POWER SOLUTIONS INTERNATIONAL

PSI 32L SERVICE MANUAL

Large Spark-Ignition (LSI)

PSI ENERGY

7610018-13

A Product by Power Solutions International
Wood Dale, IL

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Note: Engine accessory and component locations may differ from those presented in the images within this manual based on various applications and package manufacturers using this engine.

REVISION CONTROL INFORMATION

Revision Level	Release Date	Change Description (s)
1	01/10/2020	Initial Release
2	08/07/2020	Updated torque value for flywheel bolts, updated oil pump removal and installation process and include new part numbers for guide pins in the special tools chart.
3	09/24/2020	Updated cylinder head torque values and sequence.
4	02/11/2021	Updated oil filter installation procedure.
5	05/11/2021	Included part numbers for both Major and Medium Repair Kits.
6	07/28/2022	Add speed sensor installation/shimming procedure. Adding greasing procedure to ignition coil boots. Reformatting
7	08/22/2022	Added torque specs and added CAC Pipe removal and installation. Added CAC pipe removal and Installation.
8	09/14/2022	Updated crankshaft phasing specification
9	10/11/2022	Updated Speed Sensor Gap specification
10	11/13/2023	Updated Oil Recommendation
11	02/07/2024	Added torque specification to mounting bolts for ignition coils Added dielectric grease details for ignition coil installation
12	04/05/2024	Added text to Page 113 step 11 to include the hardware MUST include the washer
13	8/28/2025	Added note stating cylinder head bolts may be used a maximum of three times before needing to be replaced in Cylinder Head Removal/Installation and torques pec chart

WARNING SUMMARY

- Failure to comply with the warnings below may result in serious injury to personnel.
- Avoid prolonged exposure to used oil.
- Wear protective clothing and waterproof gloves.
- Do not put oily rags in your pocket.
- Do not wear oil-saturated clothing.
- Wash work clothes frequently. Discard clothes and shoes that are soaked with oil and cannot be cleaned.
- In the event of personal injury, take first aid measures immediately.
- Always apply protective cream before work, which can help remove the oil when the skin is contaminated with mineral oil.
- Upon detection of skin irritation, seek medical treatment immediately.
- Do not use faulty or unsuitable tools.
- Stop the engine during maintenance or repair work.
- Do not touch hot parts of an engine that is running or that has just been stopped.
- Do not touch the engine when it is running.
- Let the engine cool down before carrying out any maintenance operation.
- Release the pressure in the fuel and cooling systems before disconnecting or removing hoses or associated parts.
- At operating temperature, the coolant is hot and pressurized. When the pressure is released the burning-hot liquid may be transformed into fumes.
- Any contact with this burning-hot liquid or fumes may cause serious burns.
- Let the components in the coolant system cool down before draining the system.
- Only check the coolant level when the engine has been stopped.
- Slowly unscrew the filler plug to release the pressure.
- Hot oil can cause injury. Avoid contact with the skin.
- Sulfuric acid contained in batteries is toxic and corrosive. It can burn clothing and skin or even cause blindness in case of contact with the eyes.
- When starting the engine, use ear protection.

Table of Contents

GENERAL PRECAUTIONS FOR OPERATIONS

INTRODUCTION

Most accidents related to the use, maintenance and repair of the engine are due to failure to comply with the safety regulations and basic precautions. They could therefore be avoided by acknowledging the risks that you face and by taking the corresponding preventive measures. To operate, maintain and repair this PSI equipment, you need to have the appropriate training, skills and tooling.

Failure to comply with the instructions set out in this manual may result in serious or even fatal accidents. PSI cannot foresee every possible risk. As such, the rules and instructions set out in this Manual are not exhaustive.

BEFORE ANY OPERATION INVOLVING A PSI PRODUCT

- Before carrying out any maintenance or repair work, fix a “Do not use” sign or a similar sign to the starter switches.
- Actuate the starter battery isolating switch.
- Turn off the circuit breaker located on the engine connection box if applicable.
- Turn the engine room cabinet starter switch to OFF (optional feature).
- For engines fitted with a pneumatic starter system, isolate the tanks, and drain the pipes between the tanks and the starter.
- For engines fitted with an automatic starter control device, lock the starting order on the control box.
- Before using the barring tool, always take the necessary safety precautions.
- Do not allow any unauthorized person near the engine.
- Make sure that the repair premises and surrounding area are suitable to carry out the work safely.
- Always make sure that the repair workshop or the area around the engine is clean and tidy.
- Remove any rings, chains, and watches before starting work. Wear suitable and close-fitting work wear.
- Lock the emergency buttons.
- Check that the expiry date of the protection equipment (glasses, gloves, shoes, masks, overalls, helmet, etc.) is not exceeded before starting work.
- Do not use faulty or unsuitable tools.
- Stop the engine during maintenance or repair work.

START-UP

- Never use any product to facilitate start-up (risk of explosion).
- Never start an engine, engage a gear reducer, or touch a propeller pitch control without having checked beforehand that this operation can be carried out in complete safety for the people or the equipment.
- When starting the engine, use ear protection to prevent hearing loss.
- Only start or stop the engine using the switches designed for this in the engine room control box, the bridge console, control boxes, etc.
  When the engine starts, the power loss must never be below 18 VDC.

SEALS

- If the temperature exceeds 300°C (572°F), the engine seals may produce corrosive hydrofluoric acid. Always use protective gear when touching seals subject to high temperatures.
- Always use rubber thick gloves and safety glasses during decontamination operations.
- Clean the seals and the contaminated surfaces using a 10% calcium dioxide solution or another cleaning product.
- Keep any parts which have been removed in a sealed plastic bag and store them in a dedicated area.

STARTER BATTERY

- Disconnect the batteries before any operation involving the electrical circuit.
- As the battery gas is explosive, keep it away from naked flames and any source of sparks.
- Do not smoke near the fuel system and batteries.
- Never check battery charge by short circuiting it.
- Do not charge a frozen battery. Heat it up to 16°C (60°F) beforehand.
- Sulphuric acid contained in batteries is toxic and corrosive; it can burn clothing and skin or even cause blindness in case of contact with the eyes.
- To prevent accidents:
  - Fill the batteries in well-ventilated premises.
  - Wear suitable gloves and glasses.
  - Do not inhale the fumes.
- In the event of contact with a part of the body:
  - Rinse the affected part with plenty of water.
  - Apply bicarbonate of soda or lime to neutralize the acid.
  - Rinse the eyes for 10 to 15 minutes.
  - See a doctor as soon as possible.
- In the event of ingestion:
  See a doctor as soon as possible.
- Do not smoke in areas where batteries are charged.
- The batteries give off flammable fumes which can explode.
- If the batteries are in a closed area, make sure there is sufficient ventilation.
- Make sure the batteries are clean and that covers are fitted.
- The battery cables must be fitted with a circuit breaker to isolate the circuit if there is a problem. Electric wiring must be kept in good condition, properly positioned, and soundly attached.

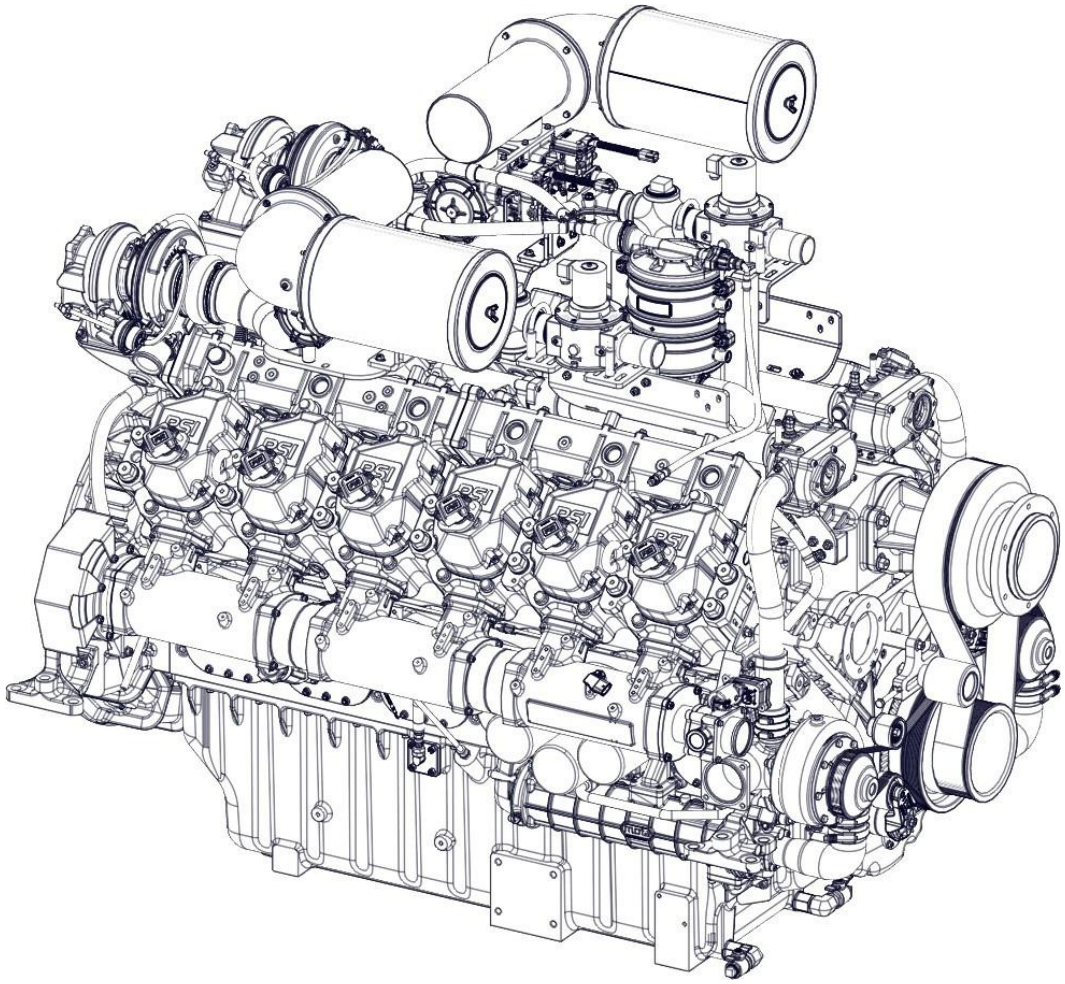
INJECTION DEVICES

- Use a fume extraction device.
- If the fuel comes into contact with the skin, it can cause injury. Consult a doctor immediately.
- Fuel, oil, and coolant contain harmful products.
- Avoid all contact with the skin and eyes. Do not ingest.
- The use of gloves and safety glasses is highly advisable.

WELDING

- Unplug all engine wiring harnesses before doing welding operations (ECU, engine cabinets, control boxes, ETC..).
- Do not use open fires.
- For all electrical or autogenous welding, use a welding permit to make the area safe.
- Make sure that the work will not affect the onboard electrical and electronic equipment.
- Make sure that the automatic fire extinguishing system is in habited before any welding or grinding work.
- Make sure that the premises where the welding will be done are suitably ventilated.
- Do not weld and do not use a torch on pipes or hoses containing flammable liquids.

THEORY OF OPERATION AND ENGINE COMPONENTS



CYLINDER BLOCK

The cast iron cylinder block is configured in a “V” shape with two banks of six integral cylinder bores at an included angle of 90 degrees. Coolant jackets surround each cylinder bore. Seven cast iron main bearing caps are each fastened by four bolts, with the crankshaft thrust taken up the rear main bearing cap. Oil cooling for each cylinder is furnished by a dedicated oil jet, which is part of the pressurized lubrication system passages machined into the block.

CRANKSHAFT

The 32L engine uses a hardened steel forged crankshaft with seven hardened main bearing journals and six connecting rod journals oriented with 120-degree phasing. Four counterweights to provide internal balance of the rotating assembly.

PISTONS AND CONNECTING RODS

All twelve pistons utilize three piston rings. One keystone ring, twist tapered ring and a coil spring loaded ring. All of which are attached to a two-piece forged steel connecting rod and a floating piston pin, retained in location by a circlip at each end of the piston pin. The forged steel connecting rod cap is retained to the connecting rod via two cap screws.

CYLINDER HEADS

All twelve cast iron cylinder heads equipped with four valves are located on the upper part of the cylinder block and forms the top of the combustion chamber. The parts connected to the cylinder head include the intake manifold, exhaust manifold, spark plug, cylinder head cover, cylinder head gasket, valves, and rocker assemblies.

CAMSHAFT

The roller camshaft utilizes seven cam journals and twenty-four cam lobes which is assembled into the cylinder block above the crankshaft. With the rotation of the camshaft the flat tappets follow the lobes machined integral to the camshaft, opening, and closing the respective valve line (push rod, rocker arm, valve and valve spring) in proper sequence.

EXHAUST MANIFOLD

A cast material exhaust manifold is attached to each cylinder head; each exhaust manifold port collects exhaust gases from the cylinders, which is attached to two separate sections of the exhaust pipe system, which are water cooled.

INTAKE MANIFOLD

Intake manifold starts by passing through the charge air cooler and then running through the throttle body and then into the cast material intake manifold.

ENGINE CONTROL MODULE (ECM)

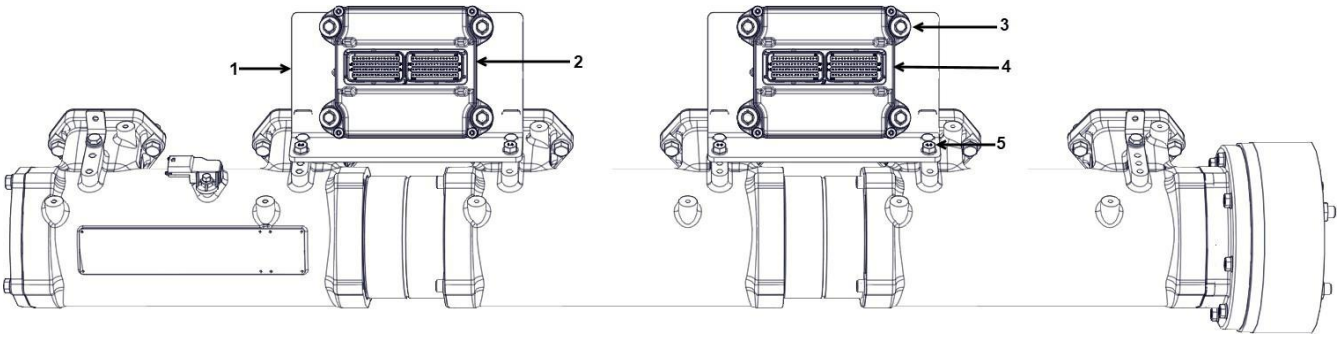


Figure 1. ECM Assembly

No.	Name
1	ECM Mounting Bracket
2	ECM
3	ECM Bolt
4	ECM
5	ECM Mounting Bracket Bolt

The 32L engine comes equipped with two Engine Control Modules (ECM), one for the secondary side (right side) and one for the primary side (left side) of the engine. The ECM monitors various engine sensors via 0–5-volt signals, this allows for optimal engine performance.

REMOVAL

1. Remove the four bolts from each ECM.
2. Remove the ECM.
3. Remove the two bolts from the ECM mounting bracket.
4. Remove the ECM mounting bracket.

INSTALLATION

1. Place the ECM mounting bracket over the intake manifold.
2. Insert and torque down the two mounting bracket bolts to 22 ft/lbs.
3. Place ECM on the ECM mounting bracket.
4. Insert and torque the four ECM bolts to the ECM mounting bracket to 10 ft/lbs.

HOISTING OF ENGINE

The engine crankshaft centerline should remain horizontal when hoisting and no vertical or incline hoisting is allowed. The engine should always be raised and lowered slowly. Lifting rings resistance is reduced when the angle between the slings or the chains and the engine fall below 90°.

Use a lifting device as illustrated below. Avoid any contact between the slings and the engine parts. Use the fastening links and slings or properly calibrated chains.

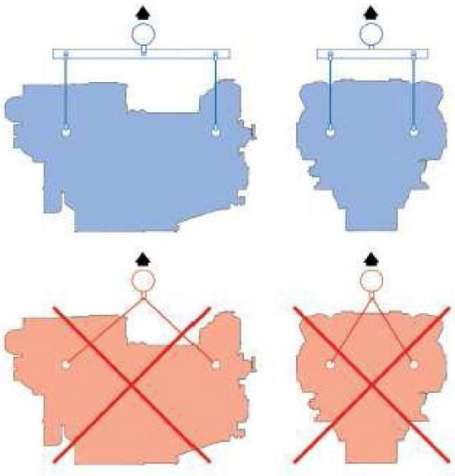


Figure 2. Hoisting Engine

LIFTING EYES

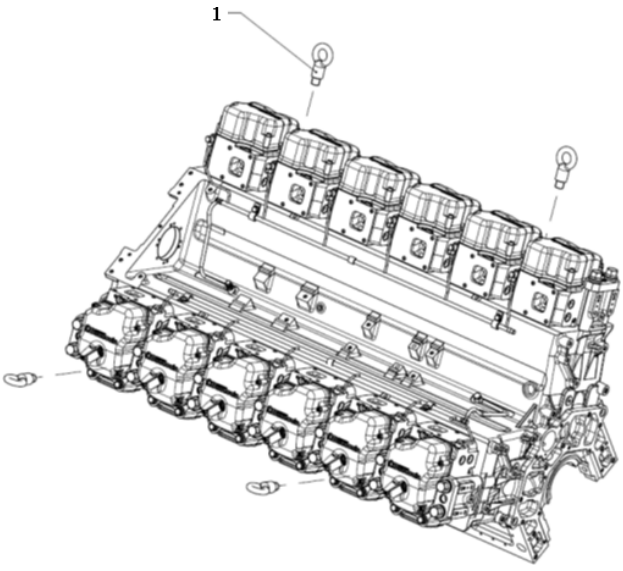


Figure 3. Lifting Eyes Assembly

No.	Name
1	Lifting Eye

REMOVAL

1. Loosen and remove all four lifting eyes.

WARNING:

Check front and rear lifting eyes for cracks or any damage, replace if any cracks or other damages are found.

INSTALLATION

1. Insert and torque all four lifting eyes to 730±5 N•m.

CYLINDER BLOCK CLEANING AND INSPECTION

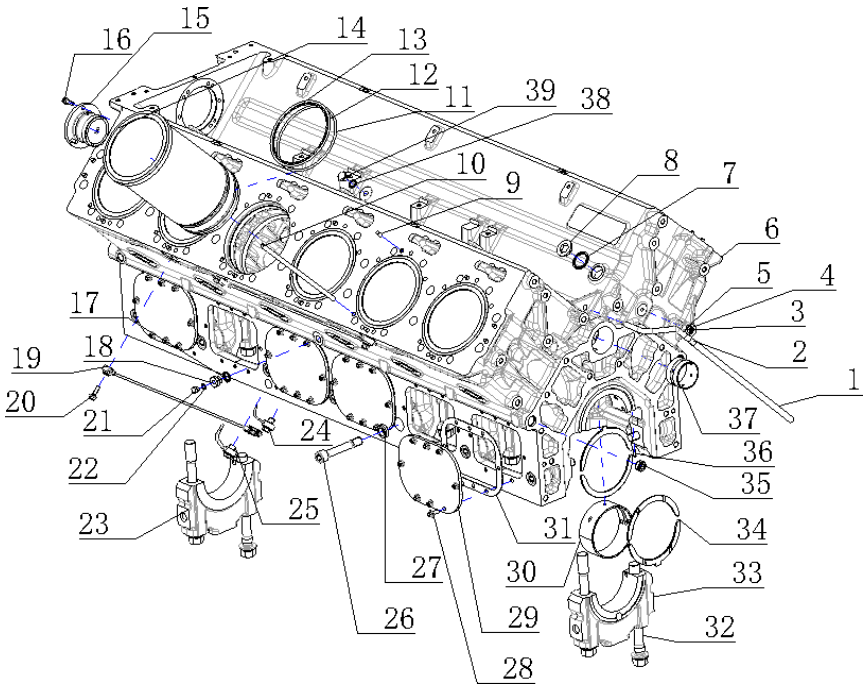


Figure 4. Cylinder Block Assembly

No.	Name	No.	Name
1	Pipe	20	Hexagonal flange bolt
2	Pipe	21	Hexagonal head plug
3	Stud	22	Washer
4	Hexagonal nut	23	Main bearing shell
5	Clamp	24	Piston nozzle assembly
6	Engine block	25	Piston nozzle assembly
7	Combination gasket	26	Main bearing shell auxiliary bolt
8	Screw plug	27	Main bearing shell auxiliary bolt
9	Cylindrical pin	28	Hexagonal flange bolt
10	Pipe	29	Sight hole cap
11	Cylinder liner gasket	30	Main shaft bushing assembly
12	O-ring	31	Gasket
13	Cylinder liner gasket	32	Thrust main bearing shell
14	Cylinder liner	33	Main bearing bolt
15	Camshaft thrust bearing	34	Thrust plate assembly
16	Hexagonal flange bolt	35	Hexagonal socket plug
17	Gasket	36	Cylindrical pin
18	Hollow plug	37	Camshaft bushing
19	Knock sensor	38	Washer
		39	Hexagonal socket plug

WARNING:

Always wear protective clothing and proper eye protection when cleaning components.

CYLINDER BLOCK CLEANING

1. Boil cylinder block in caustic solution.
2. Flush cylinder block with water or steam.
3. Clean the following areas
   a. All gasket surfaces
   b. Cylinder bores, remove excessive cylinder ridge as required.
   c. Main bearing caps.
   d. Oil galleries, remove all sludge and restrictions.
   e. Scale deposits from coolant passages
   f. All dirt and debris from threaded holes

WARNING

Wear approved safety glasses or face shield when cleaning components. Failure to comply may result in personal injury.

Wear rubber gloves and protective clothing when cleaning components. Failure to comply may result in personal injury.

4. Dry cylinder block with compressed air.
5. Lubricate cylinder bores with PSI approved motor oil to prevent rust.

CYLINDER BLOCK INSPECTION

1. Inspect the cylinder block for the following conditions:
   a. Gasket surfaces for deep gouges or other damages.
   b. All machined surfaces for burr, oil stains and scratches.
   c. Oil and water passages for burr, metal chips or any restrictions.
   d. Tappet hole should be free for any and all restrictions.
   e. Outer cracks or dents of cylinder block.

ENGINE LUBRICATION

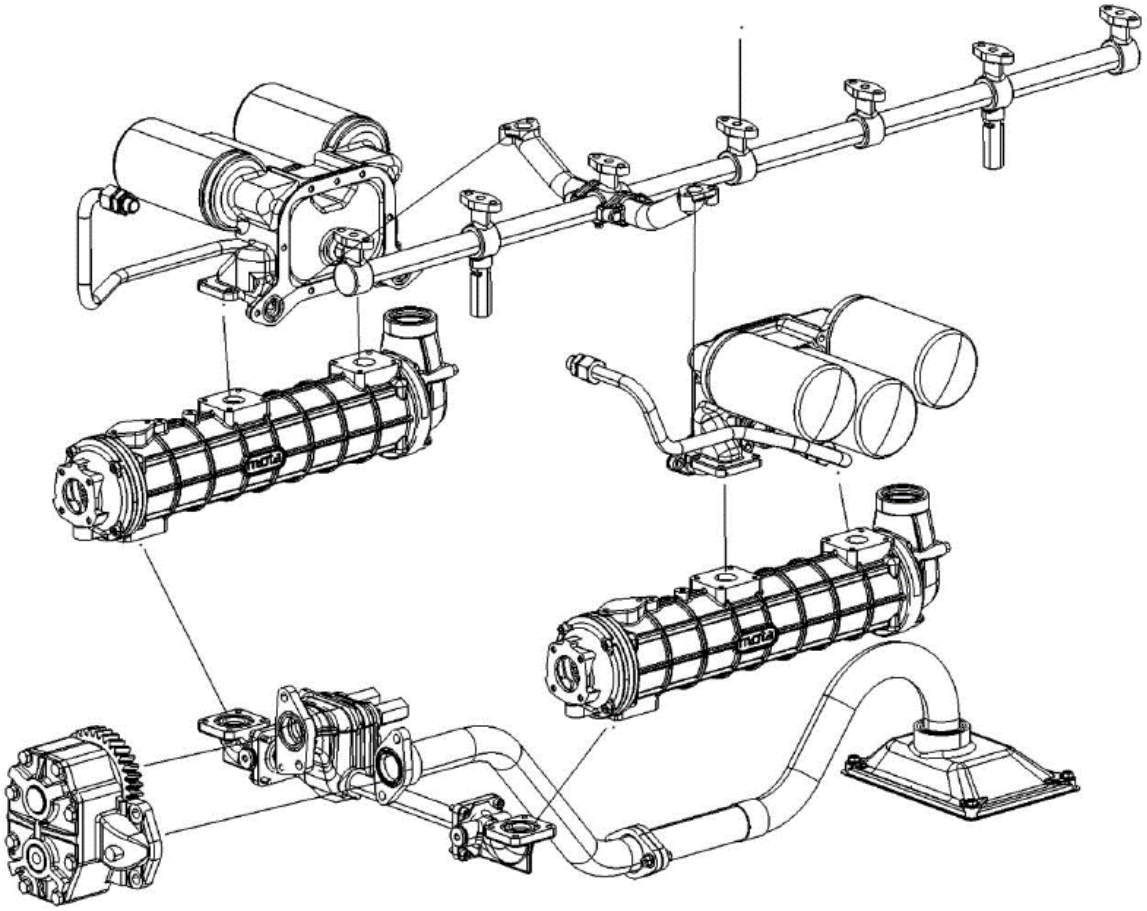


Figure 5. Lubrication System

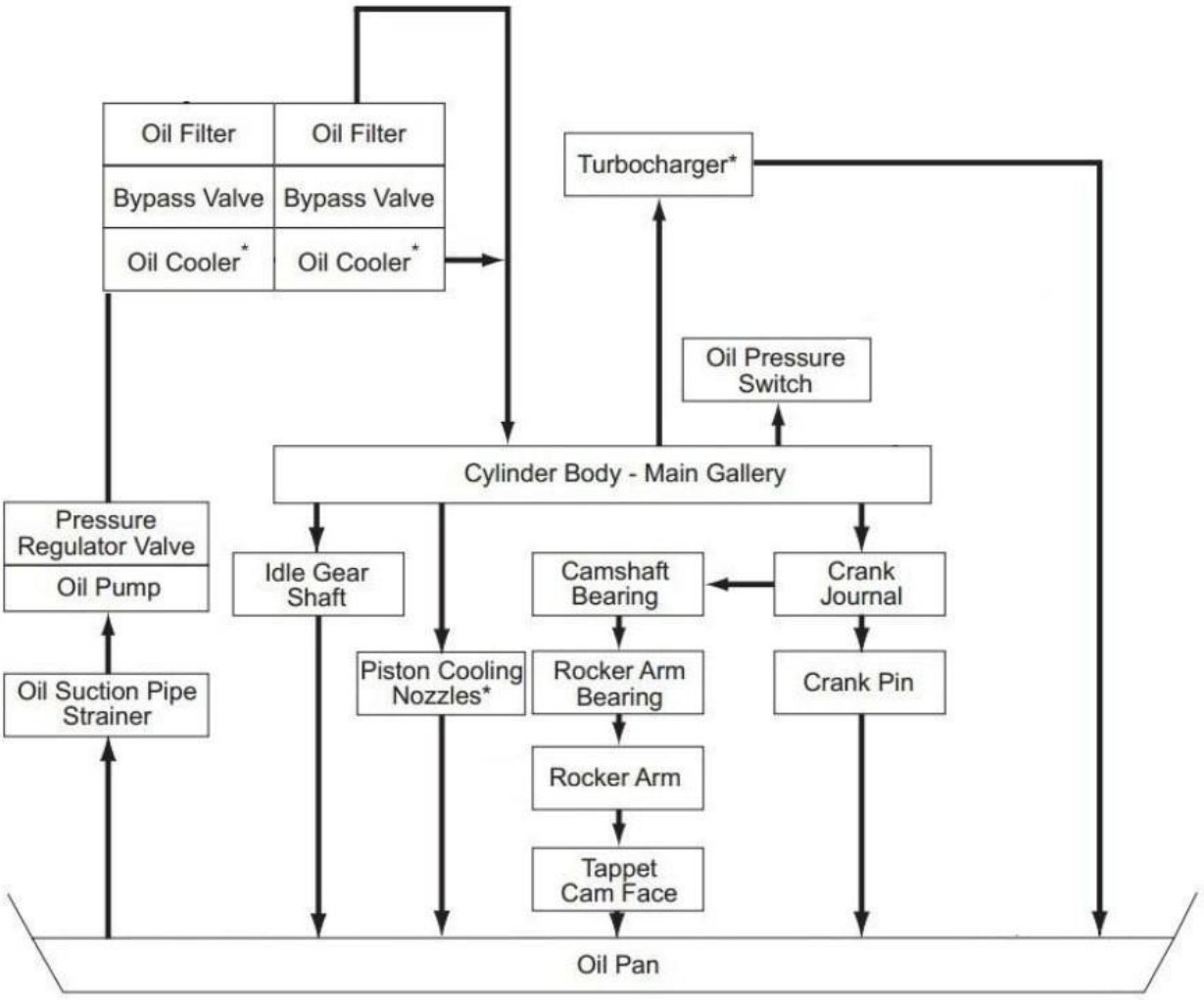
An oil pump is driven by the front crankshaft gear train connected to the oil pump assembly. A series of control valves are located inside the oil pan, along with the centrifuge valve. All control valves lead to the oil filter support assembly, which holds all oil filters. The oil pump is connected to both oil cooler sumps, along with the connecting elbows.

OIL PUMP SERVICE INFORMATION

Engine Oil Pressure

Model	At Rated Engine RPM	At Low Idle Speed
	1500-1800	
32L	0.4-0.6 MPa	More than 0.12 MPa

LUBRICATION SYSTEM DIAGRAM



ENGINE OIL DIPSTICK TUBE

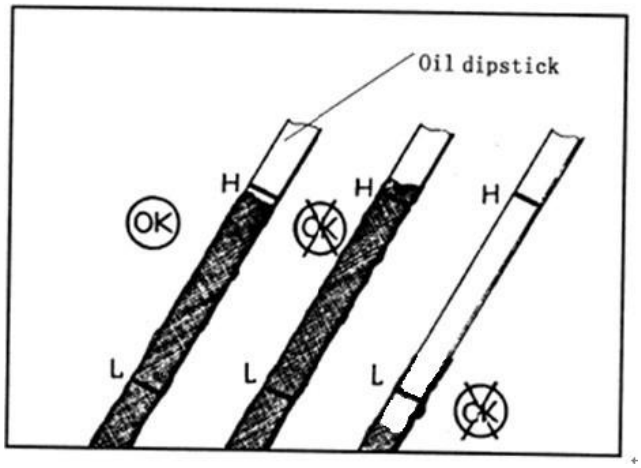


Figure 6. Engine Oil Dipstick

REMOVAL

1. Remove engine oil dipstick from engine oil dipstick tube.
   - Check oil level. (Refer to figure 6.)
2. Remove upper oil dipstick from oil pan.
3. Remove washer and nut and then remove lower dipstick from oil pan.

INSTALLATION

1. Install washer and nut and tighten down onto oil pan.
2. Install upper oil dipstick to oil pan.
3. Install engine oil dipstick in engine oil dipstick tube.

FRONT ENGINE ACCESSORY DRIVE (FEAD)

ENGINE BELT ROUTING

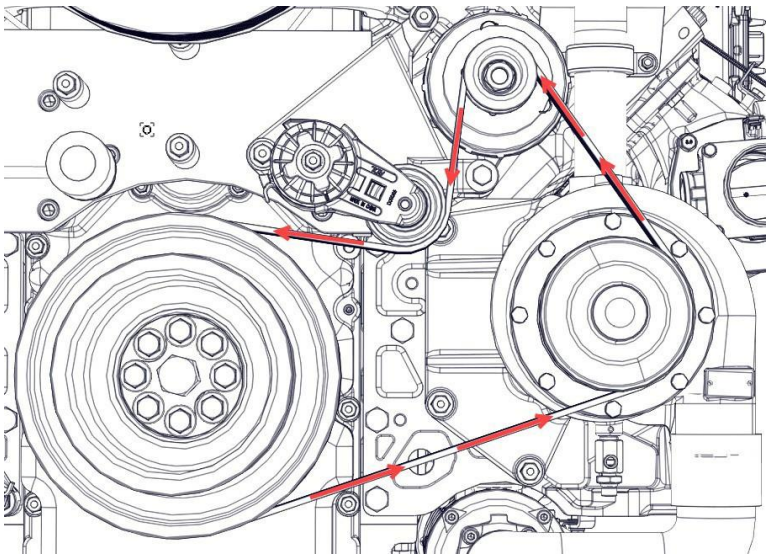


Figure 7. Left-Hand Belt Routing

Left-Hand belt runs under the automatic belt tensioner, over and around the crankshaft pulley, around the water pump, over the alternator pulley and back under the automatic belt tensioner.

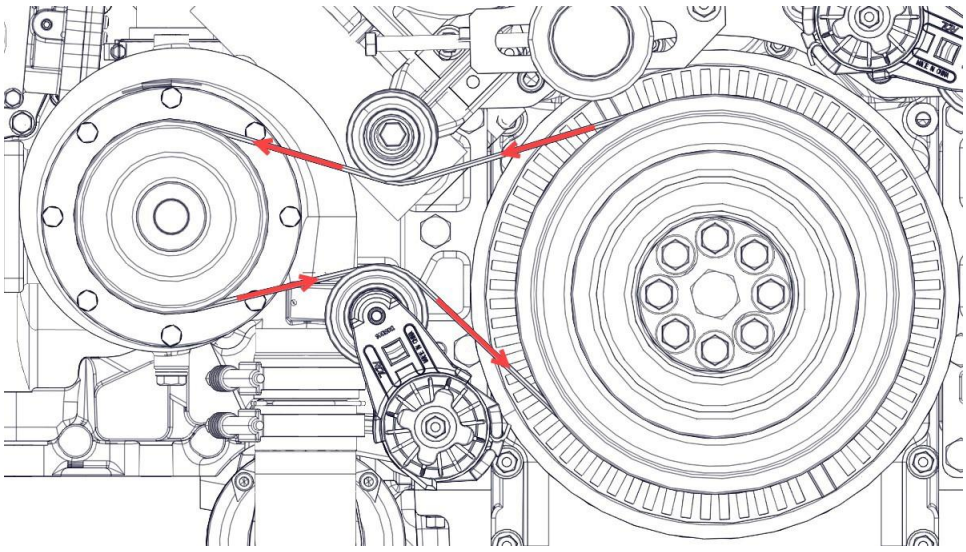


Figure 8. Right-Hand Belt Routing

The right-hand belt runs over the automatic belt tensioner, under and around the crankshaft pulley, under the idler pulley, over and around the water pump pulley and back over the automatic belt tensioner.

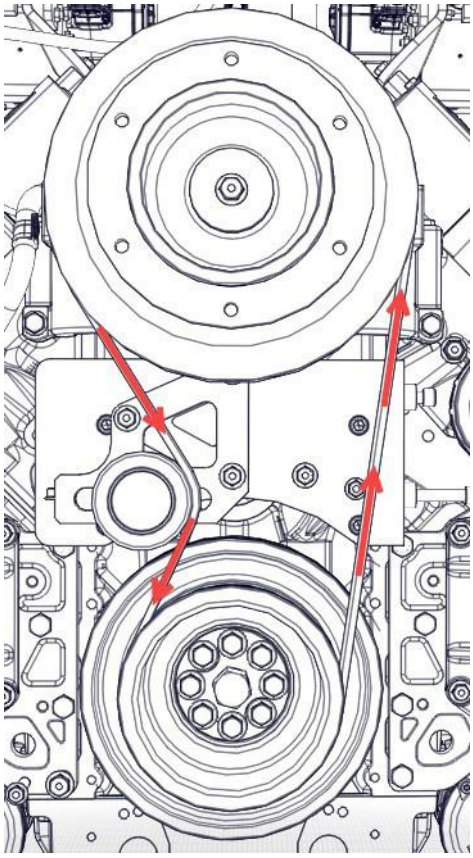


Figure 9. Serpentine Belt Routing

The grooved serpentine belt runs under the crankshaft pulley, over the fan pulley and to the left of the belt tensioner

ALTERNATOR PULLEY ASSEMBLY

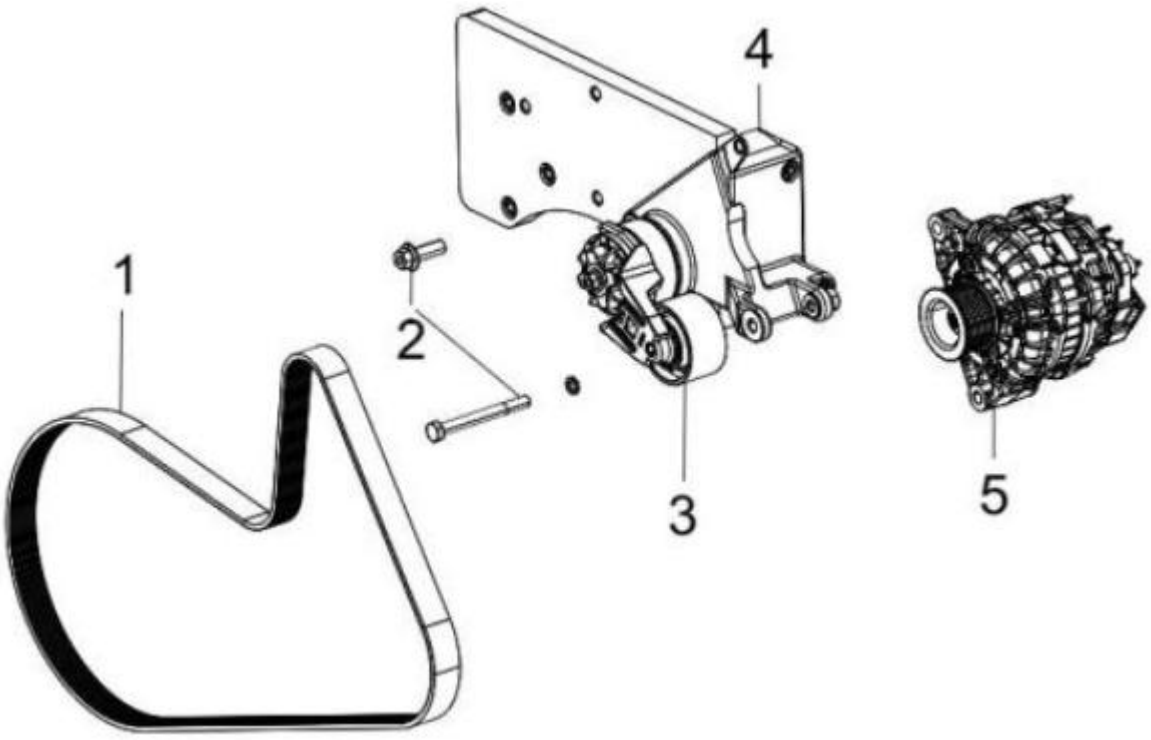


Figure 10. Alternator Pulley Assembly

REMOVAL

1. Disconnect both the battery and electrical wires from the alternator.
2. Loosen the serpentine belt (Figure 10, 1) by operating the tensioner(Figure 10, 3).
3. Remove the bolts (Figure 10, 2) from the bracket (Figure 10, 4). Remove the alternator (Figure 10, 5).
4. Loosen and remove the bolts from the alternator pulley bracket.

INSTALLATION

1. Install alternator bracket.
2. Insert and torque down the four alternator bracket bolts.
3. Insert and torque down the center alternator pulley bolt.

LEFT-HAND WATER PUMP ASSEMBLY

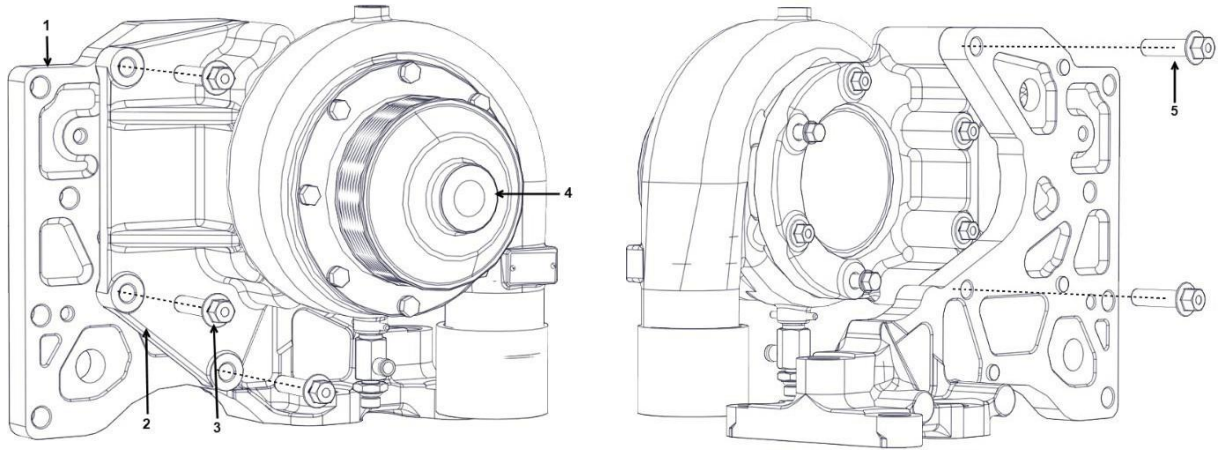


Figure 11. Left-Hand Water Pump Assembly

No.	Name
1	Left-Hand Engine Mount
2	Left-Hand Water Pump Bracket
3	Bolt
4	Left-Hand Water Pump
5	Bolt

REMOVAL

1. Remove the three bolts on the left-hand water pump assembly bracket.
2. Remove the two rear bolts from the water pump pulley bracket.
3. Carefully remove the water pump pulley bracket.

INSTALLATION

1. Carefully place the left-hand water pump bracket assembly onto the left-hand engine mount.
2. Install and torque down the two rear bolts to the water pump pulley bracket.
3. Install and torque down the three front bolts to the water pump pulley bracket.

