code will be set.

Conditions that set a trouble code are generally caused by a sensor or other component sending an out-of-normal range signal to the ECU. An example is a disconnected intake air pressure sensor which would set a P0237 code.

Code	Part or System	Mode	Run Or Condition	Engine Can Start	Check Engine Alarm
No Code	Coolant Temp	Under 0°C (32°F)	1000 rpm	yes	no
No Code	Coolant Temp	Over 108°C (226°F)	reduce	yes	no
No Code	Coolant Temp	Over 110°C (230°F)	reduce	yes	alarm
No Code	Charge Air Temp	Over 110°C (230°F)	reduce	yes	no
No Code	Boost Pressure Reading	4BY2 - over 1.9 bar (27.5 psi) (relative*) or 2.9 bar (42.0 psi) (absolute**) 6BY2 - over 2.3 bar (33.3 psi) (relative*) or 3.3 bar (42.9 psi) (absolute)	reduce	yes	alarm
No Code	Fuel Temperature	Over 90°C (194°F)	reduce	yes	no
No Code	Neutral Switch	Only in case of analog throttle or in case of CAN-fault (U0001), wrong configuration - neutral position	no	no	alarm
P0001	Fuel Metering Unit	Not connected	reduce	yes	alarm
P0003	Fuel Metering Unit	Short circuit to Ground	no	no	alarm
P0004	Fuel Metering Unit	Short circuit to B+	reduce	yes	alarm
P0087	Rail Pressure Governor Deviation	Fuel rail pressure out of range	reduce or shut off	depends on fault	alarm

Code	Part or System	Mode	Run Or Condition	Engine Can Start	Check Engine Alarm
P0088	Rail Pressure Governor Deviation	Fuel rail pressure out of range	reduce or shut off	depends on fault	alarm
P0089	Rail Pressure Governor Deviation	Fuel rail pressure out of range	yes	yes	alarm
P0090	Fuel Pressure Control Valve	Not connected	no	no	alarm
	Rail Pressure Governor Deviation	Fuel rail pressure out of range	reduce	yes	alarm
P0091	Fuel Pressure Control Valve	Short circuit to Ground	reduce	yes	alarm
P0092	Fuel Pressure Control Valve	Short circuit to B+	no	no	alarm
P0112	Charge Air Temp	Over 125°C (257°F)	reduce	yes	alarm
	Charge Air Temp Sensor	Short circuit to B+	reduce	yes	alarm
P0113	Charge Air Temp	Under -20°C (-4°F)	reduce	yes	alarm
	Charge Air Temp Sensor	No connection / short circuit to Ground	reduce	yes	alarm
P0117	Coolant Temp Sensor	Short circuit to B+	reduce	yes	alarm
P0118	Coolant Temp Sensor	No connection / short circuit to Ground	reduce	yes	alarm
P0122	Throttle Signal	Both throttle signals are missing / short circuit to Ground	1600	yes	alarm
	Throttle Signal	Throttle signal 1 is missing / short circuit to Ground	reduce	yes	alarm
P0123	Throttle Signal	Both throttle signals are short circuited to B+	1600	yes	alarm
	Throttle Signal	Throttle signal 1 short circuit to B+	reduce	yes	alarm
P0182	Fuel Temperature Sensor	Short circuit to B+	reduce	yes	alarm
P0183	Fuel Temperature Sensor	No connection / short circuit to Ground	reduce	yes	alarm
P0192	Fuel Rail Pressure Sensor	Short circuit to Ground	reduce	yes	alarm
P0193	Fuel Rail Pressure Sensor	No connection / short circuit B+	reduce	yes	alarm
P0201	Injector No. 1	Open circuit / short circuit to Ground	reduce	yes	alarm
P0202	Injector No. 2	Open circuit / short circuit to Ground	reduce	yes	alarm
P0203	Injector No. 3	Open circuit / short circuit to Ground	reduce	yes	alarm
P0204	Injector No. 4	Open circuit / short circuit to Ground	reduce	yes	alarm
P0205	Injector No. 5	Open circuit / short circuit to Ground	reduce	yes	alarm
P0206	Injector No. 6	Open circuit / short circuit to Ground	reduce	yes	alarm
P0222	Throttle Signal	Both throttle signals are missing / short circuit to Ground	1600	yes	alarm
	Throttle Signal	Throttle signal 2 is missing / short circuit to Ground	reduce	yes	alarm
P0223	Throttle Signal	Both throttle signals are short circuited to B+	1600	yes	alarm
	Throttle Signal	Throttle signal 2 short circuited to B+	reduce	yes	alarm
P0230	Fuel Feed Pump	Not connected	no	no	alarm
P0231	Fuel Feed Pump	Short circuit to Ground	reduce	yes	alarm
P0232	Fuel Feed Pump	Short circuit to B+	no	no	alarm

