POWER SOLUTIONS INTERNATIONAL

53L SERVICE MANUAL

Large Spark Ignited Engine

PSI ENERGY

A Product by Power Solutions International
Wood Dale, IL

7610022-8

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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	10/13/2020	Initial Release
2	02/05/2021	Update the torque specifications chart to include the new oil supply to water pump banjo bolts.
3	02/23/2021	Updated oil filter installation procedure and included procedure for the new Pre-Lube Pump Assembly.
4	02/11/2021	Updated formatting, new cover page, added speed sensor installation, added major component's location.
5	02/07/2024	Added ignition coil bolt torque specs and requirement for dielectric grease when re-installing ignition coils
6	07/18/2024	Updated Valve Lash Specs. Added oil cooler removal and installation
7	10/08/2024	Updated flywheel torque specifications. Corrected Speed Sensor installation, added removal and installation of Crankshaft Position Sensor
8	NOT YET RELEASED	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.

WARNING SUMMARY

- Failure to comply with the below warnings 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 maybe 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.

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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.
- 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.

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

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 disabled 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.

Engine Systems

Schematic Diagrams of 53L Natural Gas Engine

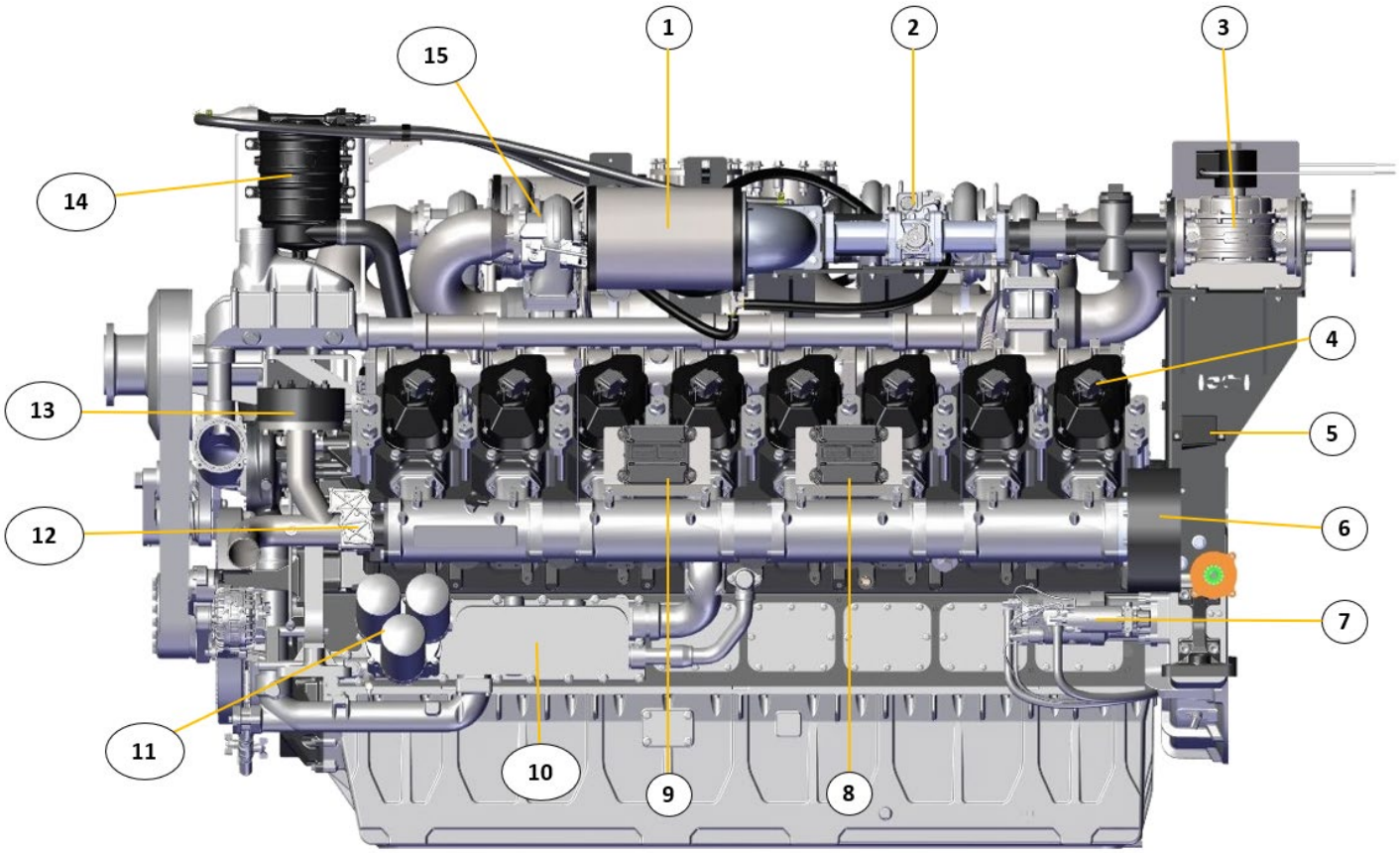


Figure 1 – Left Side View

1. Air Filter
2. Mass Flow Gas Valve
3. Fuel Lock Off
4. Ignition Coil
5. Engine Harness Fuse Box
6. Explosion Relief Valve
7. Left Side Starter
8. Secondary ECM
9. Primary ECM
10. Oil Cooler
11. Oil Filters
12. Throttle Body
13. Explosion Relief Valve
14. CCV Canister
15. Turbocharger (Front LH)

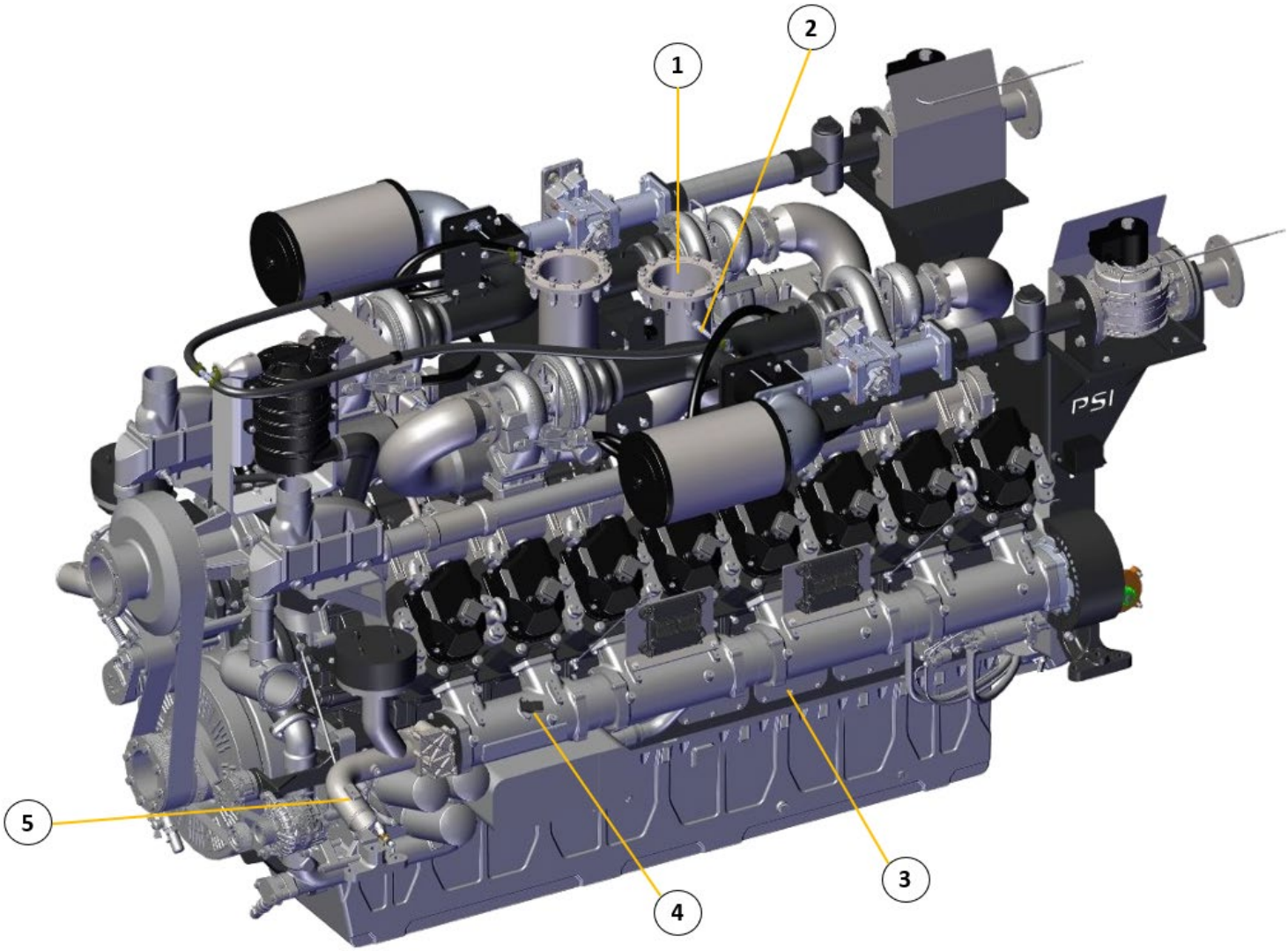


Figure 2 – Left View

1. Exhaust Outlet to Catalyst
2. Pre-Catalyst UEGO O2 Sensor (EGO 1)
3. Diagnostic Link Connector (DLC)
4. TMAP Sensor
5. Throttle Inlet Pressure (TIP) Sensor

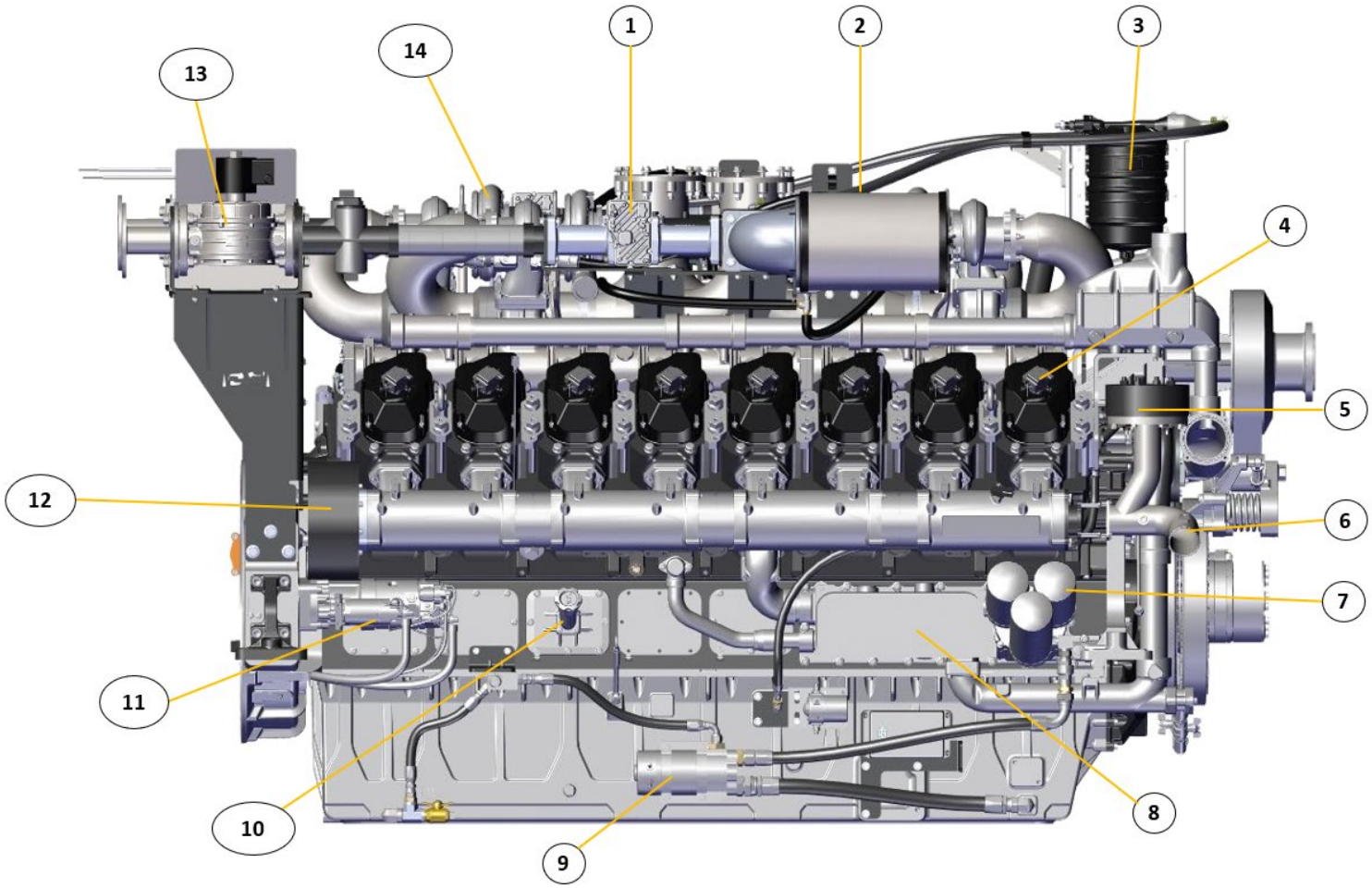


Figure 3 – Right Side View

1. Mass Flow Gas Valve
2. Air Filter
3. CCV Canister
4. Ignition Coil
5. Explosion Relief Valve
6. Air/Fuel Inlet from CAC
7. Oil Filters
8. Oil Cooler
9. Oil Pre-Lube System
10. Oil Fill Port
11. Starter (RH Side)
12. Explosion Relief Valve
13. Fuel Lock Off Valve
14. Turbocharger (Rear RH)

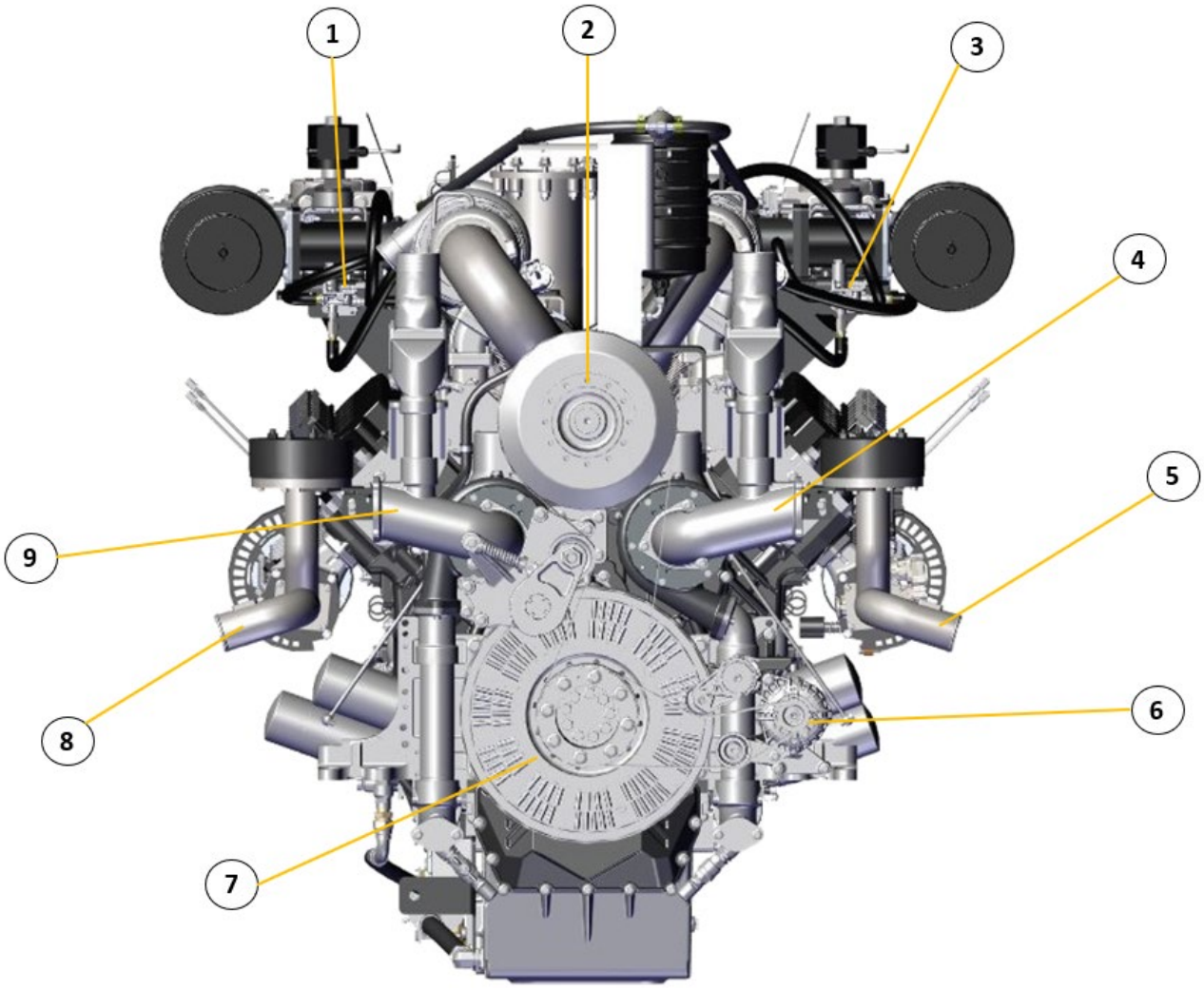
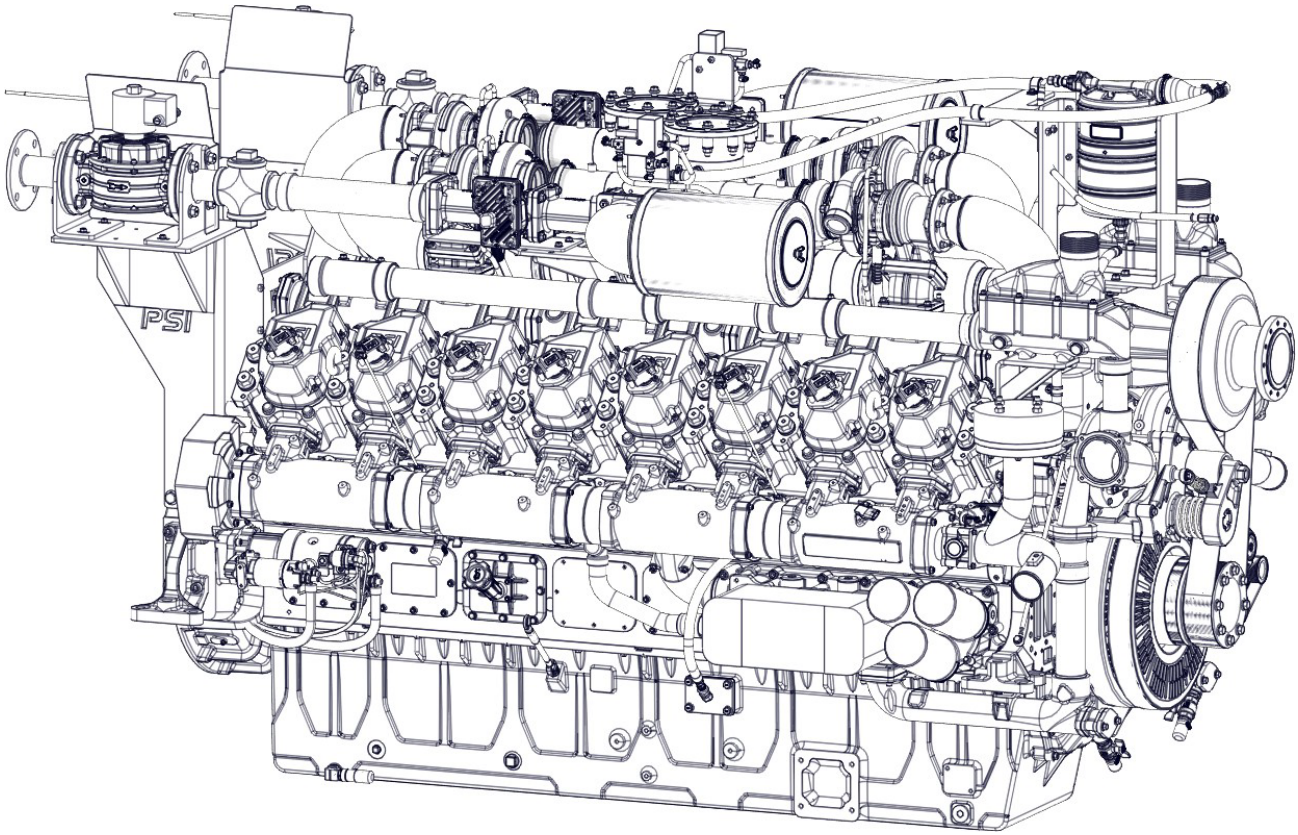


Figure 4 – Front View

1. Wastegate Control Valve
2. Fan Hub
3. Wastegate Control Valve
4. Coolant Outlet (to Radiator)
5. Air/Fuel Inlet from CAC
6. Engine Alternator
7. Harmonic Balancer (Vibration Dampener)
8. Air/Fuel Inlet from CAC
9. Coolant Outlet (to Radiator)



THEORY OF OPERATION AND ENGINE COMPONENTS

CYLINDER BLOCK

The cast iron cylinder block is configured in a “V” shape with two banks of eight integral cylinder bores at an included angle of 90 degrees. Coolant jackets surround each cylinder bore. Nine cast iron main bearing caps are each fastened by four bolts, with the crankshaft thrust taken up by 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 53L engine uses a hardened steel forged crankshaft with nine hardened main bearing journals and eight connecting rod journals oriented with 90-degree phasing. Twelve counterweights to provide internal balance of the rotating assembly.