LEFT-HAND AUTOMATIC BELT TENSIONER

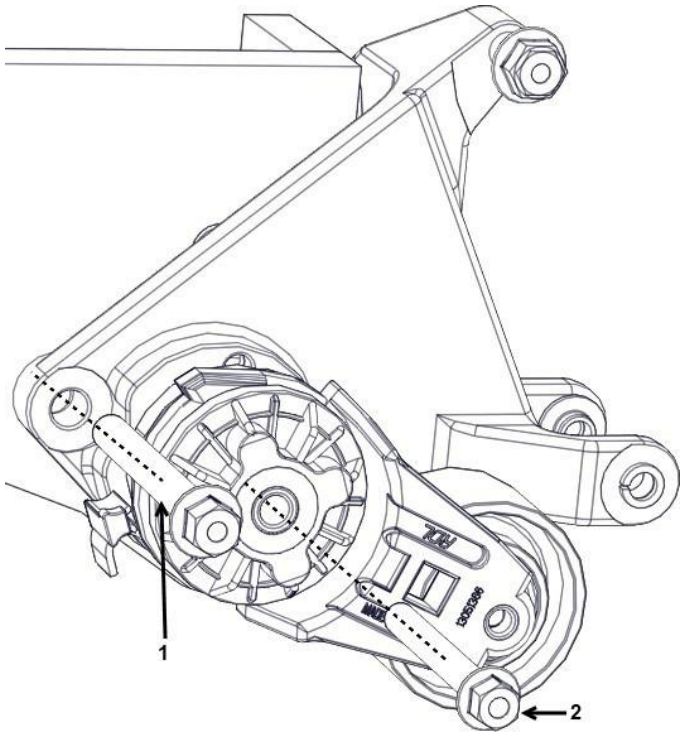


Figure 12. Left-Hand Automatic Belt Tensioner Assembly

No.	Name
1	Outer Automatic Bracket Tensioner Bolt
2	Automatic Belt Tensioner Bolt

REMOVAL

1. Remove center bolt on the automatic belt tensioner.
2. Remove automatic belt tensioner.
3. Remove all three outer bracket bolts.
4. Remove automatic belt tensioner bracket.

INSTALLATION

1. Install and torque down all three outer automatic belt tensioner bracket bolts.
2. Install and torque down the center automatic belt tensioner bolt.

MANUAL FAN BELT TENSIONER ASSEMBLY

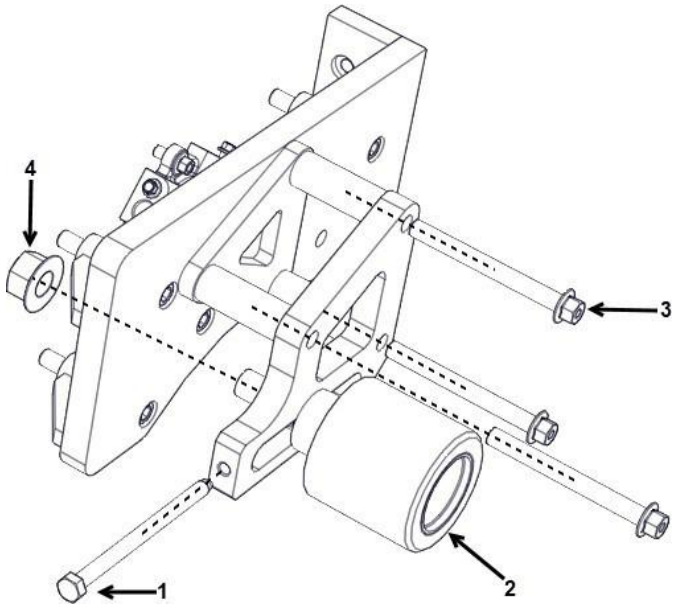


Figure 13. Manual Fan Belt Tensioner Assembly

No.	Name
1	Side Manual Belt Tensioner Bolt
2	Manual Belt Tensioner
3	Manual Belt Tensioner Bracket Bolts
4	Rear Manual Belt Tensioner Nut

REMOVAL

1. Remove the side manual belt tensioner.
2. Remove the rear manual belt tensioner nut.
3. Remove the manual belt tensioner.
4. Remove the three manual belt tensioner bracket bolts.
5. Remove the manual belt tensioner bracket.

INSTALLATION

1. Place manual belt tensioner bracket on cylinder block.
2. Insert and torque down all three manual bet tensioner bracket bolts.
3. Place manual belt tensioner onto the bracket.
4. Feed the manual belt tensioner nut through the rear of the tensioner and torque down the nut.
5. Insert and torque down the side manual belt tensioner bolt.

RIGHT-HAND WATER PUMP PULLEY ASSEMBLY

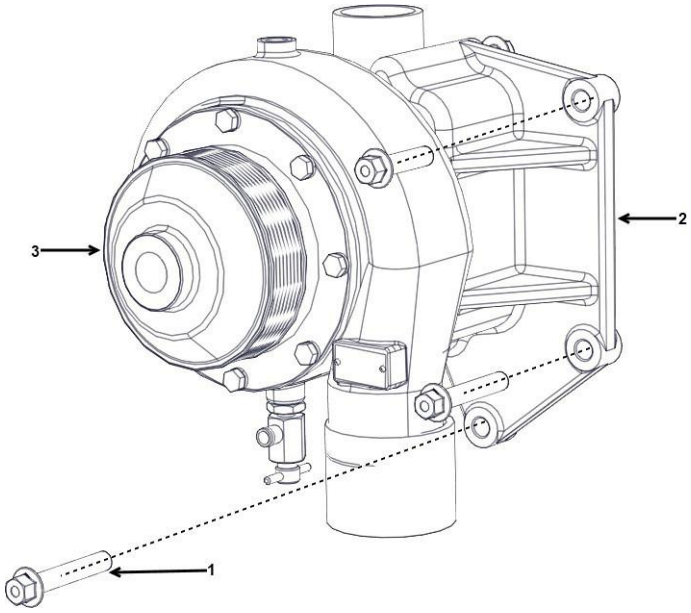


Figure 14. Right-Hand Water Pump Pulley Assembly

No.	Name
1	Right-hand water pump bracket bolts
2	Right-hand water pump bracket
3	Right-hand water pump pulley

REMOVAL

1. Remove the three right-hand water pump bracket bolts.

Note:

The right-hand automatic belt tensioner needs to be removed to remove the right-hand water pump assembly.

2. Remove the eight bolts on the back of the right-hand water pump. (Refer to Figure 15)

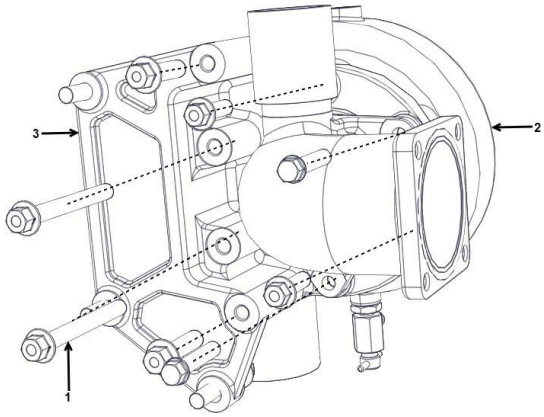


Figure 15. Rear Right-Hand Water Pump Pulley Assembly

No.	Name
1	Rear right-hand water pump bracket bolts
2	Right-hand water pump
3	Right-hand water pump bracket

3. Remove the right-hand water pump and bracket.

INSTALLATION

1. Place the right-hand water pump bracket and align the holes onto the right-hand engine mount.
2. Insert and torque down the top right bolt to assist in the installation process. (Refer to Figure 16.

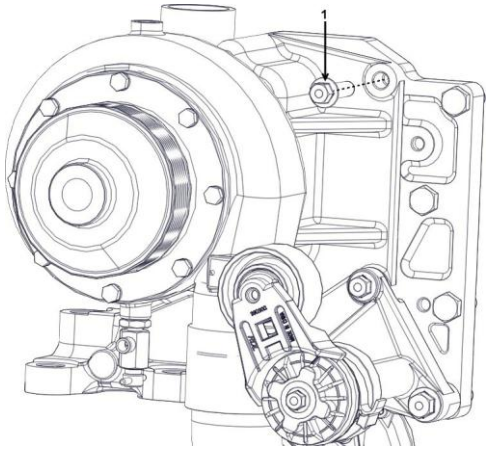


Figure 16. Right-Hand Water Pump/Engine Mount Bolt

3. Insert the right-hand automatic belt tensioner and torque down the remaining bolts to the right-hand water pump bracket. (Refer to Figure 17.)
4. Insert and torque down the eight bolts in the back of the right-hand water pump bracket.

RIGHT-HAND AUTOMATIC BELT TENSIONER ASSEMBLY

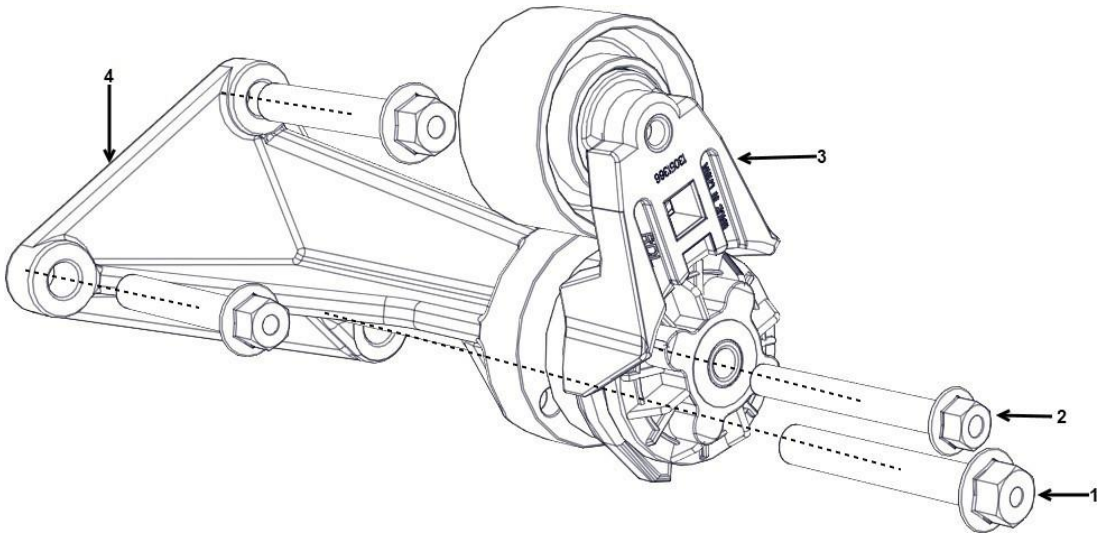


Figure 17. Right-Hand Automatic Belt Tensioner Assembly

No.	Name
1	Right-hand automatic belt tensioner bracket bolts
2	Right-hand automatic belt tensioner bolt
3	Right-hand automatic belt tensioner bracket
4	Right-Hand Automatic Belt Tensioner Bracket

REMOVAL

1. Remove the right-hand automatic belt tensioner bolt.
2. Remove the right-hand automatic belt tensioner.
3. Remove the three right-hand automatic belt tensioner bracket bolts.
4. Remove the right-hand automatic belt tensioner bracket.

INSTALLATION

5. Place the right-hand automatic belt tensioner bracket onto the right-hand engine mount and water pump.
6. Insert and torque down the three right-hand automatic belt tensioner bracket bolts.
7. Place the right-hand automatic belt tensioner onto the bracket.
8. Insert and torque down the right-hand automatic belt tensioner bolt.

RIGHT-HAND IDLER PULLEY ASSEMBLY

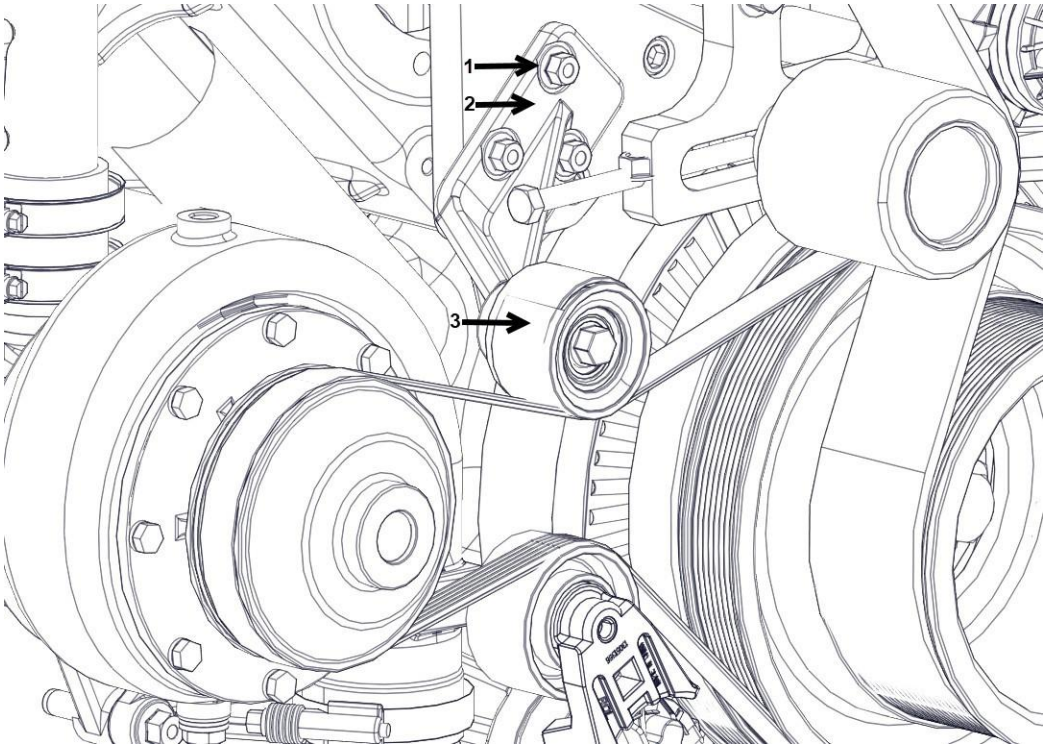


Figure 18. Right-Hand Idler Pulley Assembly

No.	Name
1	Right-hand Idler Pulley Bracket Bolts
2	Right-hand Pulley Bracket
3	Right-hand Idler Pulley

REMOVAL

1. Remove the three right-hand idler pulley bracket bolts.
2. Remove the right-hand pulley bracket.

INSTALLATION

1. Place the right-hand idler pulley bracket onto the manual belt tensioner frame.
2. Insert and torque down the three right-hand idler pulley bracket bolts.

FAN ASSEMBLY

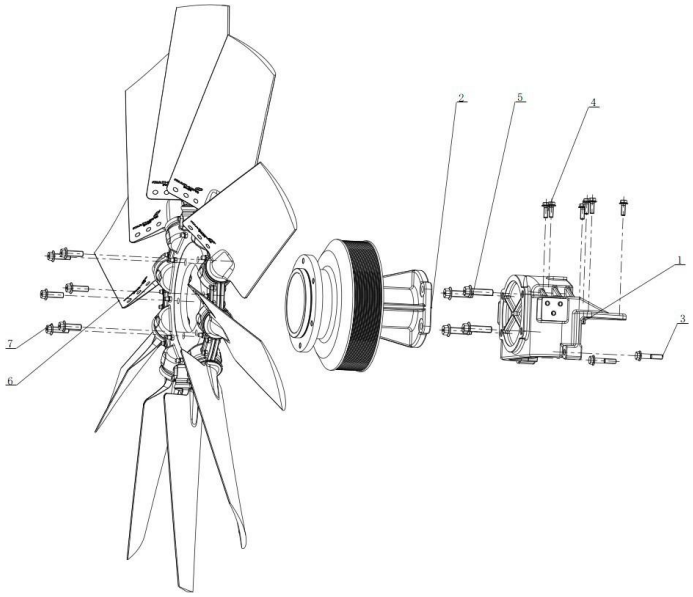


Figure 19. Fan Assembly

No.	Name	No.	Name
1	Fan support	5	Bolt
2	Fan Support Bracket	6	Fan
3	Bolt	7	Fan bolts
4	Bolt		

REMOVAL

1. Remove the six fan bolts.
2. Remove the fan.
3. Remove the four fan support bracket bolts.
4. Remove the fan support assembly

INSTALLATION

1. Clean all debris from the following components:
    a. Fan support
    b. Fan support assembly
    c. Fan
2. Place the fan support bracket above the front cover.
3. Insert and torque down the four fan support bracket bolts.
4. Place the fan onto the fan support bracket.
5. Apply blue loctite to all six fan bolts.
6. Insert and torque down the six fan bolts to 140 ft/lbs.

FRONT COVER

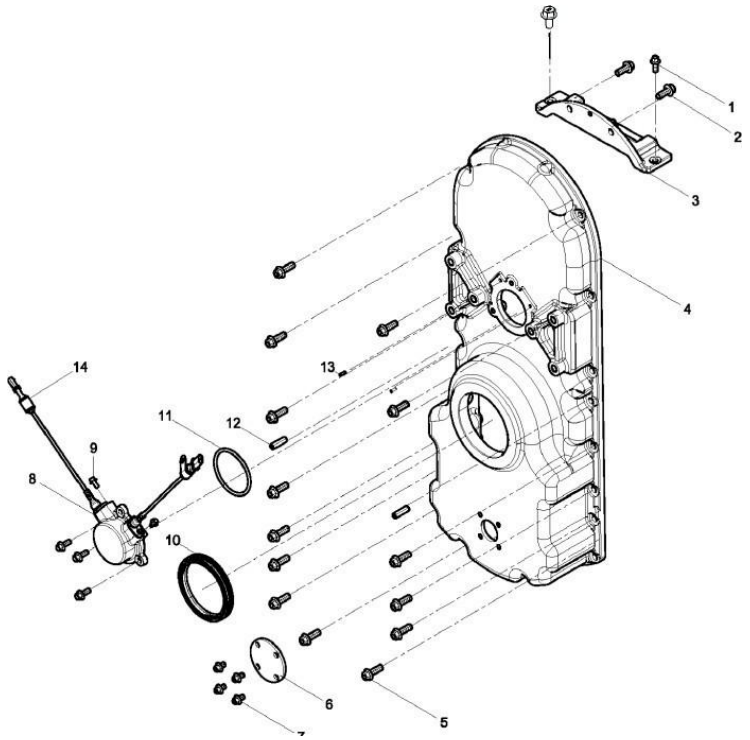


Figure 20. Front Cover Assembly

No.	Name	No.	Name
1	Bolt	8	Sensor Seat
2	Bolt	9	Bolt
3	Front Cover Bracket	10	Front Cover Seal
4	Front Cover	11	O-Ring
5	Bolt	12	Dowel Pin
6	Front Cover Plate	13	Dowel Pin
7	Bolt	14	Speed Sensor

REMOVAL

1. Drain oil and coolant into a suitable container.
2. Remove the FEAD assembly. (Refer to the FEAD section)
3. Remove the fan pulley assembly.
4. Remove the four bolts on the front cover bracket.
5. Remove the front cover bracket.
6. Remove the fourteen bolts on the front cover.
7. Using the two location pins on the front cover (refer to image below) insert two bolts into the location pins and with a soft face hammer begin to remove the front cover until it is free from the cylinder block.

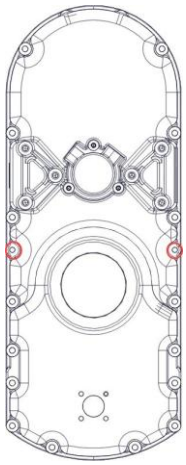


Figure 20 Continued.

NOTE:

Using the guide pins to install the front cover, prevents damaging the front crank seal.

INSTALLATION

1. Clean any debris from both surfaces of the cylinder block and rear of the front cover.
2. Apply new silicone sealant onto the back of the front cover.
3. Insert the four M10-1.5X140" front cover guide pins into the cylinder block.
4. Place the front cover into the guide pins and begin hand tighten all fourteen front cover bolts.
5. Remove the four guide pins and insert and hand tighten the remaining front cover bolts.
6. Insert and in a cross pattern tighten the fourteen front cover bolts to 65±5N•m.
7. Place the front cover bracket over the front cover.
8. Insert and torque down the four front cover bracket bolts.
9. Insert the fan pulley assembly.
10. Install the FEAD assembly. (Refer to the *FEAD* section of the manual)
11. Refer engine with oil and coolant.

TURBOCHARGERS

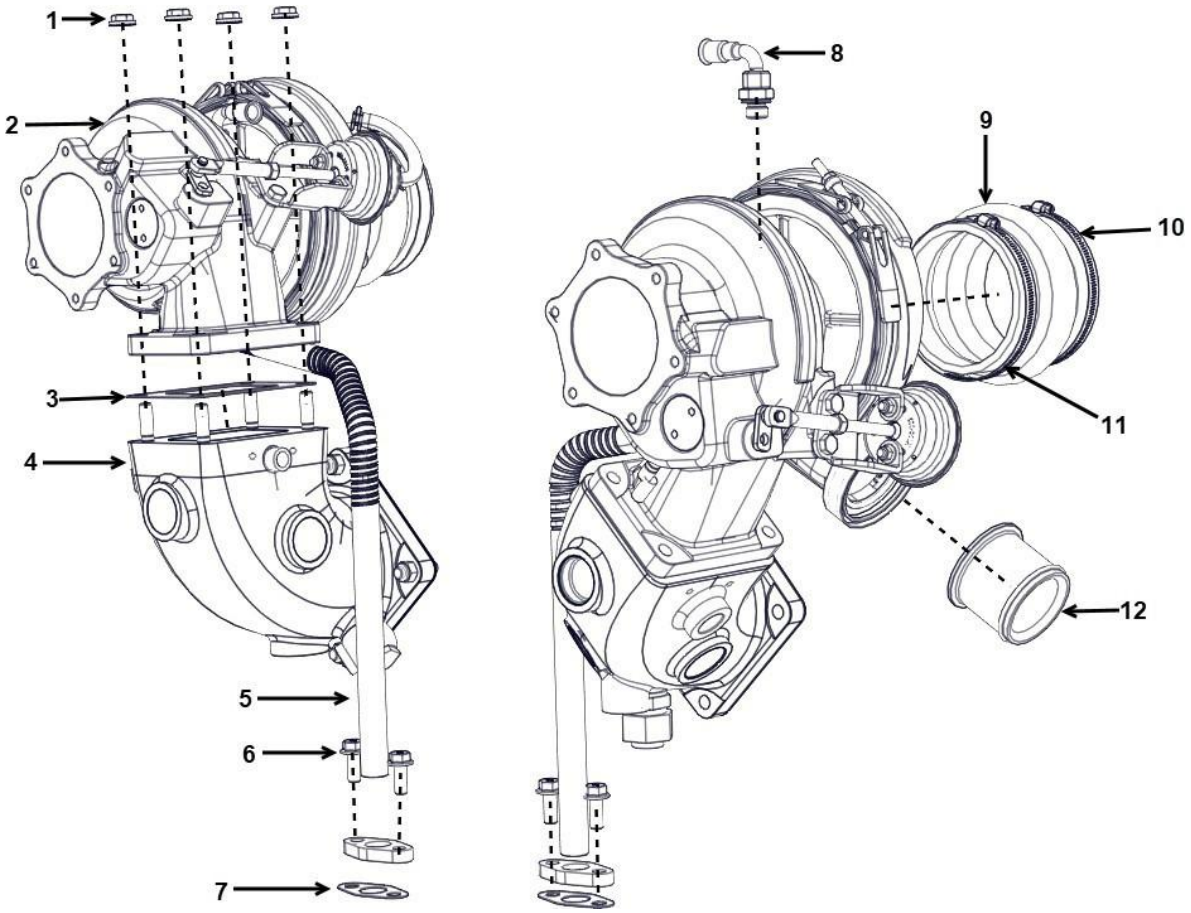


Figure 21. Turbocharger Assembly

No.	Name	No.	Name
1	Turbocharger Nut	7	Lower Oil Drain Gasket
2	Turbocharger	8	Oil Inlet Valve
3	Turbocharger Gasket	9	Turbocharger Out Hose
4	Exhaust Manifold	10	Turbocharger Hose Clamp
5	Oil Drain Tube	11	Turbocharger Hose Clamp
6	Lower Oil Drain Gasket	12	Turbocharger Tube

REMOVAL

1. Remove both turbo oil supply lines from the oil inlet valve. (Refer to Figure 22.)

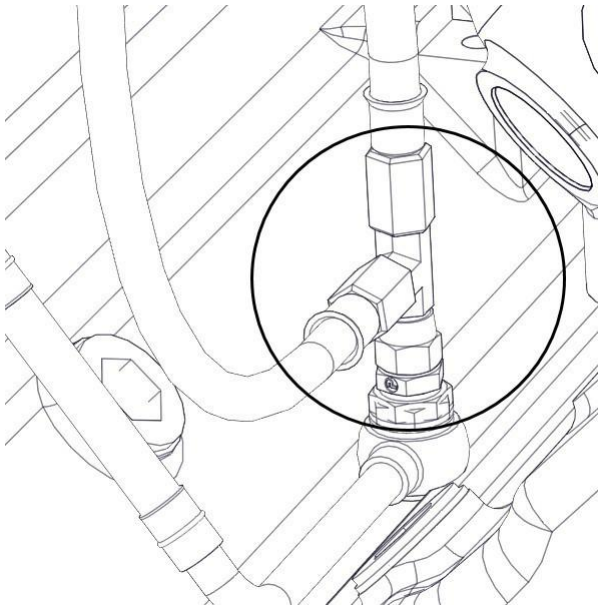


Figure 22. Turbocharger Oil Supply lines

2. Remove the top two oil drain bolts and gasket from each turbocharger.
3. Remove the lower two oil drain bolts and gasket from each turbocharger
4. Carefully remove both oil drain tubes.
    a. Ensure not to dent, damage, or scrape the oil drain tubes upon removal.
5. Remove Oil inlet valve. (If Necessary)
6. Untighten both turbocharger hose clamps (10 & 11) from each turbocharger. (Refer to Figure 21.)
7. Remove the four turbocharger nuts from each turbocharger. (Refer to Figure 21.)
8. Carefully remove both turbochargers.
9. Remove both turbocharger gaskets from the exhaust manifolds.

INSTALLATION

1. Clean any debris from both ends of the exhaust manifold and bottom of both turbochargers.
2. Place both new turbocharger gaskets over the four studs on the ends of the exhaust manifolds.

NOTE:

Both turbocharger gaskets should be placed with the round edges facing up and away from the exhaust manifolds.

3. Install both turbochargers over the turbocharger gaskets.
4. Insert and torque down all eight nuts over the four studs on the exhaust manifolds to 40 ft/lbs.
5. Level the oil inlet on both turbos using a level. (Refer to Figure 23.)
    a. Loosen the bolts on the inside of each turbo and rotate the oil inlet.
    b. Level the oil inlet.
    c. Tighten the inside bolts of each turbo.

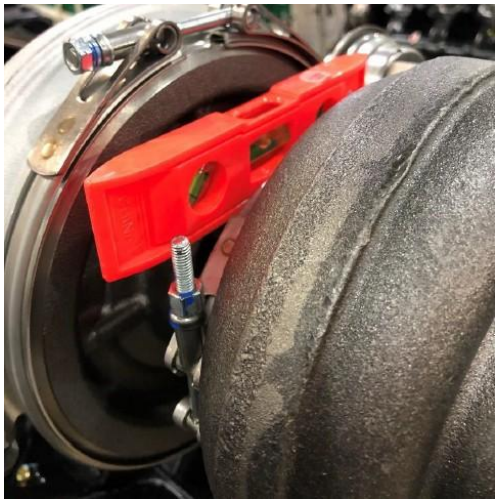


Figure 23. Oil Inlet Leveling

6. Orient both turbocharger compressor housings. (Refer to Figure 24.)
7. Tighten both V-band clamps (1 and 2) when complete. Torque clamps to 6.5 lb-ft (8.8 N·m).

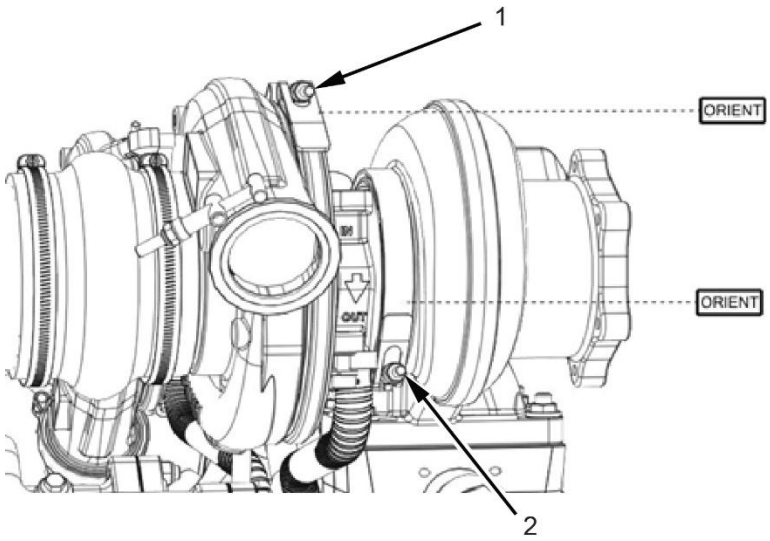


Figure 24. Compressor Housing Orientation

8. Place both washers into oil inlet. (Refer to Figure 25.)
9. Insert both oil inlet fittings and torque both fittings to 21 ft/lbs. (Refer to Figure25.)

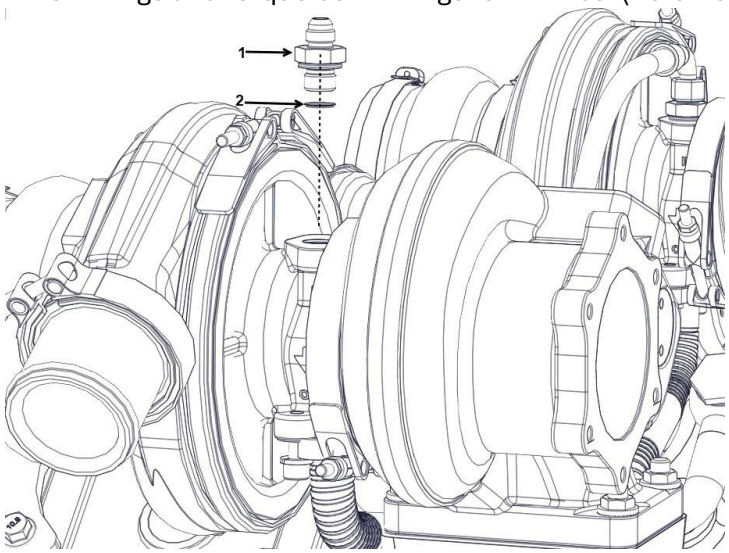


Figure 25. Oil inlet Assembly

10. Clean any debris from the bottom of the oil outlet on both turbochargers
11. Clean any debris from the top of the fly wheel housing.

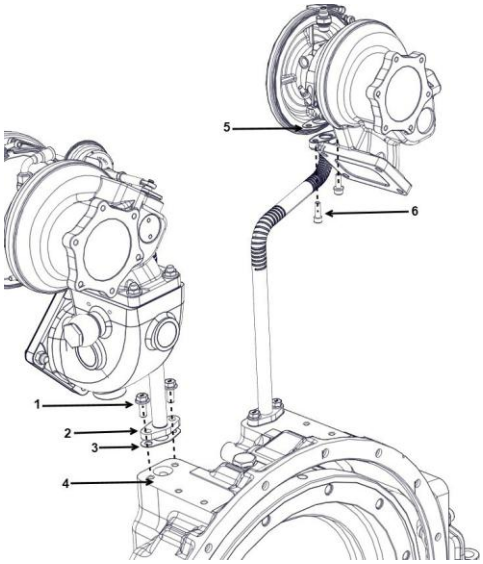


Figure 26. Oil Drain Tube Assembly

No.	Name	No.	Name
1	Lower Oil Drain Tube Bolt	4	Flywheel Housing
2	Oil Drain Tube	5	Upper Oil Drain Tube Gasket
3	Lower Oil Drain Tube Gasket	6	Upper Oil Drain Tube Bolt

12. Place the lower drain gasket over the flywheel housing and install the oil drain tube.
13. Insert and torque down both oil drain bolts to 51 ft/lbs.
14. Place upper drain gasket onto the bottom of the oil drain housing.
15. Apply PSI approved Loctite to both upper oil drain tube bolts.
16. Insert both washers then insert and torque down both upper oil drain tube bolts to 26ft/lbs.
17. Install both oil supply lines to the oil inlet fittings.

CRANK CASE VENTILATION CANISTER (CCV)

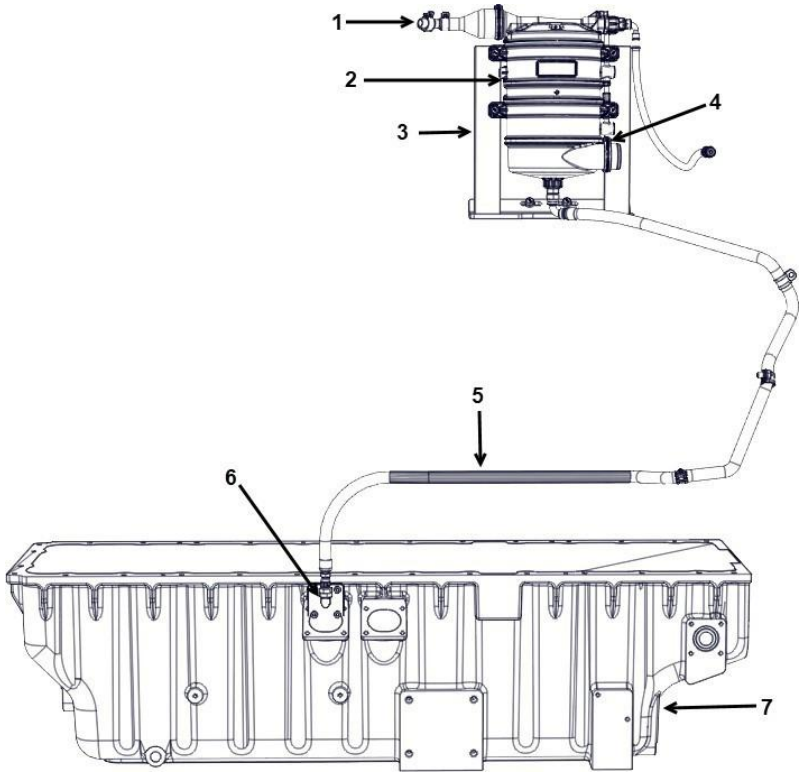


Figure 27. CCV Canister Assembly

No.	Name	No.	Name
1	CCV “Y” Hose	5	CCV Hose
2	CCV Canister	6	Oil Drain Valve
3	CCV Bracket	7	Oil Pan
4	CCV Adapter Hose Clamp		

REMOVAL

1. Disconnect the CCV hose from the oil drain valve and the boost pressure hose.
2. Remove all clamps holding down the CCV hose against the cylinder block.
3. Disconnect the CCV hose from the canister.
4. Unscrew CCV adapter hose clamp.
5. Remove all four CCV canister bolts. (Refer to Figure 28)
6. Remove CCV Canister.

INSTALLATION

1. Place CCV canister onto the CCV bracket.
2. Insert and torque down all four CCV canister bolts onto the CCV canister bracket.

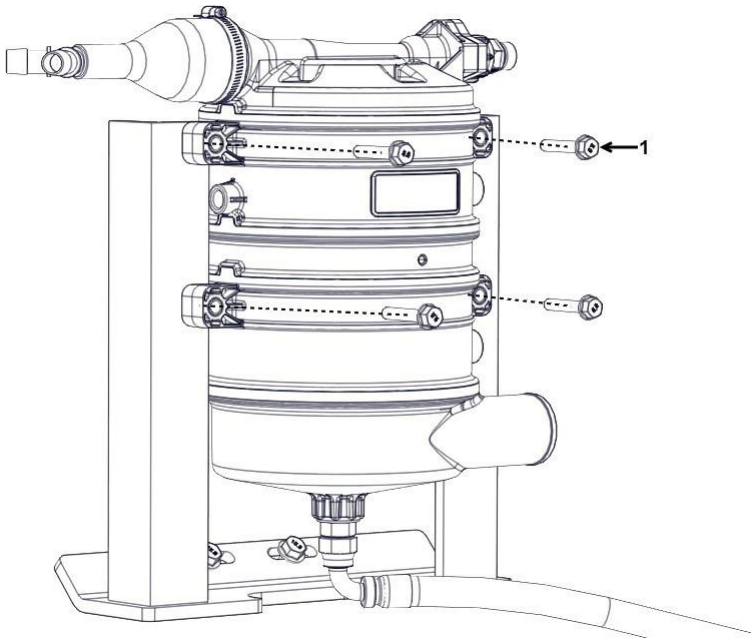


Figure 28. CCV Canister Bolts

No.	Name
1	CCV Canister Bolt

3. Clamp down the CCV adapter hose.
4. Insert and connect the CCV hose to the bottom of the CCV canister and the boost pressure hose.
5. Secure the CCV hose by clamping down the hose onto the cylinder block.

NOTE:

Ensure the CCV hose is run behind the oil filters then into the oil drain valve.

6. Connect the CCV hose onto the oil drain valve.

FUEL SYSTEM

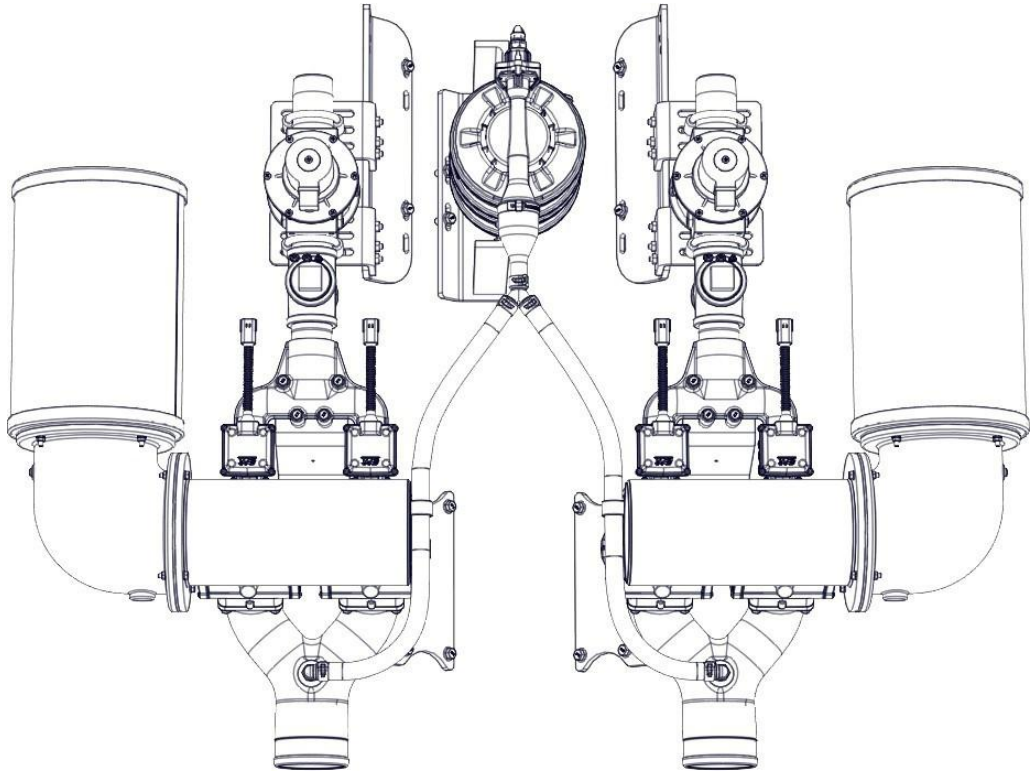


Figure 29. Fuel System Assembly

NOTE:

Each cylinder bank operates with two Direct Electronic Pressure Regulator (DEPR) and two diaphragm style variable venturi mixer.

The DEPR and mixers are not adjustable and should not be tampered with.

AIR FILTERS

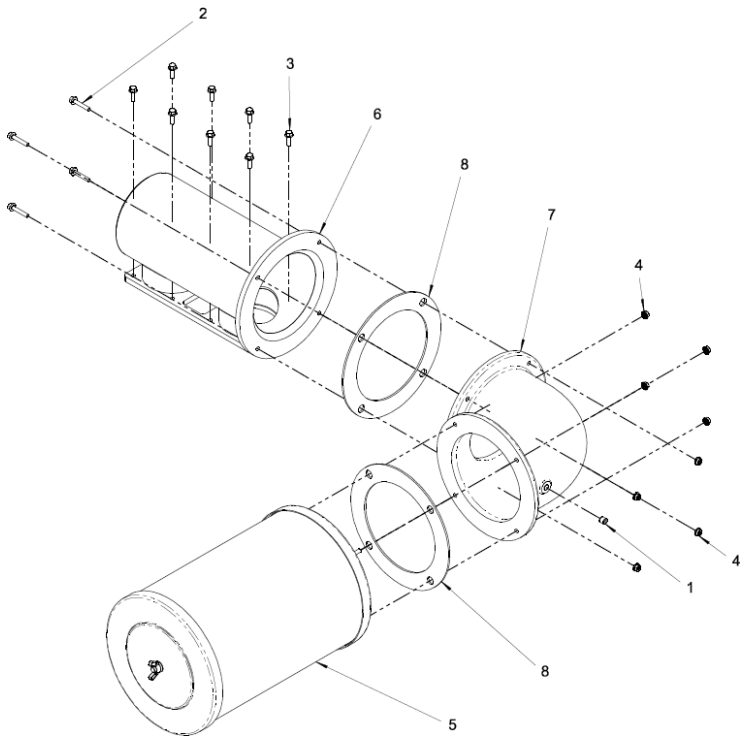


Figure 30. Air Filter Assembly

No.	Name
1	Plug
2	Bolt
3	Flange Bolt
4	Nut
5	Air Filter Element
6	Filter To Mixer Adapter
7	Elbow Adapter
8	Air Filter Gasket

REMOVAL

1. Remove all four air filter nuts.
2. Remove the air filter element along with the air filter gasket.
3. Remove all four nuts from the elbow adapter.
4. Remove air filter gasket.
5. Remove all eight flange bolts.
6. Remove the filter to mixer adapter.