Code	Part or System	Mode	Run Or Condition	Engine Can Start	Check Engine Alarm
P0236	Boost Pressure	Plausibility check with APS (ambient air pressure sensor) fail	reduce	yes	alarm
P0237	Boost Pressure	Under 0.5 bar (7.3 psi) (absolute)	reduce	yes	alarm
	Boost Pressure Sensor	No connection / short circuit to Ground	reduce	yes	alarm
P0238	Boost Pressure	4 bar (58.0 psi) (absolute)	reduce	yes	alarm
	Boost Pressure Sensor	Short circuit to B+	reduce	yes	alarm
P0243	Turbocharger Positive Boost Pressure Deviation	Leakage in the air routing (hole in the charge air pipe)	yes	yes	alarm
P0261	Injector No. 1	Short circuit to B+	reduce	yes	alarm
P0264	Injector No. 2	Short circuit to B+	reduce	yes	alarm
P0267	Injector No. 3	Short circuit to B+	reduce	yes	alarm
P0270	Injector No. 4	Short circuit to B+	reduce	yes	alarm
P0273	Injector No. 5	Short circuit to B+	reduce	yes	alarm
P0276	Injector No. 6	Short circuit to B+	reduce	yes	alarm
P0299	Turbocharger negative boost pressure deviation	Boost pressure actuator is sticking defect waste gate hose	yes	yes	alarm
P0344	Crankshaft Speed Sensor	Disagreement between camshaft speed sensor and crankshaft speed sensor	no	no	alarm
P0380	Glow Control Relay Actuator	Not connected, short circuit	yes	yes	alarm
P0562	System Voltage Low	-	yes	no	alarm
P0563	System Voltage High	-	yes	yes	alarm
P0602	Control Module Programming Error (Hwemon)	Overvoltage / undervoltage	no	no	alarm
	Shut Off Path	Control module programming error	no	no	alarm
P0607	Injector Chip Fault	Injector control module performance	no	no	alarm
P0642	Sensor Supply Monitoring 1	Short circuit	reduce	yes	alarm
P0643	Sensor Supply Monitoring 1	Short circuit	reduce	yes	alarm
P0650	Check Engine Lamp	Not connected, short circuit	yes	yes	alarm
P0652	Sensor Supply Monitoring 2	Short circuit	reduce	yes	alarm
P0653	Sensor Supply Monitoring 3	Short circuit	reduce	yes	alarm
P0670	Glow Plug Control Module	Failure, short circuit, over-current	yes	yes	alarm
P0671	Glow System - Glow Spark No. 1	Not connected, short circuit	yes	yes	alarm
P0672	Glow System - Glow Spark No. 2	Not connected, short circuit	yes	yes	alarm
P0673	Glow System - Glow Spark No. 3	Not connected, short circuit	yes	yes	alarm
P0674	Glow System - Glow Spark No. 4	Not connected, short circuit	yes	yes	alarm

Code	Part or System	Mode	Run Or Condition	Engine Can Start	Check Engine Alarm
P0675	Glow System - Glow Spark No. 5	Not connected, short circuit	yes	yes	alarm
P0676	Glow System - Glow Spark No. 6	Not connected, short circuit	yes	yes	alarm
P0689	Main Relay	Power relay sense short circuit low	no	no	alarm
P0690	Main Relay	Power relay sense short circuit high	no	no	alarm
P2049	4BY2 - Injector Bank 1	Short circuit on high side to Ground / B+	no	no	alarm
	6BY2 - Injector Bank 1	Short circuit on high side to Ground / B+	reduce	no	
P2052	4BY2 - Injector Bank 2	Short circuit on high side to Ground / B+	reduce	yes	alarm
	6BY2 - Injector Bank 2	Short circuit on high side to Ground / B+	reduce	yes	
P2227	Atmospheric Pressure	Plausibility check with BPS (boost pressure sensor) fail	yes	yes	alarm
P2228	Atmospheric Pressure	Short circuit low	yes	yes	alarm
P2229	Atmospheric Pressure	Short circuit high	yes	yes	alarm
P2614	Camshaft Speed Sensor	No connection / short circuit	reduce	yes	alarm
P2617	Crankshaft Speed Sensor	No connection / short circuit	no	no	alarm
U0001	CAN Throttle Signal	No signal	idle	yes	alarm
U0106	Glow Control Unit	No communication error	yes	yes	alarm
U0426	Immobilizer	Manipulation error	no	no	alarm

** Relative value is the value read on a pressure gauge attached to the intake pipe.*
*** Absolute is the value reported by the ECU and displayed at the helm digital display.*

AFTER TROUBLESHOOTING OR REPAIR

The engine control unit (ECU) may have generated trouble codes due to the current fault or during troubleshooting. Remember to check and clear any trouble codes after repairs are complete.