PISTON AND CONNECTING ROD

All sixteen pistons utilize three piston rings. One keystone ring: a keystone ring, a twisted ring, a twist tapered ring and a coil spring loaded ring. The piston is attached to a two-piece forged steel connecting rod by 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 sixteen cast iron cylinder heads are equipped with four valves and are located on the upper part of the cylinder block forming 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 camshaft utilizes nine cam journals and thirty-two cam lobes and is located in 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 at each cylinder head ending at the explosion relief valve.

ENGINE CONTROL MODULE (ECM)

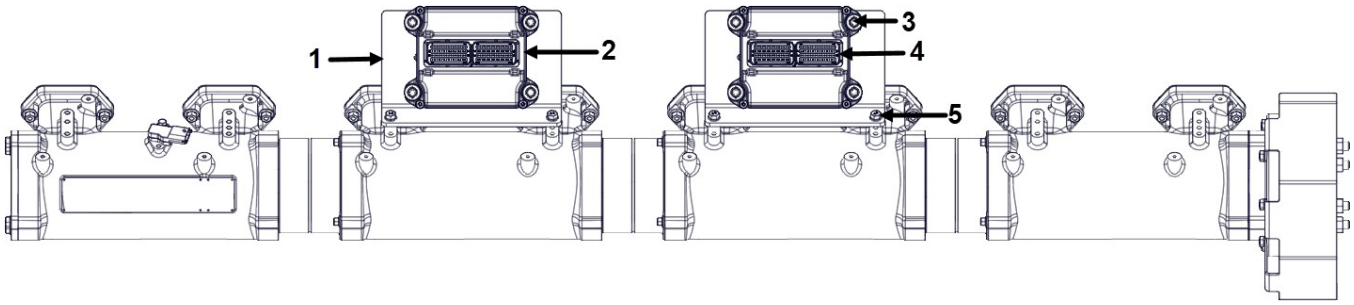


Figure 5. ECM Assembly

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

The 53L engines 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 the 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.

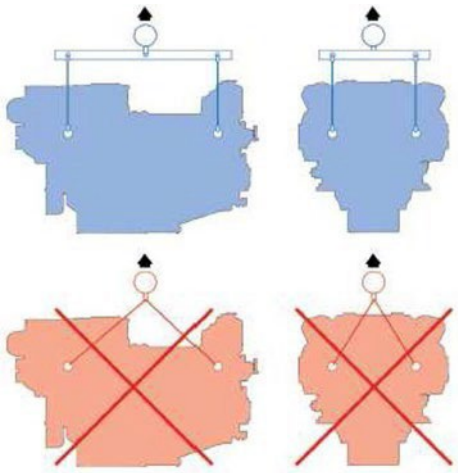


Figure 6. Hoisting Engine

Note:

- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the TIGHTENING TORQUES FOR STANDARD BOLT chart.

LIFTING EYES

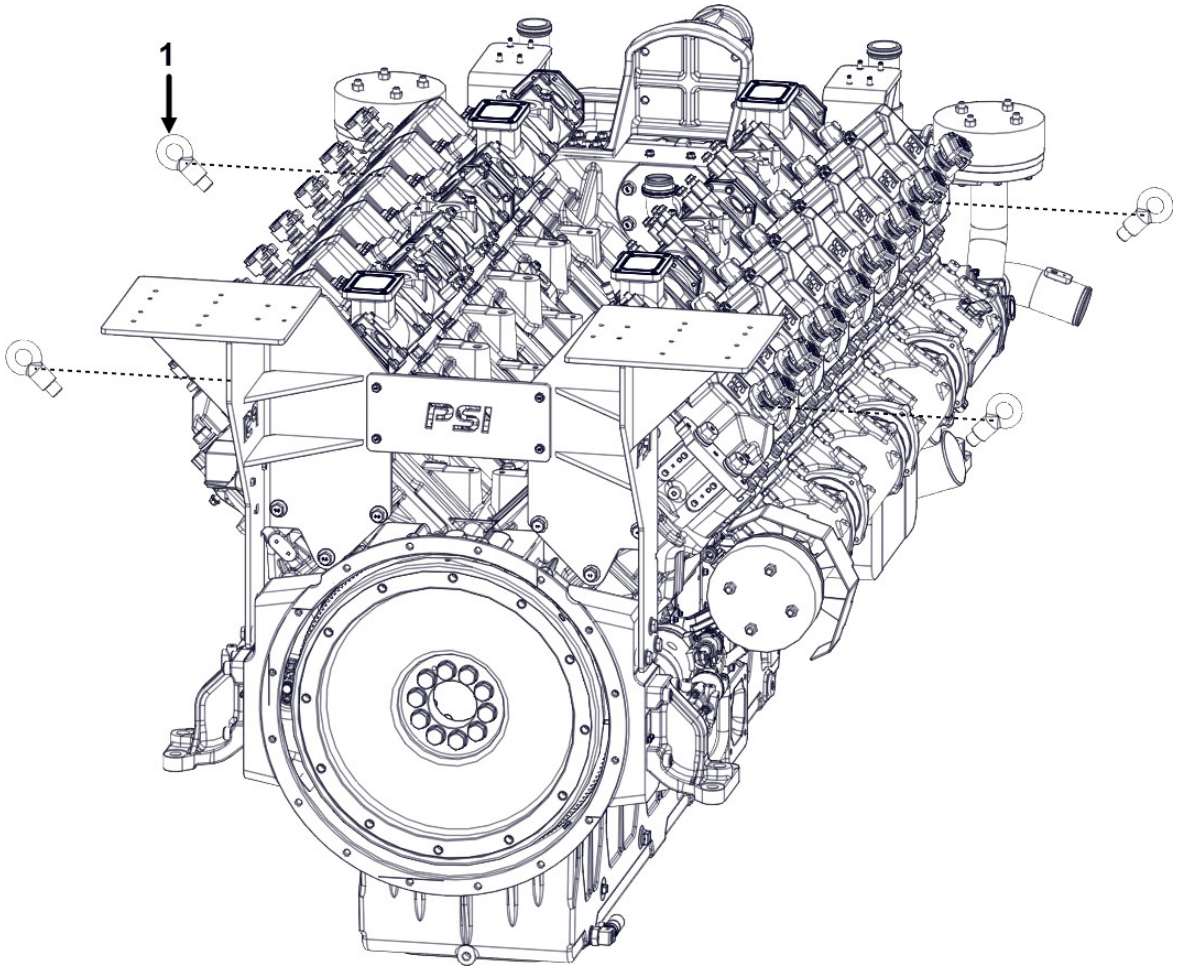


Figure 7. Lifting Eyes Assembly

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 damages, replace if any cranks or other damages are found.

INSTALLATION

1. Insert and torque all four lifting eyes to 538 ft/lbs.

ENGINE BRACKETS

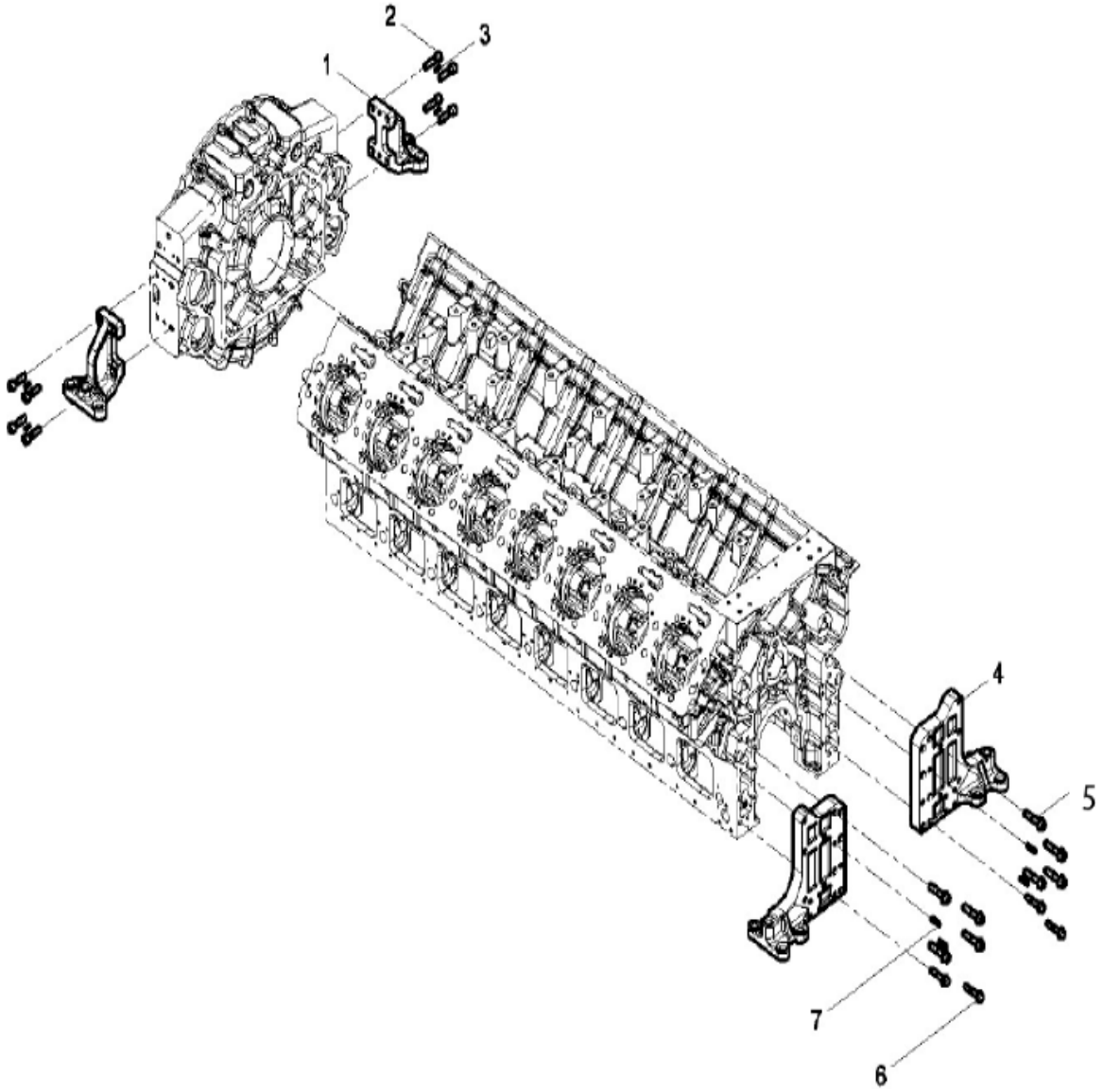


Figure 8. Engine Bracket Assembly

NO.	Name
1	Rear Engine Bracket
2	Bolt
3	Dowel Pin
4	Front Engine Bracket
5	Bolt
6	Bolt
7	Dowel Pin

Note:

- See the TIGHTENING TORQUES FOR STANDARD BOLTS chart for any bolts without a specified torque value.

REMOVAL

1. Loosen and remove bolts (Figure 8, Items 2, 5 and 6).
2. Remove engine mounts (Figure 8, Item 1 and 5).
    - The left-hand automatic belt tensioner bracket, alternator pulley bracket and idler pulley bracket must be removed in order to remove the left-hand engine mount (Figure 1, Item 4). Refer to FEAD section of the manual.

INSTALLATION

1. Clean any debris from the front of the engine block and from the sides of the flywheel housing.
2. Place engine mounts on cylinder block and flywheel housing (Figure 1, Items 1 & 4).
3. Insert and tighten bolts (Figure 8, Items 2, 5 and 6).

CYLINDER BLOCK CLEANING AND INSPECTION

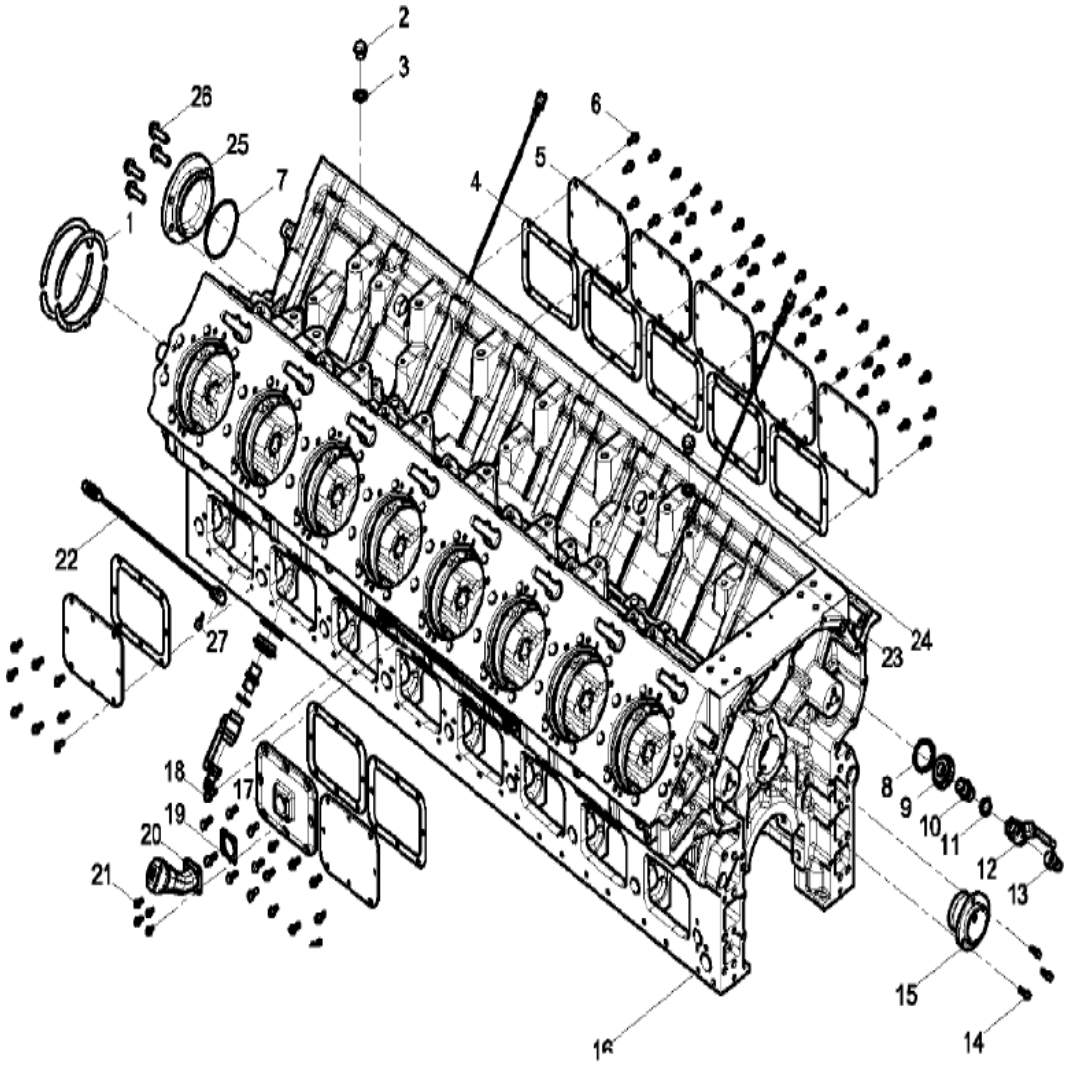


Figure 9. Cylinder Block Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Thrust Bearing	8	Seal	15	Camshaft Bushing	22	Link
2	Plug	9	Washer	16	Engine Block	23	Washer
3	Washer	10	Connector	17	Cover	24	Plug
4	Gasket	11	Nut	18	Bolt	25	Cover Plate
5	Cover	12	Water Valve	19	Filler	26	Bolt
6	Bolt	13	Pipe Gasket	20	Oil Filling Tube	27	Knock Sensor
7	Seal	14	Bolt	21	Bolt		

WARNING:

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

1. Boil cylinder block in caustic solution.
2. Flush cylinder block with water 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:

- Always wear proper PPE (Personal Protective Equipment). Failure to comply may result in personal injury.