INSTALLATION

1. Place filter to mixer adapter over the mixer.
2. Insert and torque down all eight flange bolts.
3. Clean any debris from both ends of the elbow adapter and the filter to mixer adapter.
4. Insert the air filter gasket onto the filter to mixer adapter.
5. Insert and place the elbow adapter onto the filter to mixer adapter.

NOTE:

Ensure to have the small threaded hole of the elbow adapter facing out and away from the engine. (Refer to Figure 31.)

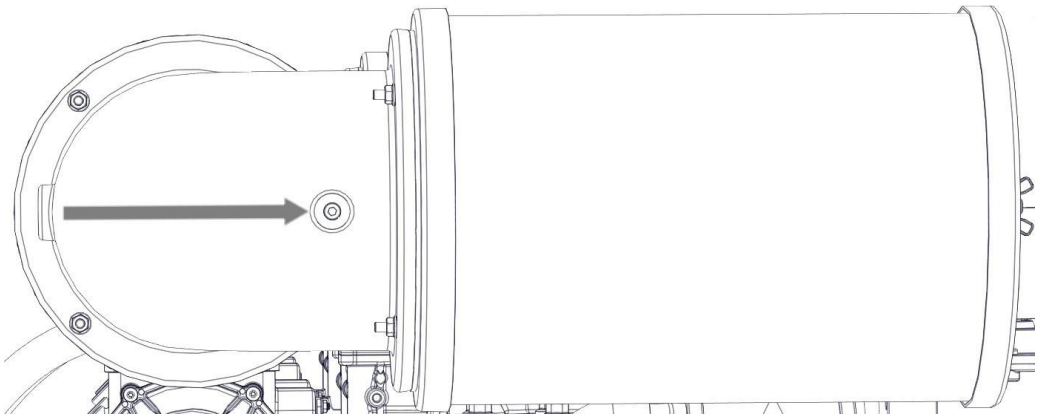


Figure 31. Elbow Adapter

6. Insert and tighten all four filters to mixer adapter nuts.
7. Clean any debris from the end of the air filter element.
8. Place the air filter gasket onto the air filter element.
9. Insert both the air filter gasket and element onto the elbow adapter.
10. Insert and tighten all four air filter element nuts.
11. Tighten the wing nut at the end of the air filter element if necessary.

DIRECT ELECTRONIC PRESSURE REGULATOR (DEPR) AND FUEL MIXER ASSEBMLY

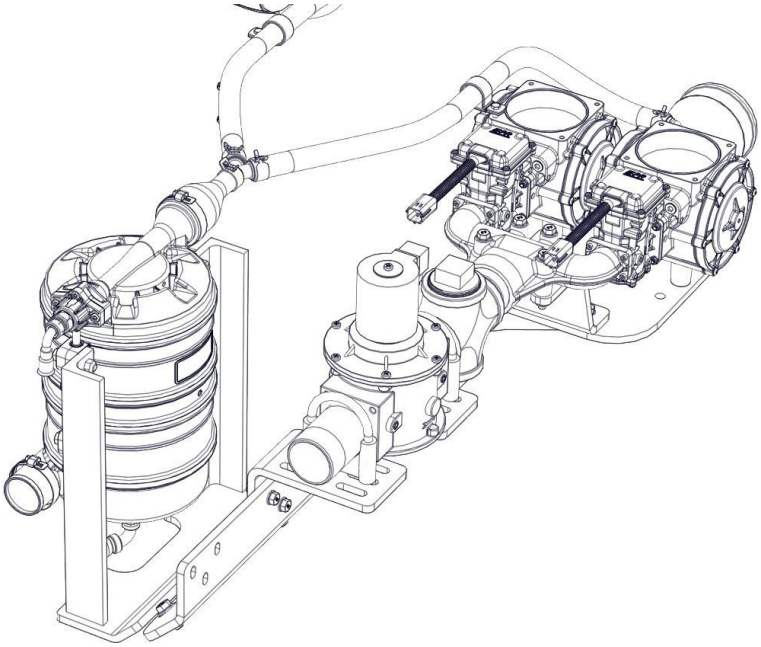


Figure 32. DEPR and Fuel Mixer Assembly

REMOVAL

1. Remove the air filter assembly. (Refer to the Air Filter Section)
2. Disconnect both CCV vapor hoses from the back of each mixer assembly.
3. Disconnect both clamps on the mixer to turbo adapter hose.
4. Remove the three hex cap bolts underneath the dual mixer bracket. (Refer to Figure33.)

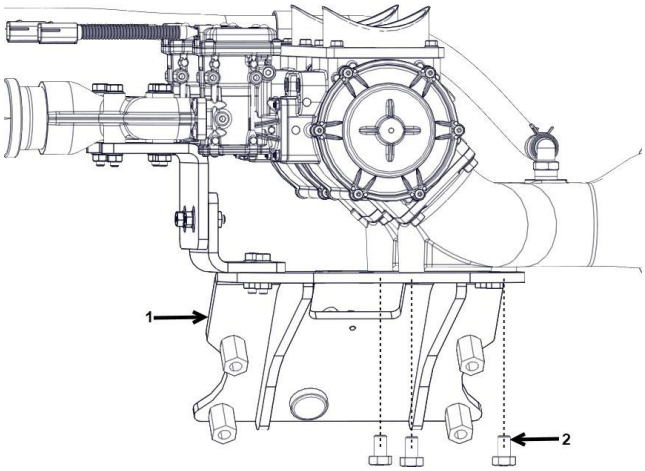


Figure 33. Dual Mixer Bracket Assembly

No.	Name	No.	Name
1	Dual Mixer Bracket	2	Hex Cap Bolt

5. Remove the four bolts directly above the dual DEPR bracket. (Refer to Figure 34.)

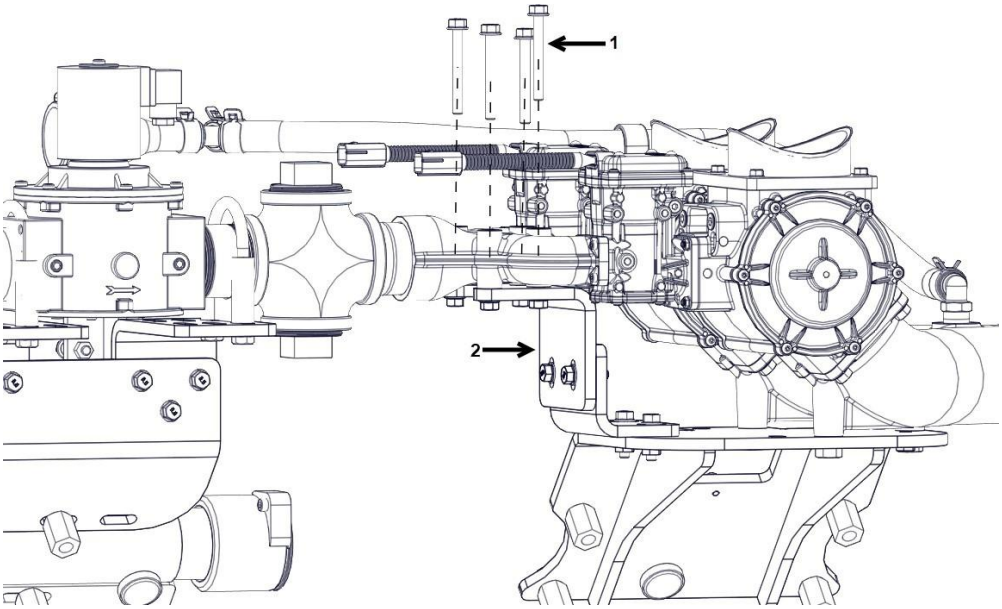


Figure 34. DEPR Bracket Assembly

No.	Name
1	Bolts
2	Dual DEPR Bracket

6. Remove the four nuts directly below the “U” clamps bolts and the upper lock off bracket. (Refer to Figure 35.)

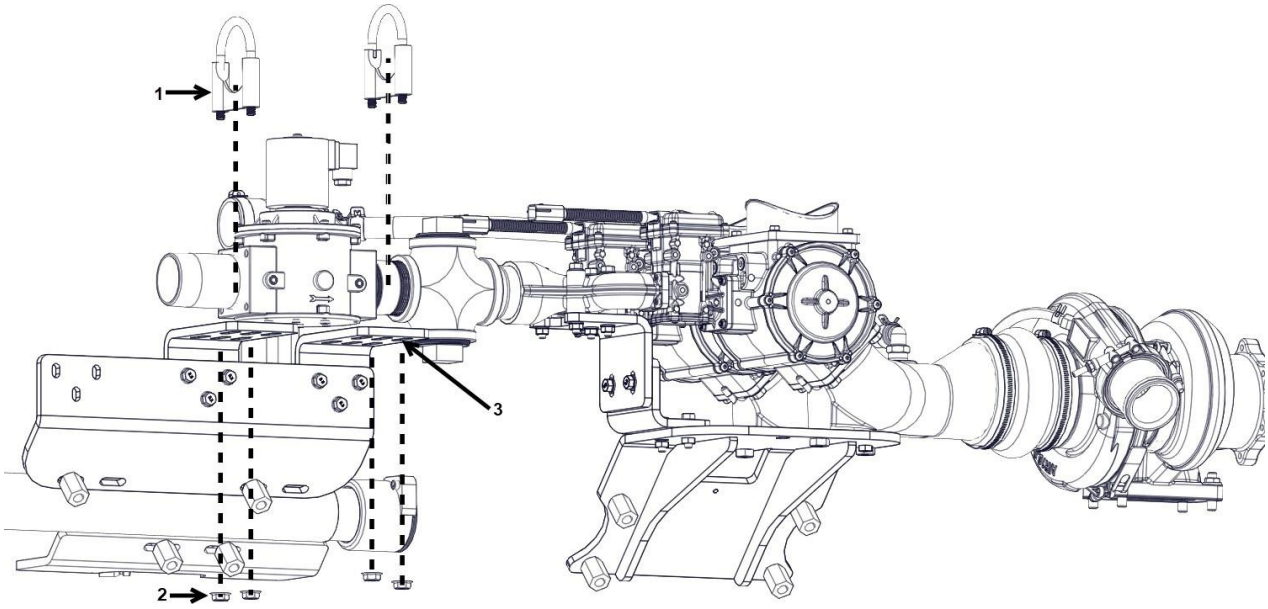


Figure 35. Upper Lock off Bracket Assembly

No.	Name
1	“U” Clamp Bolt
2	Nut

7. Carefully remove the entire DEPR and fuel mixer assembly.

INSTALLATION

1. Ensure all fuel mounts have been mounted before installing the DEPR and fuel mixer assembly. (Refer to the FUEL MOUNTING BRACKETS section)

NOTE:

Loosening the fuel mounts may ease the DEPR and fuel mixer installation process.

2. Carefully place the DEPR and fuel mixer assembly over the upper lock off bracket, DEPR bracket and dual mixer bracket.
3. Apply PSI approved Loctite to the three hex cap bolts.
4. Insert and torque down the three hex cap bolts from the bottom of the dual mixer bracket to 12 ft/lbs.
5. Insert and torque down the four DEPR bolts to 22 ft/lbs.
6. Place “U” clamp bolt over the lock off valve and through the upper lock off bracket.
7. Insert and torque down the two nuts directly under the upper lock off bracket onto the “U” clamp bolts.
8. Reconnect both CCV vapor hoses to the back of each mixer assembly.
9. Reconnect both clamps on the mixer to turbo adapter hose.

FUEL MOUNTING BRACKETS

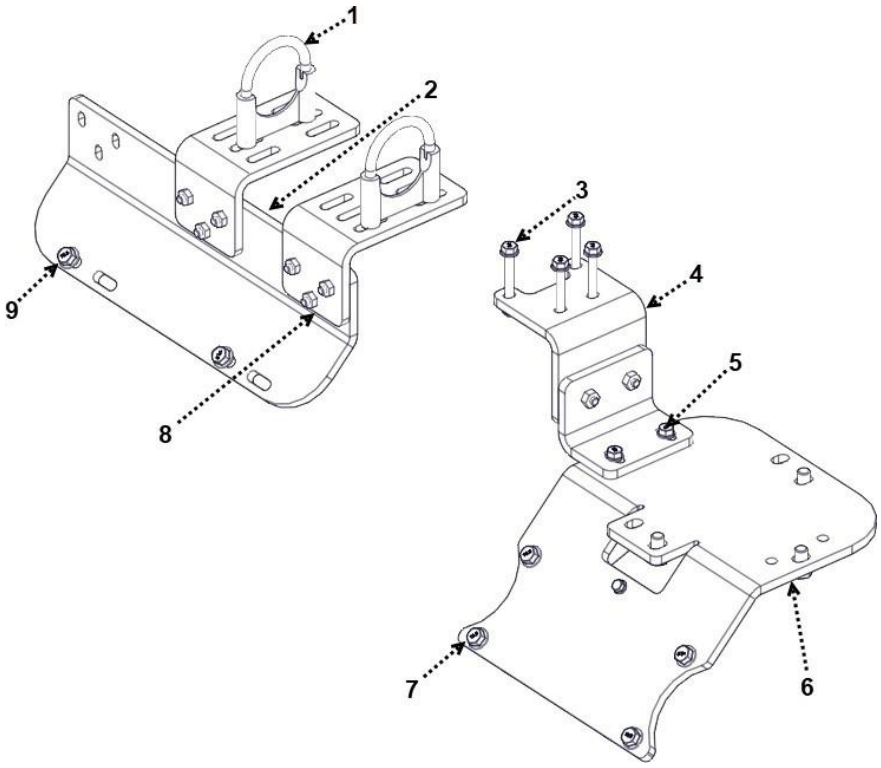


Figure 36. Fuel Mounting Bracket Assembly

No.	Name
1	“U” Clamp
2	Lower Lock off Bracket
3	Bolt
4	Dual DEPR Bracket
5	Bolt
6	Dual Mixer Bracket
7	Bolt
8	Upper Lock off Bracket
9	Bolt

REMOVAL

1. Remove the air filter assembly. (Refer to the Air Filter Section)
2. Remove DEPR and fuel mixer assembly. (Refer to the DEPR and FUEL MIXER ASSEMBLY Section)
3. Remove the two bolts that feed into the dual DEPR bracket and run through the dualmixer bracket.
4. Remove each dual DEPR bracket.
5. Remove the four bolts that feed into the dual mixer bracket and run through theexhaust manifold.
6. Remove each dual mixer bracket.
7. Remove the three bolts on each upper lock off bracket.
8. Remove each upper lock off bracket.
9. Remove the two bolts on each of the lower lock off bracket.
10. Remove each lower lock off bracket.

INSTALLATION

1. Place the dual mixer bracket towards the back of the engine by the turbochargers over the exhaust manifold. (Refer to Figure 37.)
2. Insert and torque down the four bolts to 60 ft/lbs. (Refer to Figure37.)

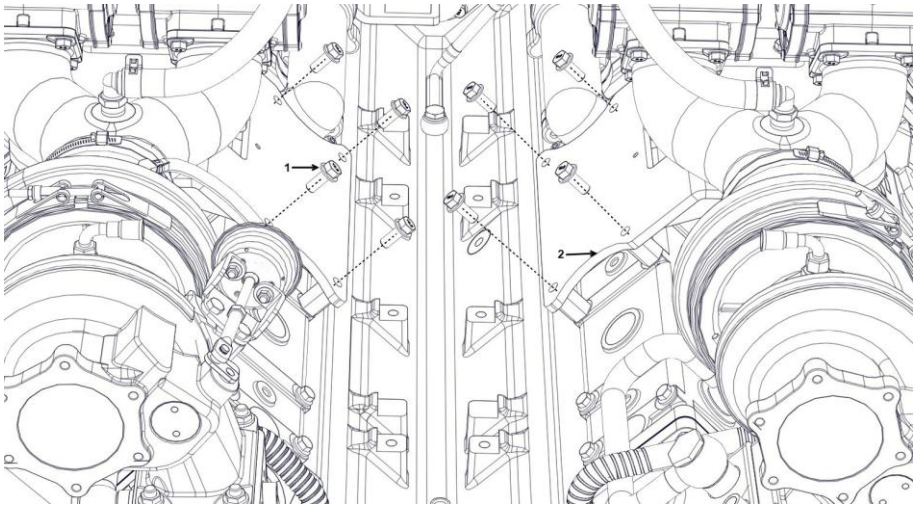


Figure 37. Dual Mixer Bracket Assembly

No.	Name
1	Bolt
2	Dual Mixer Bracket

3. Place the dual DEPR bracket over the dual mixer bracket. (Refer to Figure38.)
4. Insert and torque down both bolts into the dual DEPR and dual mixer brackets to 22 ft/ lbs. (Refer to Figure 38.)

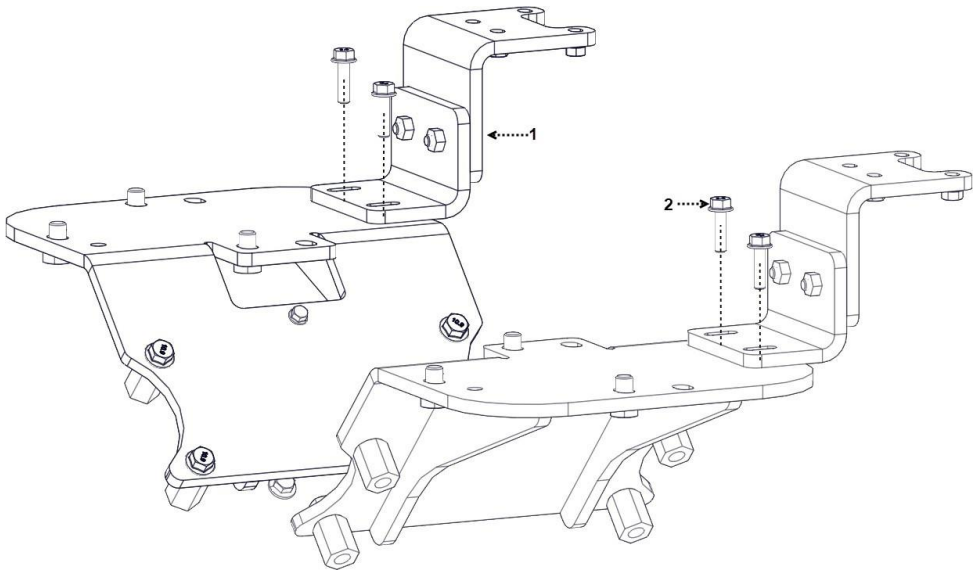


Figure 38. Dual DEPR Bracket Assembly

No.	Name	No.	Name
1	Dual DEPR Bracket	2	Bolt

5. Place each lower lock off bracket over the exhaust manifold to the left and right of the CCV canister.
6. Insert and torque down the two bolts to each lower lock off bracket. (Refer to Figure 39).

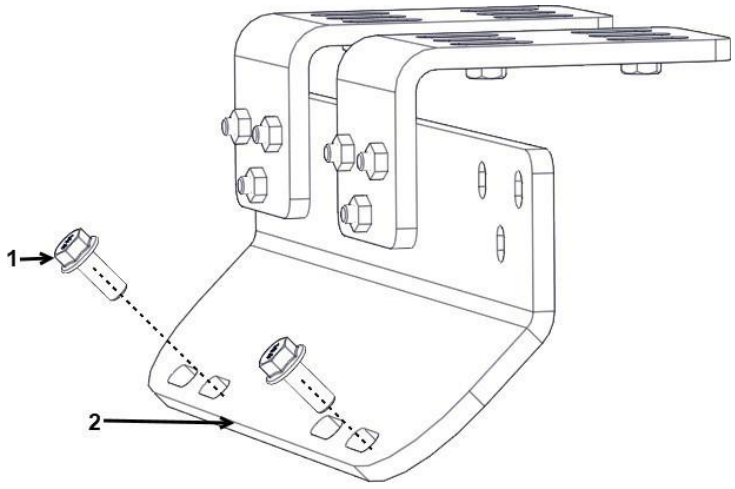


Figure 39. Lower Lock off Bracket

No.	Name	No.	Name
1	Bolt	2	Lower Lock-Off Bracket

7. Place the upper lock off bracket on the lower lock off bracket. (Refer to Figure 40.)
8. Insert the bolt into the upper and lower lock off bracket.
9. Insert and toque down the nut behind the upper lock off bracket. (Refer to Figure 40.)

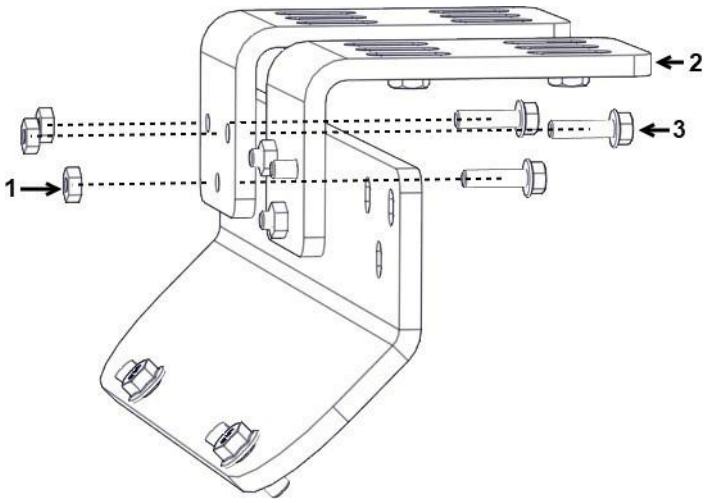


Figure 40. Upper Lock off Bracket Assembly

EXHAUST MANIFOLD

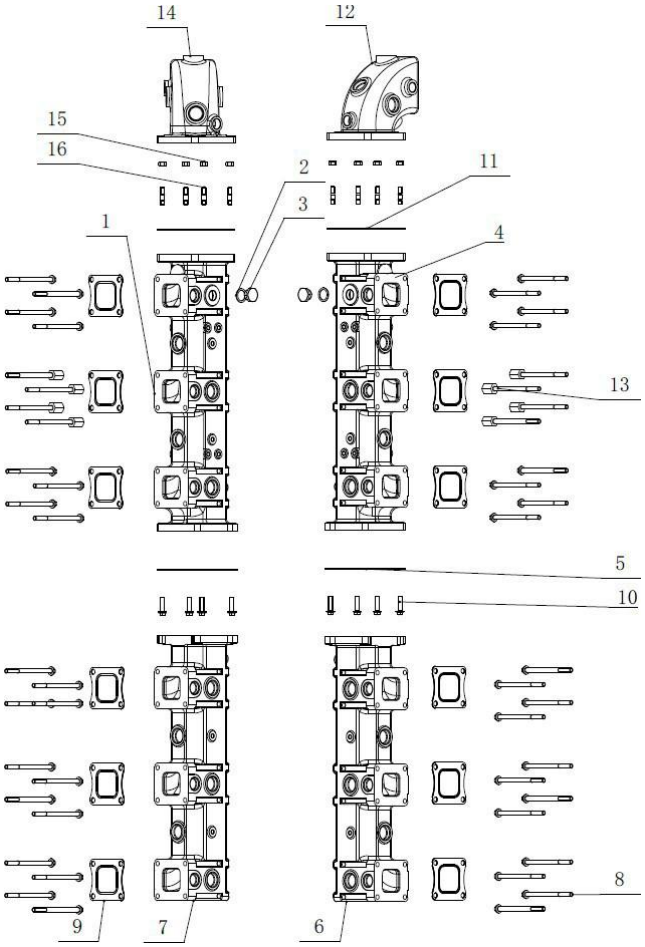


Figure 41. Exhaust Manifold Assembly

No.	Name	No.	Name
1	Exhaust Manifold	9	Exhaust Manifold to Cylinder Head Gasket
2	Washer	10	Bolt
3	Head Plug	11	Gasket
4	Exhaust Manifold	12	Exhaust Manifold to Turbo Assembly
5	Exhaust Manifold Mid Gasket	13	Bolt
6	Exhaust Manifold	14	Exhaust Manifold to Turbo Assembly
7	Exhaust Manifold	15	Nut
8	Bolt	16	Stud

NOTE:

The exhaust manifold is made up of three different sections.

All fuel system components must be removed before dissembling the exhaust manifold.

REMOVAL

1. Drain the coolant from the engine into a suitable container.
2. Remove the water pump tubes leading to the mid-section of the exhaustmanifold.
3. Remove all exhaust manifold assembly bolts.
4. Loosen the exhaust manifold and cylinder head fastening bolts and remove the exhaust manifold and gasket in sections to ensure safe removal.
5. Loosen the connecting bolts between the exhaust manifolds and remove the exhaust manifold gasket.

INSTALLATION

1. Clean any debris from the cylinder head.
2. Insert and tighten the water pump tubes.
3. Place the exhaust manifold gasket onto the cylinder head and tighten the connectingbolts between the exhaust manifolds.
4. Apply pipe thread sealant on the exhaust manifold bolts that push through the pushrod cavity.
5. Place the exhaust manifold and insert and tighten the exhaust manifold and cylinder head fastening bolts.
6. Insert and tighten the exhaust manifold stud nut.

INTAKE MANIFOLD

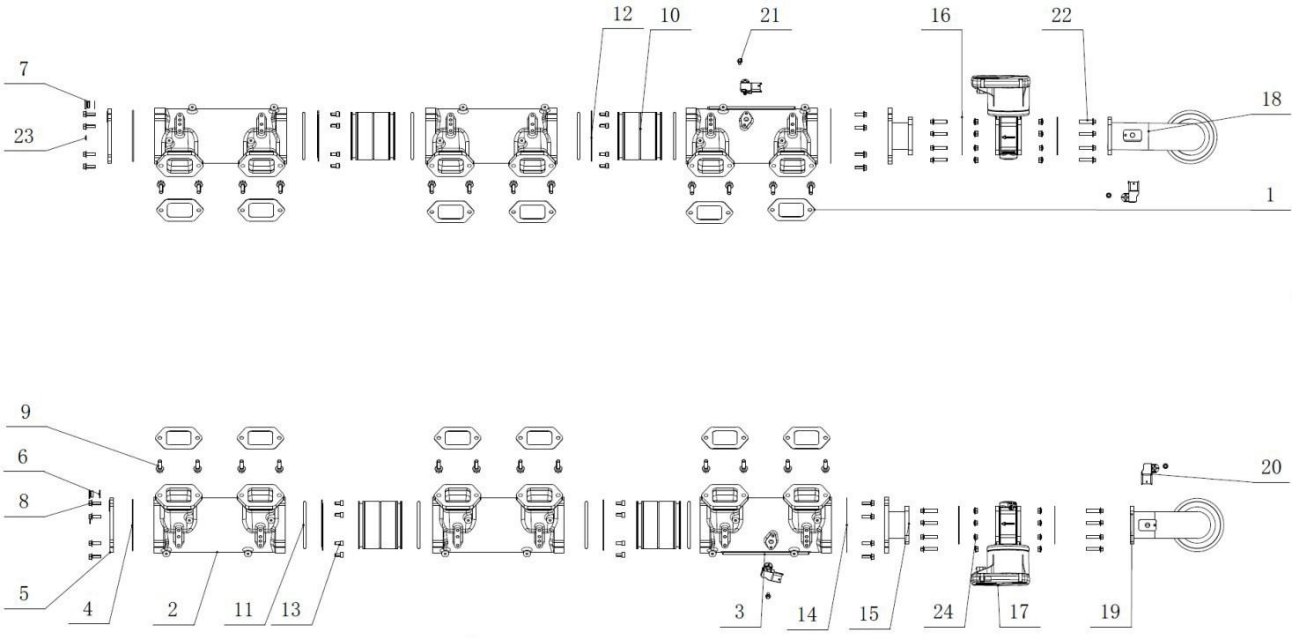


Figure 42. Intake Manifold Assembly

No.	Name	No.	Name
1	Intake manifold gasket	13	Head Cap Screw
2	Intake manifold	14	Intake Manifold Gasket
3	Intake manifold	15	Mixed Air Intake Manifold
4	O-Ring	16	Gasket
5	Intake manifold cover	17	Throttle Body
6	Washer	18	Intercooler Air Pipe Assembly
7	Bolt	19	Intercooler Air Pipe Assembly
8	Bolt	20	Intake Air Temperature and Pressure Sensor
9	Bolt	21	Bolt
10	Intake manifold Adapter	22	Bolt
11	O-Ring	23	Washer
12	Thrust ring	24	Nut

REMOVAL

1. Remove the two bolts on each ECM bracket.
2. Remove all intake manifold bolts.
    a. Remove the intake manifold in sections to ensure careful disassembly.
3. Loosen the hexagon flange bolts to remove the intake manifold cover and O-ring.
4. Loosen the thrust ring bolts and remove the intake manifold, connecting pipe and O-ring.

INSTALLATION

1. Clean any debris from the cylinder head.
2. Insert intake manifold gasket on cylinder head.
3. Insert intake manifold, connecting pipe and O-ring and tighten the thrust ring bolts.
4. Insert the intake manifold cover and O-ring and tighten the hexagon flange bolts.
5. Insert and tighten the intake manifold bolts.
6. Insert and torque down both the ECM bracket bolts to the intake manifold.

EXPLOSION RELIEF VALVE

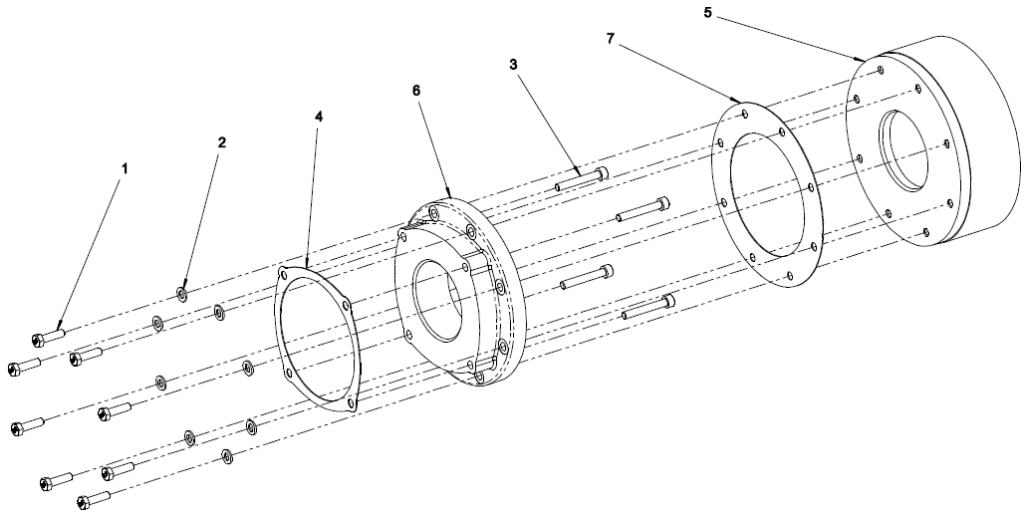


Figure 43. Explosion Relief Valve Assembly

No.	Name
1	Bolt
2	Flat Washer
3	Bolt
4	Throttle Adapter Gasket
5	Relief Valve
6	Relief Valve Adapter
7	Relief Valve Gasket

CAUTION:

Do not remove valve unless specifically requested by PSI.

REMOVAL

1. Remove the eight bolts from the rear of the relief valve.

CAUTION:

The relief valve is 22 pounds and could cause extreme harm if not handled accordingly.

2. Remove the explosion relief shield.
3. Remove the relief valve.
4. Remove the relief valve gasket.
5. Remove the four bolts from the relief valve adapter.
6. Remove the throttle adapter gasket.

INSTALLATION

1. Clean any debris from both intake manifolds.
2. Place relief valve adapter gasket onto the relief valve adapter.
3. Insert both relief valve adapter and gasket onto the end of the intake manifold.
4. Apply PSI approved Loctite to all four relief valve adapter bolts.
5. Insert and torque down all four relief valve adapter bolts to 27 ft/lbs.
6. Clean any debris from the surface of the relief valve.
7. Place all eight washers onto the eight relief valve bolts.
8. Carefully place the relief valve gasket and relief valve onto the relief valve adapter.
9. Place the explosion relief shield on the back of the relief valve and ensure the shield is pointed out and away from the engine.
10. Insert and torque down the eight washers and bolts in the below sequence to 27 ft/lbs. (Refer to Figure 44.)

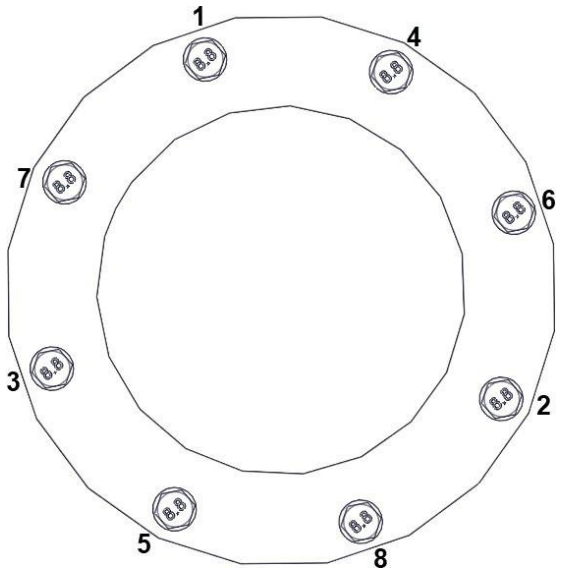


Figure 44. Explosion Relief Valve Torquing Sequence

IGNITION COIL

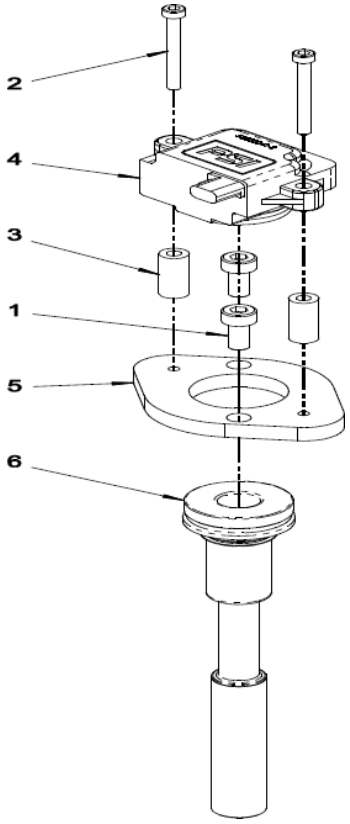


Figure 45. Ignition Coil Assembly

No.	Name
1	Bolt
2	Bolt
3	Spacer
4	Ignition Coil
5	Ignition Coil Bracket
6	Ignition Coil Boot

REMOVAL

1. Remove the two bolts on the ignition coil.
2. Remove the ignition coil.
3. Remove the two spacers directly below the ignition coil.
4. Remove the two bolts on the ignition coil bracket.
5. Remove the ignition coil bracket.
6. Remove ignition coil boot if necessary.

INSTALLATION

1. Apply dielectric grease to each spark plug end of the coil boot.
2. Carefully insert and torque down the spark plug (Figure 44, Item 7) to 25 ft/lbs.
3. Apply dielectric grease (Permatex Dielectric grease #81150 or equivalent) to each coil (Figure 44, Item 6).
4. Install ignition coil bracket (Figure 44, Item 5) and torque down the two ignition coil bracket bolts (Figure 44, Item 1) to 17 ft-lbs.
5. Insert the coil boot (Figure 44, Item 6) into the spark plug tube (Figure 44, Item 7) and press firmly to ensure it fully seats on the spark plug, Install the ignition coil on top of the boot.
6. Insert the ignition coil bolts and spacers (Figure 44, Items 2 & 3) and torque down the bolts to 80 in-lbs.

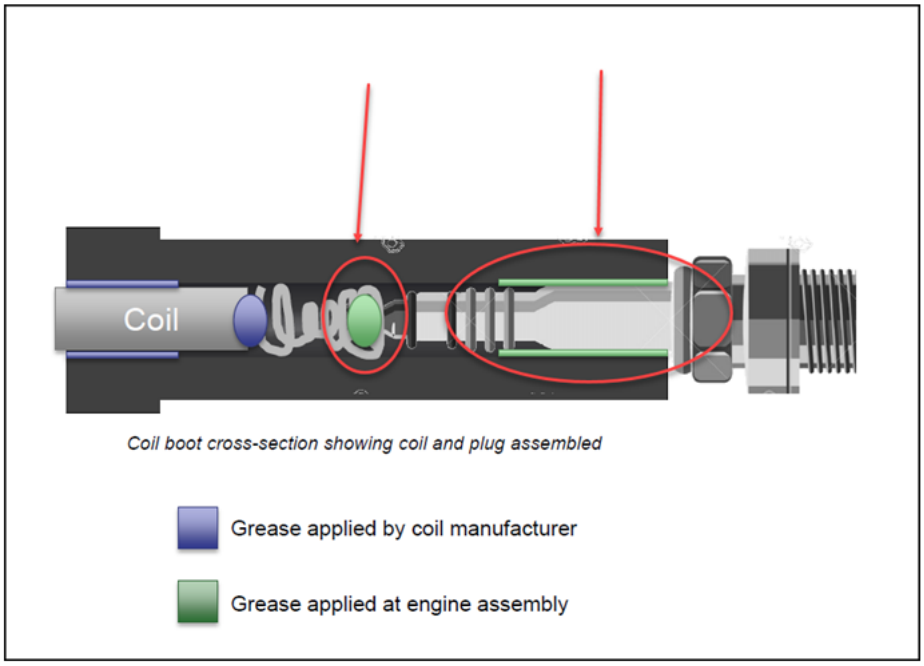


Figure 46. Dielectric Grease applied to ignition coil boots

CYLINDER HEAD COVER

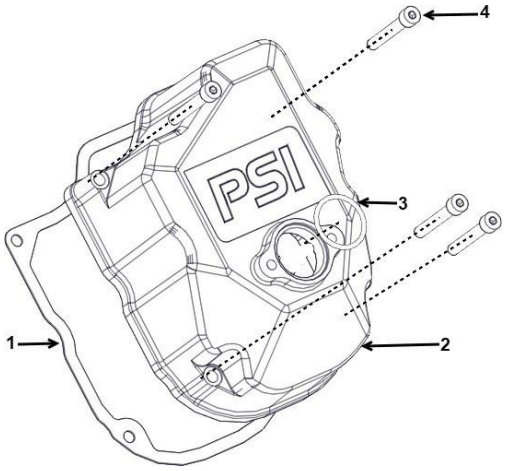


Figure 47. Cylinder Head Cover

No.	Name
1	Cylinder Head Cover Gasket
2	Cylinder Head Cover
3	Cylinder Head Ignition Coil O-Ring
4	Cylinder Head Cover Bolt

NOTE:

Removing the cylinder head requires that the spark plugs be removed in advance.

Failure to remove the spark plugs in advance could result in damages to the spark plugs because their tips are protruding from the cylinder head combustion chamber surface.

REMOVAL

1. Remove all four cylinder head cover bolts.
2. Remove Cylinder head cover and gasket.

INSTALLATION

1. Clean top of cylinder head of any debris.
2. Install gasket onto cylinder head.
3. Install cylinder head cover and tighten all four bolts to 20 ft/lbs.
4. Place the cylinder head ignition coil O-ring in preparation for ignition coil installation.

ROCKER ARMS

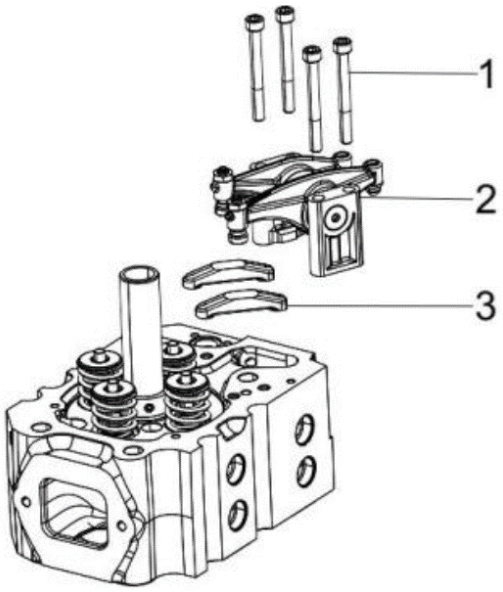


Figure 48. Rocker Arms

1. Remove the bolts (Figure 48, 1) that retain the rocker arm shaft supports.
2. Remove the rocker arm shaft assembly (Figure 48, 2) from the cylinder head.
3. Remove the valve bridge (Figure 48, 3).

NOTE:

Identify the push rods and rocker assembly components so they can be reinstalled in their original locations.

4. Remove the push rods and identify for installation.
5. Remove the rocker arm support (Figure 49, 1).
6. Slide the exhaust rocker arm assembly (Figure 49, 2) out of the rocker arm shaft assembly (Figure 49, 4), rocker arm shaft sleeve (Figure 49, 3), and intake rocker arms assembly (Figure 49, 5).

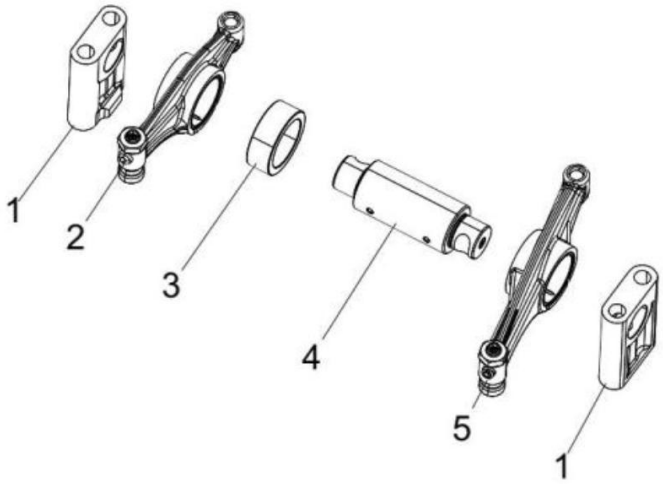


Figure 49. Rocker Arm Assembly

CYLINDER HEAD REMOVAL

1. Loosen the cylinder secondary bolts in the following order (Figure 50).

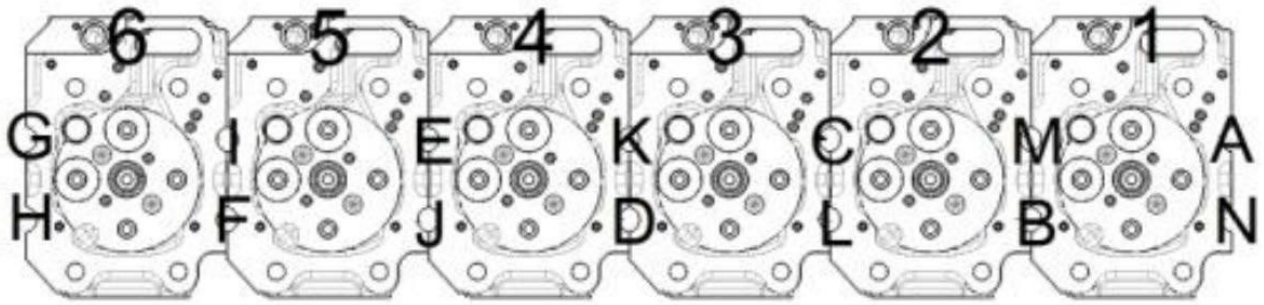


Figure 50. Cylinder Head Removal Order

NOTE:

Primary and secondary head bolts may be reused a maximum of three times and MUST be discarded after allowed usage.