4. Dry cylinder block with compressed air.
5. Lubricate cylinder block with PSI approved motor oil to prevent rust.
6. 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

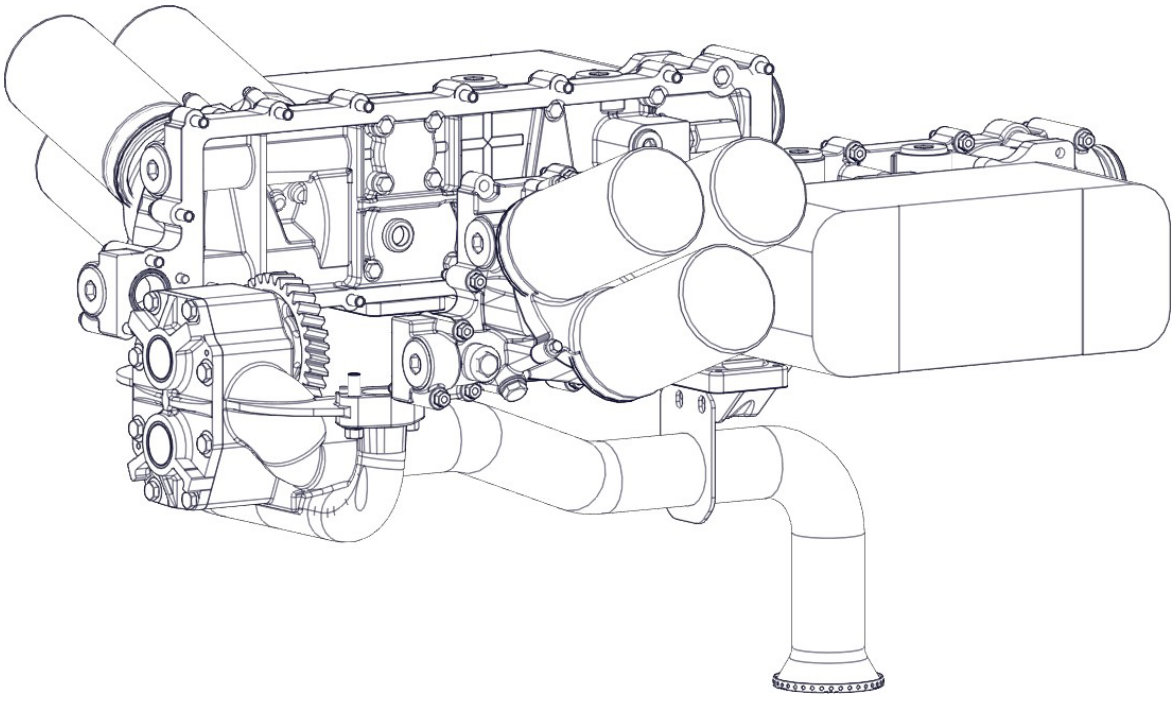


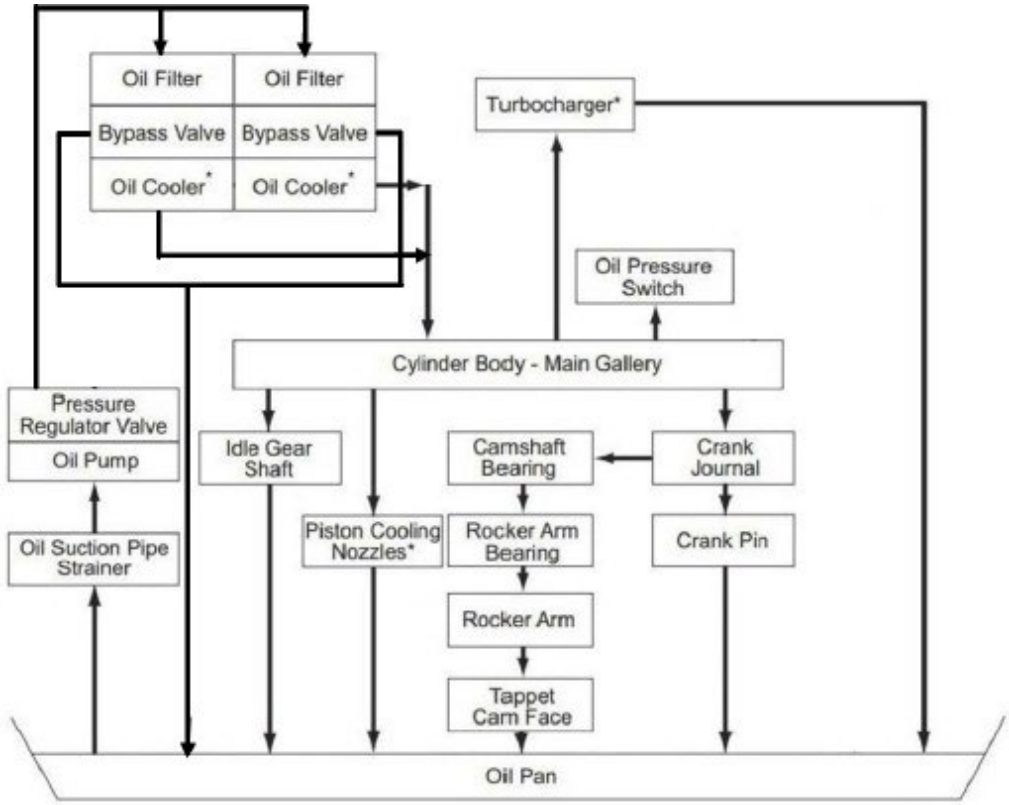
Figure 10. Lubrication System

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. All control valves lead to the oil filter support assembly, which holds all oil filters.

Engine Oil Pressure Chart

Model	At Rated Engine RPM	At Low Idle Speed
	1500-1800	
53L	58-94 PSI (0.40 – 0.65 MPa)	More than 17 PSI (0.12 MPa)

LUBRICATION SYSTEM DIAGRAM



OIL PUMP

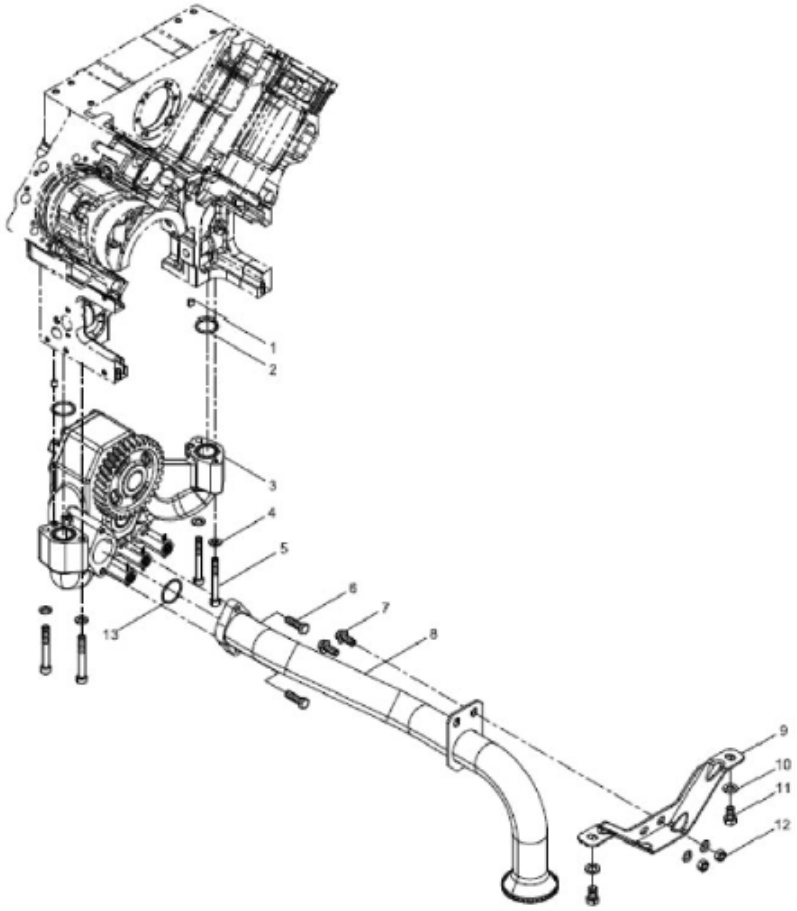


Figure 11. Oil Pump Assembly

NO.	Name	NO.	Name
1	Dowel Pin	8	Oil Strainer
2	O-Ring	9	Oil Strainer Bracket
3	Oil Pump	10	Washer
4	Washer	11	Bolt
5	Bolt	12	Nut
6	Bolt	13	O-Ring
7	Bolt		

Note:

- See the TIGHTENING TORQUES FOR STANDARD BOLTS chart for any bolts without a specified torque value.

REMOVAL

1. Drain oil into suitable container.
2. Remove the oil pan. Refer to the *REMOVAL OF OIL PAN* section of the manual.
3. Remove the four bolts and washers (Figure 11, Items 4 & 5) from under the oil pump.
4. Remove the bolt (Figure 11, Item 6) from the rear of the oil pump and remove the O-ring (Figure 11, Item 13).
5. Remove the oil pump (Figure 11, Item 3).
6. Remove both bolts from the strainer bracket (Figure 11, Item 7).
7. Carefully remove the oil strainer (Figure 11, Item 8)

Note:

- Inspect the oil pump and oil strainer or any damages.
- Check the screen of the oil strainer for any obstructions.
- Clean all connecting joints and surfaces before installing

INSTALLATION

1. Insert oil strainer (Figure 11, Item 8) onto the oil strainer bracket (Figure 11, Item 9).
2. Insert and tighten both bolts (Figure 11, Item 7).
3. Install a new O-ring (Figure 11, Item 13) and tighten bolt (Figure 11, Item 6) on the oil pump.
4. Insert new O-rings (Figure 11, Item 2) on top of the oil pump.
5. Insert and tighten down the four bolt and washers (Figure 11, Items 4 & 5) from the bottom of the oil pump.

Note:

- Lash is self-adjusted once all bolts are torqued down.

ENGINE OIL DIPSTICK TUBE

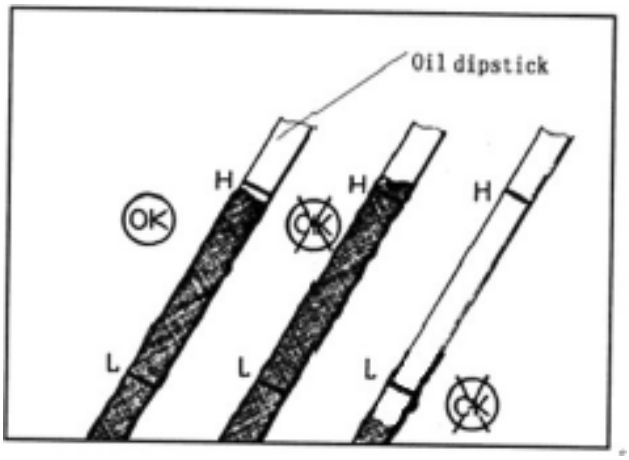


Figure 12. Engine Oil Dipstick

REMOVAL

1. Remove the engine oil dipstick from the engine oil dipstick tube.
    a. Check oil level. (Refer to Figure 12)
2. Remove upper oil dipstick tube from oil pan.
3. Remove the washer and nut, then remove the lower dipstick from the oil pan.

INSTALLATION

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

OIL FILLING TUBE

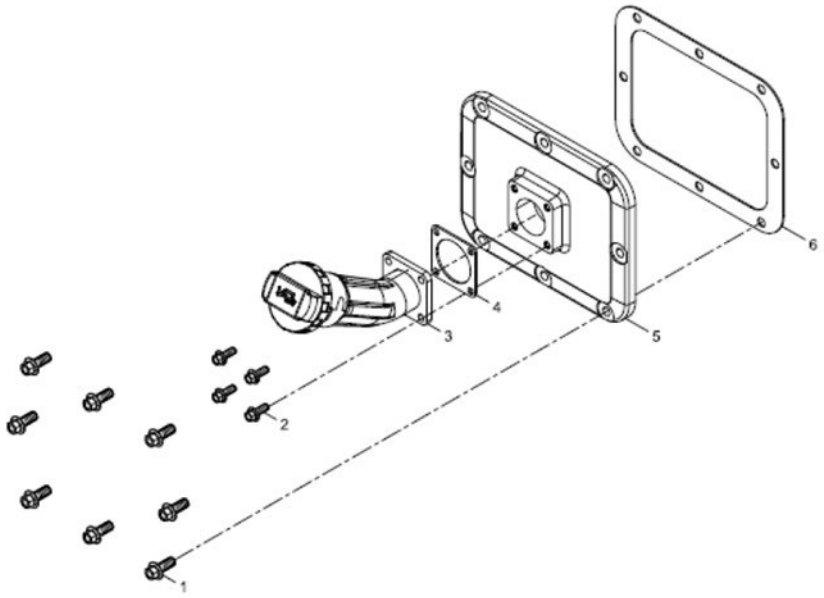


Figure 13. Oil Filling Tube Assembly

NO.	Name	NO.	Name
1	Bolt	4	Filler
2	Bolt	5	Cover
3	Oil Filling Tube	6	Gasket

Note:

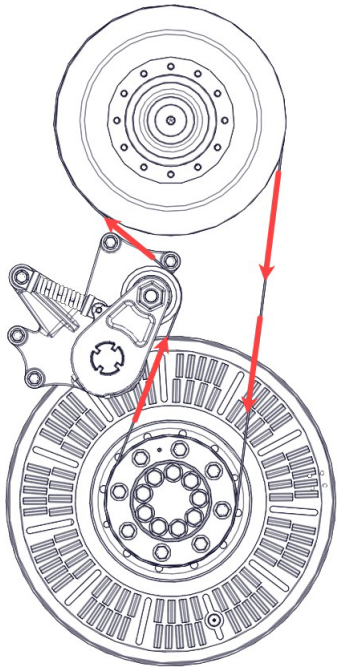
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Loosen and remove bolts (Figure 13, Items 1 & 2).
2. Remove oil fitting tube (Figure 13, Item 3).
3. Remove oil filler tube gasket (Figure 13, Item 4).

INSTALLATION

1. Place oil filler tube gasket (Figure 13, Item 4) on the cover (Figure 13, Item 5)
2. Place oil filling tube (Figure 13, Item 3) onto gasket (Figure 13, Item 4).
3. Insert and tighten bolts (Figure 13, Items 1 & 2).



ENGINE BELT ROUTING

Figure 14. Serpentine Belt Routing

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

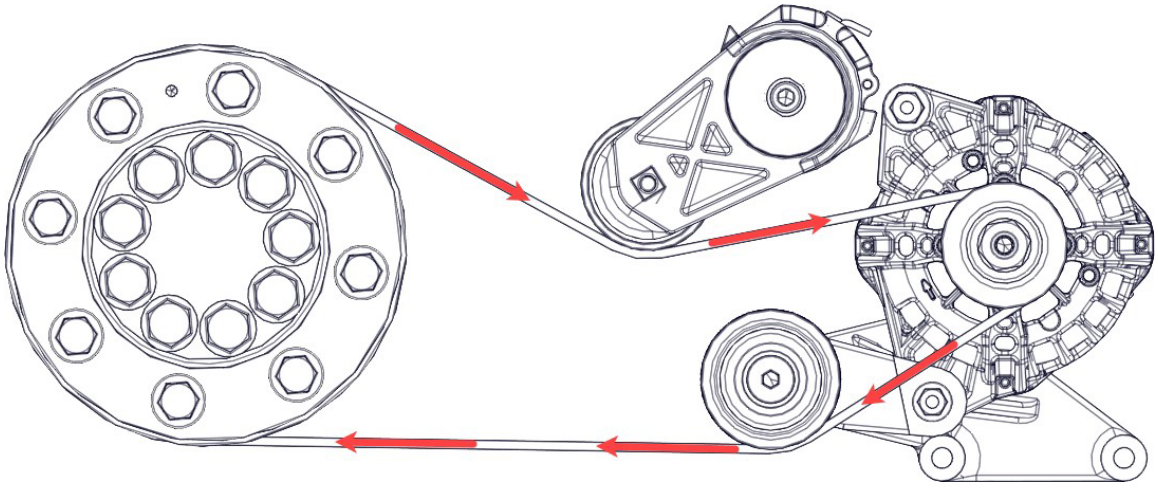


Figure 15. Left-Hand Belt Routing

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

FRONT ENGINE ACCESSORY DRIVE (FEAD)

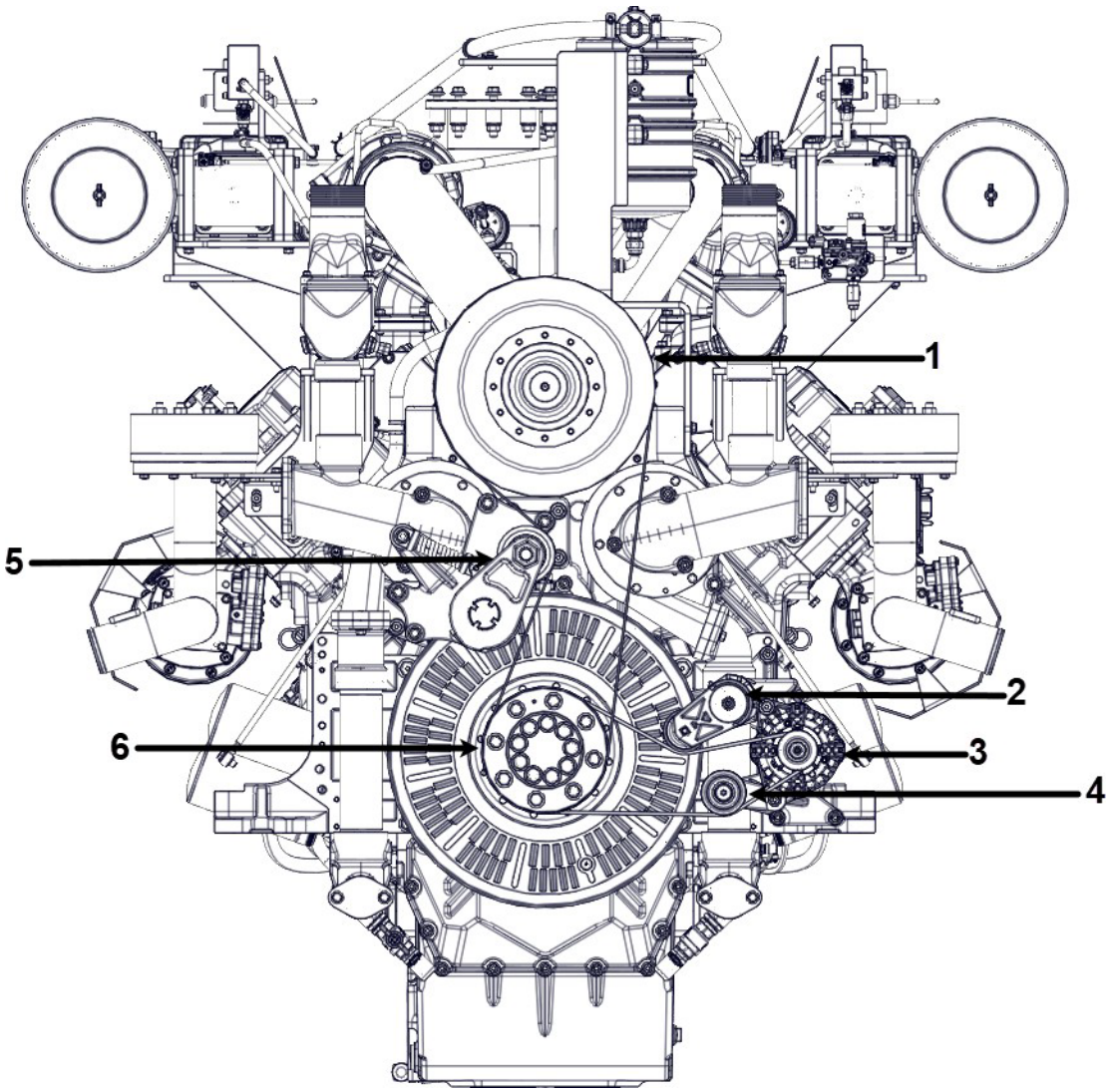


Figure 16. Front Engine Accessory Drive Assembly

NO.	Name	NO.	Name
1	Fan Pulley	4	Idler Pulley
2	Left-Hand Automatic Belt Tensioner	5	Automatic Fan Belt Tensioner
3	Alternator Pulley	6	Crankshaft Pulley