2. Remove the cylinder secondary bolts (Figure 51, 1). Take the gasket (Figure 51, 2), clamping block (Figure 51, 3) and end plate (Figure 51, 4).

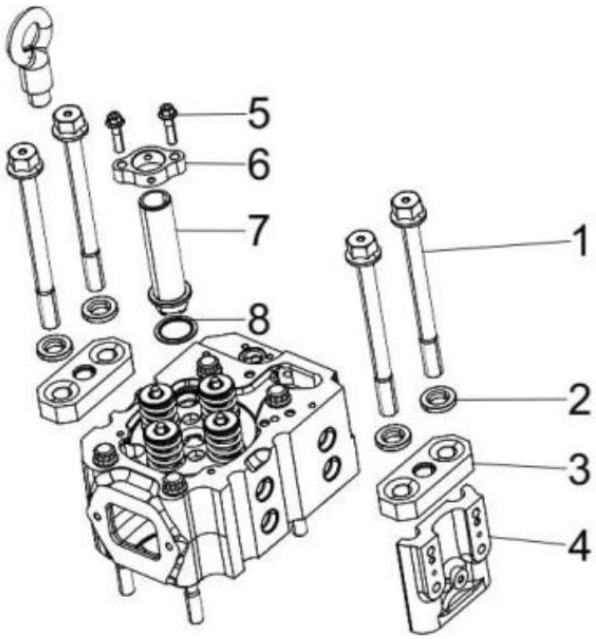


Figure 51. Cylinder head Assembly

3. Loosen the bolts (Figure 52, 5) and remove ignition coil bush clamp (Figure 52, 6).
4. Remove the ignition coil bush (Figure 52, 7) and the gasket (Figure 52, 8).
5. Remove the cylinder head main bolts in the following order (Figure 52)

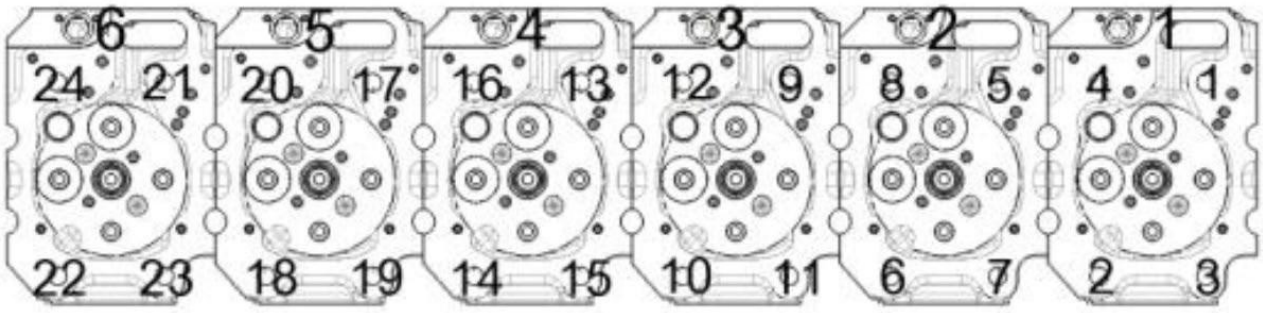


Figure 52. Cylinder Head Main Bolt Assembly

6. Lift the cylinder head away from the cylinder block (Figure 53, 2). Discard the cylinder head gasket (Figure 53, 3).

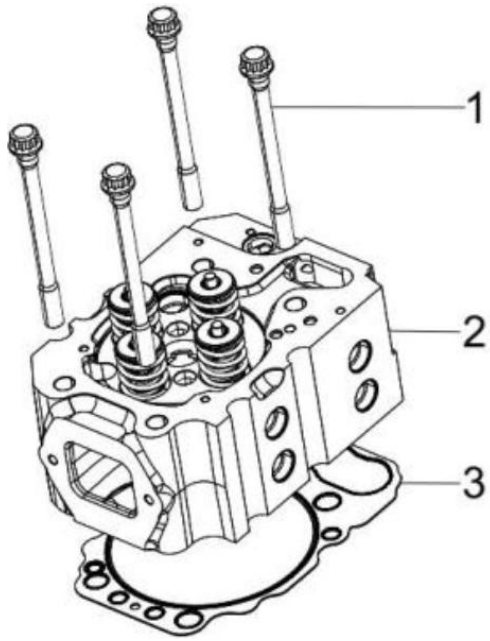


Figure 53. Cylinder Head Assembly

7. Place the cylinder head on the work bench with the combustion side down.
8. Using the valve spring compressor tool, compress the valve springs (Figure 54).

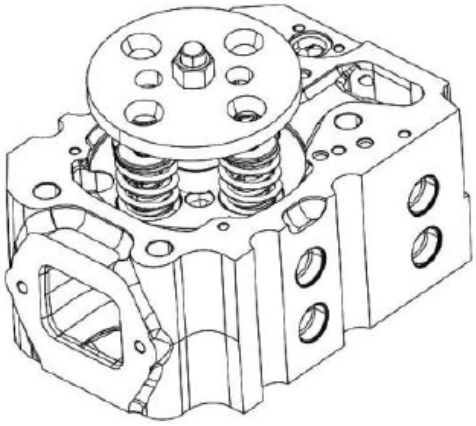


Figure 54. Valve Spring Compressor Assembly

9. Remove the valve collet (Figure 55, 1).
10. Slowly release the tension on the valve spring.
11. Remove the spring top retainer (Figure 55, 2) and outer/inner valve spring (Figure 55, 3/4).
12. Repeat the procedure with all remaining valves.

NOTE:

If the valves are to be reused, identify them so they can be installed in their original location.

13. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves (Figure 55, 7/8) from the cylinder head.
14. Remove the valve stem seals (Figure 55, 5).
15. Remove the spring bottom retainer (Figure 55, 6).

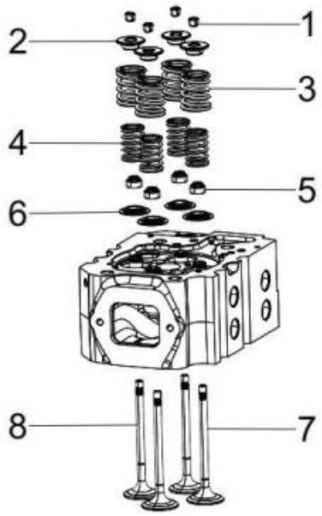


Figure 55. Cylinder Head Assembly.

NOTE:

Removal of the valve guides should be postponed until inspection and measurement procedures have been performed.

3. If the valve guides were not within specifications, use a hydraulic press to drive the valve guides (Figure 56, 1) out of the cylinder head.

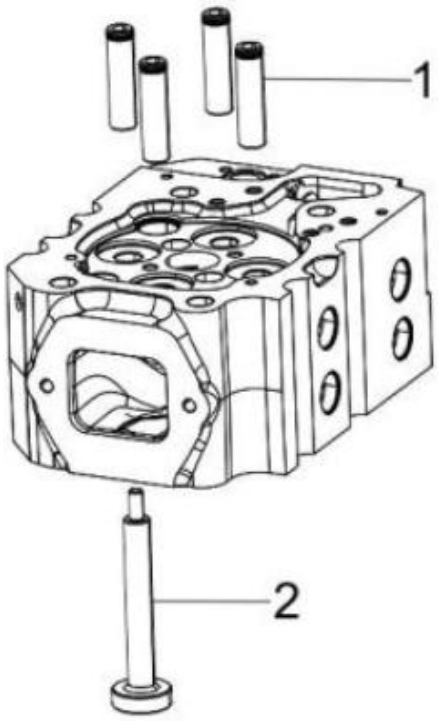


Figure 56. Cylinder Head Valve Guides

CYLINDER HEAD CLEANING AND INSPECTION

Always read and follow safety related precautions found on containers of hazardous substances like parts cleaners, primers, sealants, and sealant removers. Failure to comply could result in death or serious injury.

Thoroughly clean all components using a nonmetallic brush and an appropriate solvent. Each part must be free of carbon, metal filings and other debris.
Inspection of Cylinder Head Components Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted, or otherwise damaged. Discard any parts that do not meet its specified limit.

NOTE:

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

Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

INSPECTION OF PUSH RODS

Determine if the bend of the push rods is within the specified limit.

V-blocks must be used to inspect push rods due to the welds on the ends of the pushrods.

1. Place the push rods on a flat inspection block or layout bed.
2. Roll the push rods until a gap can be observed between a portion of the push rod and the surface of the block or layout bed.
3. Use a feeler gauge to measure the gap (Figure 57).

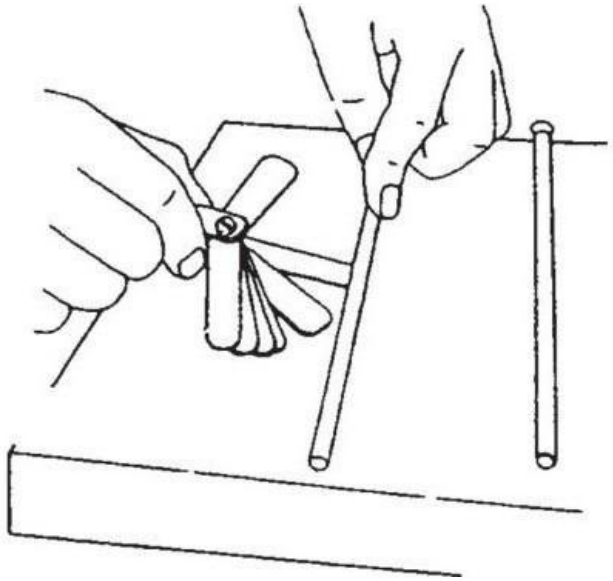


Figure 57. Push Rod Measurement

INSPECTION OF ROCKER ARM ASSEMBLY

Use a test indicator and micrometer to determine if the inside diameter of all the rocker arm support brackets and the rocker arms are within the specified limits.

Inspect the contact areas for excessive wear or damage.

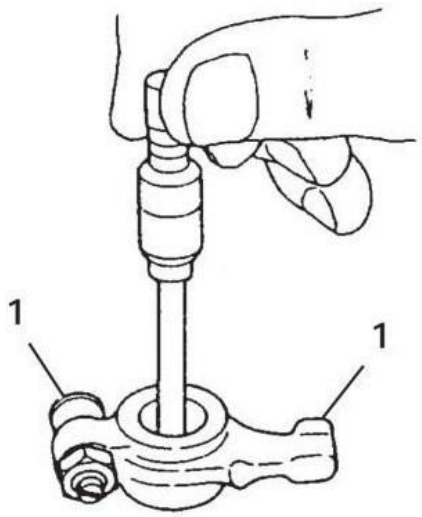


Figure 58. Rocker Arm Diameter Measurement

Use a micrometer to measure the rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart (Figure 58).

VALVE GUIDE INSPECTION

Visually inspect the valve guides for distortions, scoring or other damage.

NOTE:
Measure the valve guides while they are installed in the cylinder head.

Use a telescoping gauge and micrometer to measure the inside diameter at each end of the valve guide. Measure in three places and 90° apart (Figure 59). See Intake / Exhaust Valve and Guide chart for the service limit. Replace valve guides if not within specification.

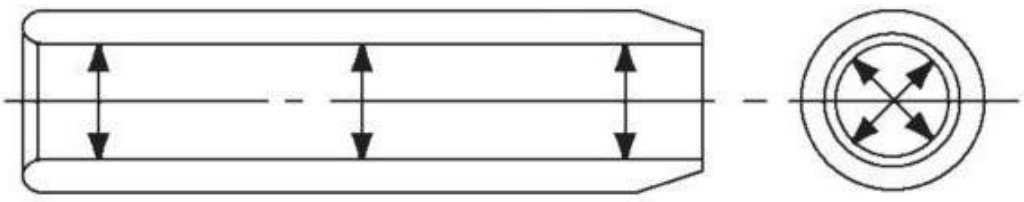


Figure 59. Valve Guide Measurement

CYLINDER HEAD INSPECTION

1. Equip the cylinder head with the water jacket tool (leak test).
2. Connect an air inlet onto the water outlet of the cylinder head. Immerse the cylinderhead in a tank of water and increase pressure up to 5 bar (Figure 60).
3. Check that there are no leaks in the intake ducts, exhaust ducts, injector sleeve, oil passages, cylinder head ceiling, valve seat housings, discard the cylinder head if necessary.

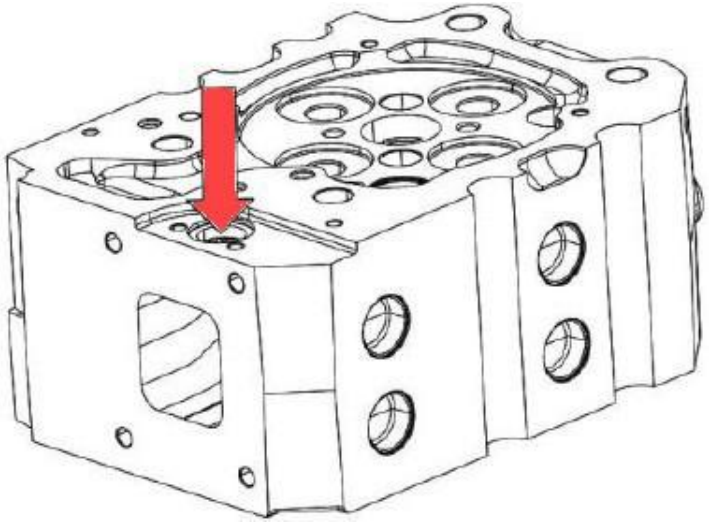


Figure 60. Cylinder Head Outlet

INSPECTION OF INTAKE AND EXHAUST VALVES

1. Visually inspect the intake and exhaust valves.
2. Replace any valves that are obviously discolored, heavily pitted, or otherwise damaged.
3. Use a micrometer to measure the valve stem diameter. Measure the valve stem near the combustion end and near the opposite end (Figure 61). See Intake / Exhaust Valve and Guide chart for the service limit.

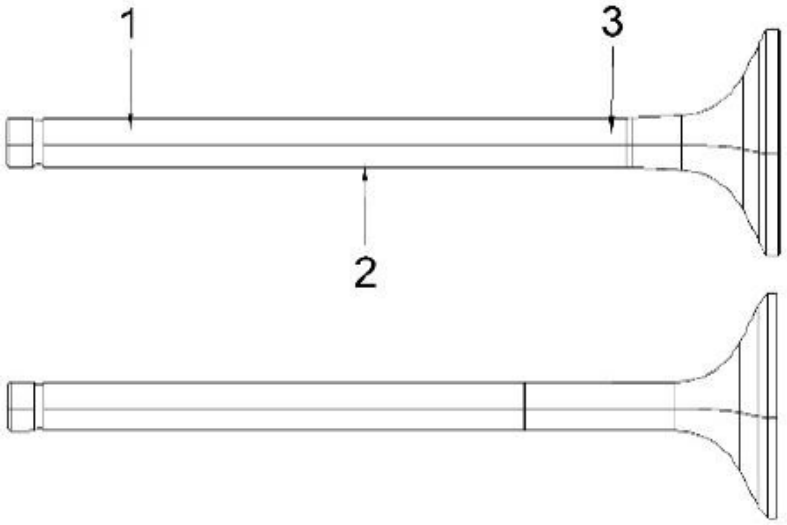


Figure 61. Valve Stem Diameter

4. Place the valve stem on a flat inspection block or layout bed. Roll the valve until a gap can be observed between a portion of the valve stem and the surface of the block or bed. Use a feeler gauge to measure the gap (Figure 62). See Intake / Exhaust Valve and Guide chart for the service limit.

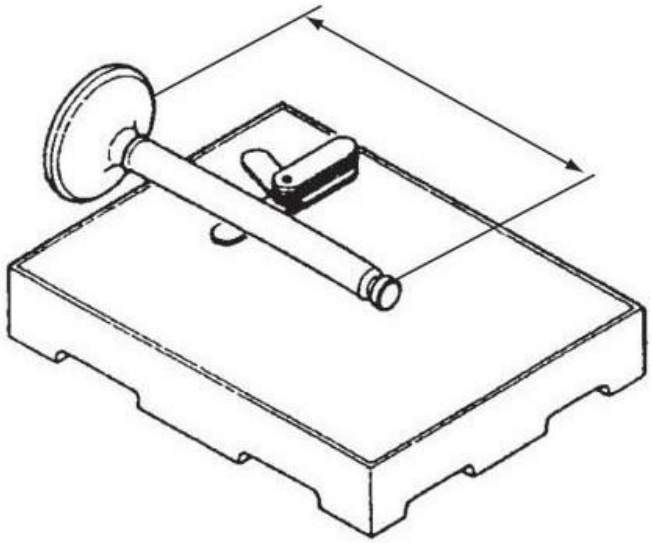


Figure 62. Valve Inspection Block

5. Insert the valves into their original locations and press them down until they are fully seated. Use a depth micrometer (Figure 63) to measure the difference between the cylinder head gasket surface and the combustion surface of each exhaust and intake valve. See Cylinder Head specification chart for the service limit.

NOTE:

Valve guides must be installed to perform this check.

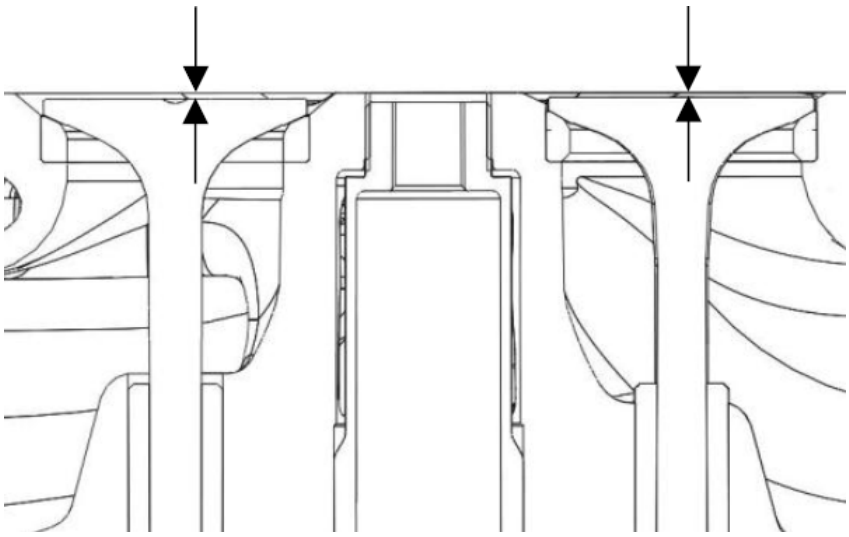


Figure 63. Valve Recession Check

VALVE SPRING INSPECTION

1. Inspect the valve springs. If damage or corrosion is seen, or if measurements exceed the specified limits, replace the springs.
2. Check for fractures on the inside and outside portions of the springs. If the valve spring is fractured, replace the valve spring.
3. Check for corrosion of the spring material caused by oxidation.
4. Use a flat surface and a square to check each spring for squareness (Figure 64). See Valve Spring specification chart for the service limit.

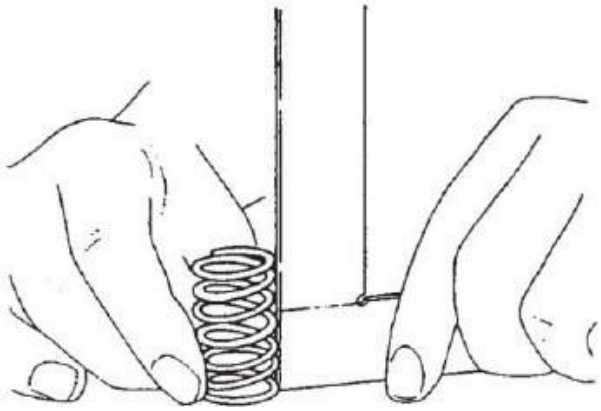


Figure 64. Valve Spring Squareness Measurement

5. Use a caliper to measure the length of the spring (Figure 65). See Valve Spring Mechanical chart for the service limit.

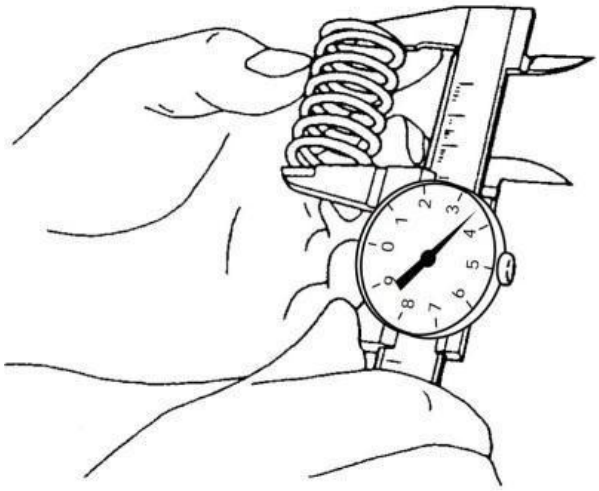


Figure 65. Valve Spring Measurement

CYLINDER HEAD REASSEMBLY

NOTE:

Lubricate all components with oil during reassembly to prevent premature wear or damage.

Use new gaskets, O-rings, and seals for cylinder head installation.

Ensure all debris is removed from all components before installation

VALVE SEAT INSTALLATION

The valve seats are installed from the desk side of the cylinder head and must be pressed in and fully bottomed out. All installation of valve seats (Figure 66A, Item 1) must be pre- approved by PSI manufacturing.

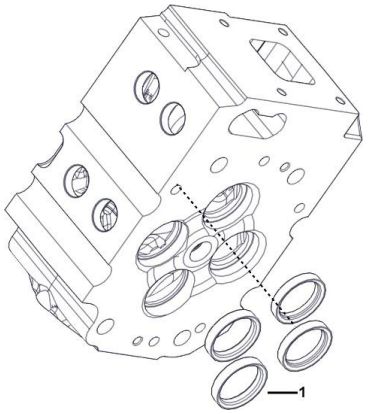


Figure 66A. Valve Seat Assembly

VALVE GUIDE INSTALLATION

The valve guides are installed into the cylinder head with an extremely tight press fit. Before installing the valve guides, place the valve guides in a freezer for at least twenty minutes. This will cause the valve guides to contract, making it easier to install the valve guides into place.

Immediately after removing the valve guides from the freezer, insert the valve guides (Figure 66B, 1) in their proper positions.

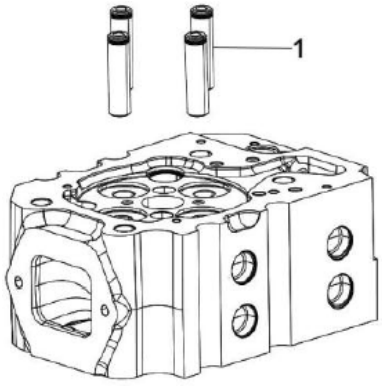


Figure 66B. Valve Guide Assembly

Finish installing the valve guides into the cylinder head to the proper height using the valve guide installation tool (Figure 67). See Valve Guide Projection specification chart.

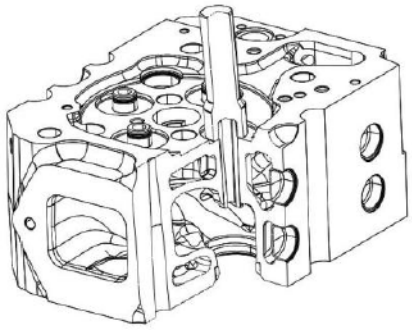


Figure 67. Valve Guide Installation Tool

INTAKE AND EXHAUST VALVE INSTALLATION

NOTE:

Always install new valve stem seals.

The exhaust valve stem seals are different than the intake valve stem seals and can be identified by either the paint marks on the outside of the seals or by the color of the compound. Ensure they are installed in the correct locations.

Always apply PSI approved engine oil to all valve stems.

Engine Model	Marking	
	Intake	Exhaust
32L	Brown	Blue

Figure 68. Valve Stem Color Chart

1. Install the valve spring bottom retainer (Figure 69, 1).

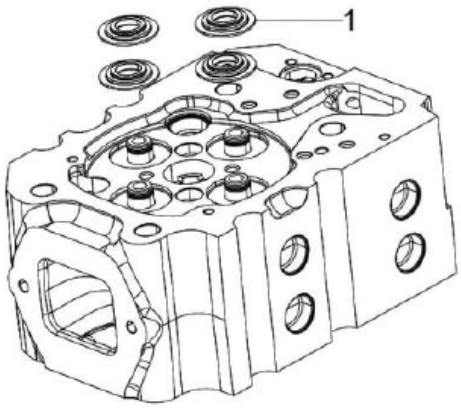


Figure 69. Valve Spring Retainer

2. Oil the lip of the valve stem seal (Figure 70, 2). Using the valve stem seal installation tool (Figure 70, 1), install a new valve stem seal on each of the valve guides.

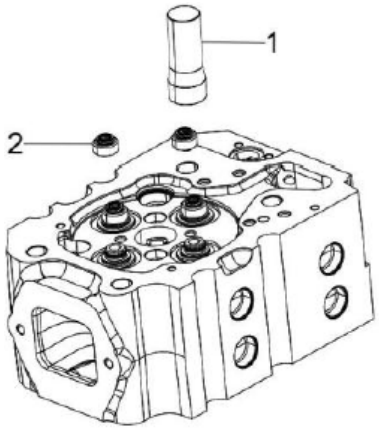


Figure 70. Vale Steam Seal Installation Tool

3. Place the cylinder head assembly on its exhaust port side.
4. Place all the valves (Figure 71, 1 & 2) in their proper location in the cylinder head.

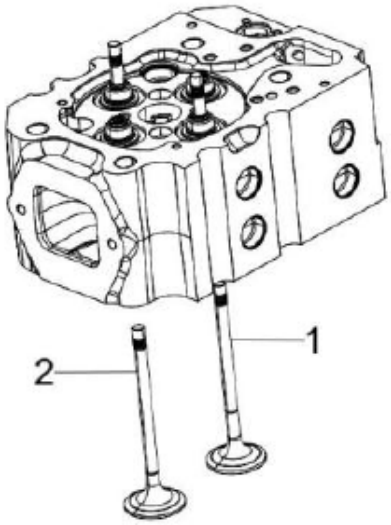


Figure 71. Valve Assembly

5. Place the cylinder head on the workbench with the combustion side down to install the valve springs. Install the valve springs (Figure 72, 3 & 4) and the spring retainer (Figure 72, 2).

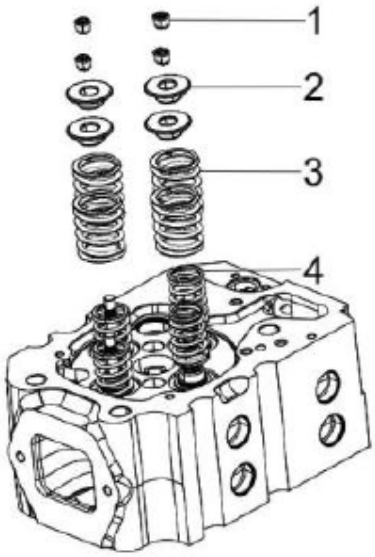


Figure 72. Valve Spring Assembly.

6. Insert the valve collets (Figure 72, 1) and slowly release the tension on the valve spring.
7. Repeat the steps on all the remaining valves.

NOTE:

The engine MUST be barred over three complete rotations before starting the engine, once new cylinder heads are installed

CYLINDER HEAD INSTALLATION

NOTE:

Primary and secondary head bolts may be reused a maximum of three times and MUST be discarded after allowed usage.

1. Carefully clean both the combustion surface of the cylinder head and the top surface of the cylinder block. Then place a new cylinder head gasket (Figure 73, 7) on the cylinder block.
2. Position the cylinder head (Figure 73,6) on the cylinder head gasket.

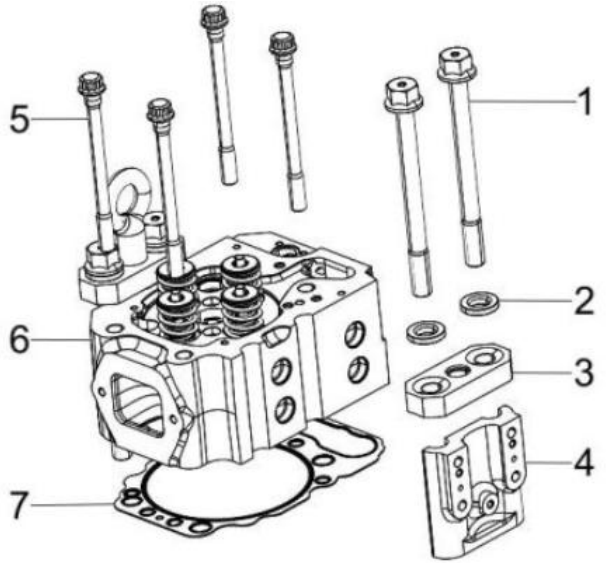


Figure 73. Cylinder Head Assembly

3. Lightly oil the threads and shoulder of the cylinder head main bolts (Figure 73, 5) and cylinder head secondary bolts (Figure 73, 1). Lightly oil the clamping block (Figure 73, 2) and end plate (Figure 73, 3).
4. Tighten the main bolts in order (Figure 74) 1 through 24 to a torque of 80 N·m.

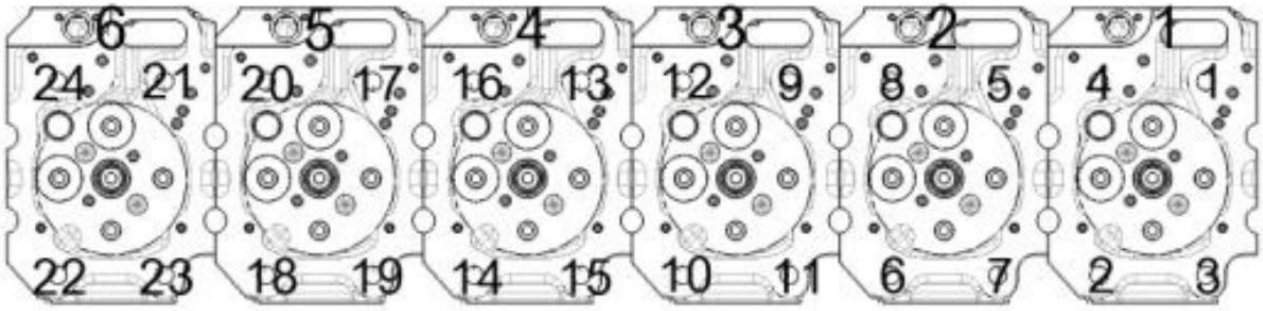


Figure 74. Main Bolt Torquing Order

5. Tighten the secondary bolts in order (Figure 75) A through N to a torque of 80N·m.

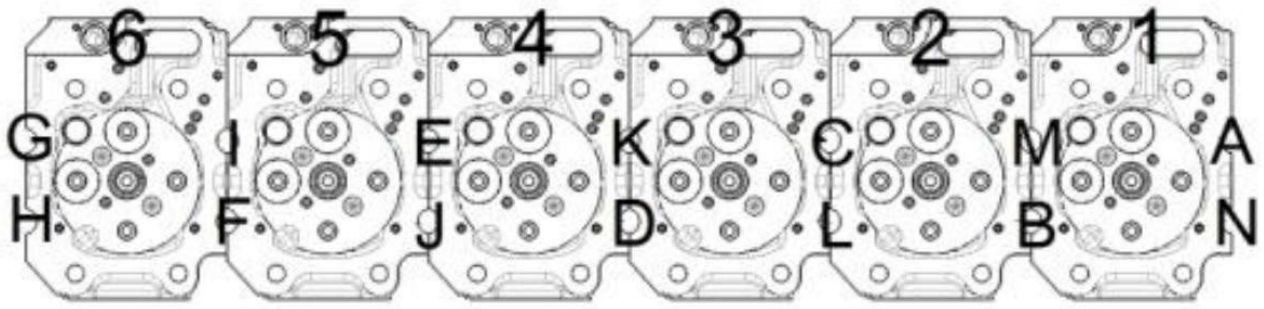


Figure 75. Secondary Bolt Torquing Order

6. Tighten the main bolts in order 1 through 24 to 80±10 N·m, then tighten the bolts to an angle of 60°±5°.
7. Tighten the secondary bolts in order A through N to 80±10 N·m, then tighten the bolts to an angle of 60°±5°.
8. Tighten the main bolts to an angle of 60°±5°.
9. Tighten the secondary bolts to an angle of 60°±5°.
10. Tighten the secondary bolts to an angle of 60°±5°.
11. Tighten the main bolts to an angle of 45°±5°.

ROCKER ARM INSTALLATION

NOTE:

Ensure the lubrication holes (Figure 76, 1) in the rocker arm shaft are oriented correctly with respect to the rocker arms (Figure 76, 2).

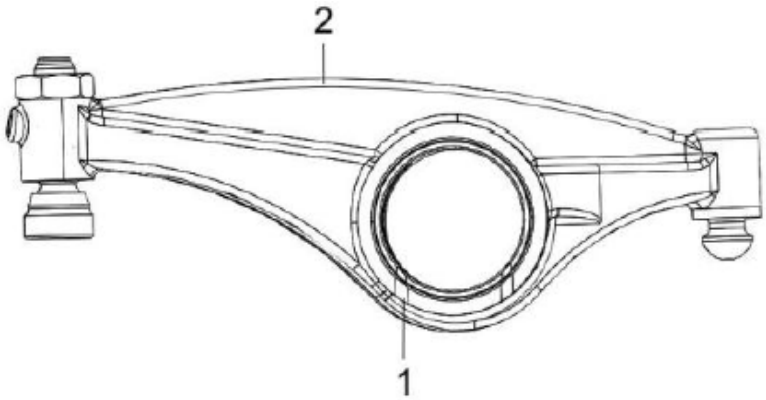


Figure 76. Rocker Arm

1. Lubricate the rocker arm shaft. Slide the rocker arm supports (Figure 77,1), and rocker arms (Figure 77, 2 & 5) onto the shaft.

NOTE:

Align the hole in the rocker arm shaft (Figure 77, 4) and the hole in the rocker arm support (Figure 77, 1).

In order to orient the valve bridge correctly, the full circle side of all valve bridges should go on the top valve while the open side goes over the bottom valve.

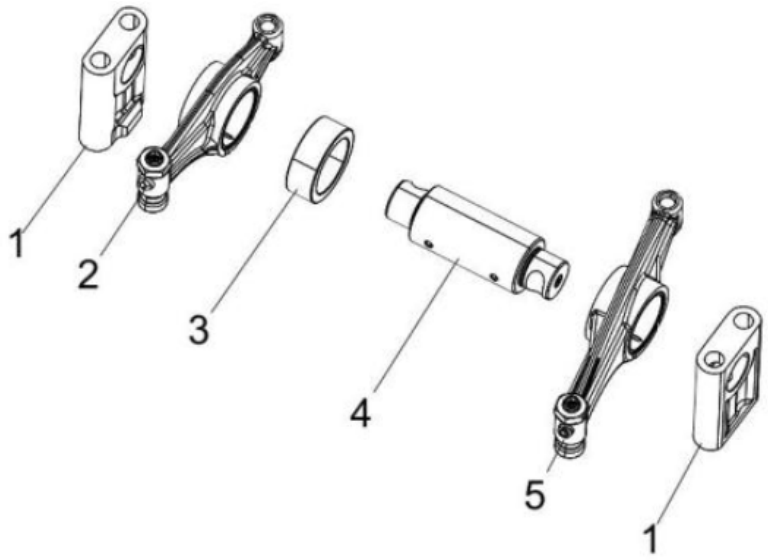


Figure 77. Rocker Arm Assembly

2. Install the ignition coil bush with thegasket.
3. Oil and put the valve bridges on thevalves.
4. Place the rocker arm shaft assembly onto the cylinder head.
5. Insert a 0.4~0.6 mm feeler gauge between rocker arm shaft sleeve (Figure77, 3), and intake rocker arms assembly (Figure 77, 5). If outside of specifications replace rocker arms.
6. If removed, reinstall the valve adjusting screws (Figure 78, 3) and the lock the nuts (Figure 78, 1).
7. Align the push rods with their respective rocker arms.
8. Reinstall and tighten the rocker arm shaft retaining bolts to the specified torque.
9. Adjust the valve clearance. See measuring and adjusting valve clearance chart.

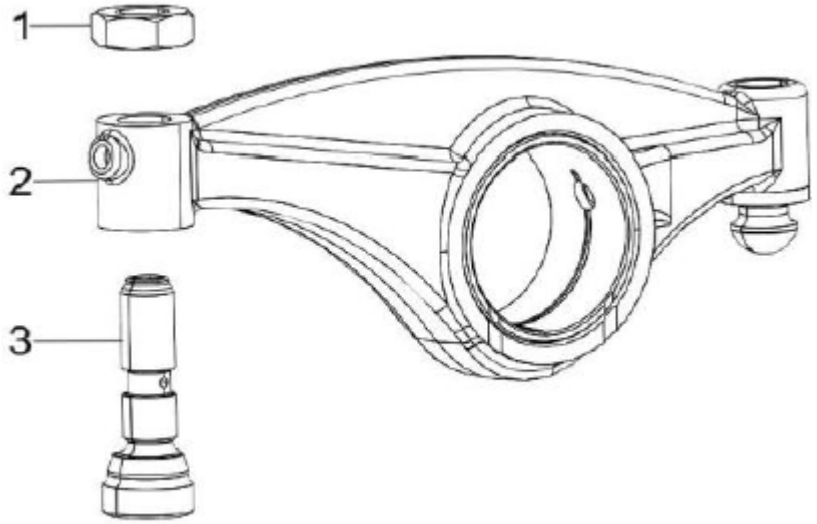


Figure 78. Rocker Arm Assembly

MEASURING AND ADJUSTING VALVE CLEARANCE

NOTE:

Measure and adjust while the engine is cold.

1. Remove the timing access cover on the flywheel to expose the timing marks on the flywheel surface (Figure 79). Remove all twelve valve covers from the engine.
2. Rotate the engine until it is at TDC #1.
3. Check the rockers on cylinder #1 (Left side of the engine closest to the rear (flywheel) end of the engine). If both rockers are loose, the valves shown below with BLUE ARROWS can be adjusted. If both valves are tight the valves shown below with RED ARROWS can be adjusted. See Figure 80.
4. Use a feeler gauge to check the clearance between the rocker arm and the valve bridge (Figure 80). Lash should be set to .022” (0.55 mm) for the intake and .039" (1.0 mm) for the exhaust. Repeat on all other valves with arrows of the same color as shown below.
5. Rotate the crankshaft 360 degrees until the timing mark is back at TDC #1 again. If the valves with the blue arrows were checked first, the valves with the red arrows may now be checked. If the valves with the red arrows were checked first, the valves with the blue arrows may now be checked.
6. Check lash on all rockers that were not previously checked. Adjust as necessary.
7. Reinstall valve covers.