ALTERNATOR PULLEY ASSEMBLY

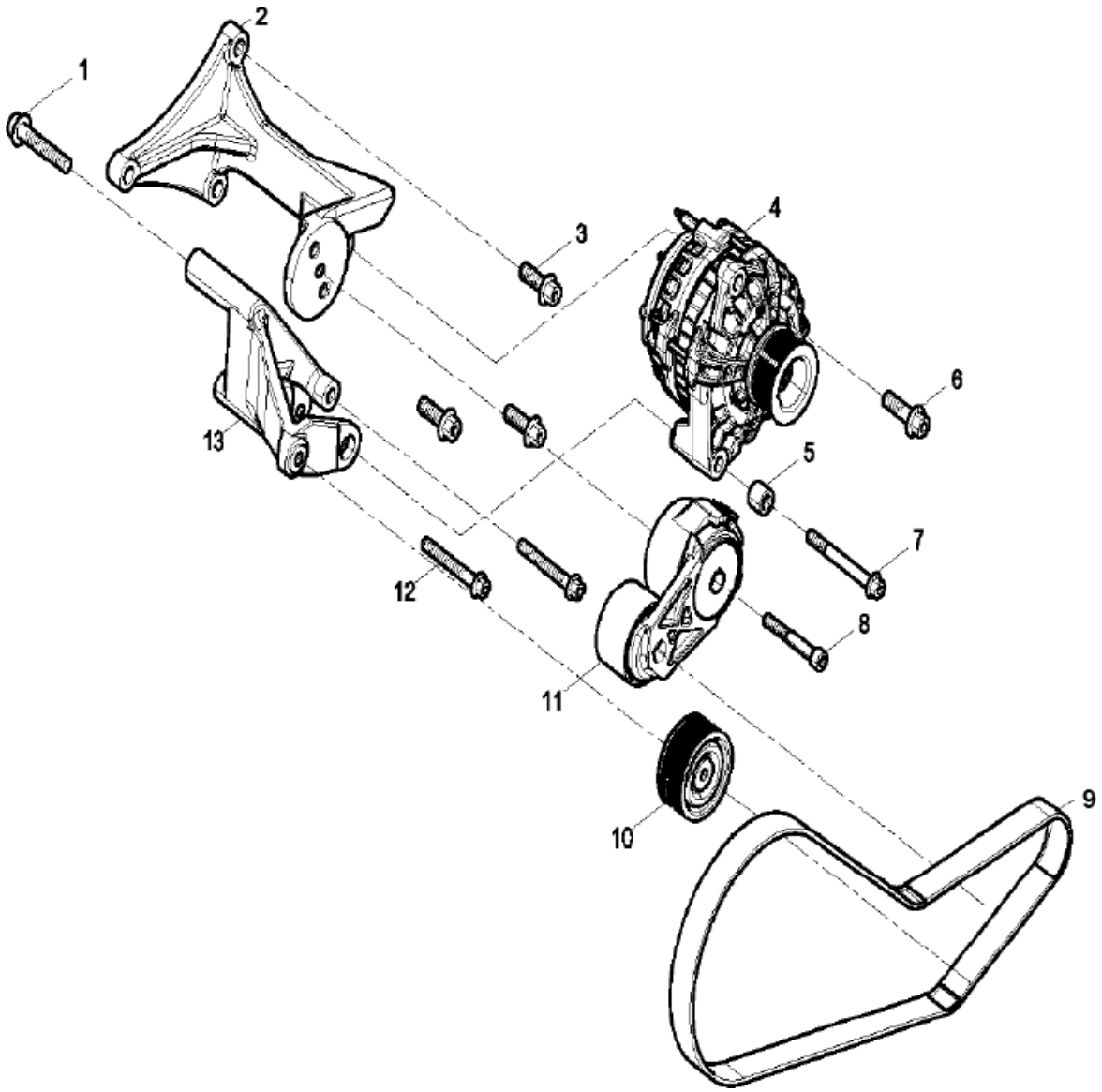


Figure 17. Alternator Pulley Assembly

NO.	Name	NO.	Name
1	Bolt	8	Bolt
2	Automatic Belt Tensioner Bracket	9	Belt
3	Bolt	10	Idler
4	Alternator	11	Automatic Tensioner
5	Sleeve	12	Bolt
6	Bolt	13	Alternator Bracket
7	Bolt		

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Insert a ½" drive ratchet or breaker bar into the square hole on the automatic belt tensioner. Pull the ratchet to take the tension off the automatic belt tensioner and remove the left-hand belt.
2. Remove the two bolts (Figure 17, Items 6 & 7) from the alternator, remove the sleeve (Figure 17, Item 5) from the alternator.
3. Remove the alternator (Figure 17, Item 4).

INSTALLATION

1. Place the alternator (Figure 17, Item 4) onto the left-hand automatic belt tensioner bracket (Figure 17, Item 2).
2. Insert the Sleeve (Figure 17, Item 5).
3. Insert and tighten both bolts (Figure 17, Item 6 & 7.)
4. Place the belt back onto the alternator pulley.

LEFT-HAND AUTOMATIC BELT TENSIONER

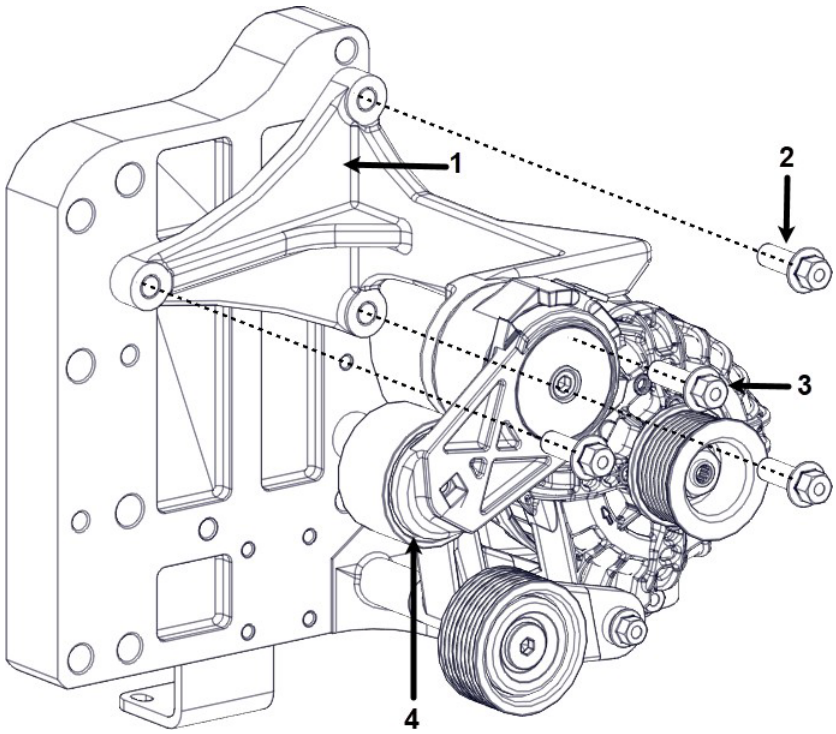


Figure 18. Left-Hand Automatic Belt Tensioner Assembly

NO.	Name	NO.	Name
1	Left-Hand Automatic Belt Tensioner Bracket	3	Bolt
2	Bolt	4	Left-Hand Automatic Belt Tensioner

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Insert a ½" drive ratchet or breaker bar into the square hole on the automatic belt tensioner. Pull the ratchet to take the tension off the automatic belt tensioner and remove the left-hand belt.
2. Remove the three bolts (Figure 18, Item 2) from the left-hand automatic belt tensioner bracket (Figure 18, Item 1).
3. Remove the left-hand automatic belt tensioner bracket (Figure 18, Item 1).

INSTALLATION

1. Place the left-hand automatic belt tensioner bracket (Figure 18, Item 1) onto the cylinder block.
2. Insert and torque the three bolts (Figure 18, Item 2) onto the left-hand automatic belt tensioner bracket.
3. Place the belt back onto the left-hand automatic belt tensioner.

LEFT-HAND IDLER PULLEY ASSEMBLY

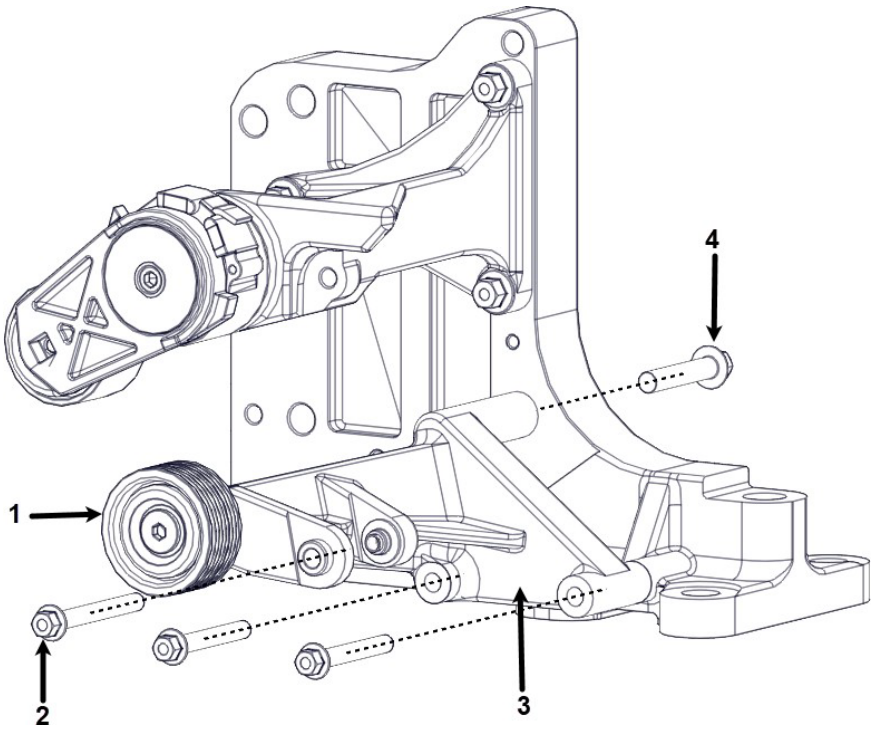


Figure 19. Left-Hand Idler Pulley Assembly

NO.	Name	NO.	Name
1	Pulley	3	Pulley Bracket
2	Bolt	4	Rear Bolt

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Insert a ½" drive ratchet or breaker bar into the square hole on the automatic belt tensioner. Pull the ratchet to take the tension off the automatic belt tensioner and remove the left-hand belt.
2. Remove the bolts (Figure 19, Item 2 & 4).
3. Remove the left-hand idler pulley (Figure 19, Item 3).

INSTALLATION

1. Place the left-hand idler pulley bracket (Figure 19, item 3) onto the engine mount bracket.
2. Insert and torque down the bolts (Figure 19, items 2 & 4).
3. Place the belt back onto the left-hand idler pulley.

AUTOMATIC FAN BELT TENSIONER ASSEMBLY

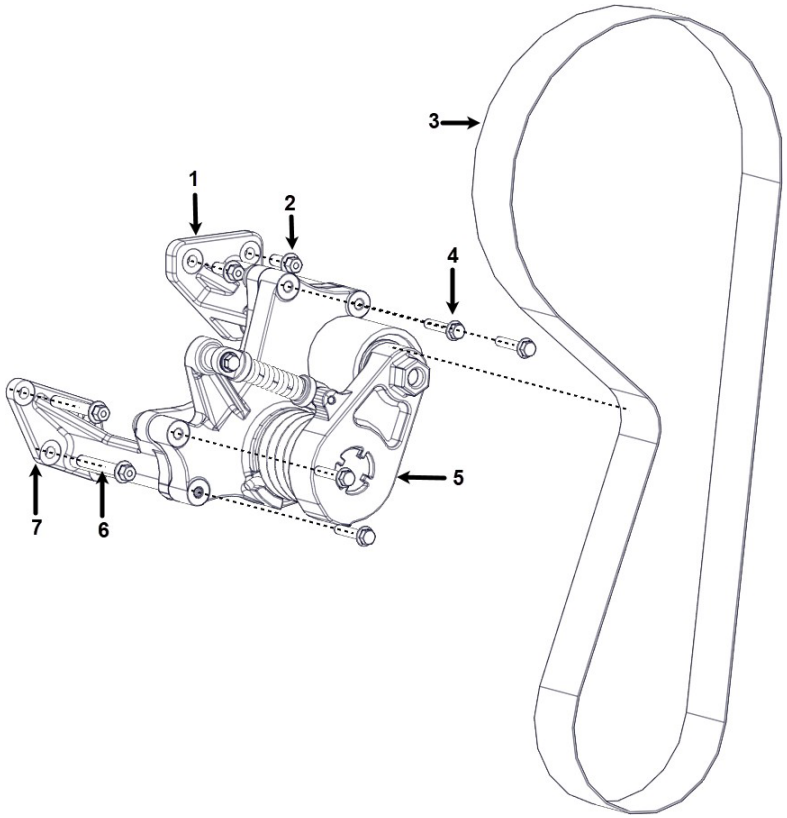


Figure 20. Automatic Fan Belt Tensioner Assembly

NO.	Name	NO.	Name
1	Bracket	5	Automatic Fan Belt Tensioner
2	Bolt	6	Bolt
3	Belt	7	Bracket
4	Bolt		

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Remove the serpentine belt (Figure 20, Item 3).
2. Remove the four bolts (Figure 20, Item 4).
3. Remove the automatic fan belt tensioner (Figure 20, Item 5).
4. Remove the seven bolts (Figure 20, Items 2 & 7) from the automatic fan belt tensioner bracket (Figure 20, Items 1 & 7).

INSTALLATION

1. Place the automatic fan belt tensioner bracket (Figure 20, Items 1 & 7) onto the cylinder block.
2. Insert and torque down the seven bolts (Figure 20, Items 2 & 7).
3. Place the automatic fan belt tensioner (Figure 20, Item 5) onto the bracket and insert and torque down the four bolts (Figure 20, Item 4).
4. Place the serpentine belt (Figure 20, Item 3) back onto the automatic fan belt tensioner.

FAN ASSEMBLY

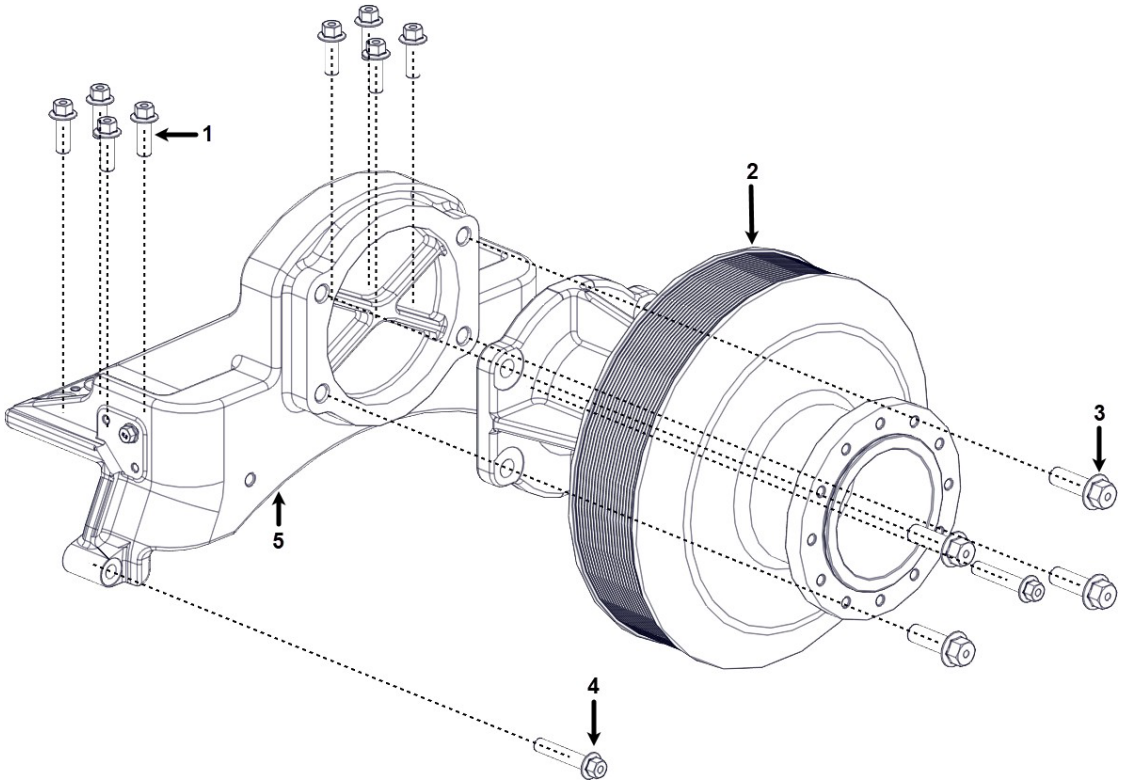


Figure 21. Fan Assembly

NO.	Name	NO.	Name
1	Bolt	4	Bolt
2	Fan Support Bracket	5	Fan Support
3	Bolt	6	

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Remove the serpentine belt, if not already removed.
2. Remove the four bolts (Figure 21, Item 3).
3. Remove the fan support bracket (Figure 21, Item 2).
4. Remove the bolts (Figure 21, Items 1 & 4).
5. Remove the fan support (Figure 21, Item 5).

INSTALLATION

1. Place the support bracket (Figure 21, Item 5) onto the top of the cylinder block.
2. Insert and torque down the bolts (Figure 21, Items 1 & 4).
3. Place the fan support bracket (Figure 21, Item 2) onto the fan support (Figure 21, Item 5).
4. Insert and torque down the four bolts (Figure 21, Item 3).
5. Place the serpentine belt back onto the fan assembly.