Figure 79

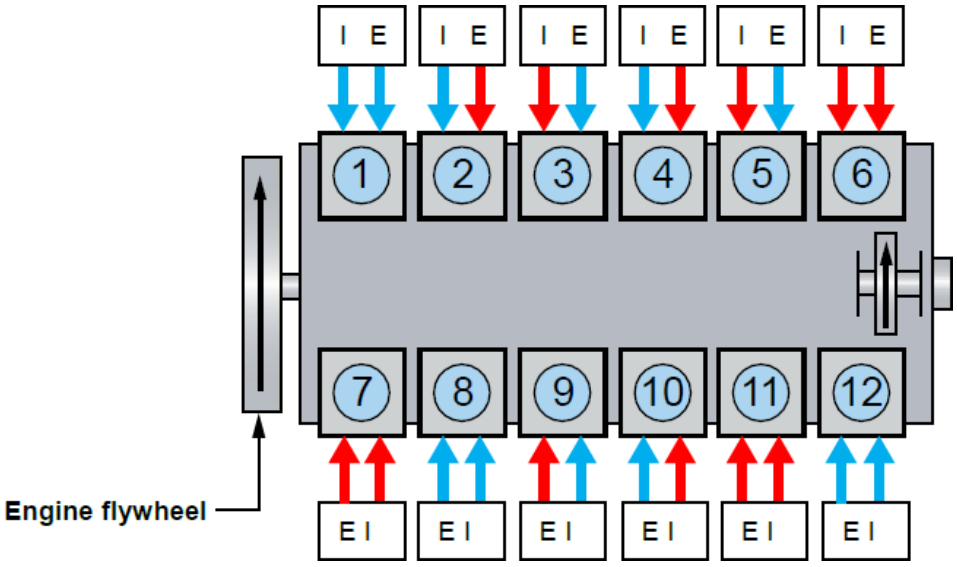


Figure 80

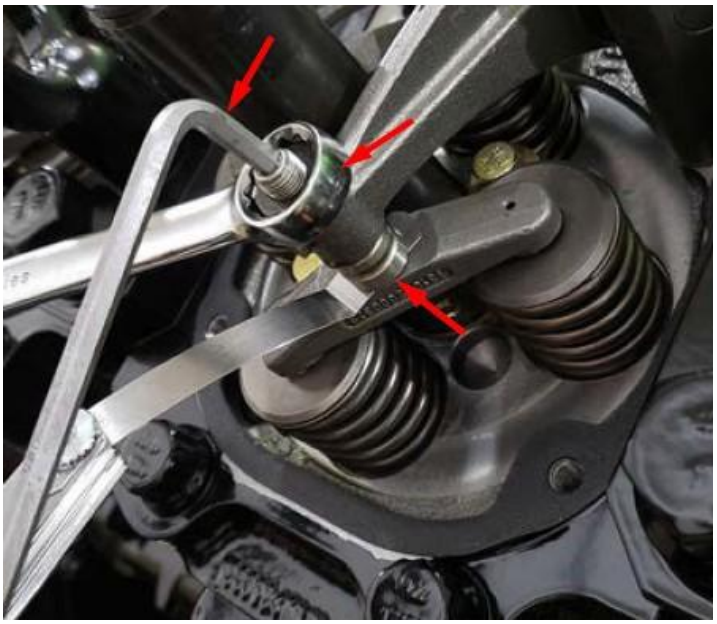


Figure 81

THROTTLE BODY

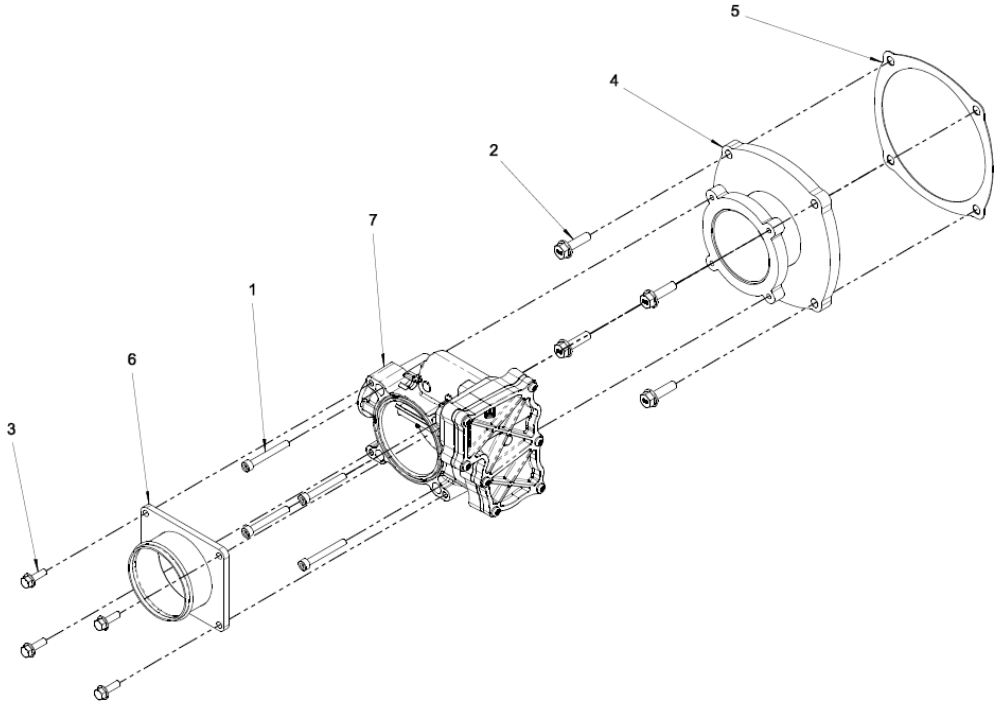


Figure 82. Throttle Body Assembly

No.	Name
1	bolt
2	Bolt
3	Flange Bolt
4	Throttle Body Adapter
5	Throttle Adapter Gasket
6	Throttle Inlet Adapter
7	Throttle Body

NOTE:

All 32L engines are equipped with two throttle bodies, one on each end of the intake manifold.

REMOVAL

1. Remove the four Flange bolts.
2. Remove the throttle inlet adapter.
3. Remove the four bolts from the throttle body.
4. Carefully remove the throttle body.
5. Remove the four throttle body adapter bolts.
6. Remove the throttle body adapter and gasket.

INSTALLATION

1. Clean any debris from the end of the intake manifold.
2. Clean the throttle body adapter from any debris and place the throttle adapter gasket onto the throttle body adapter.
3. Place both the throttle body adapter and gasket onto the end of the intake manifold.
4. Insert and torque down the four throttle body adapter bolts to 22ft/lbs.
5. Carefully install the throttle body onto the throttle body adapter.
6. Apply PSI approved Loctite to all four throttle body bolts
7. Insert and torque down the four throttle body bolts to 11 ft/lbs.
8. Place the throttle body inlet adapter onto the throttle body.
9. Insert and torque down the four-throttle body inlet adapter bolts to 10ft/lbs.

TAPPET AND PUSHRODS

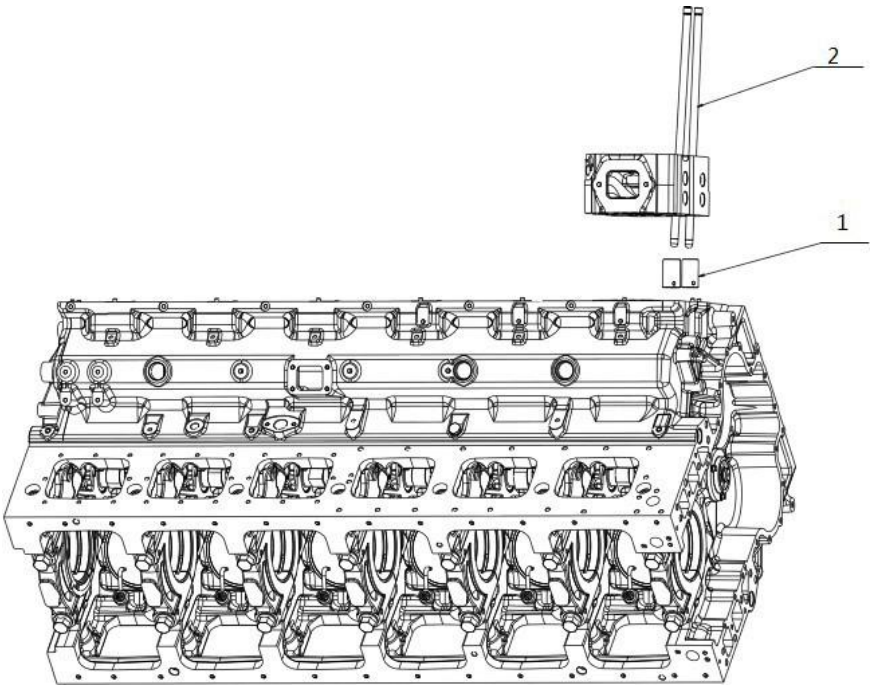


Figure 83. Tappet and Push Rod Assembly

No.	Name
1	Tappet
2	Push rod

REMOVAL

1. Once the rocker arm and rocker arm shaft are removed you may remove the pushrod.
2. Remove cylinder head to remove tappet. (See "CYLINDER HEAD" section)

NOTE:

Mark each individual push rod and tappet to ease installation process.

Tappets can stick to end of the push rod and fall into the oil pan.

INSTALLATION

1. Before assembling of the tappet, clean with compressed air and inspect the oil hole is smooth and clean of all debris.
2. Apply clean PSI approved motor oil to the bottom of the valve tappet.
3. Apply clean PSI approved motor oil to the push rod and ensure that the ball and socket heads of the push rod are sufficiently lubricated.
4. Lightly put the tappet into the tappet hole.
5. Assemble the push rod and lightly put the pushrod through the cylinder head and into the tappet socket end.

CYLINDER HEAD OIL PIPE

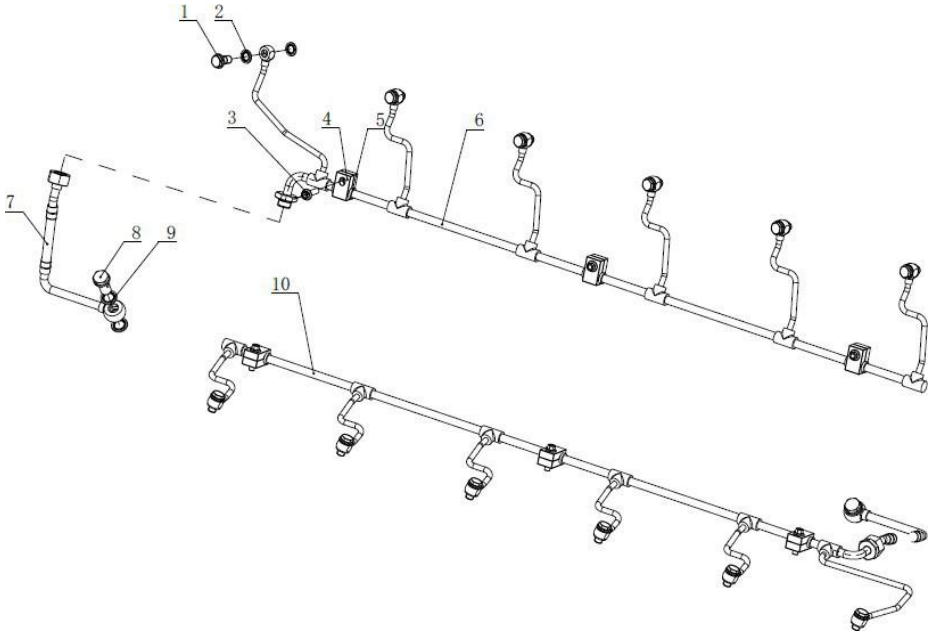


Figure 84. Cylinder Head Oil Pipe

No.	Name	No.	Name
1	Bolt	6	Rocker arm lubricating oil pipe
2	Combination gasket	7	Rocker arm lubricating oil pipe
3	Bolt	8	Bolt
4	Pipe clamp	9	Combination gasket
5	Rubber hose clamp	10	Rocker arm lubricating oil pipe

REMOVAL

1. Remove all fuel system components from the top of the engine. (Refer to the FUEL SYSTEM section)
2. Loosen and remove the hollow bolts on both ends of the lubricating oil inlet pipe which is fixed onto the engine block and cylinder heads.
3. Remove the lubricating oil inlet pipe.
4. Loosen the flange bolts fixing the pipe clamp and remove the bolts and pipe clamps.
5. Loosen and remove the hollow bolts fixed on the cylinder head and remove the cylinder head lubricating oil pipe.

INSTALLATION

1. Align the lubricating oil pipe onto the cylinder heads.
2. Insert the hollow bolts and tighten.
3. Insert the flange bolts and pipe clamp and tighten.
4. Insert the oil inlet pipe into the engine block and cylinder heads.
5. Insert the hollow bolts on both ends of the lubricating oil inlet pipe fixed into the engine block and cylinder heads to 70±5Nm.

TIMING GEARS

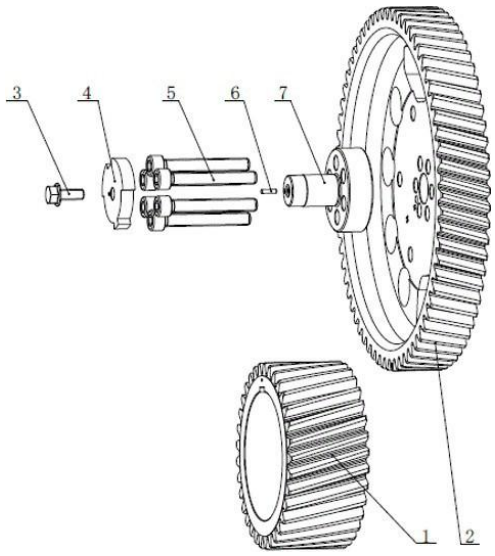


Figure 85. Timing Gears

No.	Name
1	Crankshaft Timing Gear
2	Camshaft Timing Gear
3	Bolt
4	Signal Panel
5	Hexagon socket head cap screw
6	Cylindrical Pin
7	Connecting Shaft

CHECKING CLEARANCE

1. Release the camshaft by unscrewing the adjustment screws for the entire rocker systems.
2. Verify the condition of the pinions.
3. Measure the backlash at 4 points at 90° to each pinion as well as the axial play of the camshaft.

TIMING VERIFICATION

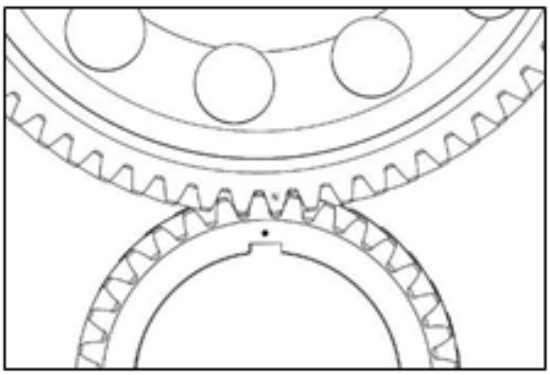


Figure 86. Timing Marks

Turn the crankshaft to make its gear mark "•" straight up and then locate the camshaft timing gear (2) via the cylindrical pin on the camshaft, adjust the camshaft timing gear (2), align the mark "N" on the gear end face with the mark "•" of the crankshaft timing gear (1) as shown below. And then install the connecting shaft (7) on the camshaft timing gear, and make sure to align the connecting shaft with the pin hole on the camshaft shaft timing gear. And then tighten the connecting shaft and camshaft timing gear to the camshaft with hexagon socket head cap screw (5). Tightening torque: (70±5) N.m. Check the backlash between the crankshaft gear and camshaft gear, and the meshing clearance should be 0.09mm-0.15mm. Then connect the signal panel (4) to the connecting shaft (7) via the cylindrical pin (6) and tighten it with hexagonal flange bolt (3). (Refer to figures 85 & 86.

CRANKSHAFT AND CAMSHAFT REMOVAL, CLEANING, INSPECTION, AND INSTALLATION

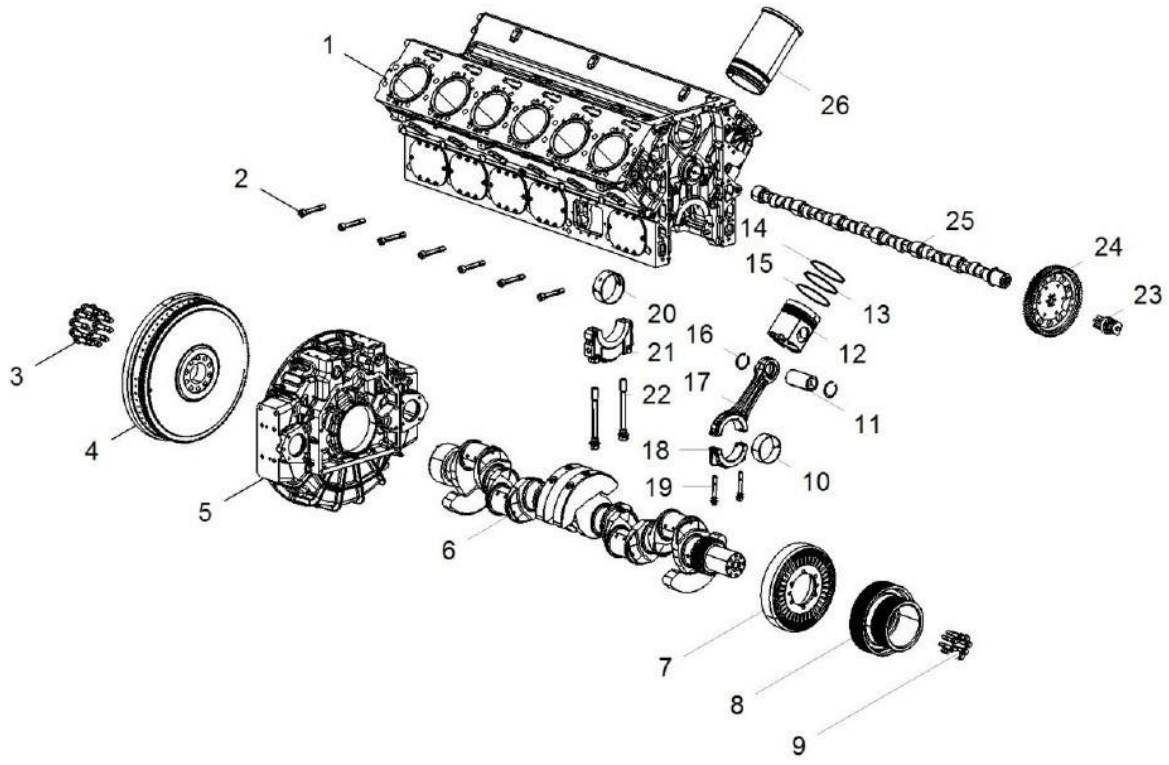


Figure 87. Crankshaft and Camshaft Components

1	Cylinder head assembly	10	Connecting rod bearing	19	Connecting rod bolt
2	Auxiliary screw	11	Piston pin	20	Main bearing
3	Flywheel bolt	12	Piston	21	Main bearing cover
4	Flywheel	13	Second ring	22	Main bearing molt
5	Flywheel housing	14	First ring	23	Bolt
6	Crankshaft	15	Oil ring	24	Camshaft timing gear
7	Torsional vibration damper	16	Piston pin retainer	25	Camshaft
8	Crankshaft pulley	17	Connecting rod	26	Cylinder liner
9	Bolt	18	Connecting rod cover		

CRANKSHAFT AND CAMSHAFT COMPONENTS

Disassembly of Engine

Prepare a clean, flat working surface on a workbench large enough to accommodate the engine components. Discard all used gaskets, O-rings, and seals. Use new gaskets, O-rings, and seals on reassembly of engine.

Note:

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.

If the engine will be completely disassembled, the following preliminary steps should be performed:

1. Disconnect the battery cables at the battery. Always disconnect the negative (-) cable first.
2. Remove the throttle cable, electrical connections, intake and exhaust system connections, and gas supply lines from the engine.
3. Remove the alternator.
4. Drain the engine coolant from the radiator and cylinder block. See Drain, Flush and Refill Cooling System with New Coolant and remove the cooling system components from the engine.
5. Remove the engine from the machine. Mount the engine to a suitable engine repair stand having adequate weight capacity.

Note:

Be sure to secure the engine solidly to prevent injury or damage to parts due to the engine falling during work on the engine.

6. Clean the engine by washing with solvent, air or steam cleaning. Carefully operate so as to prevent any foreign matter or fluids from entering the engine or electrical components remaining on the engine.
7. Drain the engine oil into a suitable container. Remove the oil filter.
8. Remove the cylinder head.
9. Remove the starter motor.

Disassembly of Camshaft and Timing Components

Discard all gaskets, O-rings, and seals. Use new gaskets, O-rings, and seals on reassembly of the camshaft and timing components.

Removal of Timing Gear Case Cover

1. Remove the thermostat group(Figure 88, 1).
2. Remove the fan bracket group (Figure 88, 2).
3. Remove the tensioner and beltgroup (Figure 88, 3).

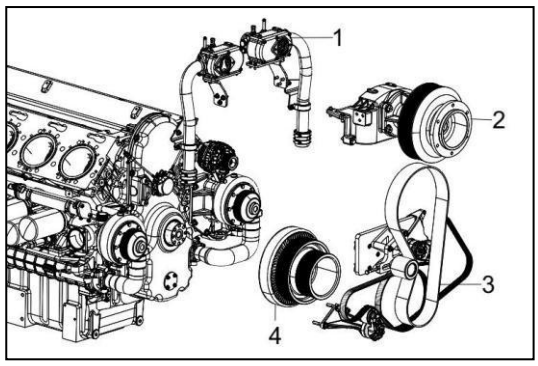


Figure 88

4. Remove the crankshaft pulley group (Figure 88, 4).

Note:

Use care not to damage the threads in the end of the crankshaft when removing the crankshaft pulley.

5. Disconnect the connecting wiring harness of speed sensor (Figure 89,2). Remove the speed sensor if necessary.
6. Remove the bolts (Figure 89, 3) that retain the gear case cover to the cylinder block and oil pan.

7. Remove the gear case cover (Figure 89, 1).

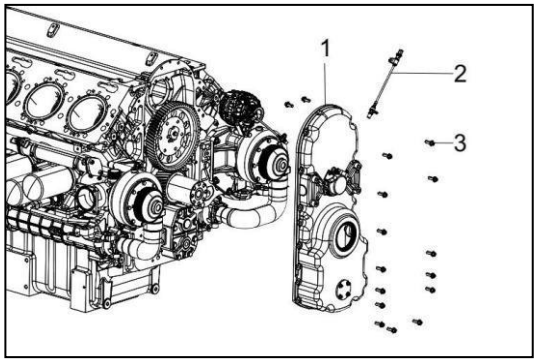


Figure 89

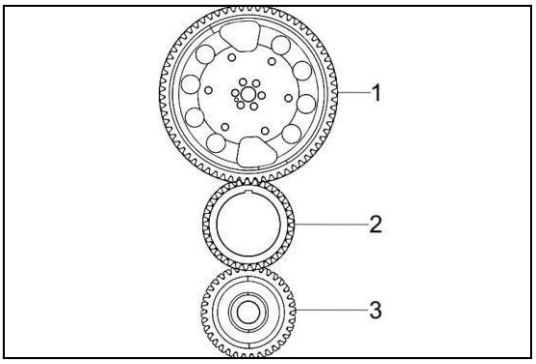
Checking Timing Gear Backlash

Prior to removing the timing gears, measure the gear backlash and determine the gear wear.

Check the backlash between each pair of mating gears (Figure 90). If not within specification, replace both mating gears. See Timing Gear Backlash on specifications for service limits.

Note:

Do not allow the gear being checked to move axially as excess end play could cause a false reading.



1- Camshaft drive gear

2- Crankshaft drive gear

3- Oil pump drive gear

Figure 90

Measuring Camshaft Gear-to-Crankshaft Gear Backlash

1. Install a dial indicator as shown in Figure 91.
2. Rotate the camshaft gear back and forth to check the camshaft gear-to- crankshaft gear backlash. The total indicator reading is the backlash. Record the measurement.

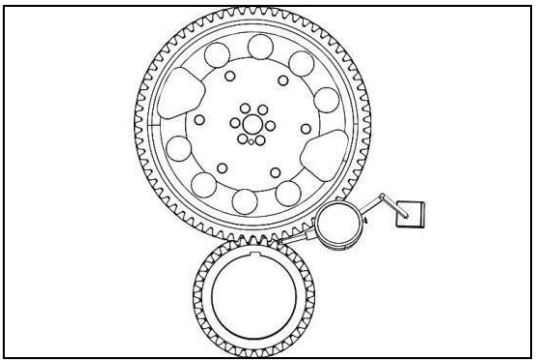


Figure 91

Removal of Camshaft

1. Before removing the camshaft, check the camshaft end play.
   - Install a dial indicator (Figure 92, 1) on the cylinder block. Move the camshaft (Figure 92, 2) back and forth to measure the end play. Record the measurement. See Camshaft specifications for the service limit.

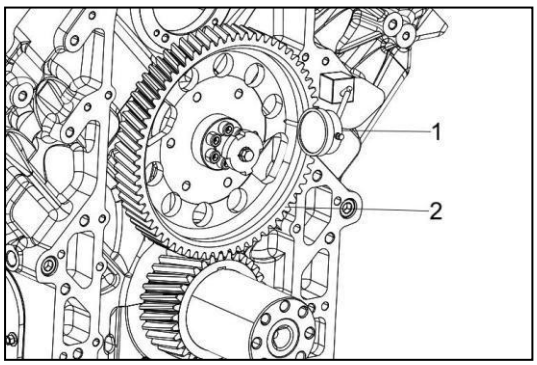


Figure 92

2. Loosen the tightening bolt and remove the signal panel (Figure 93, 2).
3. Remove the bolts (Figure 93, 3) from the connecting shaft (Figure 93, 4) of signal panel. Remove the connecting shaft, camshaft gear (Figure 93, 5).

Note:

Do not remove the crankshaft gear unless it is damaged and requires replacement. If the gear must be removed, remove it using a gear puller.

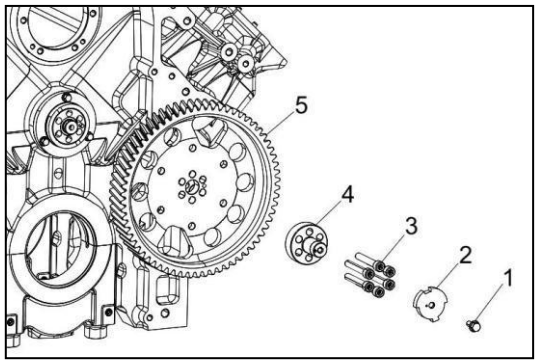


Figure 93

4. Before removing the camshaft, take out the tappet first.
5. Remove the three bolts (Figure 94, 1) retaining the camshaft thrust bearing (Figure 94, 2)
6. Slowly pull the camshaft (Figure 94, 3) assembly out of the engine being careful not to damage the camshaft bushing.

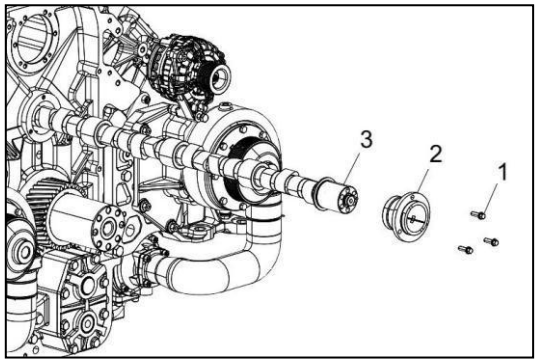


Figure 94

Disassembly of Crankshaft and Piston Components

Removal of Pistons Note:

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.

Note:

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 the pistons.

1. Remove the oil cooler group (Figure95, 1).
2. Remove the water inlet pipegroup (Figure 95, 2).
3. Remove the oil filter group (Figure95, 3).

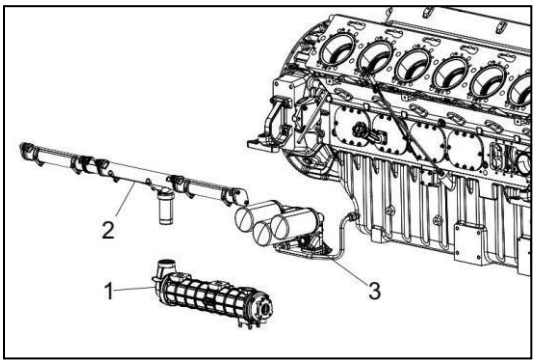


Figure 95

4. Remove the handhole covers.
5. Remove the oil filling pipe.
6. Remove the oil dipstick and dipstick pipe upper set.
7. Crank the engine so that the upper fixing bolts of the cap of the connecting rod to be removed is in line with the inspection door opening. Loosen and remove the connecting rod bolts (Figure 96, 1).
8. Remove the connecting rod cap (Figure 96, 2) with the lower half bearing .

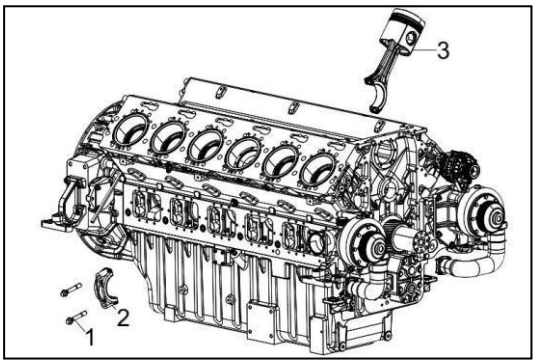


Figure 96

9. Mark the connecting rod caps and connecting rods so the caps and connecting rods stay together.

Note:

Do not allow the connecting rod to contact the crankshaft journal during piston removal. Damage to the bearing journal may result.

10. Use a wooden dowel against the connecting rod and tap the piston / connecting rod assembly out of the cylinder.
11. Mark the cylinder number on the piston and connecting rod.
12. Remove the connecting rod bearings (Figure 97, 9).
13. Remove the compression rings (Figure 97, 1) from the piston using a piston ring expander.
14. Remove the oil ring (Figure 97, 2) from the piston using a piston ring expander.

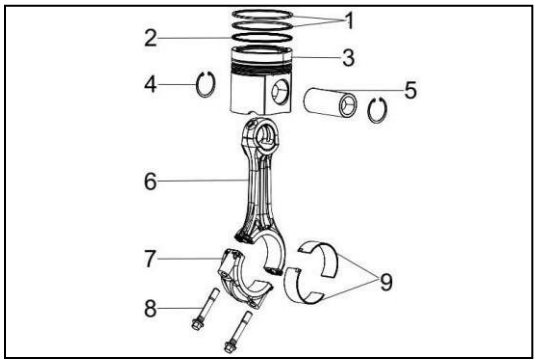


Figure 97

15. Remove the circlips (Figure 97, 4) from the piston pin.

Removal of Cylinder Liner Note:

Take care not to damage the piston jet when removing and installing the mobile coupling to the cylinder block.

1. Use cloths to protect the crankshaft tang and the bottom of the block to minimize any pollution with oil compartment.
2. Install the extraction tool (Figure 98, 1).
3. Slowly turn the nut and remove the cylinder liner and tool together.

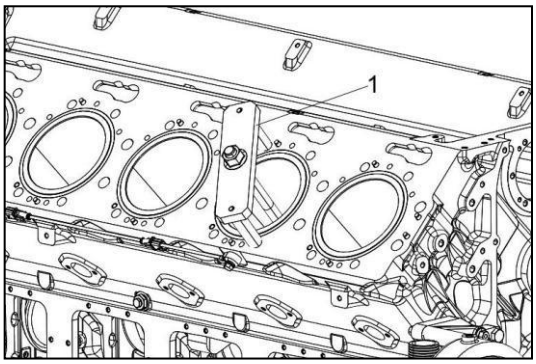


Figure 98

4. Disassemble the O-rings from the cylinder liner (Figure 99).
5. Repeat the steps until all liners are removed.
6. Clean the inside of the oil sump. Remove the protection cloths.

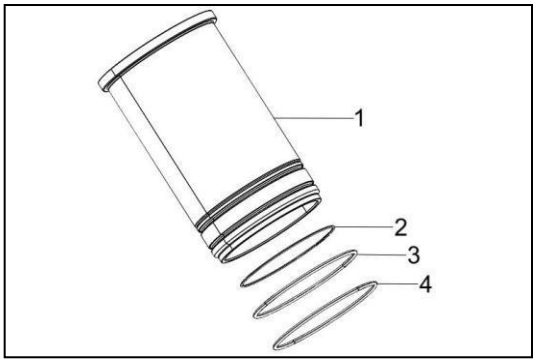


Figure 99

Removal of Oil Pan and Oil Pipeline Group

1. Remove the water pump group (Figure 100, 1) and oil pump (Figure 100, 2).

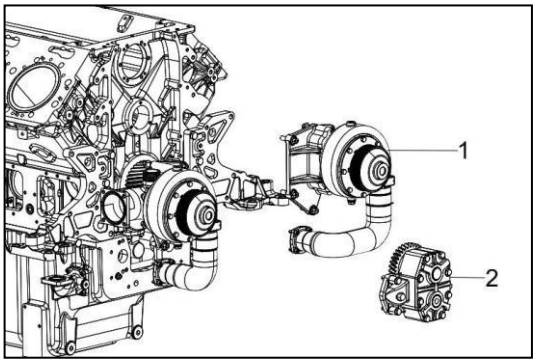


Figure 100

2. Invert the engine (oil pan up) on the engine stand.
3. Remove the oil pan (Figure 101, 1).

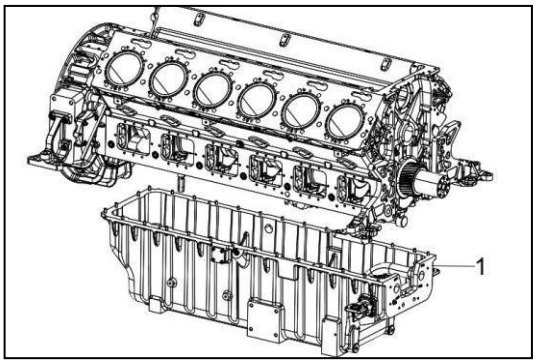


Figure 101

4. Remove the oil strainer (Figure 102, 1) in two stages.
5. Remove the pipe joints (Figure 102, 2).
6. Remove the supporting seat (Figure 102, 3), oil pipe and oil pump pressure limiting valve group (Figure 102, 4).

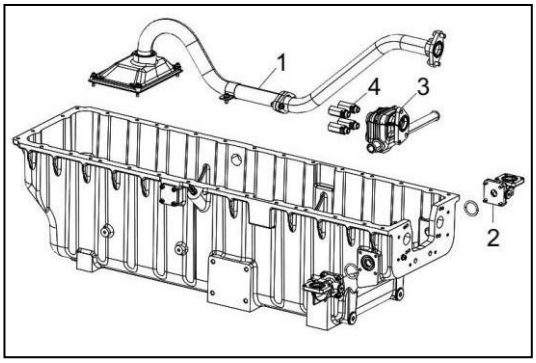


Figure 102

7. Remove the oil pipeline group (Figure 103, 1) and disassemble the oil pressure limiting valve (Figure 103, 2) if necessary.

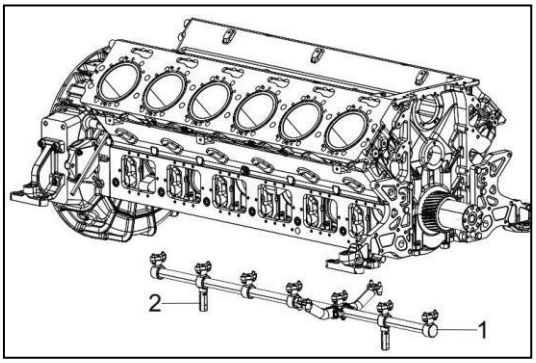


Figure 103

Note:

Replace all the O-rings if removed.

Removal of Crankshaft Removal of Flywheel

1. Remove the starter from the flywheel housing.
2. Remove two diametrically opposed bolts from the flywheel. Fit the flywheel guides (Figure 104, 1) instead.

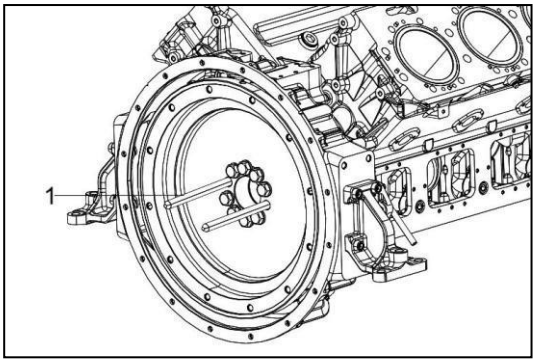


Figure 104

3. Remove all the flywheel fixing bolts (Figure 105, 1).
4. Fit suitable handling equipment for removing the flywheel. If it is difficult to remove the flywheel, use an appropriate tool to facilitate dismantling by levering at the starter hatch.
5. Remove the flywheel (Figure 105, 2) from the crankshaft.

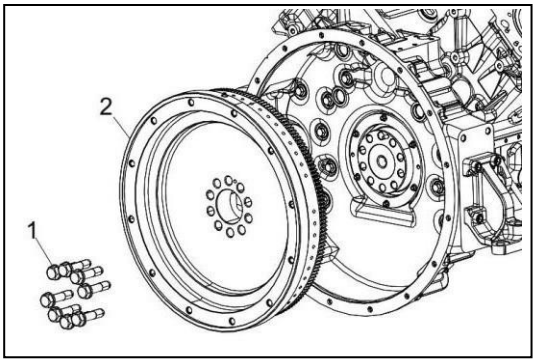


Figure 105

6. Disassemble the flywheel gear ring from flywheel if necessary.

Note:

Weight of flywheel: 116.8 kg or 255 lbs

Removal of Flywheel Housing

1. Put the rest engine group on theproper workbench.
2. Remove the engine bracket group (Figure 106).

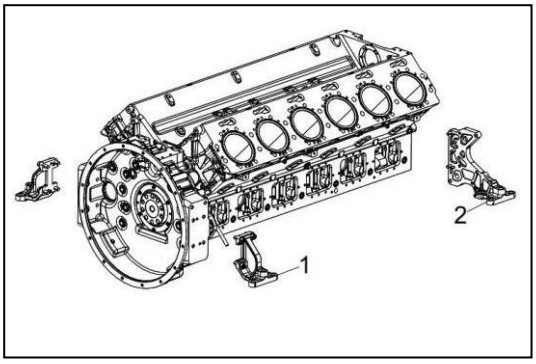


Figure 106

3. Loosen and remove the flywheel housing fasten bolts (Figure 107, 1).
4. Remove flywheel housing group(Figure 107, 2).

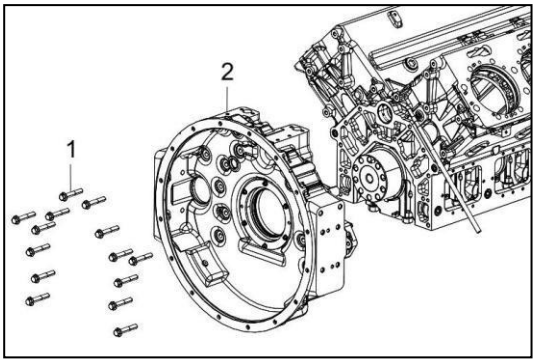


Figure 107

5. Remove the rear oil seal group from the flywheel housing.
6. Disassemble the rear oil seal (Figure 108, 2) from the rear oil seal seat (Figure 108, 3).

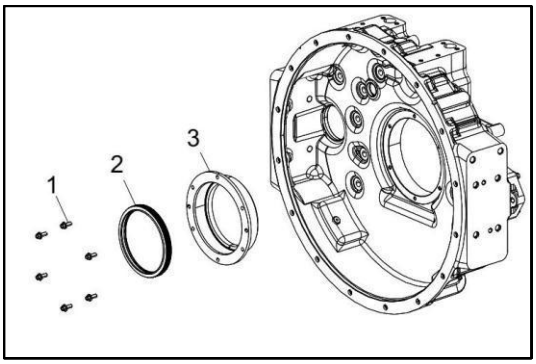


Figure 108

Removal of Crankshaft

1. Before removing the main bearing caps, measure the crankshaft end play. Use either of the following two methods.

Method A: Install a dial gauge (Figure 109, 1) on the cylinder block. Move the crankshaft (Figure 109, 2) in and out to measure the end play. Record the measurement.

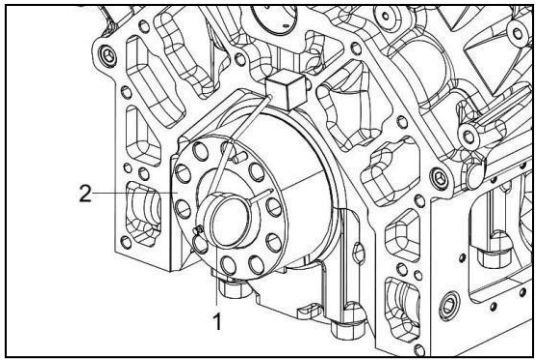


Figure 109

Method B: Use a feeler gauge to measure the clearance (Figure 110, 3) between the thrust bearing (Figure 110, 1) and crankshaft (Figure 110, 2). Record the measurement. See Thrust Bearing specifications for the service limit.

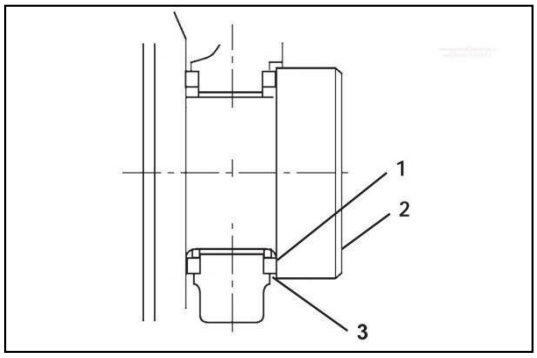


Figure 110

2. Loosen and remove the main bearing cap auxiliary bolts (Figure 111, 1) and washer (Figure 111, 1).
3. Loosen and remove the main bearing bolts (Figure 112, 1).
4. Remove the main bearing caps (Figure 112, 2). Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same order as they were removed.

Do not remove the bearing inserts at this time.

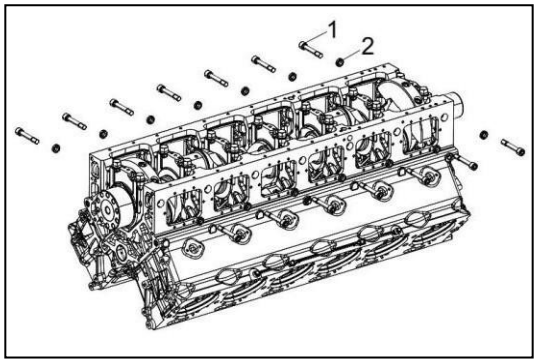


Figure 111

5. Remove the upper main bearings (Figure 111, 4) and thrust plates (Figure 112, 3).

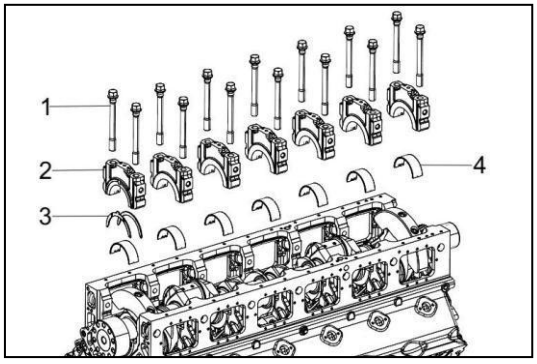


Figure 112

6. Remove the crankshaft (Figure 113, 1) from the engine.
7. Remove the bearing inserts (Figure 113, 2) and thrust plates (Figure 113, 3).

Note:

Do not remove the crankshaft gear unless the gear or crankshaft are damaged and require replacement.

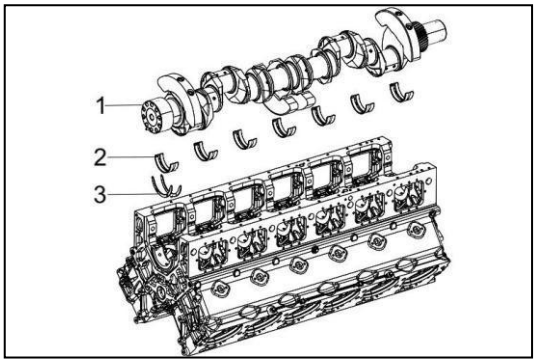


Figure 113

Removal of Piston Cooling Jet

Remove the piston cooling jet.

Inspection of Crankshaft and Camshaft Components

Thoroughly clean all components using a brush and appropriate solvent. Each part must be free of carbon, gasket material, metal filings and other debris.