CRANKSHAFT ADAPTER ASSEMBLY

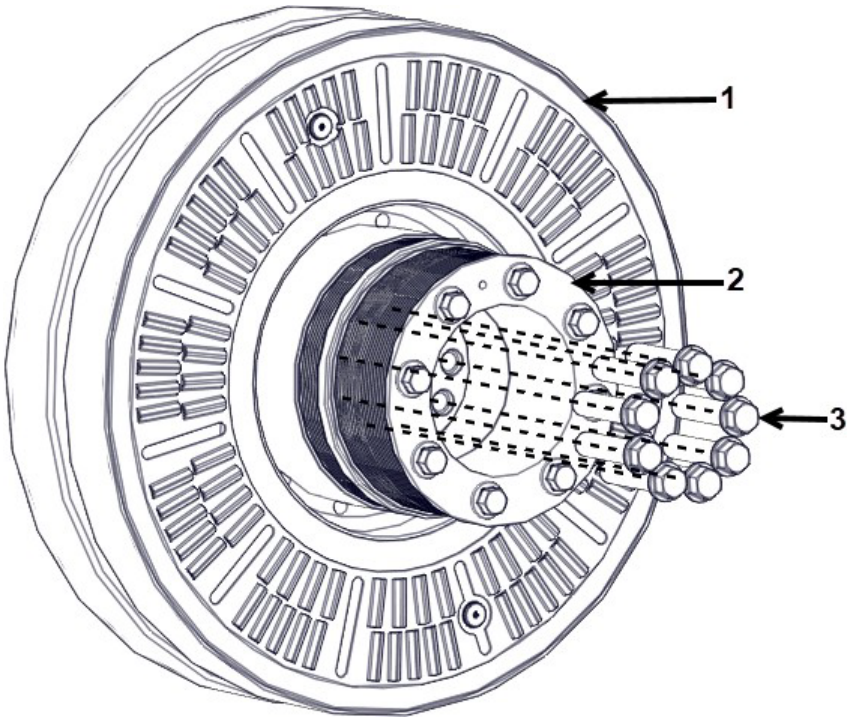


Figure 22. Crankshaft Adapter Assembly

NO.	Name
1	Crankshaft Adapter
2	Crankshaft Pulley
3	Bolt

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Remove both the fan and alternator belt.
2. Remove the nine bolts (Figure 22, Item 3) from the center of the adapter.
3. Remove the crankshaft adapter (Figure 22, Item 1).

INSTALLATION

1. Hoist the adapter (Figure 22, Item 1) on the front of the cylinder block and align the adapter accordingly.
2. Insert and torque down the nine bolts (Figure 22, Item 3).
3. Place both the serpentine and left-hand belt onto the crankshaft pulley (Figure 22, Item 2).

WATER PUMPS

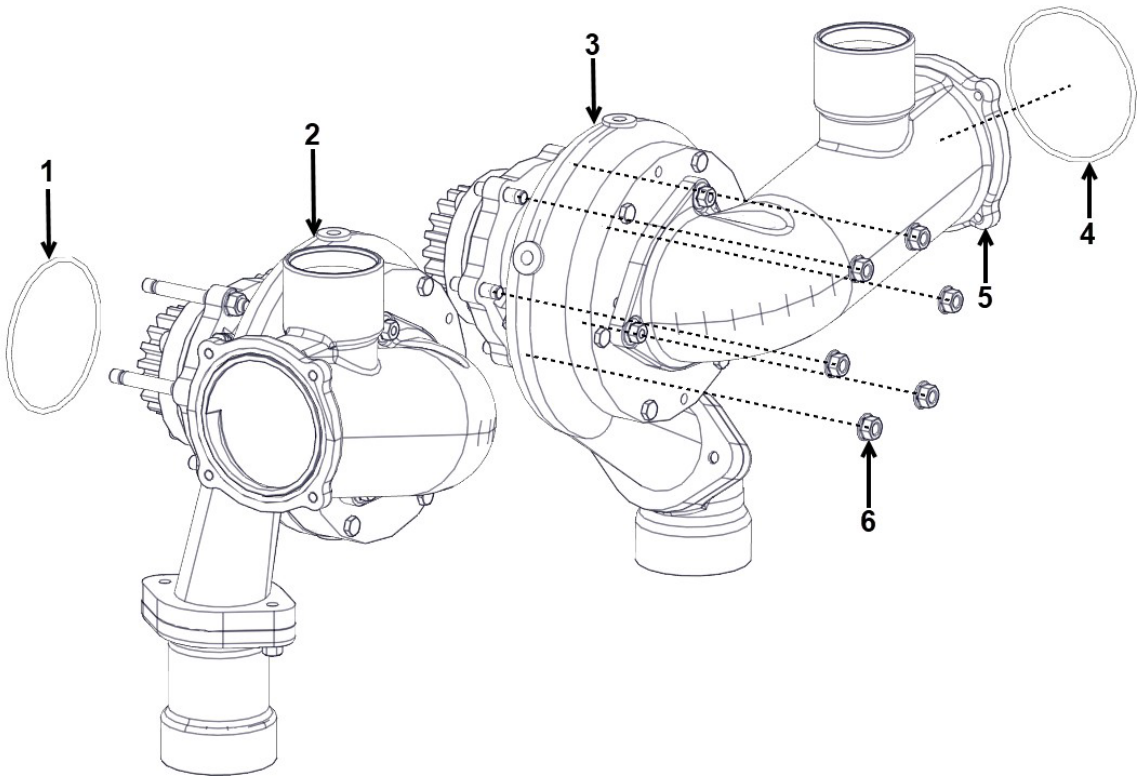


Figure 23. Water Pump Assembly

NO.	Name	NO.	Name
1	O-Ring	4	O-Ring
2	Right-Hand Water Pump	5	Water Pump Pipe
3	Left-Hand Water Pump	6	Nut

Note:

- Water Pumps are gear driven and should not be removed unless specifically requested by PSI.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Drain the coolant in the cooling system.
2. Loosen and remove all connecting pipes going into both water pumps.
3. Loosen and remove the six nuts (Figure 23, Item 6) on both water pumps.
4. Remove both water pumps carefully (Figure 23, Items 2 & 3).
5. Remove both O-rings (Figure 23, Item 1).

INSTALLATION

1. Install front cover. (Refer to *FRONT COVER* section of the manual)
2. Install new O-rings (Figure 23, Items 1 & 4) onto both water pumps.
3. Carefully install both water pumps (Figure 23, Items 2 & 3).
4. Insert and torque down the six bolts (Figure 23, Item 6) to 25 ft/lbs on each water pump.
5. Install all connecting pipes leading into both water pumps.

FRONT COVER

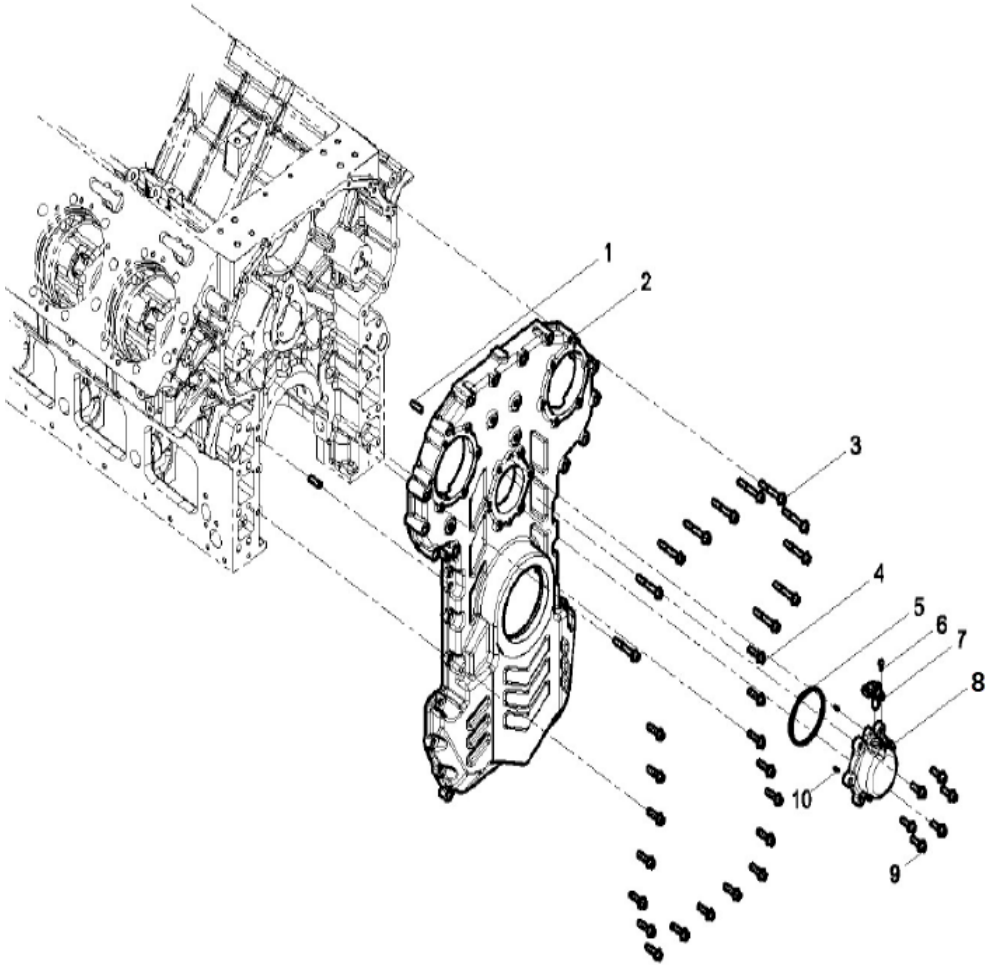


Figure 24. Front Cover Assembly

NO.	Name	NO.	Name
1	Dowel Pin	6	Bolt
2	Front Cover	7	Speed Sensor
3	Bolt	8	Sensor Seat
4	Bolt	9	Bolt
5	O-Ring	10	Dowel Pin

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Remove the entire FEAD on the engine. Refer to the *FEAD* section of the manual.
2. Drain oil into a suitable container.
3. Remove both water pumps. Refer to the *WATER PUMP* section of the manual.
4. Remove the thirty-nine bolts (Figure 24, Item 3) from the front cover.
5. Remove the front cover (Figure 24, Item 2).

Note:

- Inspect the front cover for any impact damages.

INSTALLATION

1. Clean the entire front surface of the cylinder block and back surfaces of the front cover of any debris.
2. Apply PSI approved silicone sealant on the back of the front cover (Figure 24, |Item 2).
3. Insert the two dowel pins (Figure 24, Item 1) if removed.
4. Place the front cover (Figure 24, Item 2) onto the front of the cylinder block and torque down all thirty-nine bolts (Figure 24, Item 3).
5. Install both water pumps. Refer to the *WATER PUMP* section of the manual.
6. Install the entire FEAD on the engine. Refer to the *FEAD* section of the manual.

TURBOCHARGERS

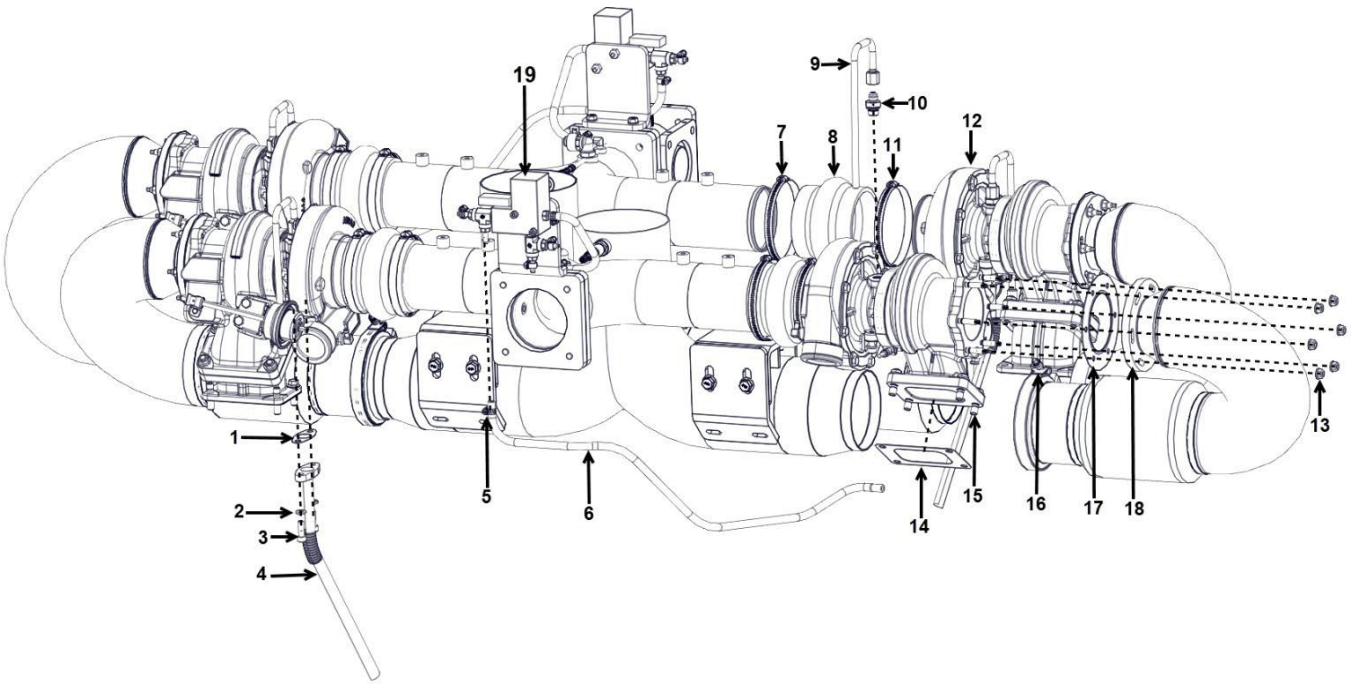


Figure 25. Turbocharger Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Gasket	5	Clamp	9	Oil Supply Line	13	Nut	17	Gasket
2	Washer	6	Vacuum Line	10	Oil Inlet Valve	14	Gasket	18	Hose
3	Bolt	7	Clamp	11	Clamp	15	Bolt	19	Electronic Boost Controller
4	Oil Drain Tube	8	Hose	12	Turbo	16	Clamp		

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Remove all turbo oil supply lines from the oil inlet valves on top of the cylinder block. (Refer to Figure 26.)

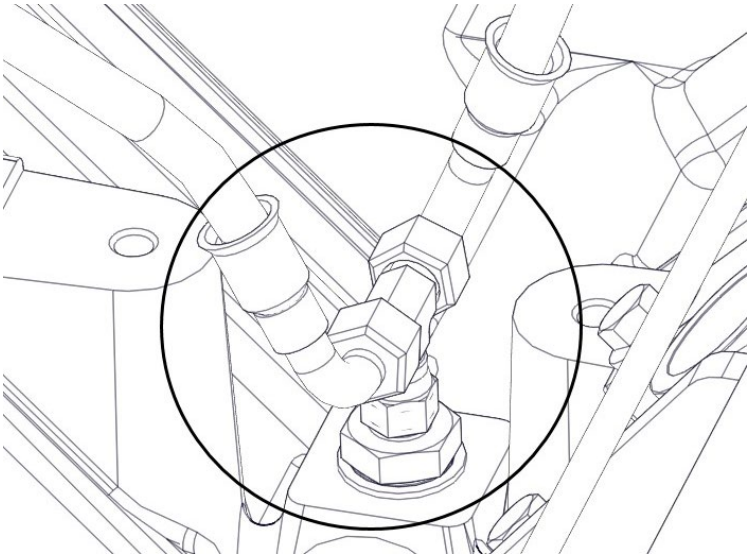


Figure 26. Turbocharger Oil Supply Lines

2. Loosen and remove all oil supply lines (Figure 25, Item 9) from the top of each turbocharger.
3. Loosen and remove all oil inlet valves (Figure 25, Item 10). (If Necessary)
4. Loosen and remove all bolts and washers (Figure 25, Items 3 & 2) from the oil drain tubes (Figure 25, Item 4).
5. Remove all oil drain tubes and gaskets (Figure 25, Items 4 & 1).
6. Remove the single bolt (Figure 27) on top of the cylinder block for all oil drain tubes.

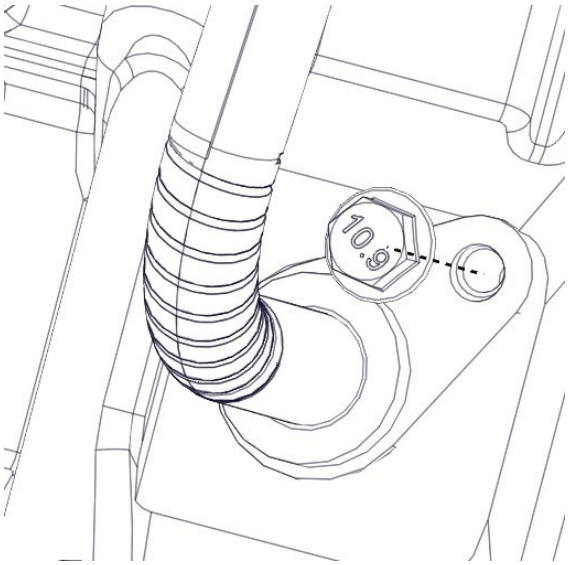


Figure 27. Oil Drain Tube Bolt

7. Remove all clamps and vacuum hoses (Figure 25, Items 5 & 6) from the electronic boost controller (Figure 25, Item 19).

8. Remove the 6 bolts (Figure 25, Item 13) from the end of each turbo.
9. Loosen the clamp (Figure 25, Item 16) and remove the hose and gasket (Figure 25, Items 18 & 17).
10. Loosen both clamps (Figure 25, Items 7 & 11) for all turbochargers.
11. Remove the hose (Figure 25, Item 8) for all turbochargers.
12. Remove the four bolts (Figure 25, Item 15) from the bottom of all turbochargers.
13. Carefully remove all turbochargers.
14. Remove all gaskets (Figure 25, Item 14) from the bottom of the turbocharger.

INSTALLATION

1. Clean any and all debris from both ends of all turbochargers and hoses leading to the turbochargers.
2. Place new turbocharger gaskets (Figure 25, Item 14) over the four studs on the ends of all the exhaust manifolds.

Note:

- All turbocharger gaskets should be placed with the round edges facing up and away from the exhaust manifold.

3. Install all turbochargers (Figure 25, Item 12) over the gaskets (Figure 25, Item 14).
4. Install the four bolts (Figure 25, Item 15) and torque to 40 ft/lbs.
5. Level the oil inlet on all turbos using a level. (Refer to figure 28)
    a. Loosen the V-bands 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 28. Oil Inlet Leveling

6. Orient all turbocharger compressor housings. (Refer to Figure 29)

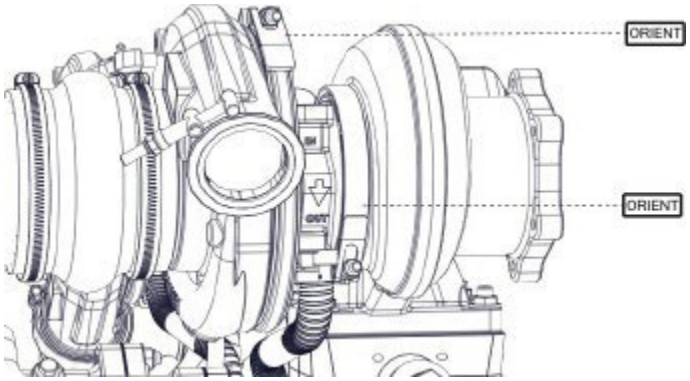


Figure 29. Compressor Housing Orientation

7. Place all washers (Figure 30, Item 2) into the oil inlet hole. Insert and torque down all oil inlet valves (Figure 30, Item 1) to 21 ft/lbs.