Measure Crankshaft Bearing Oil Clearance

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

Inspection of Cylinder Liner

1. 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 liner is fractured.
2. Inspect cylinders liner for roundness, taper, or evidence of scoring. Collect and record the measurements. Replace the cylinder liner if the measurements are not within specification.

Take measurements at three places (Figure 114) (a, b, c), and in two directions (d and e) in each cylinder liner.

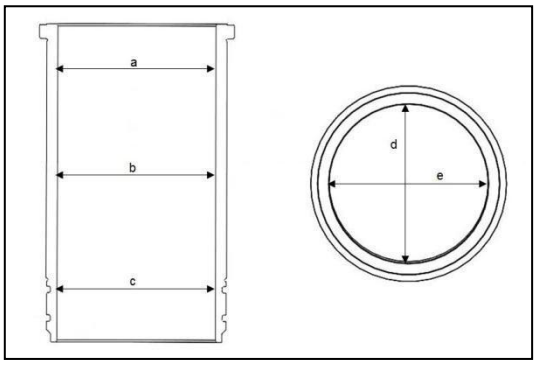


Figure 114

Inspection of Pistons, Piston Rings and Piston Pin

Notes:

• On an engine with low hours, the pistons, piston rings may be reused if they are found to be within specifications. The pistons and piston rings must be reinstalled in the same cylinders from which they were originally removed.

• On an engine with high hours, the pistons rings should be replaced. The piston and cylinder liner should be replaced as necessary.

1. Clean piston ring grooves using a piston ring groove cleaning tool. Follow manufacturer's instructions for correct operation.
2. Wash the pistons in an appropriate solvent using a soft brush.
3. Visually inspect each piston for cracks. Pay particular attention to the ring lands between the piston ring grooves.
4. Measure the diameter of the piston skirt at 90° to the wrist pin bore as shown (Figure 115). Measurements must be taken at a specified distance (Figure 115, 1) from the bottom of the piston, based on engine model. Record the measurements. See Piston specifications.

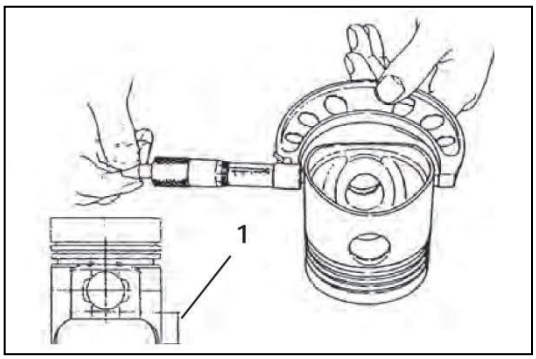


Figure 115

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection to obtain piston-to-cylinder clearance. Record the

measurements.

Measure the diameter of the piston pin bore on both sides of the piston (Figure 116). See the mechanical specifications chart. Record the measurements.

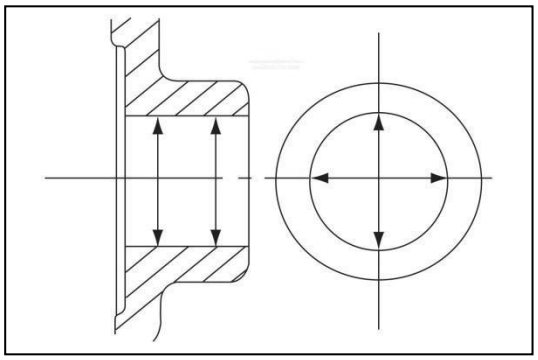


Figure 116

6. Measure the outside diameter of the piston pin in three places and at 90° (Figure 117). See the mechanical specifications chart. Record the measurements.

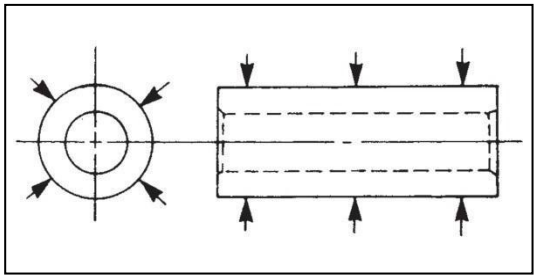


Figure 117

7. Use a micrometer, measure the thickness of each piston ring. See the piston mechanical specifications chart. Record the measurements.

Notes:

• On an engine with low hours, the pistons, piston rings and cylinders may be reused if they are found to be within specifications.

• On an engine with high hours, the pistons rings should be replaced. The piston and cylinder liner should be replaced as necessary.

8. Place each compression piston ring in the groove as shown (Figure 118). Use a feeler gauge to measure the clearance between the piston ring and the piston ring land. Record the measurements. See Piston Ring mechanical specifications chart. Replace the piston if not within specification.

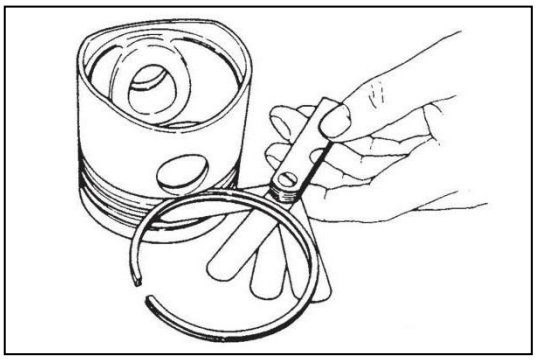


Figure 118

9. To measure piston ring end gap, insert each compression piston ring (Figure 119, 1), one at a time, into the cylinder. Use a piston with the piston rings removed to slide the ring into the cylinder bore until it is approximately 1.18 in. (30 mm) (Figure 119, 2) from the bottom of the bore. Remove the piston. Measure the end gap (Figure 119, 3) of each piston ring. Record the measurements. See Piston Ring mechanical specifications chart.

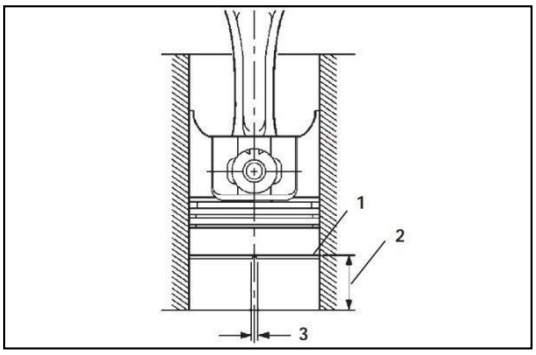


Figure 119

Always check the piston ring end gap when installing new piston rings.

10. Repeat the above steps for each cylinder and piston assembly

Inspection of Connecting Rod

1. Measure the piston pin bushing bore using a bore gauge (Figure 120, 1). Replace the bushing if not within specifications. If the bushing has been removed, measure the inside diameter of the connecting rod small end (Figure 120, 2). See Connecting Rod mechanical specifications.

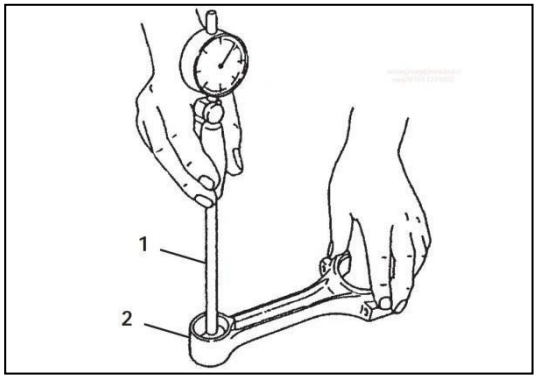


Figure 120

2. Place the connecting rod bearing inserts into the connecting rod and connecting rod cap. Install the rod cap and tighten the bolts to the specified torque.
3. Measure the inside diameter. See Crankshaft mechanical specifications chart.

Inspection of Tappet

1. Inspect the tappet contact surfaces for abnormal wear (Figure 121, 1).
2. Measure the outside diameter of the tappet stem (Figure 121, 2). See the mechanical specifications chart for the service limit.

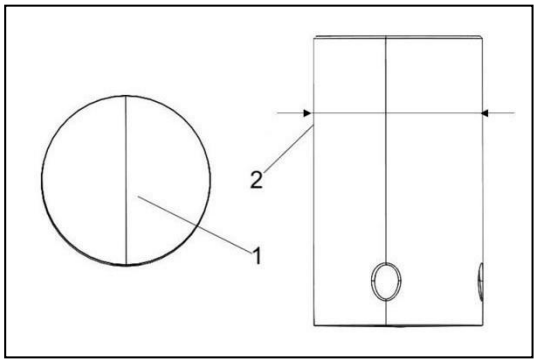


Figure 121

Inspection of Crankshaft

1. Place the crankshaft endjournals (Figure 122, 4) on V-blocks.
2. Place a dial indicator (Figure 122, 3) on a center main bearing surface.

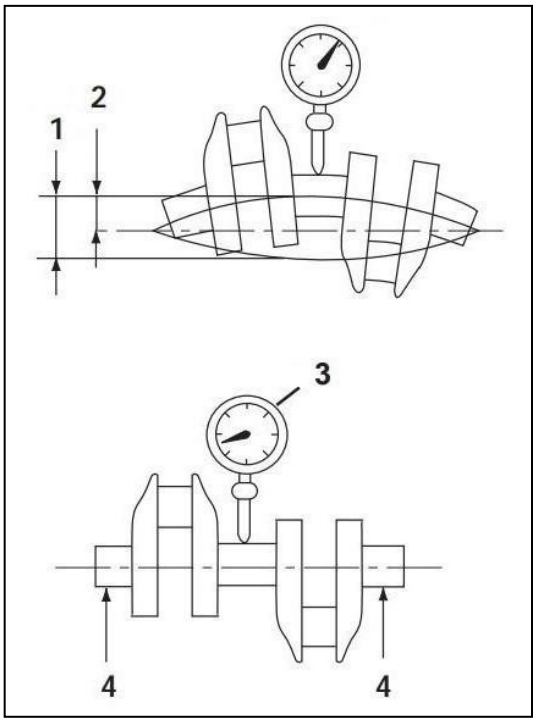


Figure 122

3. Rotate the crankshaft andobserve runout. See Crankshaft Mechanical Specifications chart.
4. Use the color check method or Magnaflux® to inspect the crankshaft for cracks. Replace the crankshaft if evidence of fractures is found.
5. Measure the outside diameter of each crankpin (Figure 123, 2) and main earing journal (Figure 123, 1). See the Crankshaft mechanical specifications chart. Take measurements at several places around each bearing surface. If not within specification, grind the journals and install undersize bearings, or replace the crankshaft.

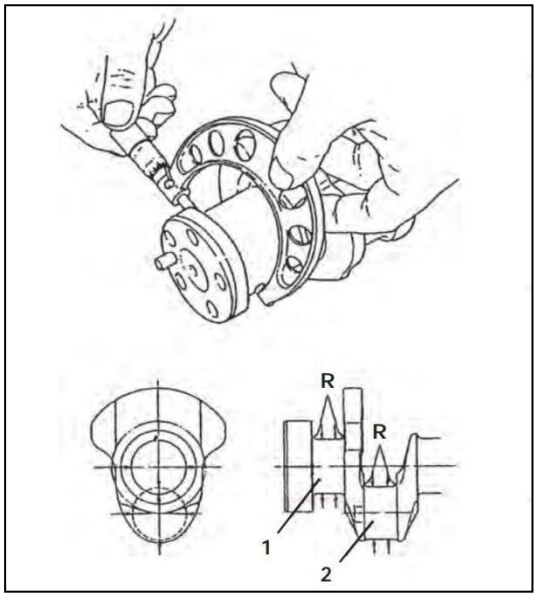


Figure 123

Inspection of Camshaft

1. Use V-blocks and a dial indicator to check camshaft bend (Figure 124). Place the indicator on the center bearing journal.

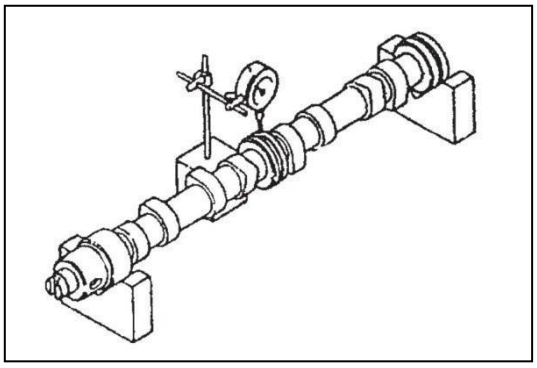


Figure 124

2. Rotate the camshaft and observe the runout.
3. See the Camshaft specifications chart.
4. Measure the height of each lobe (Figure 125, 1). See the Camshaft specifications chart.

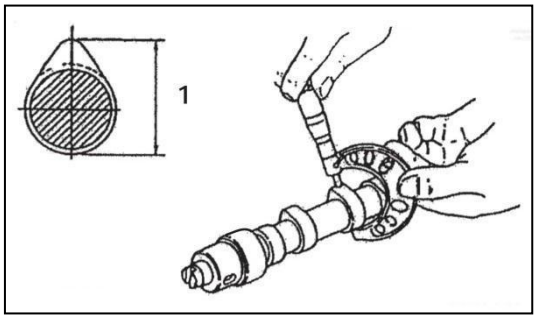


Figure 125

5. Measure the diameter of the gear end, intermediate, and flywheel end bearing journals. See the Camshaft specifications chart.

Inspection of Camshaft Bushing and Bores

1. Measure the I.D. of the front bushing and the remaining bores in the cylinder block. See the Camshaft specifications chart
2. If the camshaft bushing is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the cylinder block will require replacement as there are no bearing inserts used.

Reassembly of Crankshaft and Piston Components

Notes:

- Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.
- Use new gaskets, seals, and O-rings during assembly.
- Liberally apply clean engine oil to all internal parts during assembly.
- All fasteners should be tightened to a given torque. If a special torque is not provided in the Special Torque Chart, tighten to standard torque specifications. See Tightening Torques for Standard Bolts and Nuts chart.

Installation of Cylinder Liner

1. Equip the liner with new seals (Figure 126) coated with grease or clean oil.

Note!

The O-rings can be used only once.

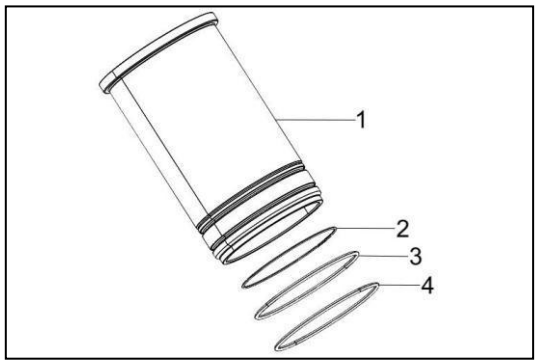


Figure 126

2. Carefully clean the liner housing. Visually inspect and dimensionally check the bores.
3. Coat the bore contact areas with grease or clean oil. Slide the liner into its housing.
4. Manually, center the liner and apply vertical pressure to initiate nesting.
5. Install the cylinder liner installer (Figure 127, 1) on the engine block and nest the liner (Figure 127, 2) using the special tool.

Note:

The liner has no pre-defined orientation.

6. Basically, you just put the liner back in the same position it was in before. For a new liner, the supplier mark should always be at 12 o'clock.
7. Remove the tool, taking care not to bump or scratch the liner bore.
8. Measure cylinder liner protrusion, the value is 0.05-0.10mm.

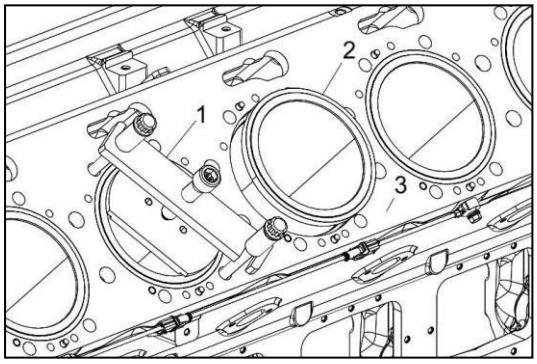


Figure 127

Reassembly of Pistons Note:

The actual appearance of the match marks on the piston and connecting rod may vary, but they will always be in the same locations.

1. Select the parts needed to reassemble the piston and connecting rod for one cylinder.

Note:

The rings must always be replaced when fitting a new liner.

2. Carefully clean the ring grooves of the piston (Figure 128, 3). Fit the piston rings (Figure 128, 1 & 2) with the special tool.
3. After fitting the rings, check that the rings move easily and do not catch on the grooves. Making sure the marking faces the top of the piston.

Note:

1st groove: Keystone firing ring.

The marking TOP must face the top of the piston.

2nd groove: Sealing ring.

The marking CYPR must face the top of the piston.

3rd groove: Scraper ring.

No marking. Does not matter which way up it is fitted.

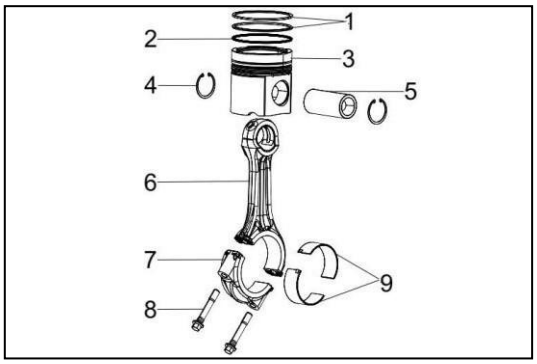


Figure 128

4. Check all the connecting rods (Figure 128, 6) and make sure that the connecting rods are in the same weight group.

Note:

The piston does not have a mounting direction. In principle, the manufacturer marking on the top of the piston will be oriented towards the flywheel side.

5. Fit the 1st circlip (Figure 128, 4) onto one end of the piston shaft.
6. Lightly oil the bore openings and insert the piston pin (Figure 128, 5) into the first part of the bore.
7. Present the connecting rod and continue to insert the piston pin until it butts up against the circlip on the opposite bore.
8. Fit the second circlip.

Note:

In case of difficulty inserting the shaft, you can heat the piston in an oven to a temperature of about 60°C.

9. Stagger the piston ring end gaps at 120° intervals (Figure 129). Do not position the top piston ring end gap in line with the piston pin.

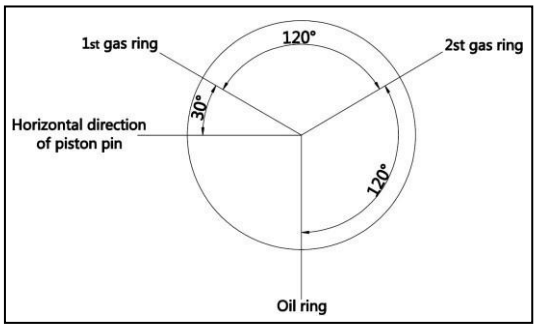


Figure 129

Installation of Crankshaft

1. Install the piston cooling jet.
2. If removed, reinstall the timing gear on the crankshaft.
3. Reinstall new main bearing (Figure 130, 2) and thrust plate (Figure 130, 3) in the cylinder block and main bearing caps.

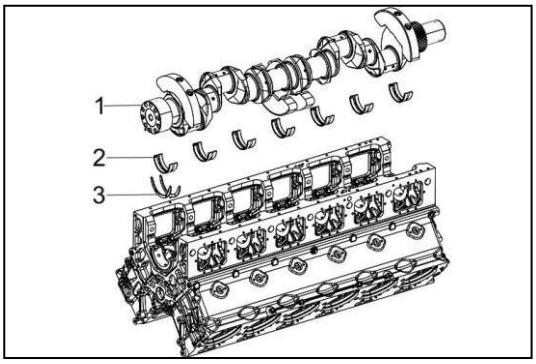


Figure 130

4. Apply a liberal coat of clean engine oil to the bearings and crankshaft journals.
5. Place the crankshaft (Figure 131, 1) into the engine.

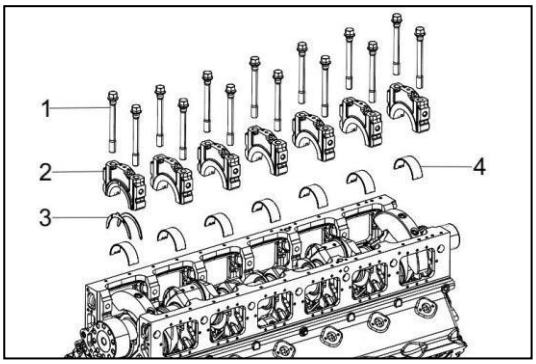


Figure 131

6. Reinstall new main bearing (Figure 131, 4) and thrust plate (Figure 129, 3) in the main bearing caps (Figure 131, 2).

Note:

Making sure the lubrication grooves face the area of friction.

7. Reinstall the main bearing caps (Figure 131, 2).

Note:

If it is difficult to put the main bearing caps, put a wall spreader between the wall of the two rear bearings. Perform stressing of the cylinder block (max. 0.25 mm).

8. Apply a light coat of clean engine oil to the bearing cap main bolts (Figure 132, 2) and auxiliary bolts (Figure 132, 1) with washer (Figure 132, 2).

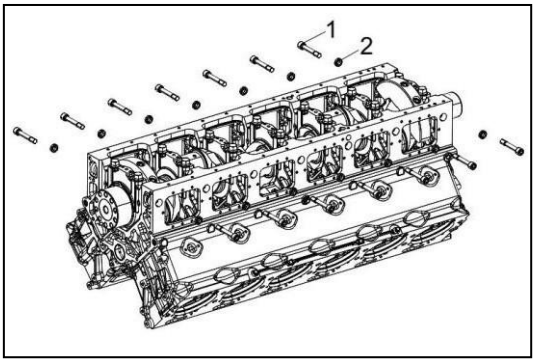


Figure 132

9. Tighten the main bearing bolts in the following sequence (Figure 133):
   a. Tighten them to a torque of 180± 10 N·m.
   b. Tighten each cap screw in alphabetical order (A to N) to an angle of 60°.
   c. Tighten each cap screw in alphabetical order (A to N) to an angle of 60°.
10. Tighten all the side bolts in numerical order (1 to 7) to a torque of 270±20 N·m.

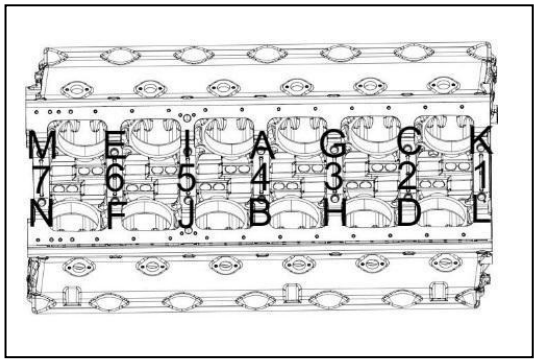


Figure 133

11. Rotate the crankshaft to assure it turns freely.

Note:

After the first disassembling of main bearing bolts by the user, the original main bearing bolts can be reused for at most 4 times.

Installation of Flywheel Housing and Flywheel

Installation of Flywheel Housing

1. If removed, install the camshaft first.
2. Assemble the rear oil seal group on the flywheel housing (Figure 134).

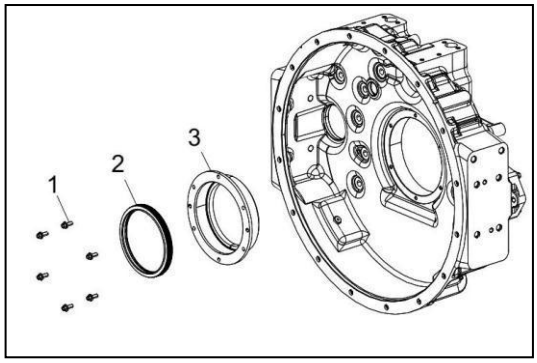


Figure 134

3. Knock the grooved pin into the pin hole in the rear end of engine body if removed.
4. Apply silicone sealant to the joint face of flywheel housing.
5. Install the flywheel housing (Figure 134, 2) to the rear end of engine block by using guide rod.
6. Apply Loctite 242 sealant coated at the threads of the flywheel housing bolts (Figure135,1).

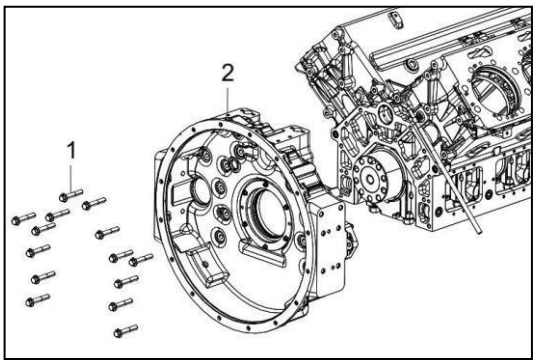


Figure 135

7. Tighten the bolts in two steps inthe following sequence (Figure 136):
   - Tighten the bolts to 80 Nm.
   - Tighten the bolts to 180±10 Nm.

Note:

The flywheel cover bolts can be used fortwo times.

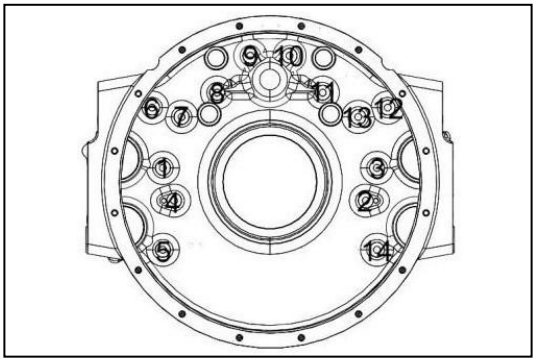


Figure 136

Installation of Flywheel

1. Assemble the flywheel ring to the flywheel if removed.

Note:

When install the flywheel ring, heat the gear ring to 250°C.

2. Fit the flywheel guide rods on the crankshaft.
3. Apply a film of oil to the threads and under the head of the flywheel fixing bolts (Figure 137, 1).
4. Using suitable handling, install the flywheel (Figure 137, 2) on the crankshaft.

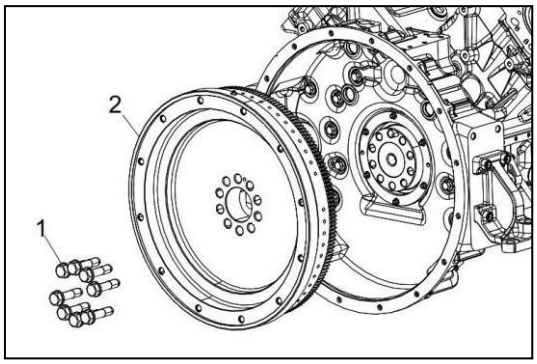


Figure 137

5. Tighten the bolts in two steps in the following sequence (Figure 138):
   - Tighten the bolts to 180 Nm.
   - Tighten the bolts to an angle of +60°Nm.

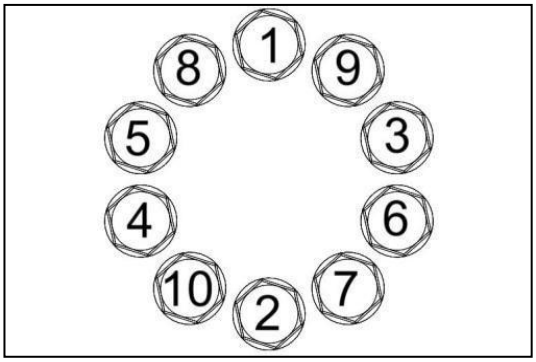


Figure 138

6. Install the engine bracket group.

Install of Connecting Rod and Piston Note:

Do not allow the connecting rod to contact the crankshaft journal during piston installation. Damage to the crankshaft bearing journal may result.

1. Lubricate the piston, piston rings, and cylinder with clean engine oil or assembly lubricant.
2. Rotate the crankshaft so the crankpin for the piston being installed is near bottom dead center.

Note:

Ensure the piston ring gaps are located correctly (Figure 139).

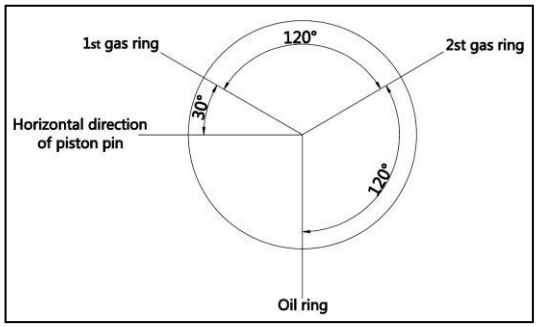


Figure 139

3. Using a piston ring compressor (Figure 140, 1), compress the piston rings.

Note:

Apply a film of oil onto the ring set before compressing.

4. Apply a film of oil to the liner, crank pin, half-bearings, and the connecting rod bolts.
5. Lower the mobile coupling (Figure 140, 2) until the connecting rod big end and its half-bearing are in place on the crank pin.

Note:

Guide the con rod big end to prevent the crank pin escaping and blocking during the operation.

6. Reinstall the connecting rod cap (Figure 140, 3). Fit the connecting rod bolts (Figure 140, 4) and fully engage the cap (turn the crankshaft to facilitate fitting of bolts).
7. Tighten the connecting rod bolts (Figure 140, 4) in two steps:
   - Tighten the bolts to 200 N·m.
   - + angle of 60°.
   - + angle of 45°.

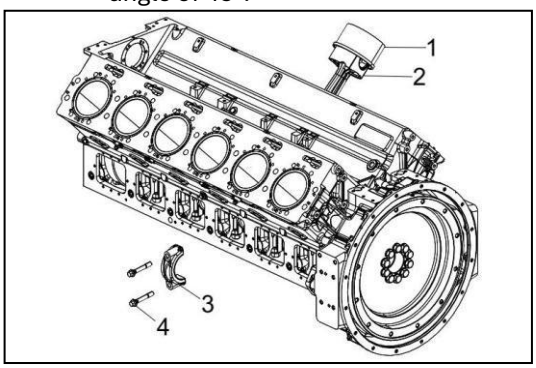


Figure 140

8. Check the radial play of the connecting rod with a feeler gauge set.
9. Reinstall the remaining pistons in their respective cylinders.
10. Install all the handhole cover.

Reassembly of Camshaft and Timing Components

Installation of camshaft Note:

It is better to install the camshaft before installing the flywheel housing and flywheel.

1. If removed, install a new camshaft bushing using the appropriate service tool.
2. Apply a film of oil to the camshaft and the camshaft bushing.
3. Install the camshaft (Figure 141, 2), gradually rotate it as you insert it.

Note:

Use the camshaft installment tool (Figure 141, 1) if necessary.

4. Apply a film of oil to the bearing bore. Fit the bearing (Figure 141, 3), taking care to position the lubrication groove at the top at 12 o'clock.
5. Apply a film of Loctite 242 to the fasten bolts (Figure 141, 4) and tighten to a torque of 31N·m.

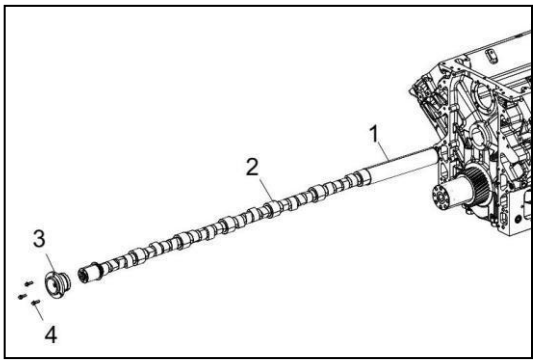


Figure 141

Installation of Timing Gears

1. Turn the crankshaft so that the "0" engraved on the pinion is at 12 o'clock. (the pinion keyway is also positioned at 12 o'clock).
2. Install the camshaft gear (Figure 142, 5) and the connecting shaft (Figure 142, 4) of signal panel.

Note:

The "N" mark on the camshaft wheel must be facing the "0" on the crankshaft timing gear (142).

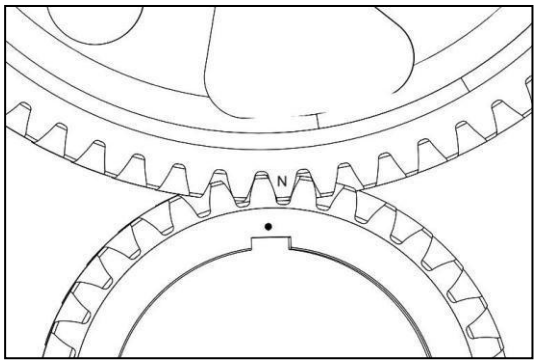


Figure 142

3. Apply a film of Loctite 242 to the fastening bolts (Figure 143, 3) and tighten the bolts.
4. Install the signal panel (Figure 143, 2).

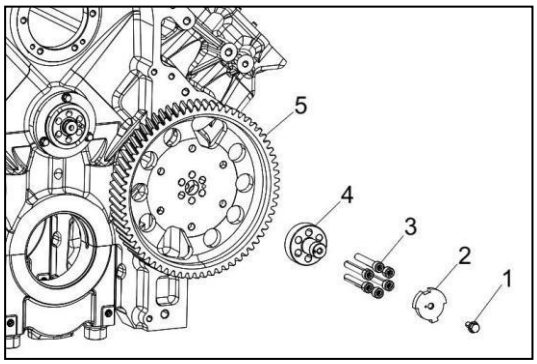


Figure 143

Installation of Oil Pan and Oil Pipeline Group

1. Assemble the oil pressure limiting valve if removed (Figure 144, 2).
2. Install the oil pipeline group (Figure 144, 1).

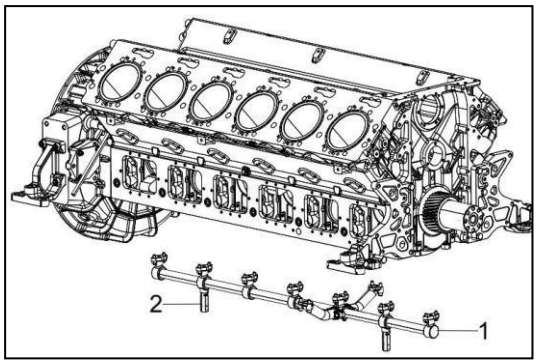


Figure 144

3. Assemble the oil pan group if disassembled (Figure 145).

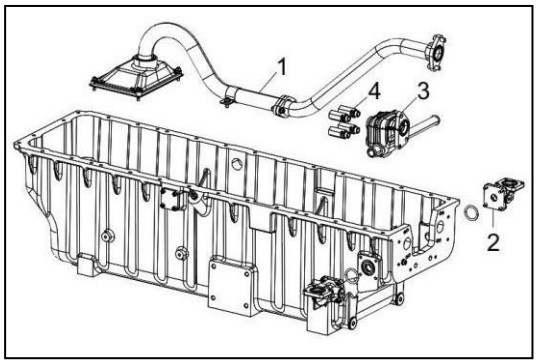


Figure 145

4. Install the oil pan on the engine block (Figure 146, 1).

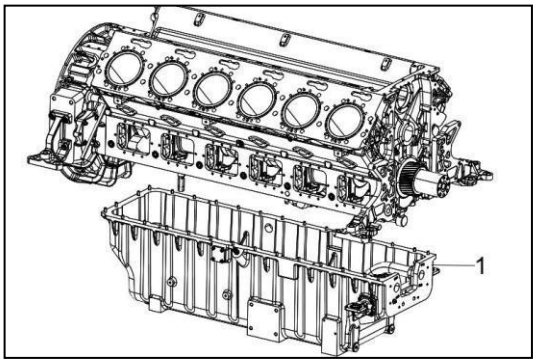


Figure 146

Note:

Replace all the O-seal rings if removed.

Installation of Front-End Cover Group

1. Put new O-seal ring (Figure 147, 1) on the oil pump (Figure 147, 2).
2. Install the oil pump on the oil pan.

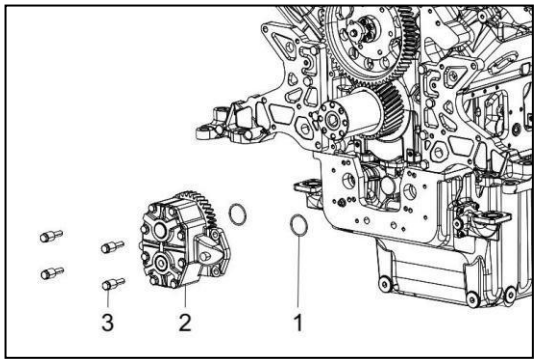


Figure 147

3. Apply a film of sealant joint surface.
4. Install the front-end cover (Figure 148, 1) to the engine block. Pay attention to the locating pin.
5. Apply Loctite sealant 242 to the threads of the bolts (Figure 148, 3). Tighten the bolts to recommended torque.
6. Install the front oil seal (Figure 148, 4).

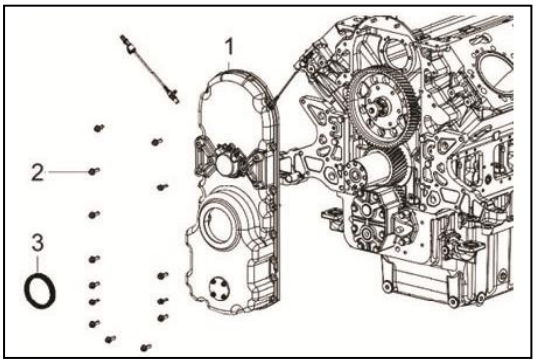


Figure 148

7. Using a dial indicator, measure the speed sensor in inches and zero it out
8. Take the dial indicator and place it where the speed sensor was removed, once flush up against the flywheel housing record the measurement.
9. The speed sensor specification is 0.110” +/- .015 using the custom .010” shims bring the gap within range (some engines may not require any). The gap should never be smaller than .095”.
10. Reinstall the speed sensor (Figure 149, 2) and shims (Figure 149, 1).
11. Loctite sealant 242 to the threads and Install bolt (Figure 149, 3) to secure speed sensor (Figure 149, 2). Tighten the bolt to recommended torque
12. Connect the connecting wring when the engine harness is installed

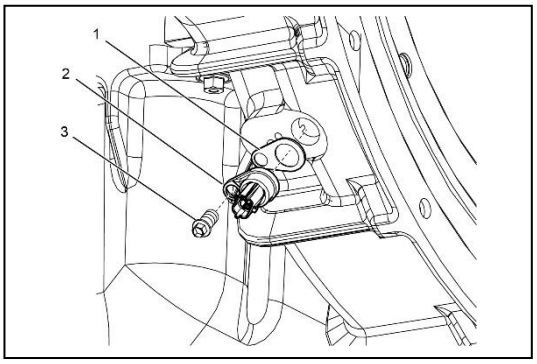


Figure 149

Final Reassembly of Engine

1. Reinstall the starter motor.
2. Reinstall the cylinder head.
3. Reinstall the engine in the machine.
4. Reconnect the coolant lines.
5. Reinstall the alternator.
6. Reconnect and adjust the throttle cable.
7. Reconnect all electrical connections.
8. Fill the engine with oil and coolant.
9. Reconnect the battery cables, negative (-) cable last.

OIL PAN

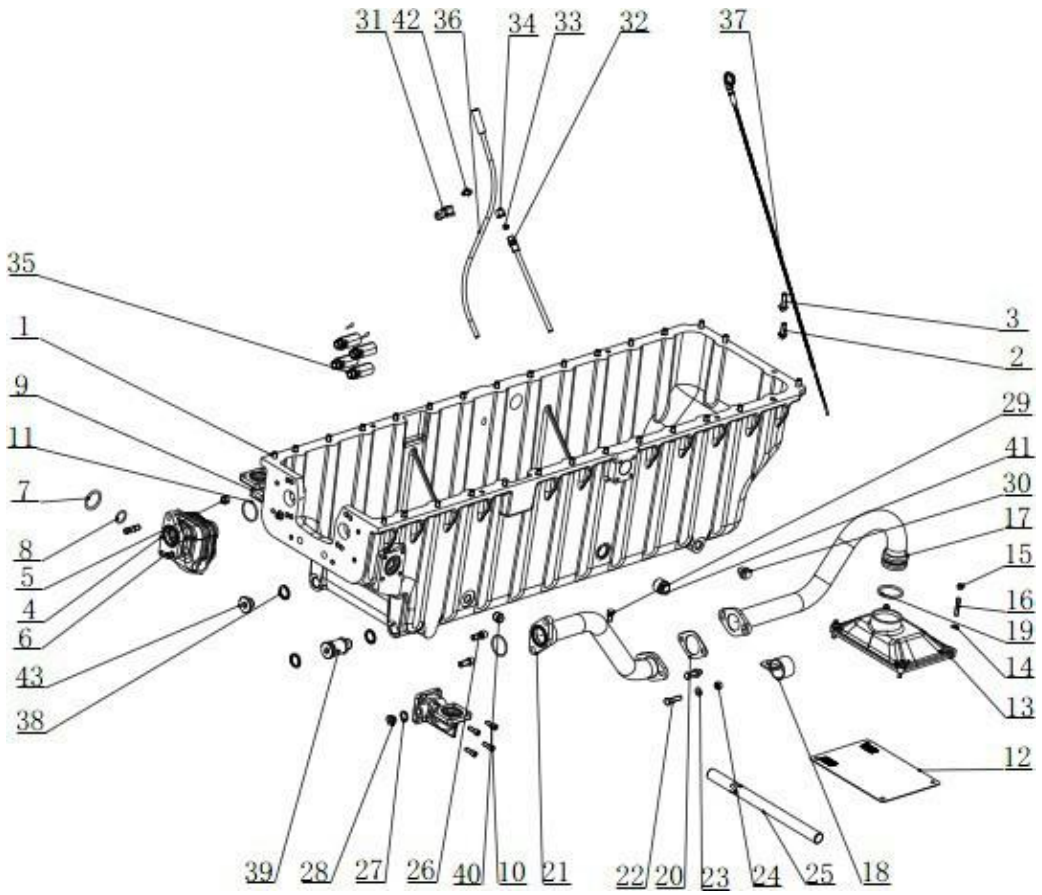


Figure 150. Oil Pan Assembly

No.	Name	No.	Name
1	Oil pan	23	Plain washer
2	Bolt	24	Nut
3	Hexagonal flange bolt	25	Pipe
4	Support seat	26	Hexagon socket head cap screw
5	Hexagon nut, style 1	27	Gasket
6	Stud	28	Hexagonal socket plug
7	O-ring	29	Hexagon head bolt - full thread
8	O-ring	30	Plug
9	Oil inlet elbow	31	Pipe clamp assembly
10	Hexagon socket head cap screw	32	Lower oil dipstick combination group
11	O-ring	33	Washer
12	Suction filter strainer	34	Nut

13	Suction filter cover	35	Pressure limiting valve of oil pump
14	Plain washer	36	Upper components of oil dipstick
15	2-type all-metal hexagon locking nut	37	Oil dipstick
16	Stud	38	Combination gasket
17	Rear suction port	39	Pipe
18	Clamp	40	Square head tapered plug
19	O-ring for mechanical seal	41	Ramp plug
20	Gasket	42	Hexagonal flange bolt
21	Front suction pipe	43	Plug
22	Hexagon head bolt		

REMOVAL

1. Drain Oil.
2. Remove oil dipstick assembly and be careful not to damage the dipstick.
3. Remove all oil pan bolts from the engine block, be sure to use a crane to lift the cylinder block off the oil pan.
4. Remove the oil inlet elbow, suction filter cover, suction filter strainer, safety valve and seats in the oil pan.

INSTALLATION

1. Install the oil inlet elbow, suction filter cover, suction filter strainer, safety valve and seats into the oil pan.
2. Apply silicone to the oil pan surface, which should be continuous without interruption.
3. Lift the cylinder block onto oil pan.
4. Apply PSI approved sealant to the threads of all hexagon socket head bolts, tighten the bolts, and wipe off the excessive silicone.
5. Tighten the hexagon head plugs, pipe joints and gaskets on the oil pan.

OIL TEMPERATURE/PRESSURE SENSOR

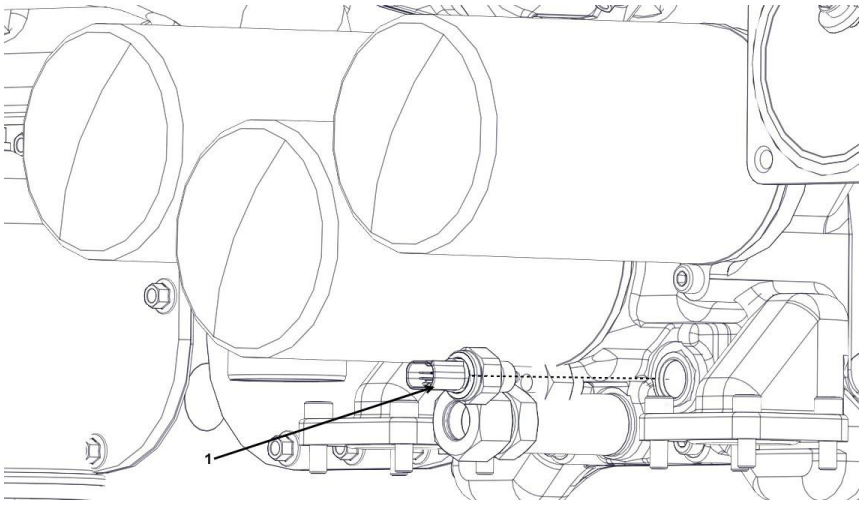


Figure 151. Right Oil Temperature/Pressure Senor

Note:

There are two oil temperature/pressure sensors, located directly below the oil filter on each side of the cylinder block.

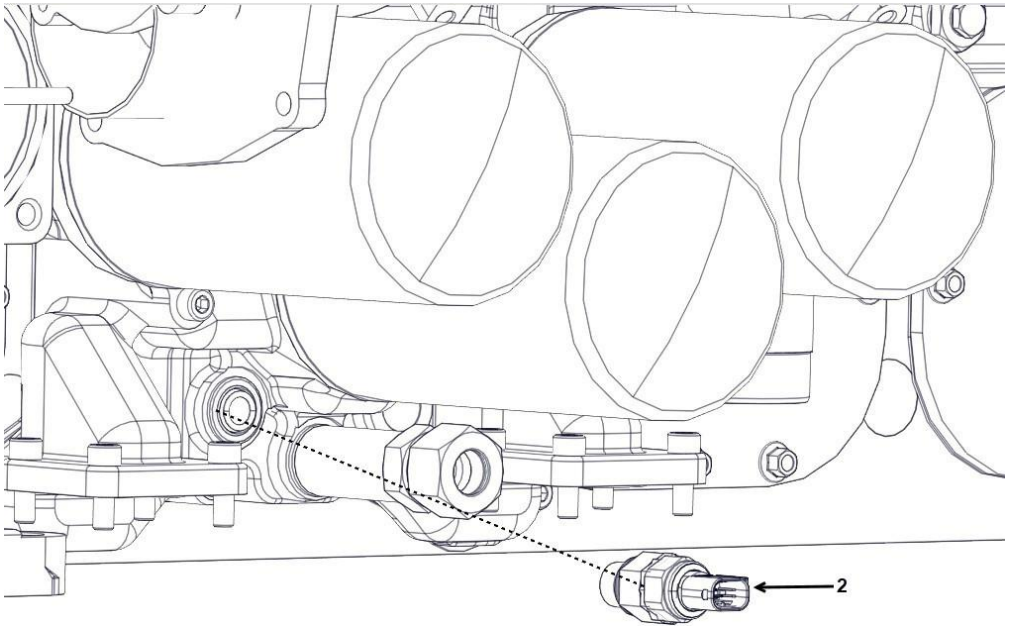


Figure 152. Left Oil Temperature/Pressure Sensor

No.	Name
1	Right Oil Temp/Pressure sensor
2	Left Oil Temp/Pressure senso

REMOVAL

1. Disconnect both oil temperature/pressure sensor harnesses.
2. Remove each oil temperature/pressure sensor from each side of the cylinder block, below the oil filters.

INSTALLATION

1. Apply PSI approved sealant to the threads of both the oil temperature/pressure sensor.
2. Insert and torque down both oil temperature/pressure sensors to 65 ft/lbs if equipped with adapter, if only installing the sensor torque down to 25 ft/lbs.
3. Reconnect both oil temperature/pressure sensor harnesses.

OIL COOLER

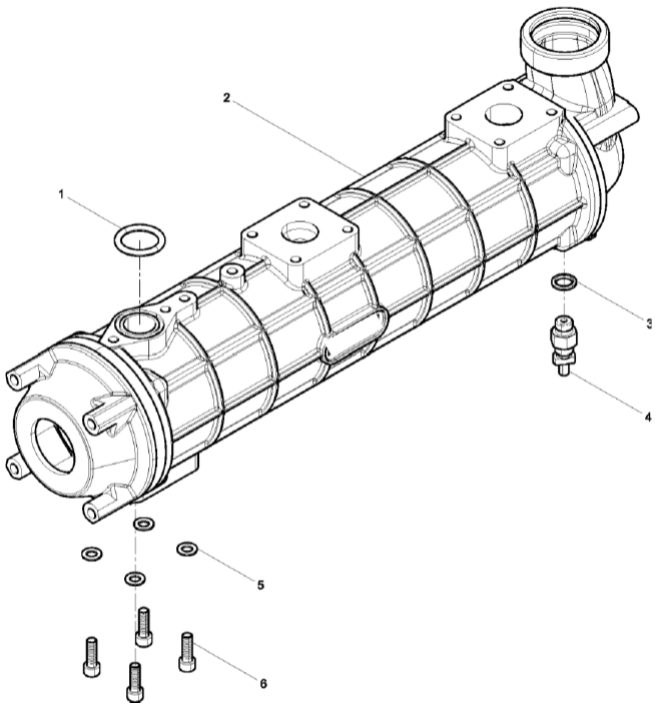


Figure 153. Oil Cooler Assembly

No.	Name
1	Oil Ring
2	Oil Cooler
3	Washer
4	Water Valve
5	Washer
6	Bolt

REMOVAL

1. Drain the cooling system.

Note:

Depending on the cooler accessibility, removal of the support/cooler assembly is recommended.

2. Remove the four lower water pump pipe bolts and remove the lower water pump pipe (Figure 154-1).

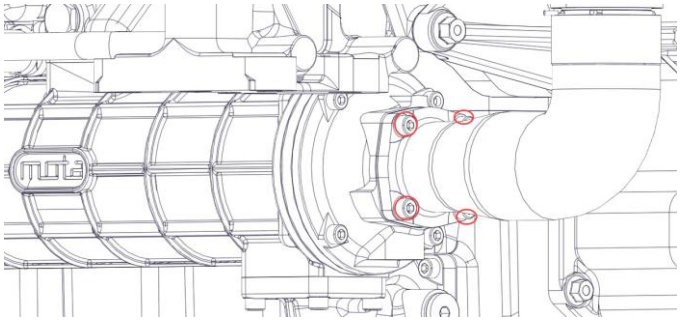


Figure 154-1.

3. Remove all oil cooler assembly mounting bolts (Figure 154-2).

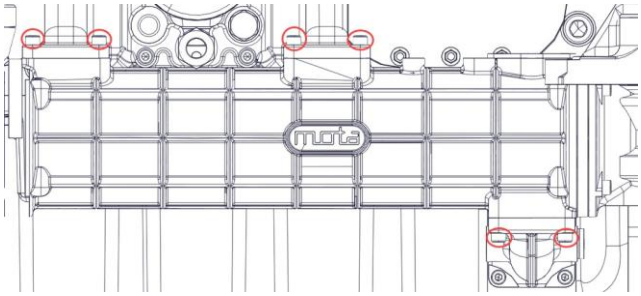


Figure 154-2.

4. Turn the oil cooler assembly away from the engine and pull down (Figure 154-3).

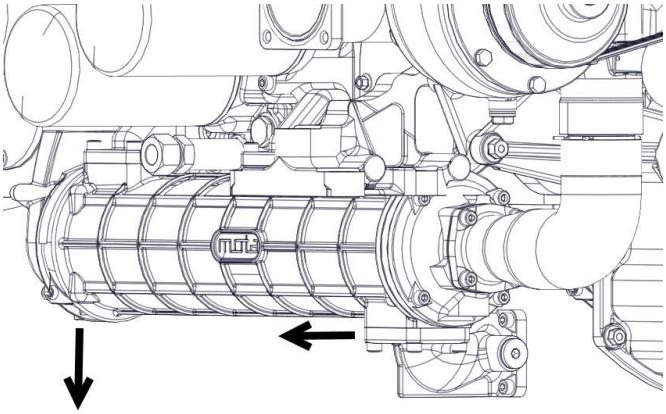


Figure 154-3.

5. Repeat steps 1-4 for the opposite end oil cooler.

INSTALLATION

1. Ensure all new O-rings are installed (Figure 154-4).

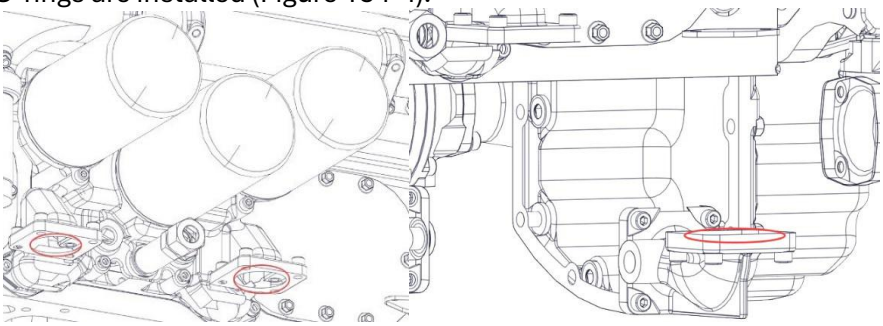


Figure 154-4.

2. Install the new oil cooler and hand tighten all bolts (Figure 154-5).

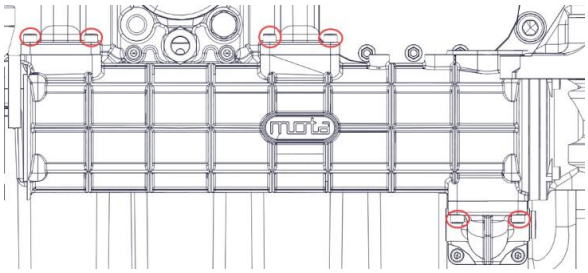


Figure 154-5.

3. Loosen top oil cooler bolts and adjust bolts to hand-tight position until no gap remains between surfaces (Figure 154-6).

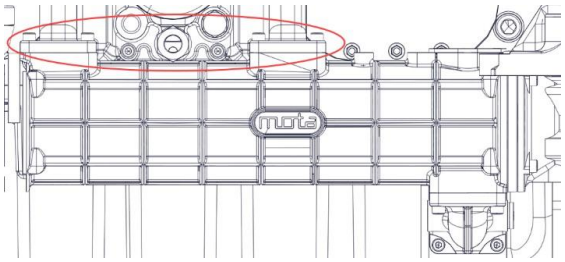


Figure 154-6.

4. Remove lower elbow by removing the eight mounting bolts and remove the O-rings from elbow, **DO NOT** discard O-rings (Figure 154-7).

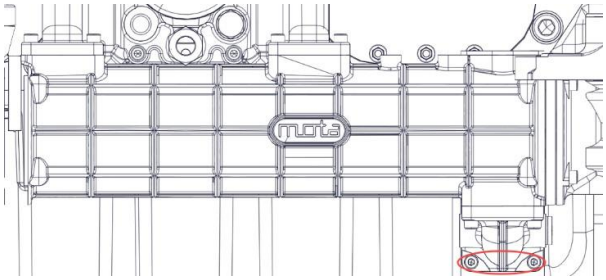


Figure 154-7.

5. Reinstall lower elbow **WITHOUT O-Rings**. Adjust bolts to hand-tighten position, only until no gap remains between surfaces (Figure 154-8).

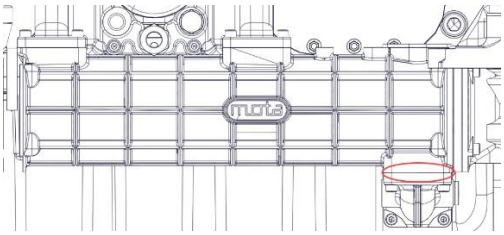


Figure 154-8.

6. Adjust the oil cooler to ensure 0 gap position naturally remains for the lower bracket. Wipe and clean surfaces so no residual oil/grease is present (Figure 154-9).

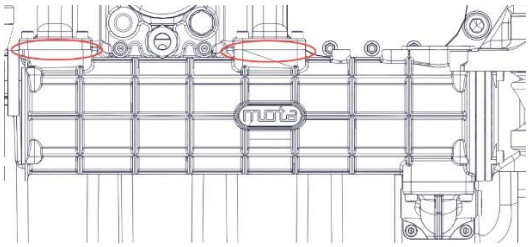


Figure 154-9.

7. Torque the upper bolts to 18 ft/lbs and ensure there is no gap for the lower elbow sealing surfaces (Figure 154-10).

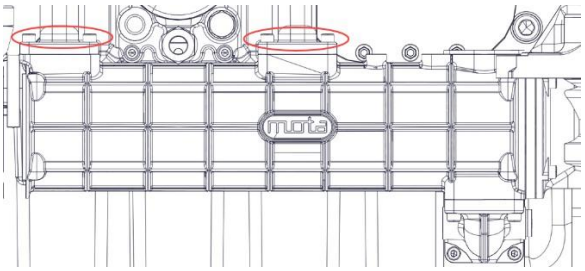


Figure 154-10.

8. Remove the lower elbow by removing the eight bolts and reinstall O-rings onto elbow, then reinstall the eight bolts by hand tightening back onto the lower elbow (Figure 154-11).

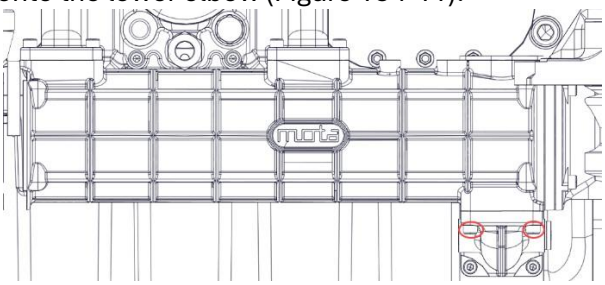


Figure 154-11.

9. Torque the four elbow bolts interfacing oil pan to 15 ft/lbs (Figure 154-12).

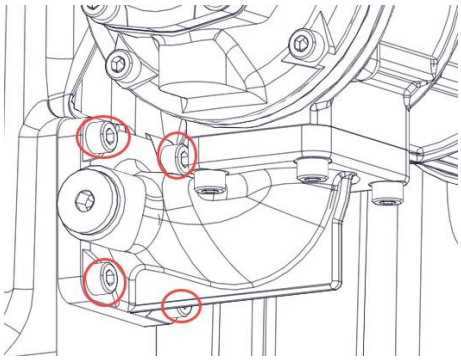


Figure 154-12.

10. Torque the four elbow bolts interfacing the oil cooler to 15 ft/lbs (Figure 151-13).

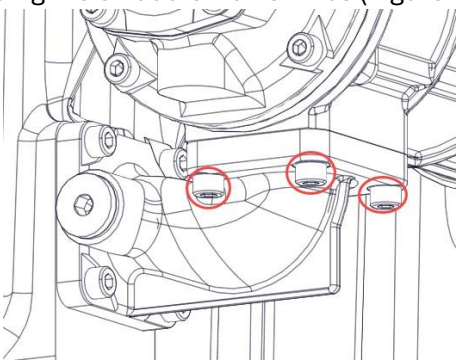


Figure 154-13.

11. Install original lower water pipe hose with the original hardware and MUST include the washer and replace with new gasket.
12. Torque down the four bolts to 106 in/lbs.

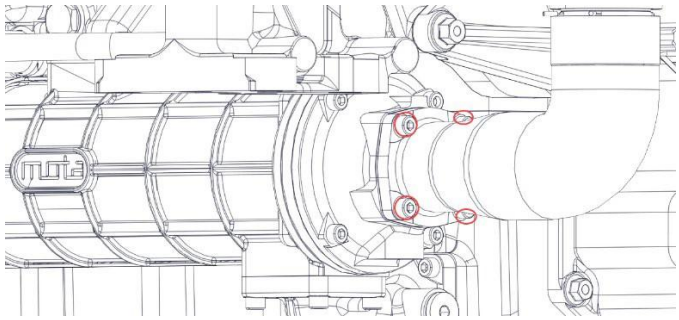
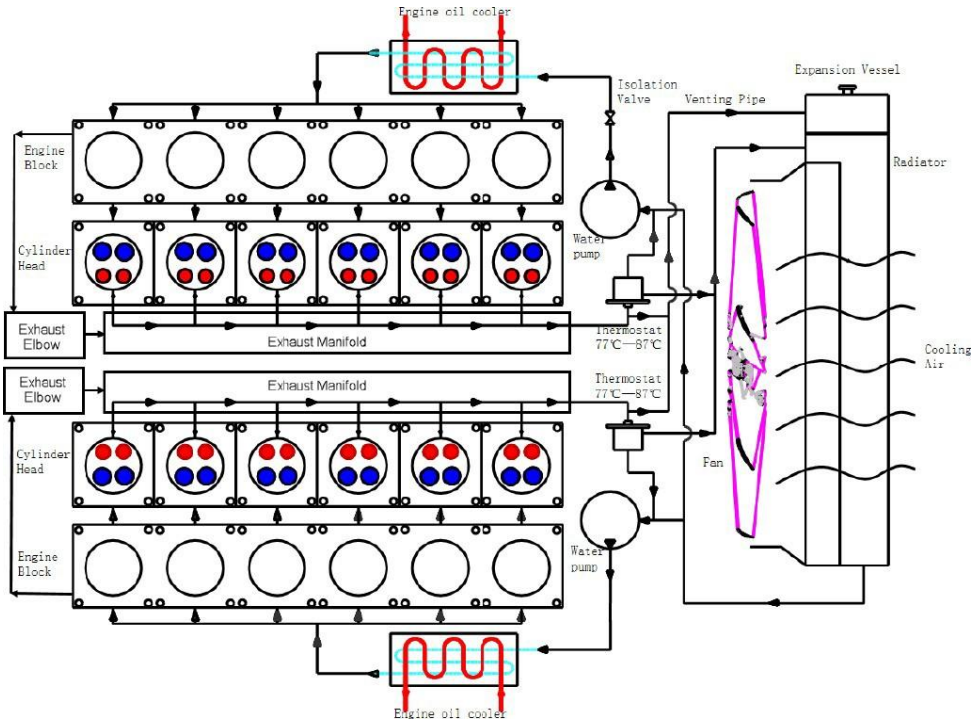


Figure 154-14.

13. Refill engine coolant to max capacity of 29.1 gallons and radiator to 25 gallons (If applicable).
14. Repeat steps 1-12 for opposite end oil cooler.

COOLING SYSTEM DIAGRAM



OIL PUMP

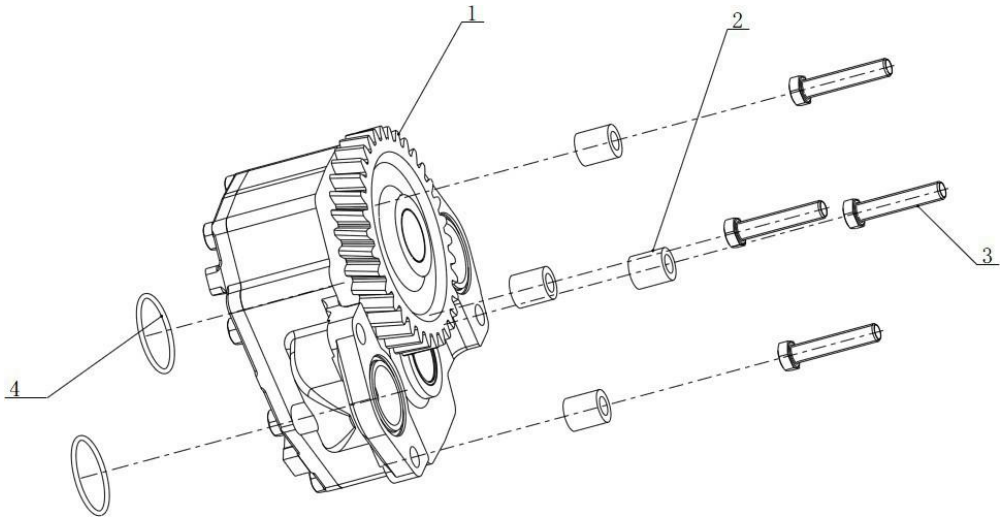


Figure 155. Oil Pump Assembly

No.	Name
1	Oil pump
2	spacer
3	Bolt
4	O-ring

REMOVAL

1. Drain oil and coolant into a suitable container.
2. Remove entire FEAD assembly, refer to *Front Engine Accessory Drive (FEAD)* section of the manual.
3. Remove front cover refer to *FRONT COVER* section of the manual.
4. Loosen the oil pump bolts (Figure 155, Item 3).
5. Remove the oil pump assembly (Figure 155, Item 1).
6. Remove the oil pump inlet and outlet O-ring (Figure 155, Item4).

INSTALLATION

Clean all debris from the cylinder block surface before installing oil pump.

1. Apply oil to the inlet and outlet O-rings (Figure 155, Item 4)
2. Install the oil pump inlet and outlet O-ring.
3. Apply blue loctite on all four bolts (Figure 155, Item 3).
4. Place oil pump onto the cylinder block.
5. Insert and in a cross pattern torque each bolt to 81 ft/lbs.
6. Measure gear lash with a dial indicator, lash should be between 0.40-0.70mm.
7. Install front cover, refer to *FRONT COVER* section of the manual.
8. Install the entire FEAD assembly, refer to *Front Engine Accessory Drive (FEAD)* section of the manual.
9. Refill engine with oil and coolant.

FLYWHEEL HOUSING

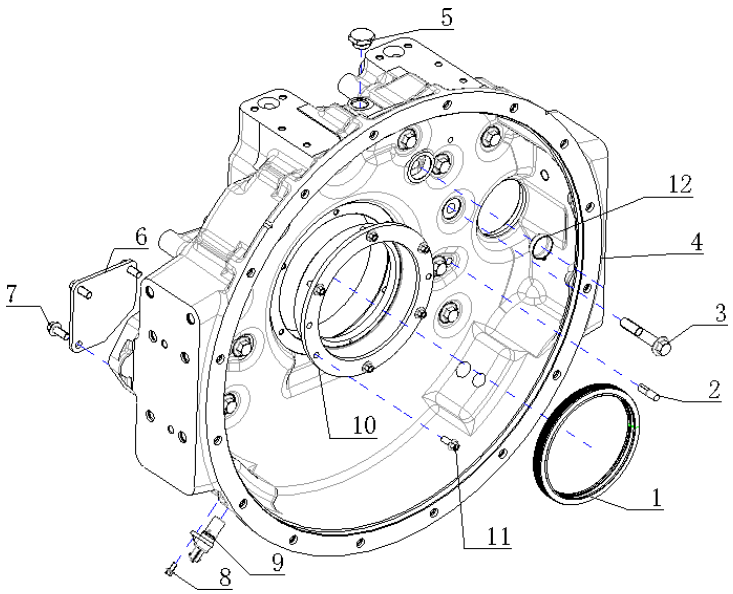


Figure 156. Flywheel Housing

No.	Name
1	Rear oil seal
2	Groove pin
3	Hexagonal flange bolt
4	Flywheel housing
5	Hexagonal head plug
6	Cover
7	Hexagonal flange bolt
8	Hexagonal flange bolt
9	Speed sensor
10	Rear oil seal seat
11	Hexagonal flange bolt
12	Bowl plug

REMOVAL

1. Remove all bolts from the flywheel housing.

NOTE:

Flywheel should be hoisted and seated slowly.

2. Remove rear oil ring (If necessary).
3. Remove Groove pin.

INSTALLATION

1. Install the cover and insert the three hexagon flange bolts.
2. Insert the two pins into the flywheel housing.
3. Attach a washer to the head screw plug and then screw it into the flywheel housing.
4. Apply PSI approved motor oil onto the rear main oil seal.
5. Press the rear main oil seal into the flywheel housing.
6. Clean all debris from the cylinder block and flywheel housing surfaces.
7. Apply sealant to the rear of the flywheel housing surfaces.
8. Install the flywheel cover guide rods onto the flywheel cover, pass the flywheel cover through the slotted pin by means of flywheel cover slings
9. Apply PSI approved sealant to all flywheel housing bolts.
10. Insert and tighten the bolts in a star pattern to 180N.m.

ENGINE OIL FILTER AND OIL REPLACEMENT

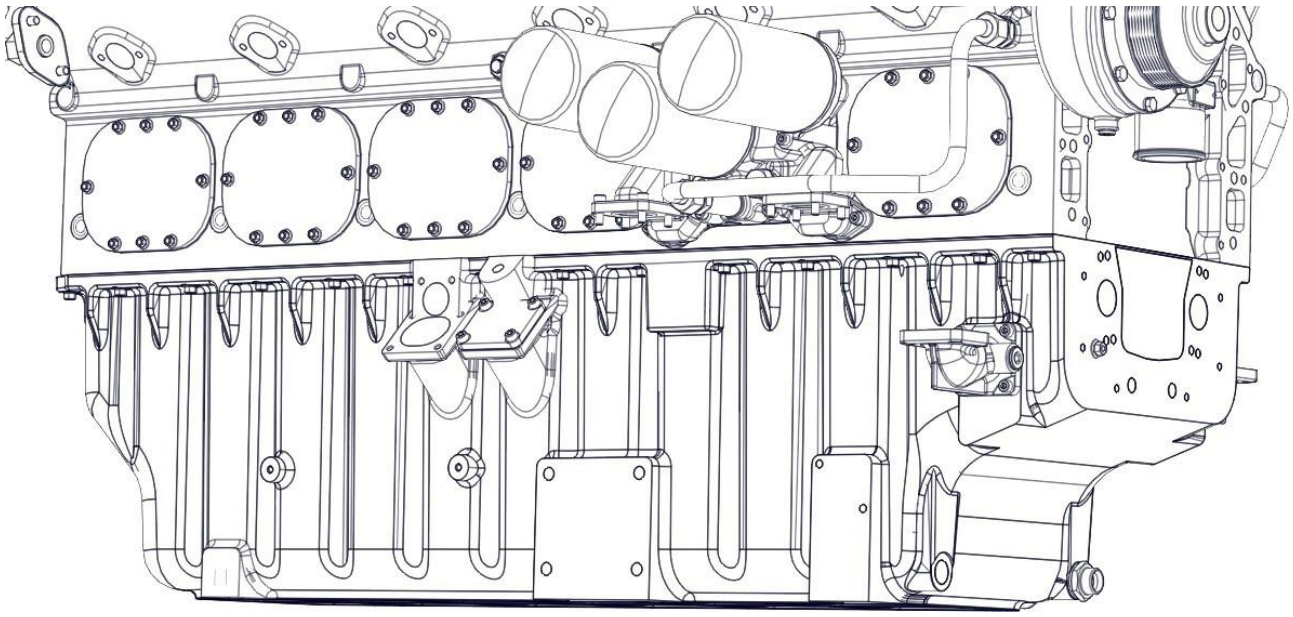


Figure 157. Engine Oil pan and Filters

OIL FILTER REMOVAL

1. Separate the oil filter from the oil filter seat.
2. Remove the coupling bolts between the oil filter seat and the engine block.
3. Remove the pressure limiting valve in the secondary oil pressure

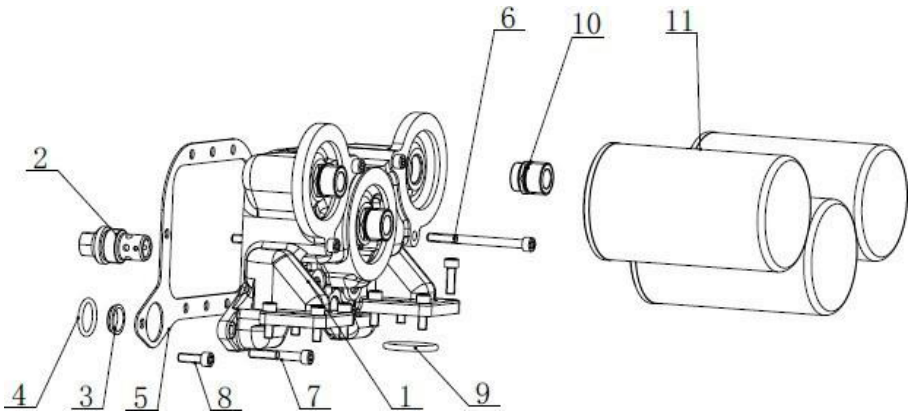


Figure 158. Oil Filter Assembly

No.	Name
1	Oil filter seat
2	Pressure limiting valve
3	Bushing
4	O-ring
5	Gasket
6	Hexagon socket head cap screw
7	Hexagon socket head cap screw
8	Hexagon socket head cap screw
9	O-ring
10	Connector body
11	Oil filter

OIL FILTER INSTALLATION

1. Install the secondary oil pressure along with the pressure limitingvalve.
2. Installing the coupling bolts between the oil filter seat and the engine block.
3. Hand tighten the oil filters onto the oil filter seat.
4. 1/2 turn each oil filter past hand tighten.

OIL DRAIN AND FILOIL DRAIN AND FILL

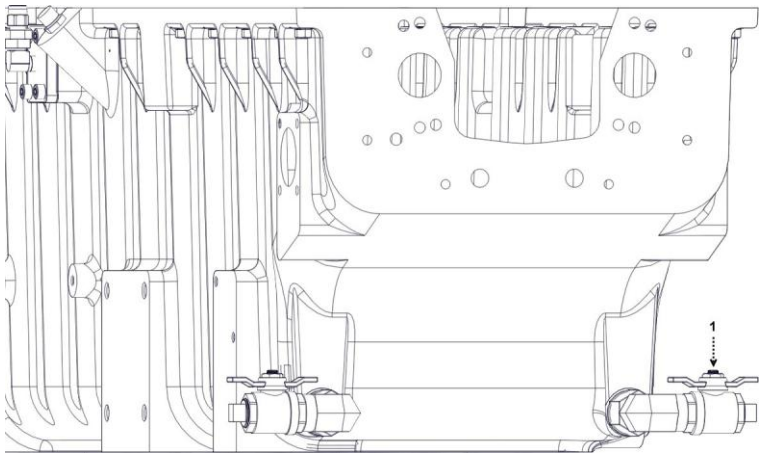


Figure 159. Oil Drain Valve

No.	Name
1	Drain Valve

1. If the engine is cold, start it and allow it to run for a few minutes to get the oil warmand circulating. Shut the engine down and disconnect the negative battery cable from the battery.
2. Attach a collection hose to the fitting (Figure 159). Drain the oil into a suitable container. When the oil has completely drained, close the valve, remove the hose and reinstall the dust cap. Dispose of the drained oil in accordance with environmental regulations.
3. Open the filler cap and add engine oil (up to 120 quarts) until the level reaches the high mark on the dipstick
4. Reinstall the filler cap.
5. Start the engine and run at idle with no load applied
6. Inspect the engine and filters for any oil leaks.
7. Shut the engine down, wait at least five minutes for the oil to drain back into the sump pump and recheck the oil level. More oil may need to be added to replace the oil that filled the filters.

OIL RECOMMENDATION

When the 32L engine is being filled for the first time, oil should be filled to the max scale of 113 liters.

SAE viscosity level	Applicable ambient temperature (℃)
15W-40	-20-40

Figure 160.

WATER PUMP

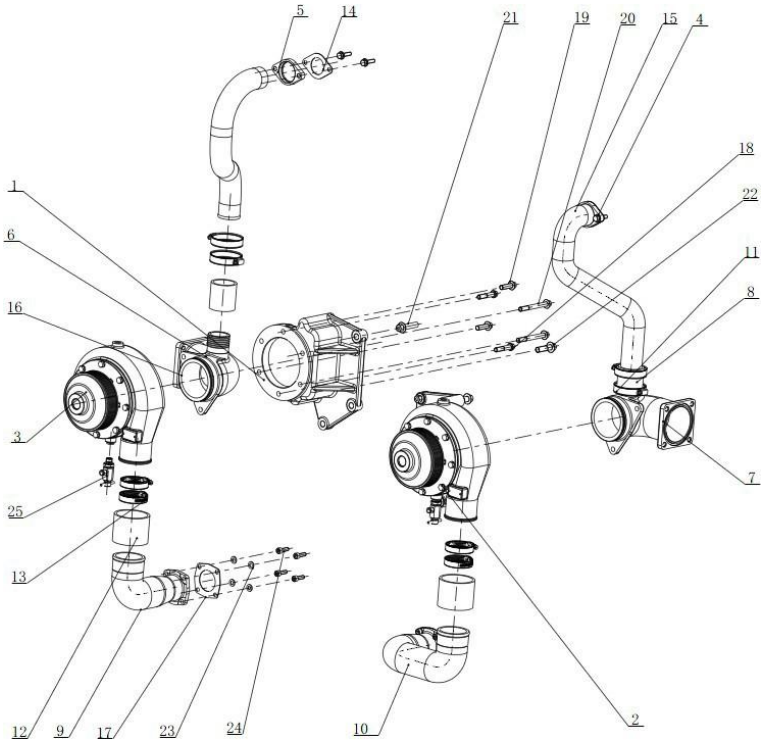


Figure 161. Water Pump Assembly

No.	Name	No.	Name
1	Water pump bracket	14	Gasket
2	Water pump bracket	15	Hexagon Flange Bolt
3	Water pump	16	O-Ring Seal
4	Water pump - water pipe	17	Gasket
5	Pump return pipe assembly	18	Bolt
6	Pipe joint	19	Bolt
7	Pipe joint	20	Bolt
8	Coolant connection hose	21	Bolt
9	Outlet elbow	22	Bolt
10	Outlet Elbow	23	Washer
11	Clamp	24	Bolt
12	Hose	25	Drain Valve
13	Clamp		

REMOVAL

1. Remove lower fan guards on both sides of the engine.
2. Drain coolant into a suitable container.
3. Remove the water pump fan belts.
4. Secure the water pump assembly to assist with bolt removal.
5. Remove the two rear bolts from the water pump assembly (Figure 162-1).

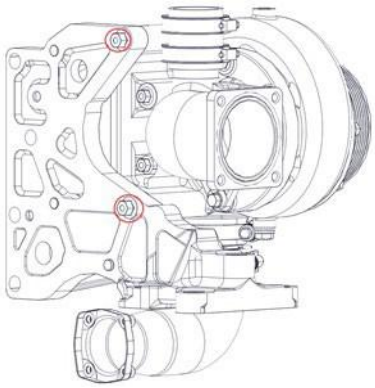
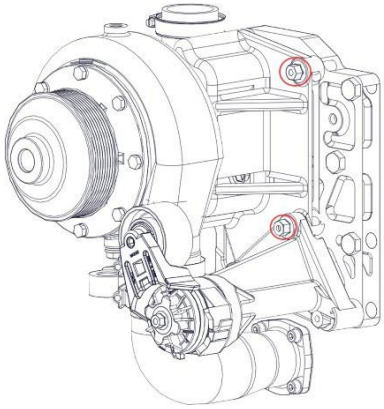


Figure 162-1.

6. Remove the two top front bolts from the water pump assembly (Figure 162-2).



7. Figure 162-2. Remove the last two bottom front bolts from the water pump assembly (Figure 162-3).

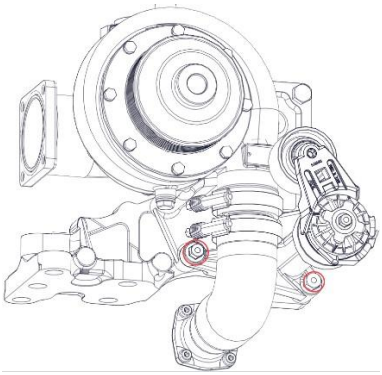


Figure 162-3

8. Remove the bolts on the water pump mounting bracket (Figure 162-4).

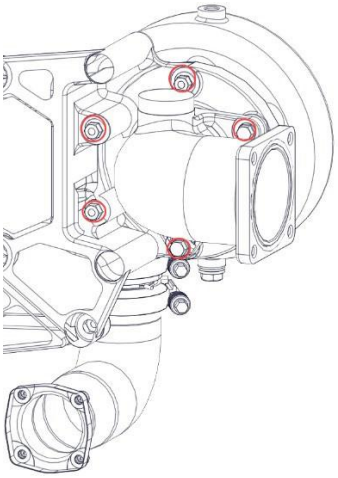


Figure 162-4.

9. Remove the water pump coolant pipe.
10. Remove the water pump mounting bracket.
11. Repeat steps 4-10 for the opposite water pump assembly.

INSTALLATION

1. Install water pump mounting bracket onto the new water pump.
2. Ensure both O-rings are installed onto the water pump outlet coupler and install into pump.
3. Insert and tighten down the remaining mounting bracket bolts onto the new water pump.
4. Strap the lift assist device onto the water pump assembly and align the water pump assembly onto the engine mounts.
5. Insert and tighten the two rear water pump assembly bolts.
6. Insert and tighten the two top front bolts from the water pump assembly.
7. Insert and tighten the last two bottom front bolts from the water pump assembly.
8. Refill engine coolant to max capacity of 29.1 gallons and radiator to 25 gallons (if applicable).
9. Repeat steps 1-8 for the water pump on the other bank of the engine.

WATER CROSSOVER PIPE AND THERMOSTAT

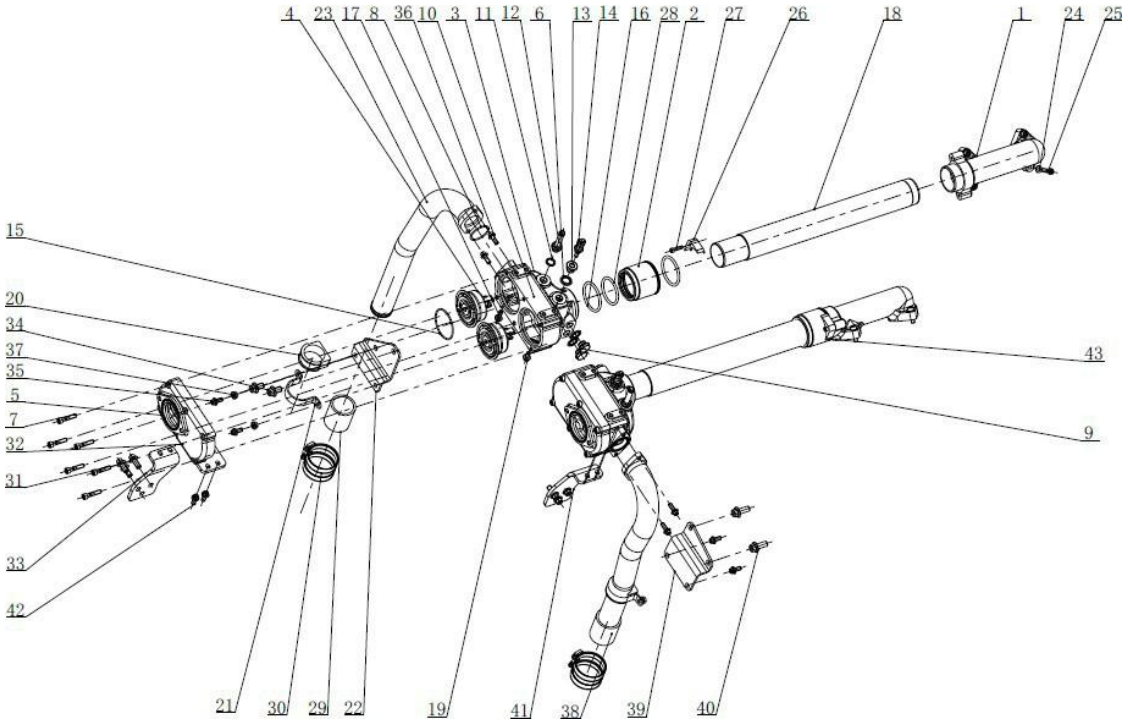


Figure 163. Thermostat Assembly

No.	Name	No.	Name	No.	Name
1	Exhaust Manifold Water Outlet Pipe	16	O-Ring	31	Bolt
2	Connecting Pipe	17	Bolt	32	Bracket
3	Thermostat Body	18	Water Pipe	33	Bracket
4	Thermostat	19	Bolt	34	Bolt
5	Thermostat Cover	20	Sleeve	35	Bolt
6	Combination Gasket	21	Clamp	36	Bolt
7	Bolt	22	Bracket	37	Bolt
8	O-Ring	23	Water Pipe	38	Water Pipe
9	Plug	24	Washer	39	Bracket
10	Head Plug	25	Bolt	40	Bolt
11	Gasket	26	Board	41	Bracket
12	Pipe Joint	27	Bolt	42	Bolt
13	Sensor Connector	28	O-Ring	43	O-Ring
14	Temperature Sensor	29	Hose		
15	O-Ring	30	Clamp		

REMOVAL

1. Drain Coolant into suitable container.
2. Remove the pump water pipe and mounting bracket.
3. Remove the thermostat body, thermostat cover and thermostat bracket.
4. Remove the water outlet pipe.
5. Separate the thermostat body from its cover and remove the thermostat.