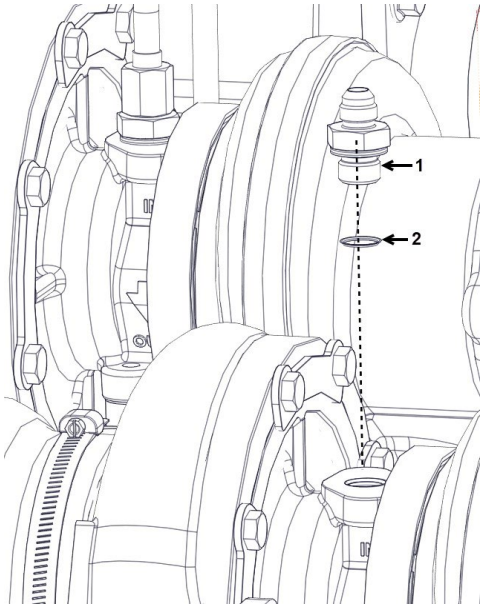
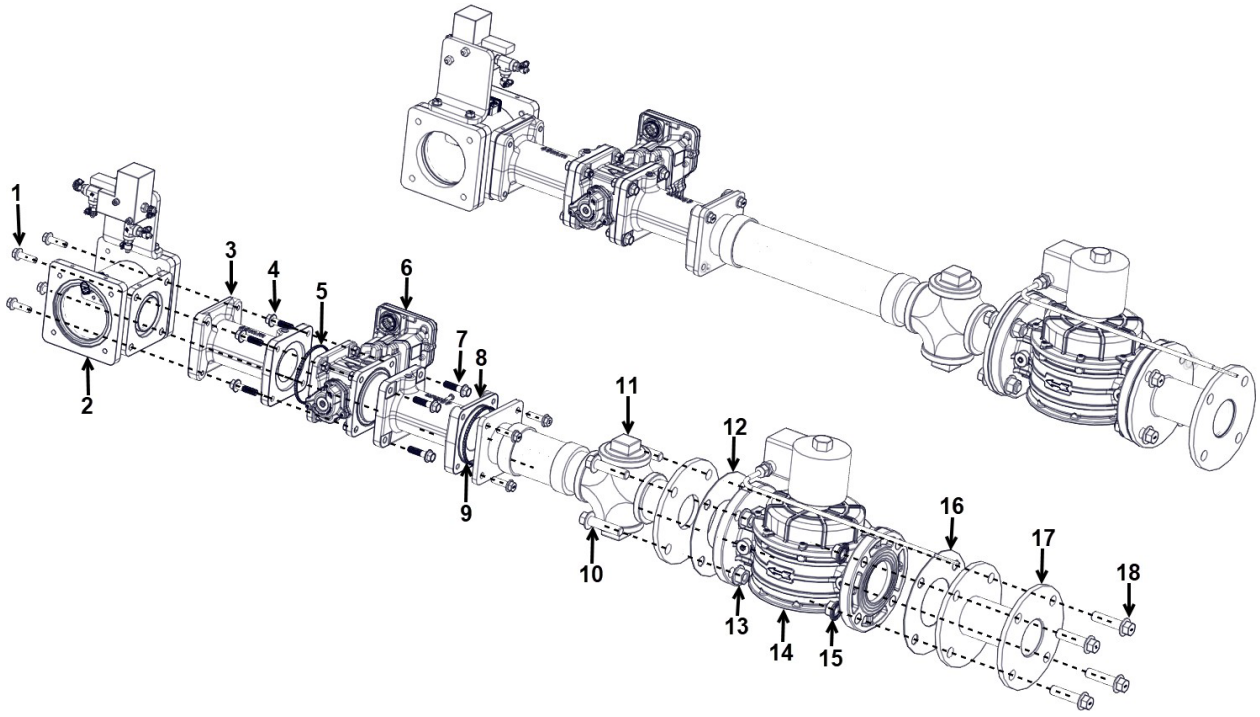


Figure 30. Oil Inlet Valve Assembly

8. Clean any and all debris from the bottom of the oil drain tube hole, which is below each turbo.
9. Clean any and all debris from the top of the cylinder block where the oil drain tubes were removed from. (Refer to image 27)
10. Place gasket (Figure 25, Item 1) onto the bottom of all turbos and place the oil drain tube (Figure 25, Item 4) onto the bottom end of the turbos.
11. Apply PSI approved 242 Loctite to both oil drain tube bolts (Figure 25, Item 3).
12. Insert the washers and bolts (Figure 25, Items 2 & 3) and torque down the oil drain tube bolts (Figure 25, Item 3) to 30 ft/lbs.
13. Insert and torque down the oil drain tube to the top of the cylinder block to 51 ft/lbs. (Refer to figure 26)

14. Place the oil supply line (Figure 25, Item 9) onto the top of all oil inlet valves (Figure 25, Item 10) and torque down the oil supply line to 30 ft/lbs.
15. Insert and torque down all oil supply lines on top of the cylinder block to 30 ft/lbs. (Refer to Figure 26)
16. Insert all clamps and hoses (Figure 25, Items 7, 8 and 11) to the end of the turbochargers.
17. Insert the gaskets (Figure 25, Item 17) on the 6 bolts on the end of all turbos.
18. Insert the hose (Figure 25, Item 18) onto the end of the turbochargers.
19. Insert and torque down the 6 nuts (Figure 25, Item 13) to 20 ft/lbs.
20. Insert the opposite end of the hose (Figure 25, Item 18) onto the open end and torque down the clamp (Figure 25, Item 16) to secure the hose.
21. Insert the vacuum line (Figure 25, Item 6) using the clamp (Figure 25, Item 5) onto the electronic boost controller (Figure 25, Item 19) and insert the opposite end of the vacuum line (Figure 25, Item 6) onto the wastegate.



FUEL SYSTEM

Figure 31. Fuel System Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Bolt	6	Mass Flow Gas Valve	11	2X Cross Fitting	16	Gasket
2	Nozzle	7	Bolt	12	Gasket	17	Lock off
3	Adapter	8	Adapter	13	Nut	18	Bolt
4	Bolt	9	O-Ring Seal	14	Lock-Off Valve		
5	O-Ring Seal	10	Bolt	15	Nut		

Note:

- Do not remove the fuel system unless specified by PSI.
- If the fuel system is removed use all new gaskets and O-rings (Figure 31, Items 5, 9, 12 & 16)
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

Removal

1. Remove the four bolts and nuts (Figure 31, Item 10, 13, 15 & 18) from the lock-off valve (Figure 31, Item 14).
2. Remove the two bolts (Figure 32) from the bottom of the cross-fitting bracket.

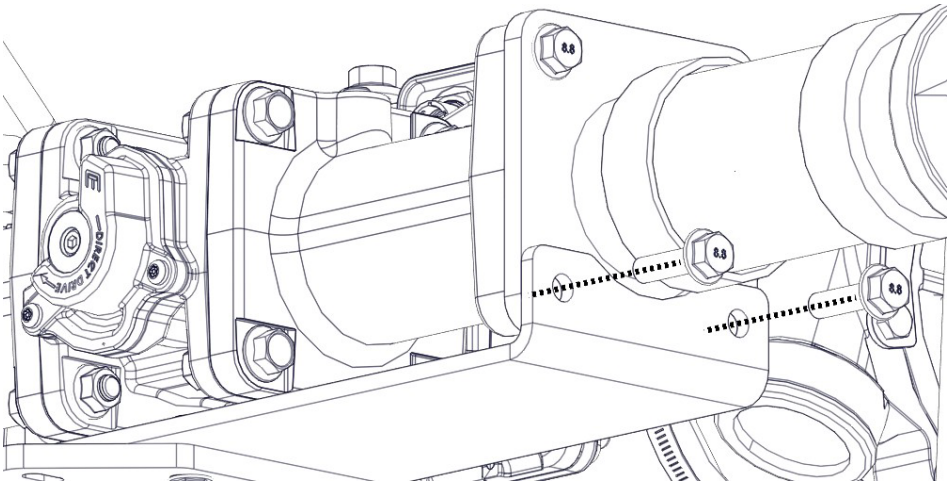


Figure 32.

3. Remove the four bolts (Figure 33) from the bottom of the nozzle bracket.

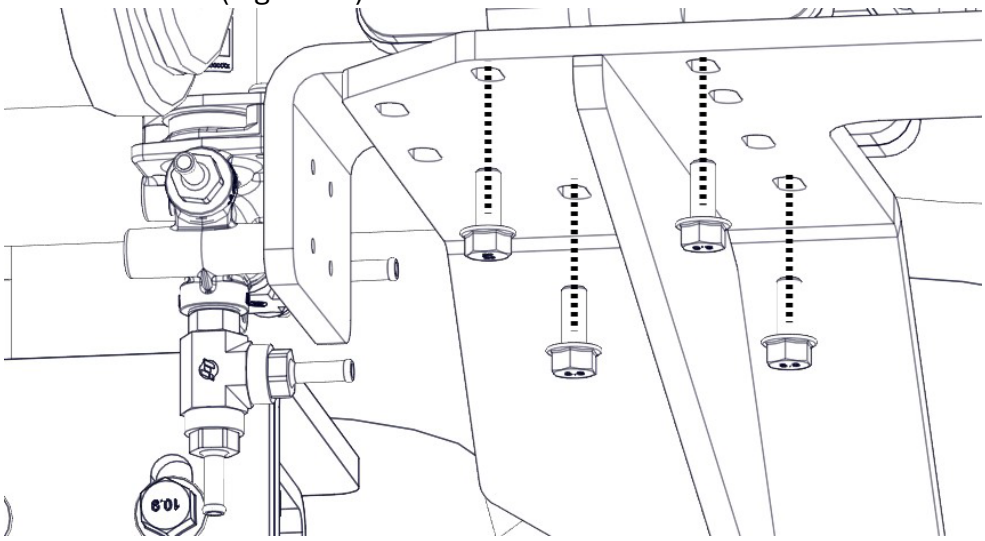


Figure 33.

4. Remove the two bolts (Figure 34, Item 1) on the electronic boost control bracket and remove all bolts on the nozzle (Figure 34, Items 2 & 3).
5. Remove the air filter and O-ring, refer to the AIR FILTERS Section of the manual.

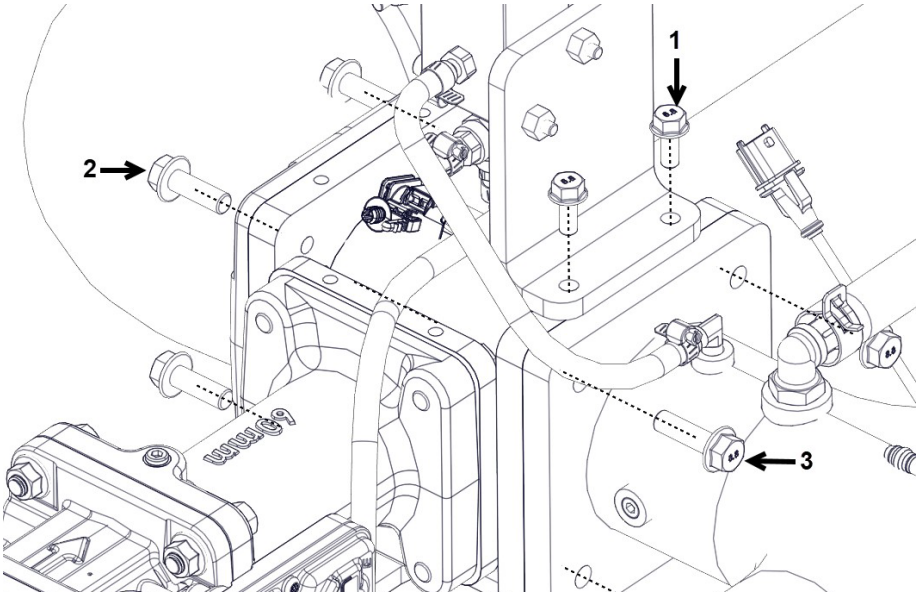


Figure 34.

NO.	Name
1	Bolt
2	Bolt
3	Bolt

6. Remove the two hoses from the electronic boost control if necessary.
7. Remove the entire fuel system from the fuel system brackets.
8. Repeat steps 1-7 for the opposite fuel system.

INSTALLATION

1. Place the entire fuel system onto the fuel system brackets. Ensure the Mass Flow Gas Valve and Lock-Off Valve arrows (Figure 35) are facing the front of the engine (when facing the flywheel).

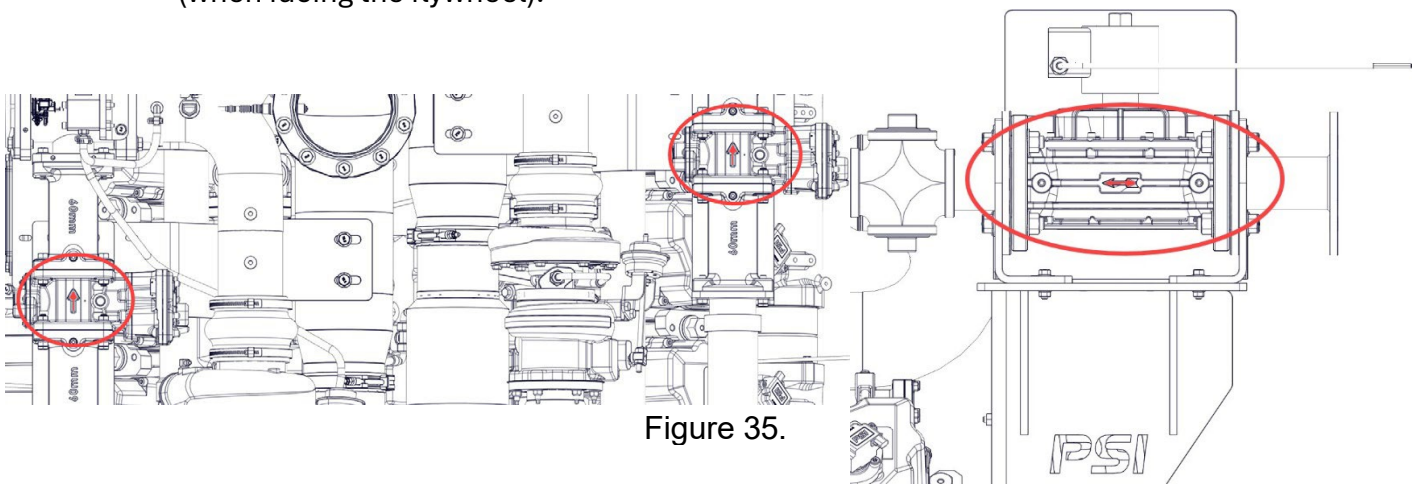


Figure 35.

Note:

- Hand tighten all bolts first before torquing down all fuel system bolts.
- Ensure all fuel kits are leveled parallel from front to back using a level.

2. Insert and hand tighten the four bolts and nuts (Figure 31, Item 10, 13, 15 & 18) from the lock-off valve (Figure 31, Item 14)
3. Insert and hand tighten the two bolts (Figure 32) from the bottom of the cross-fitting bracket.
4. Insert and hand tighten the four bolts (Figure 33) from the bottom of the nozzle bracket.
5. Torque the four bolts and nuts (Figure 31, Item 10, 13, 15 & 18) from the lock-off valve (Figure 31, Item 14) to 30 ft/lb.
6. Torque the two bolts (Figure 32) from the bottom of the cross-fitting bracket 12 ft/ lb.
7. Torque the four bolts (Figure 33) from the bottom of the nozzle bracket to 22 ft/lbs.
8. Install a new O-ring onto the nozzle (Figure 31, Item 2) then insert the air filter and torque down all four bolts (Figure 34, Item 2) to 22 ft/lb.
9. On the opposite end of the nozzle (Figure 31, Item 2) insert and torque down the four bolts (Figure 34, Item 3) to 30 ft/lb.
10. Place the electronic boost control bracket onto the nozzle and insert and torque down the two bolts (Figure 34, Item 1) to 22 ft/lb.
11. Insert and clamp down the two hoses from the electronic boost control if removed during the removal process.
12. Repeat steps 1-11 for the opposite fuel system.

CRANK CASE VENTILATION CANISTER (CCV)

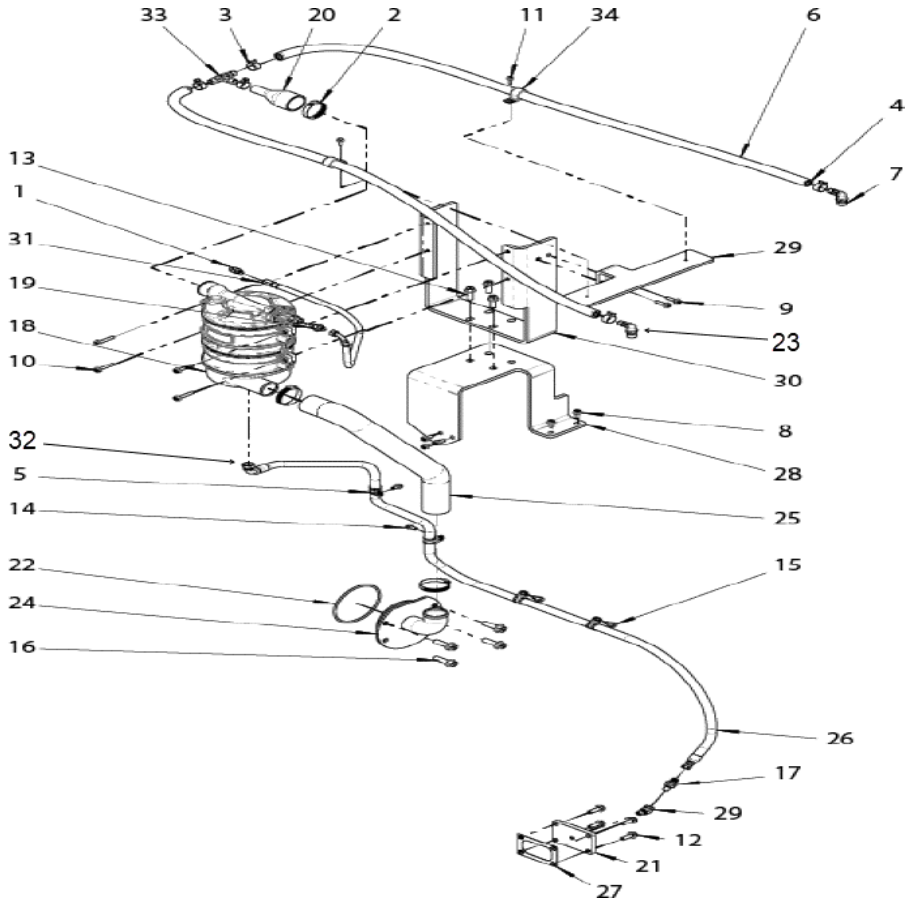


Figure 36. Crank Case Ventilation Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Fitting	10	Bolt	19	Fitting	28	Breather
2	Hose Clamp	11	Flange Bolt	20	Silicone Hose	29	Fitting
3	Hose Clamp	12	Bolt	21	CCV Oil Drain Hose	30	Bracket
4	Vapor Hose	13	Flange Bolt	22	O-Ring Seal	31	Hose
5	Clamp	14	Flange Bolt	23	Fitting	32	Heat Sleeve
6	Insulation	15	Bolt	24	Adaptor	33	Tee Fitting
7	Fitting	16	Bolt	25	Hose	34	Clamp
8	Bolt	17	Drain Breather	26	Oil Drain Hose		
9	Bolt	18	CCV Canister	27	Gasket		

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Disconnect the oil drain hose (Figure 36, Item 26) from the oil drain fitting (Figure 36, Item 29).
2. Remove all bolts and clamps (Figure 36, Item 5 & 15) holding down the oil drain hose against the cylinder block.
3. Disconnect all hoses coming from the top and bottom of the CCV canister (Figure 36, Item 18).
4. Remove the four CCV canister bolts (Figure 36, Item 10).
5. Remove the CCV canister (Figure 36, Item 18).

INSTALLATION

1. Place the CCV canister (Figure 36, Item 18) onto the CCV bracket (Figure 36, Item 30).
2. Insert and torque down all four CCV canister bolts (Figure 36, Item 10) onto the CCV canister bracket (Figure 36, Item 30).
3. Reconnect all hoses coming from the top and bottom of the CCV canister (Figure 36, Item 18).
4. Secure the oil drain hose (Figure 36, Item 26) by clamping down the hose onto the cylinder block.

Note:

- Ensure the CCV hose is routed behind the Intake manifold and oil filters then into the oil drain valve.

5. Connect the oil drain hose onto the oil drain fitting (Figure 36, Item 29).

AIR FILTERS

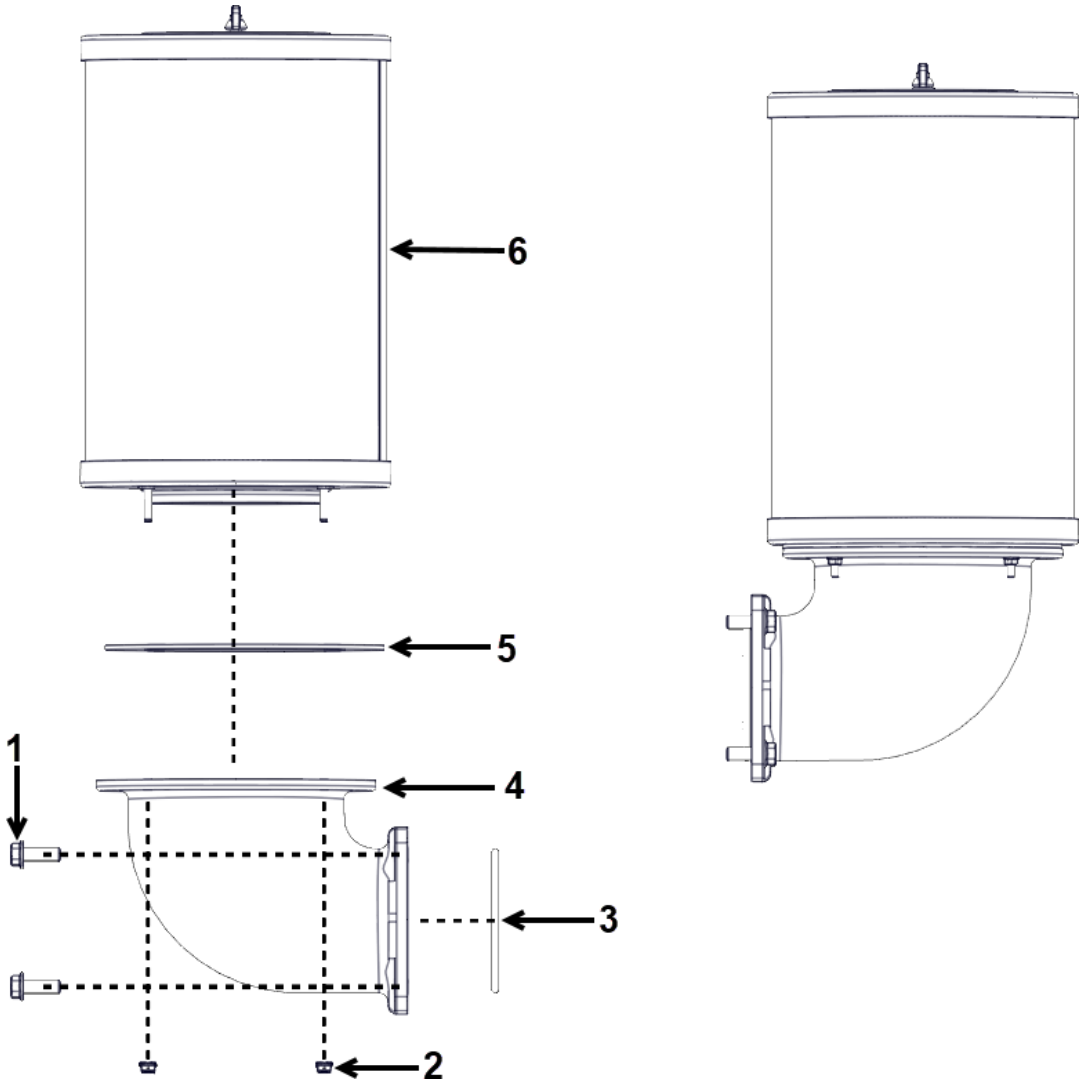


Figure 37. Air Filter Assembly

NO.	Name	NO.	Name
1	Bolt	4	Elbow
2	Nut	5	Gasket
3	O-Ring	6	Air Filter

Note:

- See the TIGHTENING TORQUES FOR STANDARD BOLTS chart for any bolts without a specified torque value.

REMOVAL

1. Remove the four bolts (Figure 37, Item 1) from the elbow (Figure 37, Item 4).
2. Remove the elbow (Figure 37, Item 4), then remove the O-ring (Figure 37, Item 3).
3. Remove the four nuts (Figure 37, Item 2).
4. Remove the air filter (Figure 37, Item 6), then remove the gasket (Figure 37, Item 5).
5. Repeat steps 1-4 for the opposite air filter.

INSTALLATION

1. Place a new O-ring (Figure 37, Item 3) onto the nozzle.
2. Place the elbow (Figure 37, Item 4) onto the O-ring and nozzle and torque down the four bolts (Figure 37, Item 1).
3. Place a new gasket (Figure 37, Item 5) onto the elbow and place the air filter (Figure 37, Item 6) onto the gasket.
4. Insert and torque down the four nuts (Figure 37, Item 2).
5. Repeat steps 1-4 for the opposite air filter.

FUEL MOUNTING BRACKETS

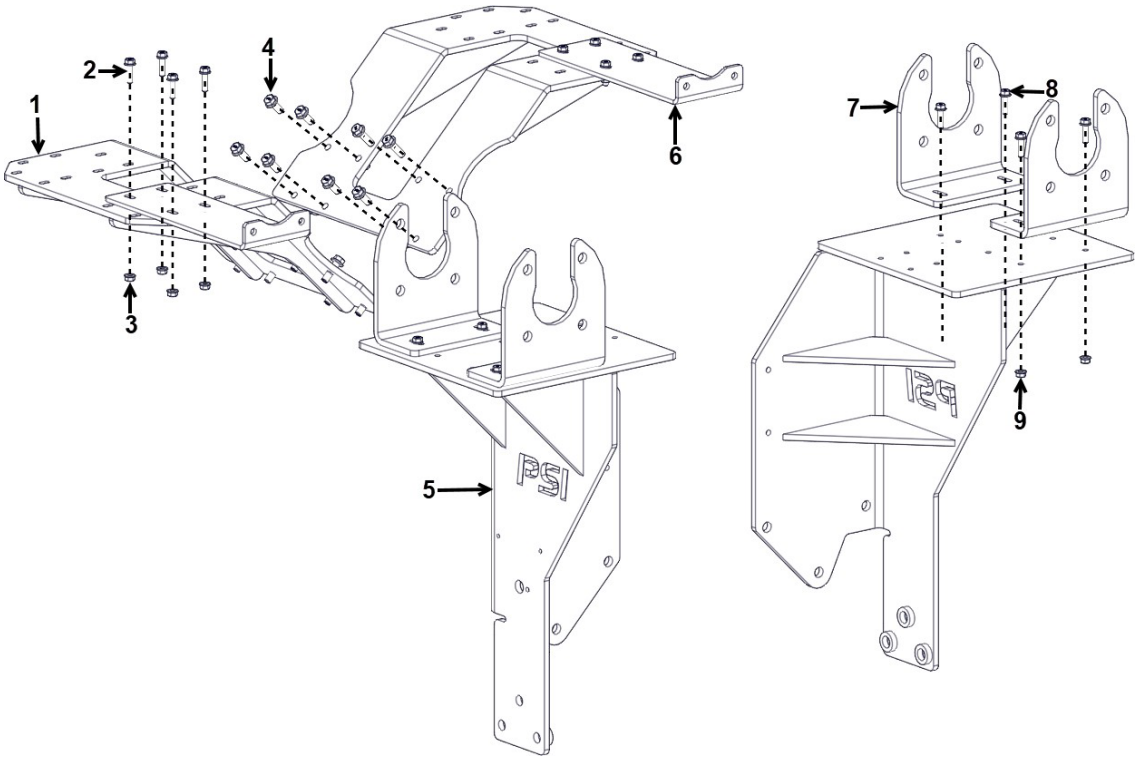


Figure 38. Fuel Mounting Bracket Assembly

NO.	Name	NO.	Name
1	Bracket	6	MFG Bracket
2	Bolt	7	Lock-Off Bracket
3	Nut	8	Bolt
4	Bolt	9	Nut
5	Bracket		

Note:

- Hand tighten all fuel mounting bracket bolts before torquing to the specified torque value.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Remove the four nuts and bolts (Figure 38, Item 8 & 9) from the lock-off brackets (Figure 38, Item 7).
2. Remove the lock-off brackets (Figure 38, Item 7).
3. Remove the four nuts and bolts (Figure 38, Items 2 & 3) from the MFG bracket (Figure 38, Item 6).

4. Remove the MFG bracket (Figure 38, Item 6).
5. Remove the eight bolts (Figure 38, Item 4) from the fuel bracket (Figure 38, Item 1).
6. Remove the fuel bracket (Figure 38, Item 1).
7. Repeat steps 1-6 for the opposite fuel brackets.

INSTALLATION

1. Place the fuel bracket (Figure 38, Item 1) onto the top of the cylinder block.
2. Insert and torque down the eight bolts (Figure 38, Item 4).
3. Place the MFG bracket (Figure 38, Item 6) on top of the fuel bracket (Figure 38, Item 1).
4. Insert and torque down the four nuts and bolts (Figure 38, Items 2 & 3).
5. Place the lock-off brackets (Figure 38, Item 7) on top of the fuel bracket (Figure 38, Item 5).
6. Insert and torque down the four nuts and bolts (Figure 38, Item 8 & 9).
7. Repeat steps 1-6 for the opposite fuel brackets.

EXHAUST MANIFOLD

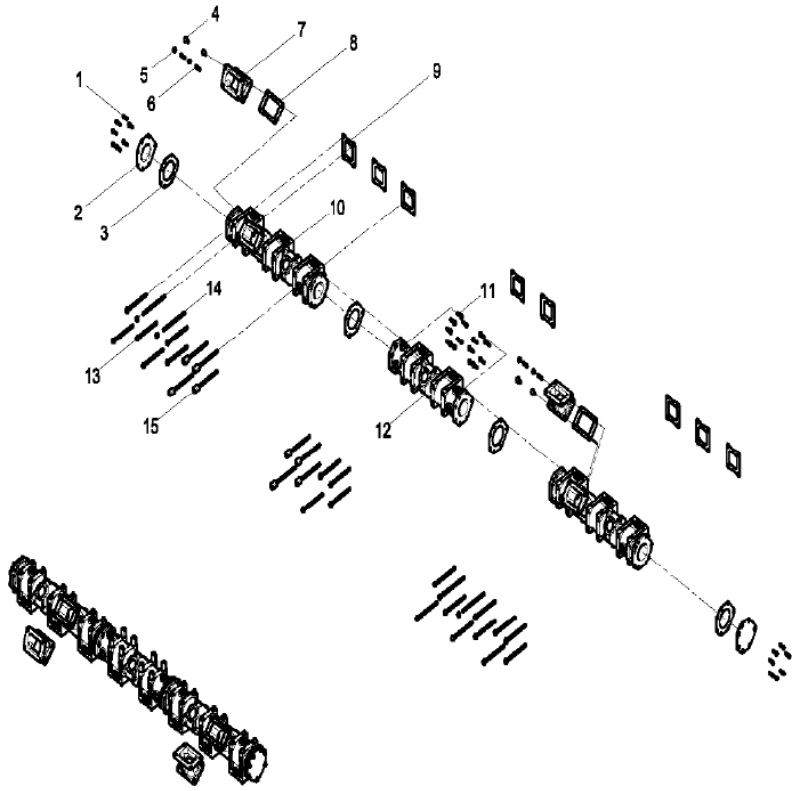


Figure 39. Exhaust Manifold Assembly

NO.	Name	NO.	Name	NO.	Name
1	Bolt	6	Bolt	11	Bolt
2	Plate	7	Exhaust Pipe	12	Exhaust Manifold
3	O-Ring	8	Gasket	13	Bolt
4	Bolt	9	Gasket	14	Bolt
5	Lock Nut	10	Exhaust Manifold	15	Bolt

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.
- The exhaust manifold gaskets must be replaced when disassembled.
- The exhaust manifold bolts can be reused twice only.
- The exhaust manifold is made up of three sections.
- The turbocharger, fuel system and fuel brackets assemblies must be removed.

REMOVAL

1. Drain the coolant from the engine into a suitable container.

2. Remove all exhaust piping connected to the ends of the exhaust manifolds and turbochargers.
3. Remove the four bolts (Figure 39, Item 4) from each of the exhaust pipes (Figure 39, Item 7).
4. Remove the exhaust pipes (Figure 39, Item 7) and the gaskets (Figure 39, Item 8).
5. Remove the twelve bolts (Figure 39, Items 13 & 15) from all three sections of the exhaust manifolds (Figure 39, Item 10).
6. Remove the six bolts (Figure 39, Item 1) from the sides of each section of the exhaust manifolds (Figure 39, Item 10).
7. Remove the three sections of the exhaust manifolds (Figure 39, Item 10) and remove the gaskets (Figure 39, Item 3 & 9).
8. Remove the two bolts (Figure 40, Item 2) from the exhaust pipe (Figure 40, Item 1) and remove the exhaust pipe (Figure 40, Item 1).
9. Remove the O-ring (Figure 40, Item 3) located directly on top of each cylinder head.
10. Repeat steps 1-9 for the opposite exhaust manifold.

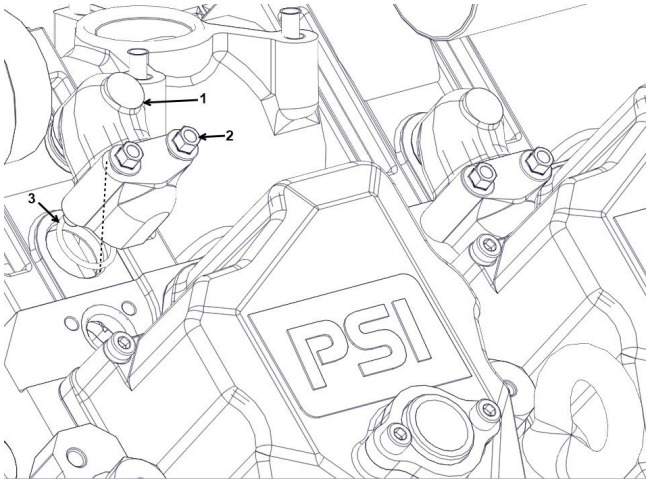


Figure 40.

NO.	Name
1	O-Ring
2	Pipe
3	Bolt

INSTALLATION

1. Clean any debris from the top of each cylinder head.
2. Install new gaskets (Figure 39, Item 3 & 9) onto the cylinder heads and between the three sections of the exhaust manifolds (Figure 39, Item 10).
3. Install the six bolts (Figure 39, Item 1) from the sides of each section of the exhaust manifolds (Figure 39, Item 10).

4. Apply Loctite 242 sealant onto the threads of all twelve bolts (Figure 39, Items 13 & 15).
5. Insert and torque down the twelve bolts (Figure 39, Items 13 & 15).
6. Place new gaskets (Figure 39, Item 8) onto the top of front and rear sections of the exhaust manifolds.
7. Place the exhaust pipes (Figure 39, Item 7) on top of the new gaskets (Figure 39, Item 8).
11. Insert and torque down the four bolts (Figure 39, Item 4) from each of the exhaust pipes (Figure 39, Item 7).
8. Install new O-rings (Figure 39, Item 3) on each cylinder head port.
9. Place the exhaust pipe (Figure 40, Item 1) onto the cylinder head.
10. Insert and torque down the two bolts (Figure 40, Item 2).
11. Repeat steps 1-10 for the opposite exhaust manifold.

INTAKE MANIFOLD

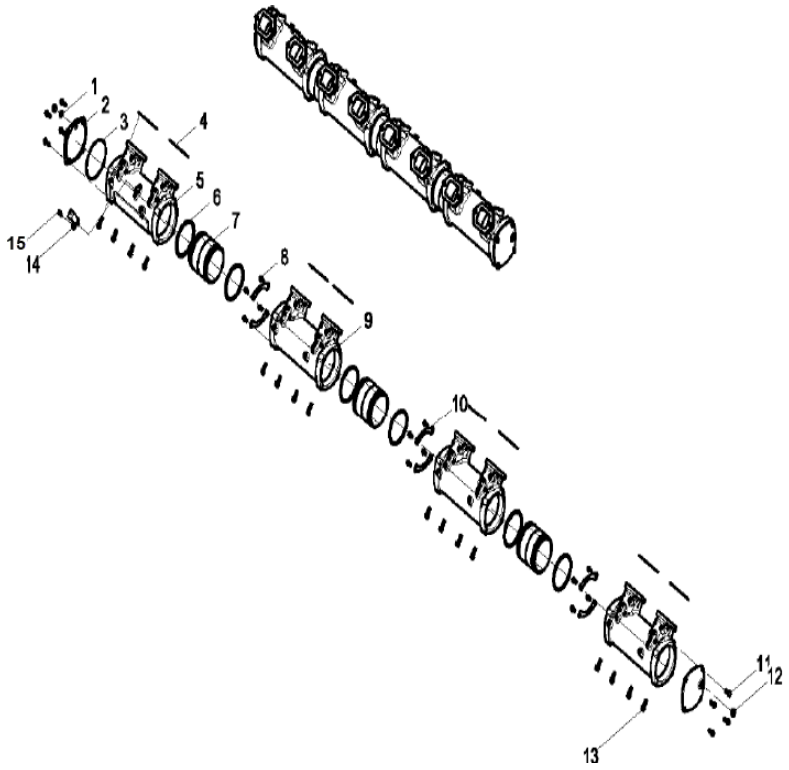


Figure 41. Intake manifold Assembly

NO.	Name	NO.	Name	NO.	Name
1	Washer	6	O-Ring	11	Bolt
2	Plate	7	Connecting Pipe	12	Plug
3	Gasket	8	Bolt	13	Bolt
4	Gasket	9	Intake Manifold	14	Sensor
5	Intake Manifold	10	Thrust Ring	15	Bolt

Note:

- Intake manifold is made up of four sections.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.
- The left-hand intake manifold will have both ECM's, ensure to handle the harnesses carefully when removing and installing the intake manifold.