Note:

Inspect O-ring and pipes for any damages.
Inspect thermostat, opening temperature is 168°F (76°C).

INSTALLATION

1. Insert thermostat into the thermostat body cover and install.
2. Insert the water outlet pipe into the thermostat body.
3. Insert the thermostat bracket.
4. Insert the mounting bracket and the pump water pipe.

PISTON AND CONNECTING ROD

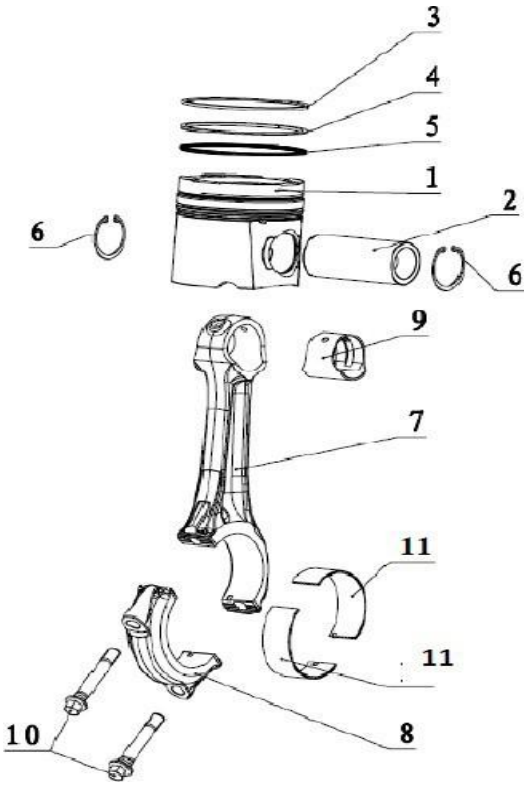


Figure 164. Piston and Connecting Rod Assembly

No.	Name	No.	Name
1	Piston	7	Connecting Rod
2	Piston Pin	8	Connecting Rod
3	Keystone Barrel Faced Ring	9	Bushing
4	Twist Taper Faced Ring	10	Bolt
5	Coil Spring Loaded Oil-Control Ring	11	Bearing
6	Piston Pin Circlip		

REMOVAL

1. Remove the carbon deposits on the top of the cylinder carefully, do not damage the cylinder interior.
2. Rotate the crankshaft to keep the piston at BDC.
3. Remove both connecting rod bolts.
4. Remove the connecting rod cap and bearing.
5. Rotate the crankshaft to TDC and carefully remove the piston with a wooden hammer.
6. Remove the circlips on both sides of the piston carefully with an internal circlip caliper.
7. Push out the piston pin.
8. Remove all three piston rings with a piston ring plier and mark them respectively.

WARNING:

Use care when removing piston and connecting rod assembly to prevent connecting rod from damaging crankshaft or cylinder bore.
Mark pistons to cylinder block position to aid installation.

CLEAN AND INSPECTION

1. Inspect all piston rings, connecting rod, pistons, rod caps and bolts for the following:
    a. Burr
    b. Scratches
    c. Cracks
    d. Discoloration
    e. Any debris
    f. Eroded areas
    g. Scuffed or damaged skirt
    h. Piston ring grooves for nicks, burrs or other damages
    i. Out of round conditions
    j. Connecting rod for twisting
    k. Connecting rod bolt holes for stripped or damaged threads
2. Clean all pistons, connecting rods, rod caps, piston rings and bolts in solvent
3. Dry all components with compressed air

WARNING:

Wear approved safety glasses or face shield when cleaning components.
Failure to comply may result in personal injury.

Wear rubber gloves and protective clothing when cleaning components.
Failure to comply may result in personal injury.

INSTALLATION

1. Ensure to clean all cylinder bores and surfaces.
2. Install all three piston rings with piston ring pliers. (Refer to Figure 165)

Figure 165. Piston Ring Pliers

3. Insert connecting rod busing, if disassembled.
4. Align connecting rod and insert the piston pin.
5. Insert both piston pin circlips using a piston circlip caliper.
6. Coat the following components with clean PSI approved motor oil:
    a. Pistons
    b. Piston rings
    c. Cylinder block bore
    d. Upper and lower connecting rod bearing surfaces
7. Install the upper bearing on piston and connecting rod assembly.
8. Lift the cylinder block and place it on a titling device.
9. Install the piston and connecting rod assembly through the top of the corresponding cylinder block.
10. Firmly hold piston ring compressor and tap top of piston with a wooden hammer until all piston rings have entered the cylinder bore.
11. Guide the connecting rod onto the crankshaft journal.
12. Install lower bearing and connecting rod cap.
13. Torque the connecting rod bolts. (Refer to Page 100 for connecting rod bolt torquing sequence)

ALTERNATOR

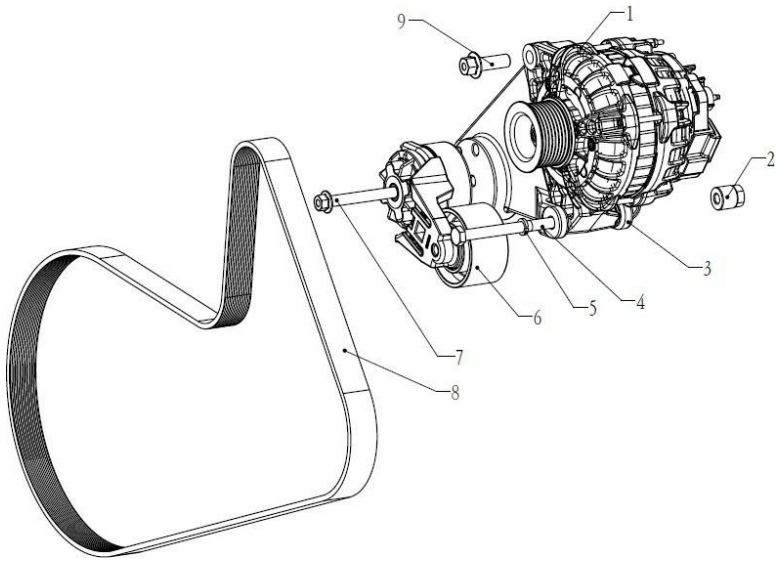


Figure 166. Alternator Assembly

No.	Name	No.	Name
1	Alternator	6	Auto tensioner
2	Nut	7	Hexagonal flange bolt
3	Alternator bracket	8	Ribbed belt
4	Hexagon head bolt	9	Hexagonal flange bolt
5	Spring washer		

REMOVAL

1. Disconnect the wires from the back of the alternator
2. Insert a ½" ratchet or breaker bar into the automatic belt tensioner hole and pull to relieve belt tension. Slip the belt off the tensioner pulley and remove from the engine.
3. Remove the automatic belt tensioner.
4. Loosen the bolts securing the alternator to the bracket and remove the alternator.

INSTALLATION

1. Place the alternator on the bracket and install the bolts.
2. Install the automatic belt tensioner.
3. Insert a ½" ratchet or breaker bar into the hole on the automatic belt tensioner and pull to move the pulley. Loop the alternator belt around the alternator pulley, crank pulley, and tensioner. Slowly release the tension on the ratchet to apply tension to the belt. Verify that the belt is fully seated in all grooves on the alternator and crank pulleys.
4. Reconnect the wires on the back of the alternator.

STARTER MOTOR

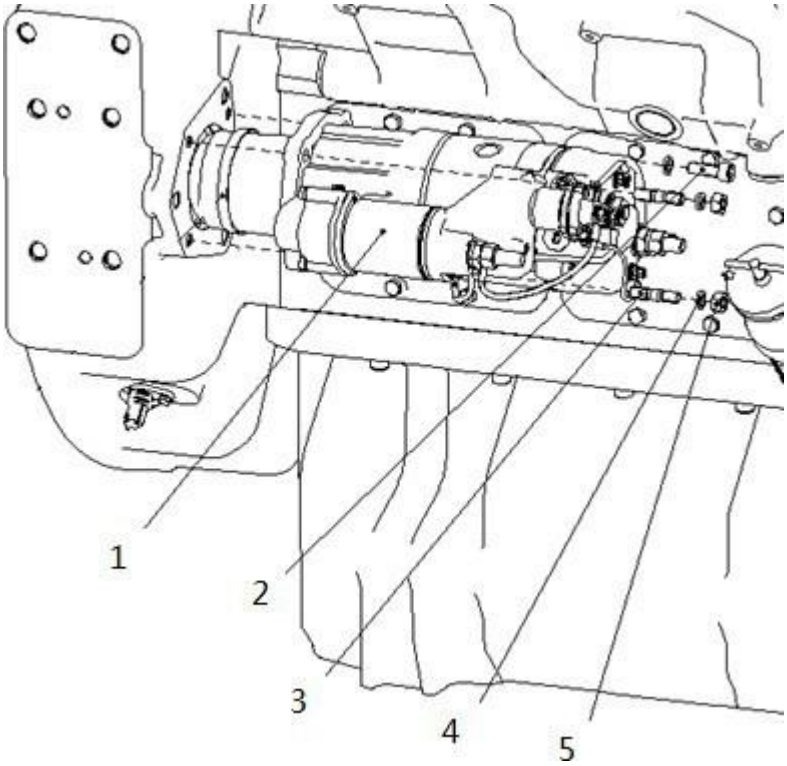


Figure 167. Starter Motor Assembly

No.	Name	No.	Name
1	Starter motor	4	Standard Spring Washer
2	Hexagon Socket Head Cap Screw	5	Nut
3	Stud t		

WARNING:

To avoid accidental engine starting, disconnect the battery cable from the negative (-) battery terminal. Completely tape all metal surfaces of the disconnected battery cable end in order to prevent contact with other metal surfaces.

REMOVAL

1. Remove the hexagon socket head cap screws and spring washers.
2. Remove the hexagon nuts and spring washers.
3. Loosen the starter wire and hold the starter with both hands to remove it along the starter gear rotation axis.

INSTALLATION

1. Install two studs on the flywheel housing.
2. Install the starter and make sure to keep the motor drive gear opening direction towards the fly wheel ring gear.
3. Install the spring washers and tighten the hexagon socket head caps and the hexagon nuts.

CHARGE AIR COOLER (CAC) PIPES

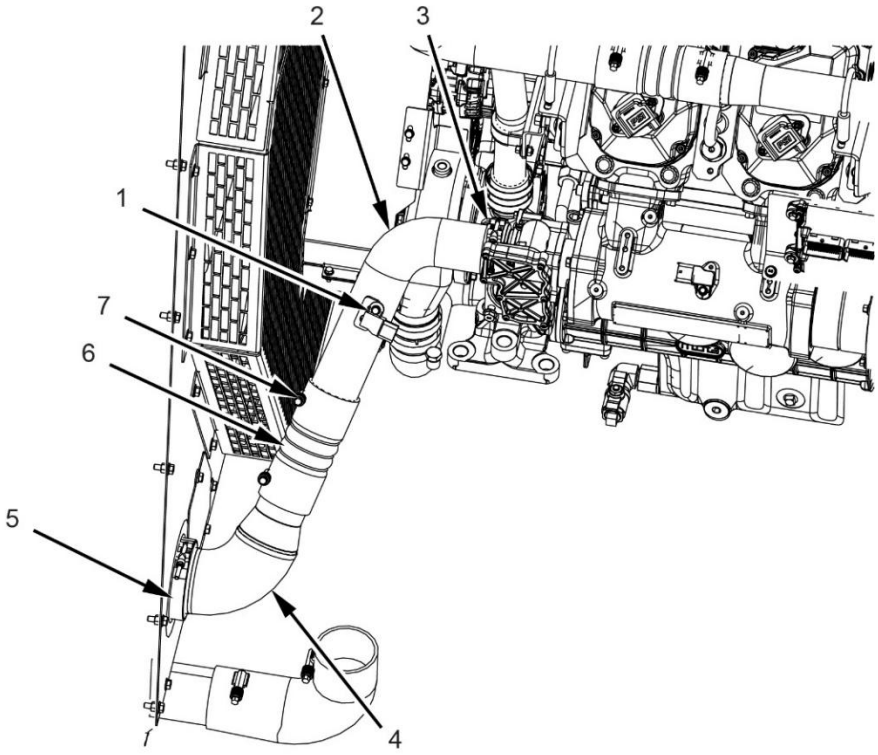


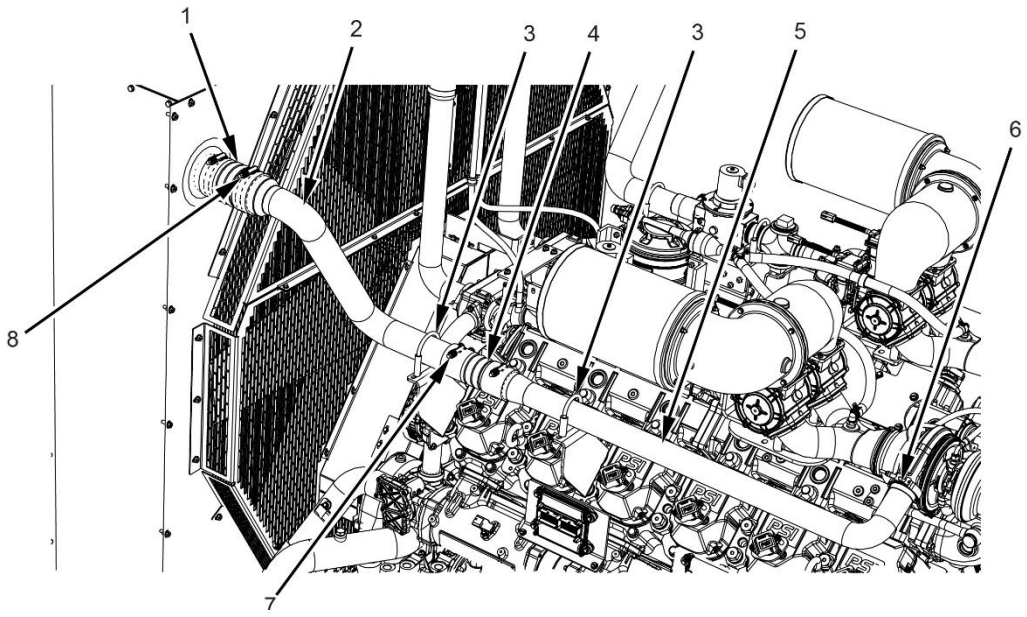
Figure 168. CAC Pipes Assembly

REMOVAL

1. Remove sending unit (1) by removing one bolt from CAC pipe 52000367 (2).
2. Remove V-Band clamp (3) and loosen hose clamp (7) on hose (6) and remove CAC pipe 52000367 (2). Discard O-ring seal (not shown).
3. Remove V-Band clamp (5) and loosen hose clamp (7) on hose (6) and remove CAC pipe 52000438 (4). Discard O-ring seal (not shown).

INSTALLATION

1. Install new O-ring seal (not shown) (52000437) and install CAC pipe 52000438 (4) on CAC with V-Band clamp (5). Do not tighten.
2. Install hose (6) on CAC pipe 52000438 (4). Do not tighten.
3. Install CAC pipe 52000367 (2) on hose (6). Do not tighten.
4. Install new O-ring seal (not shown) (32501278) on CAC pipe 52000367 (2) and install to engine with V-Band clamp (3). Do not tighten.
5. Ensure pipes and hoses align and tighten all fittings. Torque V-Band clamp (5) to 15 lb-ft (20.3 N·m) and V-Band clamp (3) to 7.5 lb-ft (10.1 N·m). Torque hose clamps (7) to 6 lb-ft (8.1 N·m).
6. Install sending unit (1) with one bolt from CAC pipe 52000367 (2).



REMOVAL

Note

Left side shown, right side similar.

1. Remove the two U-Clamps (3) securing CAC pipe 52000380 (5) and CAC pipe 52000374 (2).
2. Remove V-Band clamp (6) and loosen bolt on hose (4) and remove CAC pipe 52000380 (5). Discard O-ring seal (not shown).
3. Loosen hose clamp (8) on hose (1) and loosen hose clamp (7) on hose (4) and remove CAC pipe 52000374 (2).
4. Repeat steps 1-3 for right side.

INSTALLATION

Note

Left side shown, right side similar.

1. Install CAC pipe 52000374 (5) on hose (4). Do not tighten.
2. Install new O-ring seal (not shown) (52500073) and install CAC pipe 52000380 (5) on engine and install V-Band clamp (6). Do not tighten.
3. Install hose (4) on CAC pipe 52000380 (5). Do not tighten.
4. Install hose (4) on CAC pipe 52000374 (2) and install to hose (1).
5. Ensure pipes and hoses align and tighten all fittings.
6. Install the two U-Clamps (3) securing CAC pipe 52000380 (5) and CAC pipe 52000374 (2). Torque U-Clamp to 15 lb-ft (20.3 N·m). Tighten hose clamps (7) and (8), torque to 6 lb-ft (8.1 N·m).
7. Tighten V-Band clamp (6), torque to 7.5 lb-ft (10.1 N·m).
8. Repeat steps 1-7 for right side.

TORQUE SPECIFICATIONS

Data for Tightening Torque			
Tightening of screws and nuts	**Thread**	**Assembly**	**Recommended tightening torque (N·m)**
Injector pipe nut	M14×1.5	Lub. oil	40±3
	M16×1.5	Lub. oil	
Screw for return pipe of injector	M8×1	Lub. oil	8±0.5
Screw for adjust plate of alternator	M8 (10.9)	Lub. oil	35±3
Screw for fixing bracket rod of alternator	M10 (10.9)	Lub. oil	65±5
Exhaust manifold bolt	M10 (10.9)	Loctite 242	65±5
Intake manifold bolt	M10 (10.9)	Loctite 242	65±5
Engine hanger plate screw	M12 (10.9)	Lub. oil	110±5
Screw for fixing turbocharger oil outlet pipe	M10 (10.9)	Loctite 242	65±5
Screw for fixing fuel injection pump bracket onto pump	M10 (10.9)	Lub. oil	45±3
Nut for fixing fuel injection pump bracket onto block (double end stud)	M8 (12.9)	Lub. oil	0±3
Fuel injection pump inter gear screw	M10 (10.9)	Loctite 242	65±5
Fuel injection pump gearing screw	M12 (12.9)	Loctite 242	110±5
Injection pump camshaft nut	M24×1.5	Loctite 242	170±10
Oil cooler screw	M8 (10.9)	Loctite 242	35±3
Oil pump screw	M14 (10.9)	Loctite 242	180±10
Valve bridge adjusting nut	M10（10.9）	Loctite 242	45±3
Banjo Bolt (Between exhaust elbow /pipe)			70±5

Data for Tightening Torque			
Tightening of screws and nuts	**Thread**	**Assembly**	**Recommended tightening torque (N·m)**
Connecting Rod Bolt	M16×1.5	Loctite 242	Tighten the screws to a torque of 200 N·m
			Tighten the screws to an angle of 60°
			Tighten the screws to an angle of 45°
Main Bearing Bolt	M24×2	Lub. oil	Tighten the screws to a torque of（180 ±10）N•m
			Tighten the screws to an angle of 60°
			Tighten the screws to an angle of 60°
Cylinder head bolt	M16 (Main Bolt)	Lub. oil	Tighten the M16 screws in order 1-2-3-4 ...24 to a torque of 80 N·m ; Tighten the M20 screws in order A-B-C-D...N to a torque of 80 Nm
			Tighten the M16 & M20 screws to 80±10°Nm, then to an angle of 60°±5°.
			Tighten the M16 screws to an angle of 60°±5°; Tighten the M20 screws to an angle of60°±5°
	M20 (Secondary)		Tighten the M20 screws to an angle of 60°±5°; Tighten the M16 screws to an angle of45°±5°
			The reuse of the primary and secondary cylinder head bolts is limited to no more than 3 times. New bolts **MUST** be used after that.
Screw for fixing rocker Arm bracket onto cylinder head	M10 (10.9)	Lub. oil	65±5
Crankshaft damper bolt	M12 (10.9)	Loctite 242	125±5
Flywheel screw	M20×2.0	Lub. oil	Tighten the screws to a torque of 180 N•m
			Tighten the screws to an angle of 60°
Screw for fixing camshaft Thrust Plate	M8 (12.9)	Loctite 242	Tighten the screws to a torque of 15~20N•m
			Tighten the screws to a torque of39N•m
Camshaft timing gear screw	M10 (10.9)	Loctite 242	70±5
Screw for fixing oil pan onto block	M10 (10.9)	Loctite 242	75±5
Screw for adjusting rocker arm	M10（10.9）	Lub. oil	45±3

Data for Tightening Torque			
Tightening of screws and nuts	**Thread**	**Assembly**	**Recommended tightening torque (N·m)**
Flywheel housing screw	M14 (10.9)	Lub. oil	180±10
Nut for fixing starter (double end stud)	M10 (10.9)	Loctite 242	65±5
Valve bridge screw	M10 (12.9)	Loctite 242	75±5
Water pump screw	M8 (10.9)	Loctite 242	35±3
Crankshaft pulley bolt	M14 (10.9)	Loctite 242	215±10
Front cover screw	M10 (10.9)	Loctite 242	65±5
Injector holder nut	M32×1.5	Lub. oil	120±5
Turbo V-Bland Clamp	Ø 3.88"		10.1 N·m
CAC V-Bland Clamp	Ø 4.81"		20.3 N·m
Hose Clamp -SLHD	5/8"W #462, Ø4-5/8		8.1 N·m
Hose Clamp -SLHD	5/8"W #362, Ø3-5/8		8.1 N·m
Hose Clamp -SLHD	5/8"W #412, Ø4-1/8		8.1 N·m
Hose Clamp -SLF	9/16"W SAE #44 Ø3-1/4		4.0 N·m
U-Bolt Clamp	2-5/8 ID 3/8-16		20.3 N·m
U-Bolt Clamp	Ø3-1/8 X 3/8-16		20.3 N·m
V-Band Clamp	3”		10.1 N·m

MECHANICAL SPECIFICATIONS

SN.	Item	Theoretical value (mm)	Wear limit
Cylinder head			
1	Height of cylinder head	125~125.025	124.75
2	Diameter of intake valve	9.965~9.80	
3	Diameter of exhaust valve	9.945~9.960	
4	Sinkage of intake valve	1.20~1.70	2.00
5	Sinkage of exhaust valve	0.60~1.10	1.70
6	Clearance between intake valve and valve guide	0.035~0.065	0.10
7	Clearance between exhaust valve and valve guide	0.065~0.085	0.10
8	Diameter of intake valve seat	49~49.016	
9	Diameter of exhaust valve seat	42~42.015	
10	Clearance between intake valve seat and cylinder head	0.065~0.097	
11	Clearance between exhaust valve seat and cylinder head	0.065~0.097	
12	Inner diameter of valve guide	9.995~10.015	
13	Outstanding amount of valve guide	16.03~16.07	
14	Clearance between valve guide and cylinder head	0~0.29	
15	Inner diameter of injection sleeve	31~31.5	
16	Clearance of intake and exhaust valve	.022" & .039"	
17	Diameter of valve bridge	13.966~13.984	13.92
18	Inner diameter of valve bridge seat	14~14.018	14.15
19	Clearance between valve bridge and its seat	0.016~0.052	0.10

SN.	Item		Theoretical value (mm)	Wear limit
Cylinder head				
20	Inner diameter of rocker arm bushing		24.017~24.03	
21	Clearance between rocker and its bushing		0.05~0.115	
22	Diameter of rocker arm shaft		23.96~24	23.9
23	Clearance between rocker arm and rocker arm seat		0.15~0.20	
24	**Clearance between rocker arm shaft and seat**		0.017~0.043	0.10
Cylinder block				
1	Inner diameter of liner		150~150.025	150.2
2	Out diameter of liner		169.945~169.97	
3	Upper inner diameter of install hole of liner		173~173.03	
4	Lower inner diameter of install hole of liner		170~170.04	
Crankshaft, Piston and Connecting rod				
1	Diameter of install hole of piston pin		60.007~60.014	
2	Diameter of piston pin		59.99~59.997	
3	Piston pin hole		28	
4	Working clearance of piston ring opening in cold state			
	Three-piece piston ring set	1st ring	4	
		2nd ring	3.499~3.497	
		Oil ring	3.95~3.97	
5	Inner diameter of small top of connecting rod		65.95~65.969	
6	Inner diameter of big top of connecting rod		111~111.022	
8	Thickness of big top connecting rod (12M26)		50.824~50.870	
9	Inner diameter of con rod bushing		60.028~60.071	

SN.	Item	Theoretical value (mm)	Wear limit
Crankshaft, Piston and Connecting rod			
10	Inner diameter of bearing	105.095~105.147	
13	Clearance between con rod and crankshaft (6 axial)	0.2~0.29	0.36
14	Clearance between con rod and crankshaft (6 axial)	0.082~0.165	0.36
15	Clearance between main bearing cap and camshaft (6 radial)	0.082~0.165	0.36
16	Clearance between two con rod (12 axial)	0.26~0.406	0.46
17	Clearance between con rod and crankshaft (12 radial)	0.082~0.165	0.36
18	Clearance between main bearing cap and camshaft (12 radial)	0.10~0.177	0.33
19	Clearance between main bearing (with thrust) and crankshaft	0.1~0.34	0.45
22	Inner diameter of crankshaft bearing	117.985~118.040	
23	Out diameter of crankshaft bearing	126~126.025	
Valve mechanism			
1	Diameter of front part of camshaft	57.91~57.94	
2	Diameter of end part of camshaft	60.002~60.021	
3	The length of push rod	462.4	
4	Inner diameter of camshaft front bearing	58~58.030	
5	Clearance between cylinder block and front bearing(axial)	0.15~0.25	0.35
6	Clearance between cylinder block and front bearing(radial)	0.6~0.12	0.16

SN.	Item	Theoretical value (mm)	Wear limit
Valve mechanism			
7	Out diameter of camshaft bearing	71.988~72.018	
8	Inner diameter of normal camshaft bearing	60.076~60.1	60.2
9	Out diameter of normal camshaft bearing	65~65.03	
10	Out diameter of tappet	34.967~34.975	34.9
11	Inner diameter of tappet install hole	35~35.025	35.10
12	Clearance between tappet and cylinder block	0.025~0.066	0.15
13	Inner diameter of camshaft install hole	72~72.03	72.08
Oil pump and Fuel pump			

Cylinder Block

Inspection Item	Standard	Limit	Reference Page
Cylinder Liner Inside Diameter	150.0-150.025	-	
Protrusion height of cylinder liner	0.07-0.13		

Camshaft

Inspection Item		**Standard**	**Limit**	**Reference Page**
End Play		0.1-0.25	-	
Bend (1/2 the dial gauge reading)		0-0.02		
Cam Lobe Height		49.8119-50.1119		
Shaft Outside Diameter / Bearing Inside Diameter				
Gear End	Thrust Bearing Outside Diameter	72.007-72.012		
	Thrust Bearing Inside Diameter	59.0-59.013		
	Camshaft Outside Diameter	58.91-58.94		
	Oil Clearance	0.06-0.103		
Camshaft Support	Bushing Inside	60.076-60.13		
	Camshaft Outside Diameter	60.002-60.021		
	Oil Clearance	0.055-0.128		

Timing Gear Backlash

Inspection Item	Standard	Limit	Reference Page
Crank Gear, Cam Gear,	0.09-0.20	-	
Lubrication Oil Pump Gear	0.11-0.285		

CRANKSHAFT AND PISTON MECHANCIAL SPECIFICATIONS

Check appropriate parts catalog for various sizes of replacement main bearing inserts.

Inspection Item		Standard	Limit	Reference Page
Connecting Rod Journals	Journal Outside Diameter	104.991-105.013	-	
	Bearing Inside Diameter (free)	105.106-105.158	-	
	Bearing Insert Thickness	2.40-2.70	-	
	Oil Clearance	0.093-0.167	-	
Main Bearing Journal	Journal Outside Diameter	117.863-117.885	-	
	Bearing Inside Diameter (free)	119.40-120.20	-	
	Bearing Insert Thickness	3.40-3.70	-	
	Oil Clearance	-	-	

Thrust Bearing

Inspection Item	Standard	Limit	Reference Page
Crankshaft End Play	0.1-0.346	-	

Piston

Inspection Item		Standard	Limit	Reference Page
Piston Outside Diameter (Measure at 90° to the piston pin)		149.825-149.855	-	
Piston Diameter Measure Location (Upward From the Bottom of the Piston.)		24		
Piston Pin	Hole Inside Diameter	60.007-60.014		
	Pin Outside Diameter	59.990-59.997		
	Oil Clearance	0.0037-0.0240		

Piston Ring

Inspection Item		Standard	Limit	Reference Page
Top Ring	Ring Groove Width	3.613-3.616		
	Ring Width	3.575-3.605		
	Side Clearance	0.008-0.0.041		
	End Gap	0.30-0.45		
Second Ring	Ring Groove Width	3.505-3.507		
	Ring Width	3.497-3.499		
	Side Clearance	0.006-0.010		
	End Gap	0.60-0.80		
Oil Ring	Ring Groove Width	4.03-4.05		
	Ring Width	3.970-3.995		
	Side Clearance	0.035-0.08		
	End Gap	0.45-0.70		

Connecting Rod

Connecting Rod Small End

Inspection Item	Standard	Limit	Reference Page
Piston Pin Bushing Inside Diameter	59.5-59.6	-	
Piston Pin Outside Diameter	59.990-59.997		
Oil Clearance	0.39-0.497		

Connecting Rod Big End

Inspection Item	Standard	Limit	Reference Page
Side Clearance	0.093-0.167	-	

Tappet

Inspection Item	Standard	Limit	Reference Page
Piston Pin Bushing Inside Diameter	59.5-59.6	-	
Piston Pin Outside Diameter	59.990-59.997		
Oil Clearance	0.39-0.497		

Cylinder Head Specifications

Inspection Item			Standard	Limit	Reference Page
Combustion Surface Distortion (Flatness)			0.05	0.15	
Valve Recession	Intake		0.6~1.1	-	
	Exhaust		1.2~1.7	-	
Valve Seat	Seat Angle	Intake	60°	-	
		Exhaust	65°	-	
	Seat Correction Angle				

Cylinder Head

Inspection Item			Standard	Limit	Reference Page
Combustion Surface Distortion (Flatness)			0.05	0.15	
Valve Recession	Intake		0.6~1.1	-	
	Exhaust		1.2~1.7	-	
Valve Seat	Seat Angle	Intake	60°	-	
		Exhaust	65°	-	
	Seat Correction Angle				

Intake / Exhaust Valve and Guide

Inspection Item		Standard	Limit	Reference Page
Intake	Guide Inside Diameter	10.015-10.03		
	Valve Stem Outside Diameter	9.965-9.98	-	
	Valve Stem Bend	0.035–0.070	0.18	
Exhaust	Guide Inside Diameter	10.015-10.03		
	Valve Stem Outside Diameter	10.05-10.25		
	Valve Stem Bend	0.045-0.070	0.18	
Valve Guide Projection From Cylinder Head		13.3-13.7		
Valve Guide Installation Method		Cold-fitted		

Push Rod

Inspection Item	Standard	Limit	Reference Page
Push Rod Bend – All Models	0.2	0.2	

Rocker Arm and Shaft

Inspection Item	Standard	Limit	Reference Page
Arm Shaft Hole Diameter	35.017-35.030		
Shaft Outside Diameter	34.964-34.992		
Oil Clearance	0.025-0.066		

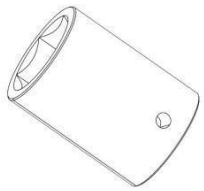
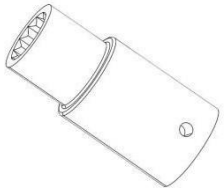
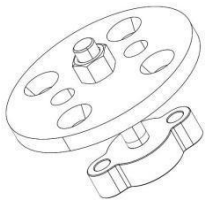
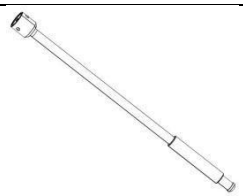
Valve Spring

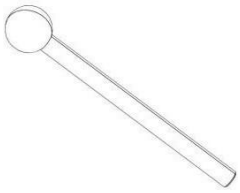
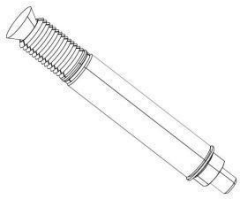
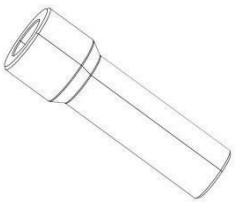
Inspection Item		Standard	Limit	Reference Page
Outer Valve Spring	Free Length	53		
	220N Pressure	42.5		
	481N Pressure	30		
Inner Valve Spring	Free Length	51.2		
	144N Pressure	38.5		
	290N Pressure	26		
Squareness	Valve Spring	-	1.5mm	

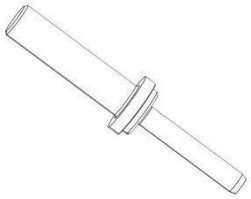
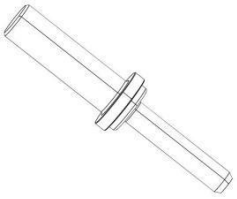
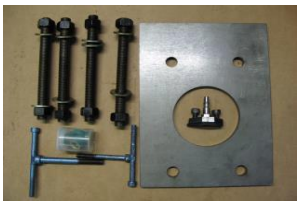
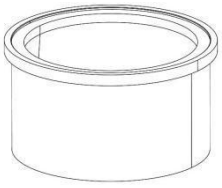
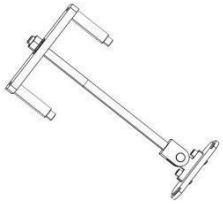
SPECIAL TOOLS

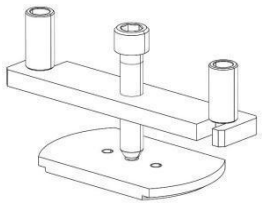
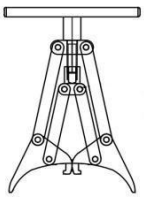
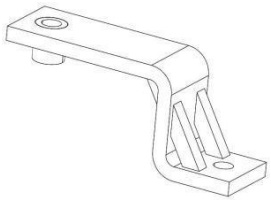
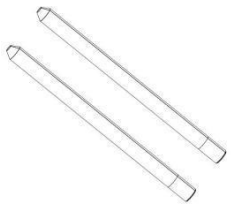
Note:

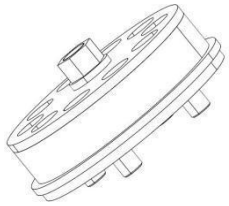
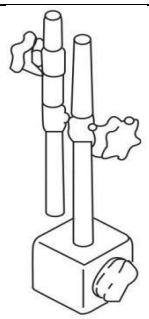
- All parts can not be individually purchased, all parts must be purchased in two separate kits (Major repair kit Z799005 or Medium repair kit Z799006)

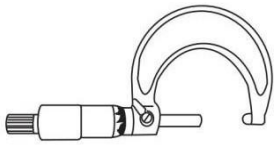
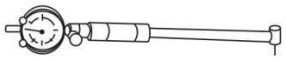
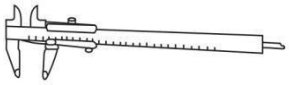
No.	Tool Name (Part Kit)	Application	Illustration
1	Main bolt socket wrench (Medium Repair Kit)	Remove/Install main bolts	
2	Secondary bolt socket wrench (Medium Repair Kit)	Remove/Install secondary bolts	
3	Valve remover (Medium Repair Kit)	Remove/Install the valve group	
4	Tappet Tool (Medium Repair Kit)	Remove/Install the tappet	

No.	Tool Name (Part Kit)	Application	Illustration
5	Flywheel locating pin (Medium Repair Kit)	Determine flywheel and valve positions	
6	Injector Bushing Removal Tool (Major Repair Kit)	Remove the injector bushing	
7	Injector Bushing installer Major Repair Kit)	Injector bushing	
8	Valve guide remover	Remove valve guide	
9	Valve guide installer	Install the valve guide	

No.	Tool Name (Part Kit)	Application	Illustration
10	Intake valve insert installer	Install the intake valve seat	
11	Exhaust valve insert installer	Install the exhaust valve seat	
12	Cylinder head hydraulic test plate	Test the sealing of cylinder head	
13	Piston Ring Compressor (Medium Repair Kit)	Install piston	
14	Liner remover (Medium Repair Kit)	Remove cylinder liner	

No.	Tool Name (Part Kit)	Application	Illustration
15	Liner Installer (Medium Repair Kit)	Install cylinder liner	
17	Flywheel Puller Assembly (Major Repair Kit)	Puller Assembly	
18	Hoisting tool (Major Repair Kit)	Lift the flywheel	
19	Flywheel guide rods (Major Repair Kit)	Remove/Install the flywheel	
20	Vibration Damper Guide Rod (Major Repair Kit)	Remove/Install the vibration damper	

No.	Tool Name (Part Kit)	Application	Illustration
21	Rear seal installer (Major Repair Kit)	Install the rear seal	
22	Front oil seal installer (Major Repair Kit)	Install the front oil seal	
23	Fuel Injector Tightening Tool (Medium Repair Kit)	Used to install/tighten the Mechanical Fuel Pump	
24	Fuel Injector Positioning Tool (Medium Repair Kit)	Used to position the mechanical fuel pump injectors	
25	Magnetic Stand	For holding the dial gauge when measuring	

No.	Tool Name (Part Kit)	Application	Illustration
26	Micrometer	For measuring the outside diameters of crankshaft, pistons, piston pins, etc.	
27	Cylinder Bore Gauge	For measuring the inside diameters of cylinder liners, bearing bores, etc.	
28	Calipers	For measuring outside diameters, depth, thickness and width	
29	4 - M10 - 1.5X140" Guide Pins (Z110202)	For Installing and removing the front cover	N/A

No.	Tool Name (Part Kit)	Application	Illustration
30	2 - M14 - 2X50" Guide Pins (Z110203)	For installing and removing the crank pulley	N/A
31	Valve Keeper Remover (Z799004)	Used for removing and installing valve keepers without removing the cylinder heads	

RECOMMENDED TORQUES FOR STANDARD BOLTS

Friction coefficient	0.125 (zinc plated)				0.14 (polished)			
Strength grade	6.9	8.8	10.9	12.9	6.9	8.8	10.9	12.9
Bolt size	Recommended torque (N·m)							
M4	2.3	2.7	3.8	4.6	2.4	2.9	4.1	4.9
M5	4.7	5.5	8.0	9.5	5.0	6.0	8.5	10
M6	8.0	9.5	13.0	16.0	8.5	10	14.0	17
M8	19	23	32	39	21	25	35	41
M10	39	46	64	77	41	49	69	83
M12	67	80	110	135	72	86	120	145
M14	105	125	180	215	115	135	190	230
M16	165	195	275	330	180	210	295	355
M18	225	270	390	455	245	290	405	485
M20	325	385	540	650	345	410	580	690
M22	435	510	720	870	465	550	780	930
M24	560	660	930	1100	600	710	1000	1200
M27	830	980	1400	1650	890	1050	1500	1800
M30	1100	1350	1850	2250	1200	1450	2000	2400
M8×1	21	25	35	42	23	27	38	45
M10×1.25	41	49	66	82	44	52	73	88
M12×1.25	74	88	125	150	80	95	135	155
M12×1.5	70	83	115	140	76	90	125	150
M14×1.5	115	140	195	235	125	150	210	250
M16×1.5	175	210	295	350	190	225	315	380
M18×1.5	255	305	425	510	275	325	460	550
M20×1.5	360	425	600	720	385	460	640	770
M22×1.5	480	570	800	960	520	610	860	1050
M24×1.5	610	720	1000	1200	650	780	1100	1300

RECOMMENDED TORQUES FOR STANDARD BOLTS -CONTINUED

Friction coefficient	0.125 (zinc plated)				0.14 (polished)			
Strength grade	6.9	8.8	10.9	12.9	6.9	8.8	10.9	12.9
Bolt size	Recommended torque (N·m)							
M27×1.5	890	1050	1500	1800	970	1150	1600	1950
M30×1.5	1250	1450	2050	2500	1350	1600	2250	2700

SEALANT APPLICATION CHART

Mark	Main use	List of locations for application of sealant	Supplement
Loctite 242	It's applied onto the threads to prevent being vibrated to looseness, with moderate strength.	Screw plug	Alternatively, the thread preapplication sealant DriLoc 204 can be preapplied.
		Control valve	
		Oil cooler bolt	
		Engine oil cooler	
		Flywheel cover bolt	
		Front end cover bolt	
		Engine oil filter base	
		Intermediate idler bolt	
		Camshaft thrust plate bolt	
		Camshaft timing gear bolt	
		Bolt, fuel return pipe fixing device, fuel pump	
		Air compressor shaft end thread Strainer bolt	
		Bolts of sensor and harness fixing device	
Loctite 262	Applied onto outer threads for locking, sealing, preventing vibration from causing looseness	Auxiliary bolt, cylinder head	
Loctite 271	Preventing looseness, fixing	Cup plug, oil drain hole	N/A
Loctite 277	For sealing between element and bore	Other cup plugs	N/A
Loctite 270	Sealing cylinder head top	Push rod, cylinder head	N/A

Mark	Main use	List of locations for application of sealant	Supplement
Loctite 518 (modified from Loctite 510)	It's applied onto shining metal surfaces for sealing purpose.	Interface between cylinder block and crankcase.	N/A
		Plates connecting engine body front end face to front end cover and connecting engine body rear end face to flywheel cover.	
		Interface between engine oil filter base and crankcase.	
		Interface between water pump rear cover and engine body front end face.	
		Interface between flywheel cover and its connecting plate.	
		Interface between cylinder block and engine oil cooler cover.	
		Interface between cylinder block	

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