REMOVAL

1. Remove the four bolts (Figure 41, Item 13) and the four bolts (Figure 41, Item 11) from each section of the intake manifolds (Figure 41, Items 5 & 9).

2. Remove the gaskets (Figure 41, Item 3 & 4) and the connecting pipes and O-rings (Figure 41, Item 6 & 7) from each section of the intake manifold as well as the thrust ring (Figure 41, Item 10).
3. Repeat steps 1-2 for the opposite intake manifold.

Note:

- All section to section bolts should not be tightened until the exhaust manifold is installed on the heads and squared. If tighten before, one of the sealing surfaces to the heads may not be seated correctly and could cause a leak.

INSTALLATION

1. Clean any debris from the sealing surface of each cylinder head and from each end of all sections of the intake manifolds.
2. Place new gaskets (Figure 41, Item 4) onto each end of the intake manifold.
3. Place each section of the intake manifolds (Figure 41, Items 5 & 9) onto the bottom of each cylinder head.
4. Hand tighten the four bolts (Figure 41, Item 13).
5. Apply clean grease onto the O-ring (Figure 41, Item 6) and place the O-ring onto each end of the intake manifold sections.
6. Place the thrust ring (Figure 41, Item 10) onto the end of each connecting pipe (Figure 41, Item 7).
7. Install each thrust ring (Figure 41, Item 10) and connecting pipe (Figure 41, Item 7) onto each end of the intake manifold sections.
8. Insert and hand tighten the four bolts (Figure 41, Item 11) on each end of the intake manifolds.
9. Once all sections of the intake manifold have been installed and all bolts have been hand tighten torque down all bolts (Figure 41, Items 11 & 13).
10. Repeat steps 1-9 for the opposite intake manifold.

EXPLOSION RELIEF VALVE

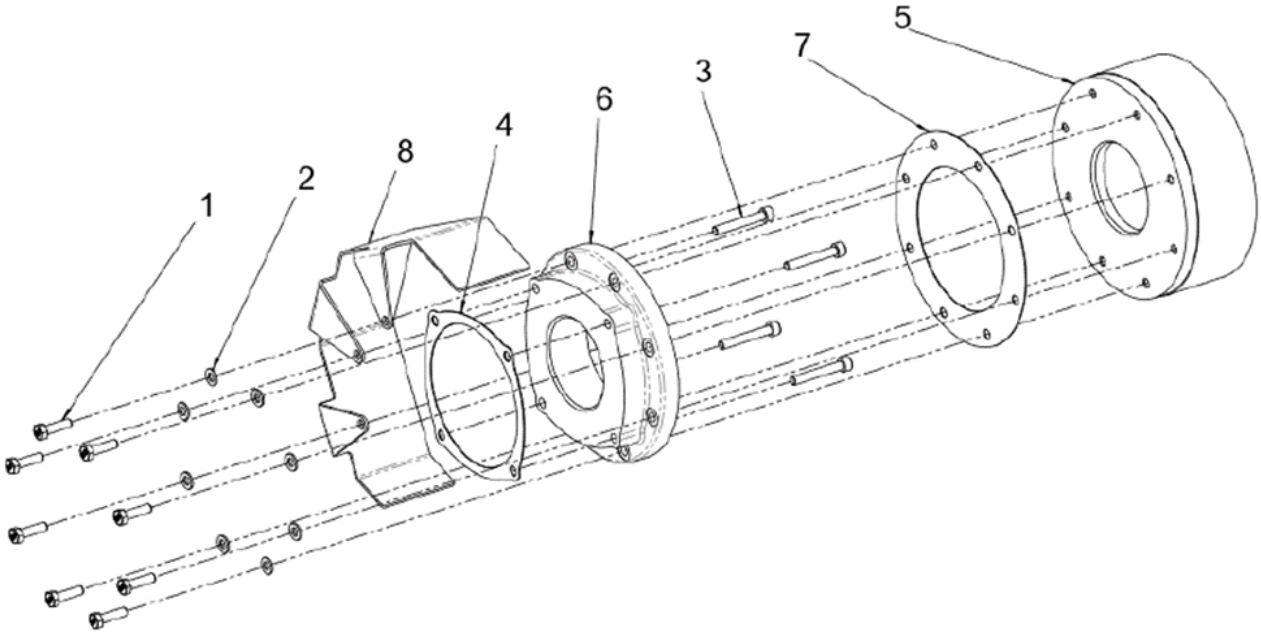


Figure 42. Explosion Relief Valve Assembly

NO.	Name	NO.	Name
1	Bolt	5	Explosion Relief Valve
2	Washer	6	Explosion Relief Adapter
3	Bolt	7	Explosion Relief Gasket
4	Throttle Adapter Gasket	8	Pressure Relief Shield

WARNING:

- Do not remove valve unless specifically requested by PSI.
- The relief valve is 22 pounds and could cause extreme harm if not handled accordingly.

REMOVAL

1. Remove the three bolts securing the explosion relief shield to the base of the relief valve, and remove the explosion relief shield (Figure 1, Item 8).
2. Remove the remaining five bolts from the base of the explosion relief valve.
3. Remove the relief valve (Figure 42, Item 5).
4. Remove the relief valve gasket (Figure 42, Item 7).
5. Remove the four bolts (Figure 42, Item 3) from the relief valve adapter (Figure 42, Item 6).
6. Remove the throttle adapter gasket (Figure 42, Item 4).
7. Repeat steps 1-6 for the opposite relief valve.

INSTALLATION

1. Clean any debris from the end of the intake manifold.
2. Place relief valve adapter gasket (Figure 42, Item 4) onto the relief valve adapter (Figure 42, Item 6).
3. Insert the relief valve adapter and gasket onto the end of the intake manifold.
4. Apply PSI approved Loctite to all four relief valve adapter bolts (Figure 42, Item 3).
5. Insert and torque down all four relief valve adapter bolts to 27 ft/lb.
6. Clean any debris from the surface of the relief valve (Figure 42, Item 5).
7. Place all eight washers (Figure 42, Item 2) onto the eight relief valve bolts (Figure 42, Item 1).
8. Carefully place the relief valve gasket (Figure 42, Item 7) and relief valve (Figure 42, Item 5) onto the relief valve adapter (Figure 42, Item 6).
9. Place the explosion relief shield (Figure 42, Item 9) on the back of the relief valve (Figure 42, Item 5) and ensure the shield is pointed out and away from the engine.
10. Insert and torque down the eight washers and bolts (Figure 42, Item 1 & 2) in the below sequence to 27 ft/lbs. (Refer to Figure 43.).
11. Repeat steps 1-10 for the opposite relief valve.

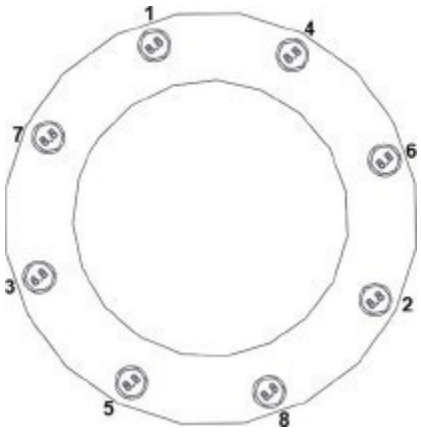


Figure 43. Explosion Relief Valve Torquing Sequence

IGNITION COIL

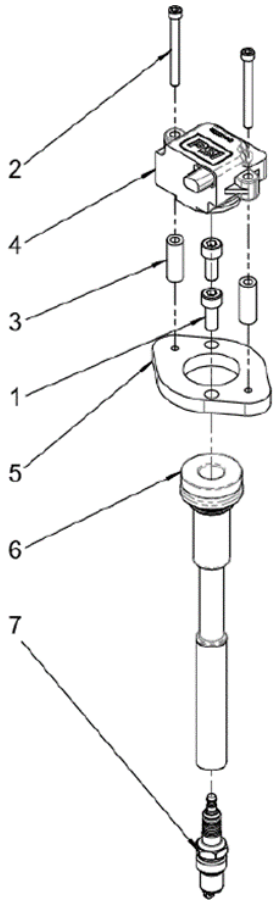


Figure 44. Ignition Coil Assembly

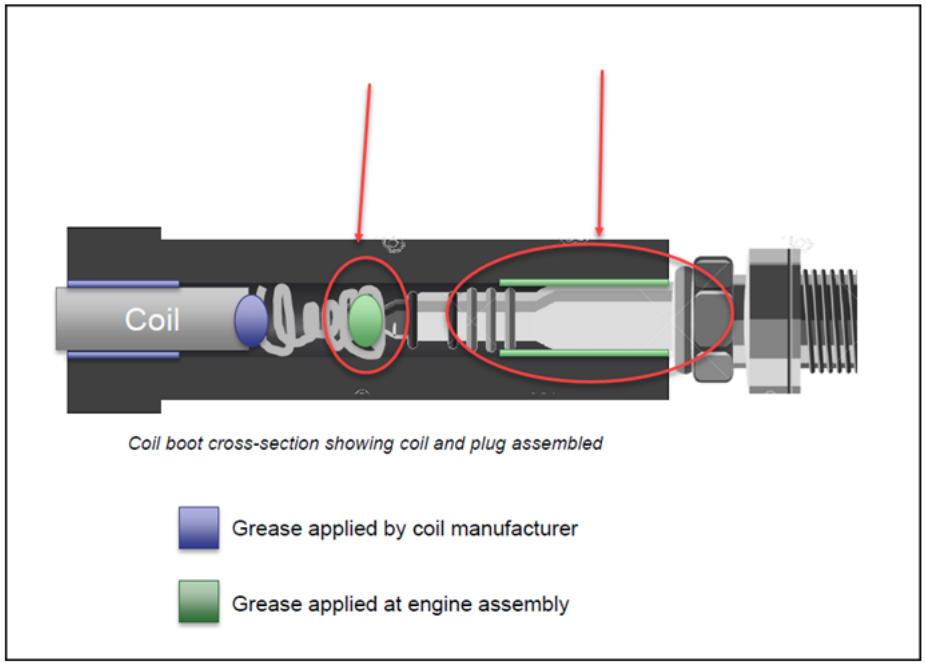
NO.	Name	NO.	Name
1	Bolt	5	Ignition Coil Bracket
2	Bolt	6	Ignition Coil Boot
3	Spacer	7	Spark Plug
4	Ignition Coil		

REMOVAL

1. Remove the two bolts and spacers (Figure 44, Item 2 & 3) on the ignition coil (Figure 44, Item 4).
2. Remove the ignition coil and ignition coil boot (Figure 44, Item 4 & 5).
3. Remove the two bolts (Figure 44, Item 1) on the ignition coil bracket (Figure 44, Item 5).
4. Remove the ignition coil bracket (Figure 44, Item 5).
5. Remove the spark plug (Figure 44, Item 7).

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.



Coil boot cross-section showing coil and plug assembled

CYLINDER HEAD COVER

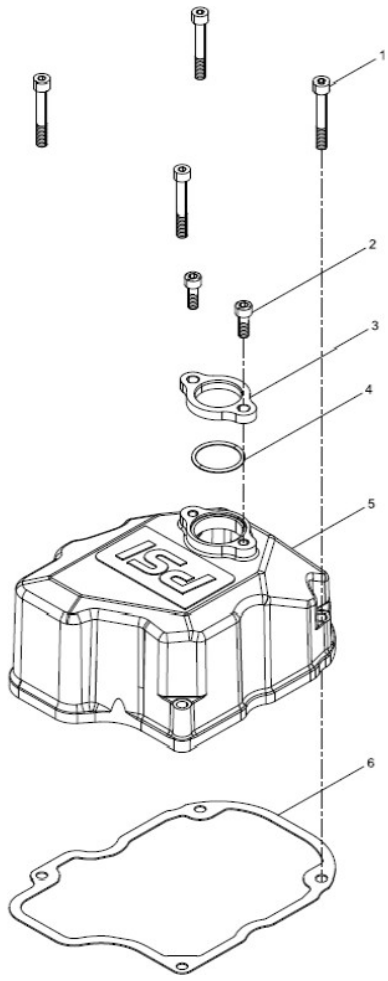


Figure 45. Cylinder Head Cover

NO.	Name
1	Bolt
2	Bolt
3	Cover
4	O-Ring
5	Cylinder Head Cover
6	Cylinder Head Cover Gasket

REMOVAL

1. Remove all four-cylinder head cover bolts (Figure 45, Item 1).
2. Remove the cylinder head cover (Figure 45, Item 5) and gasket (Figure 45, Item 6).

INSTALLATION

1. Remove any and all debris from the top of each cylinder head.
2. Install each gasket (Figure 45, Item 6) onto the cylinder head.
3. Install each cylinder head cover (Figure 45, Item 5) and insert and torque down all four bolts (Figure 45, Item 1) to 20 ft/lbs.
4. Place the cylinder head ignition coil O-ring (Figure 45, Item 4) in preparation for ignition coil installation.

ROCKER ARMS

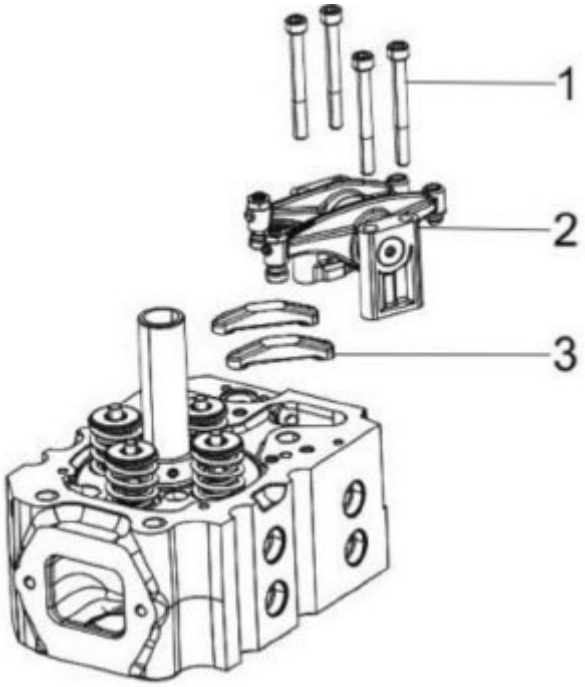


Figure 46. Rocker Arm Assembly

NO.	Name
1	Bolt
2	Rocker Arm Shaft Assembly
3	Valve Bridge

REMOVAL

1. Remove the bolts (Figure 46, Item 1) that retain the rocker arm shaft support.
2. Remove the rocker arm shaft assembly (Figure 46, Item 2) from the cylinder head.
3. Remove the valve bridge (Figure 46, Item 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 tappets and identify for installation.
5. Remove the rocker arm support (Figure 47, Item 1).
6. Slide the exhaust rocker arm assembly (Figure 47, item 2) out of the rocker arm shaft assembly (Figure 47, item 4), rocker arm shaft sleeve (Figure 47, item 3), and intake rocker arms assembly (Figure 47, item 5).

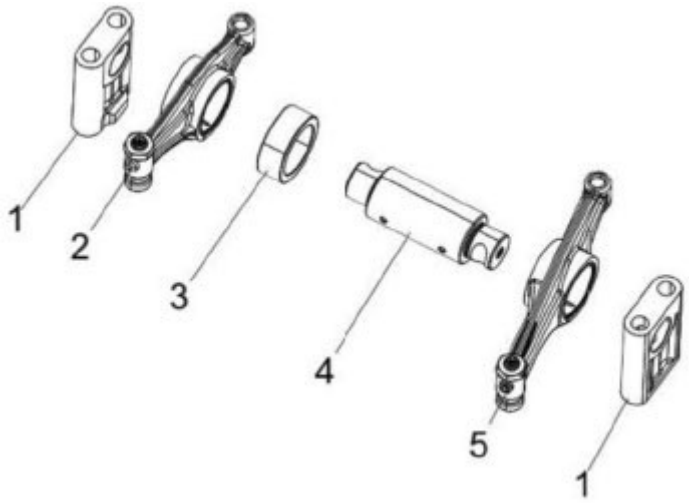


Figure 47. Rocker Arm Assembly

NO.	Name
1	Rocker Arm Support
2	Exhaust Rocker Arm
3	Shaft Sleeve
4	Rocker Arm Shaft
5	Intake Rocker Arm

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.

CYLINDER HEAD REMOVAL

1. Remove the spark plug and the two bolts (Figure 48, Item 2) from the pipe and remove the pipe (Figure 48, Item 1) from the cylinder head.

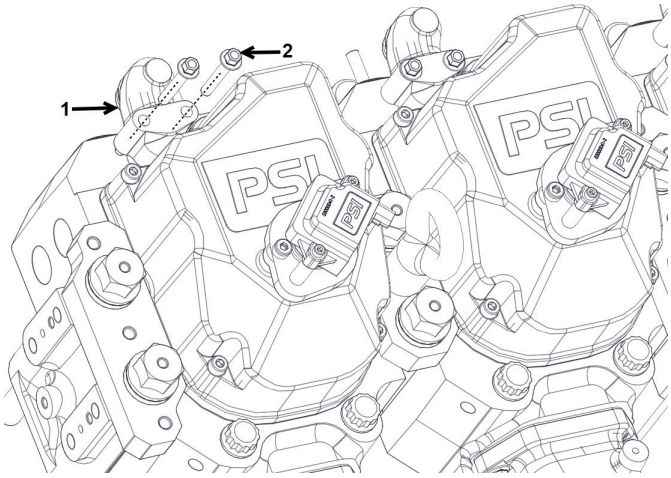


Figure 48.

NO.	Name
1	Pipe
2	Bolt

2. Loosen the cylinder secondary bolts in the following order A-R. (Refer to Figure 49).

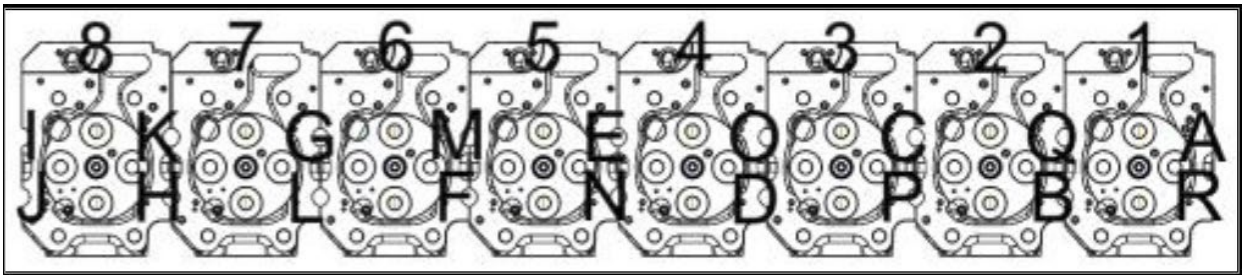


Figure 49.

NOTE:

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

3. Remove the cylinder secondary bolts (Figure 50, item 1). Remove the gasket (Figure 50, item 2), clamping block (Figure 50, item 3) and end plate (Figure 50, item 4).

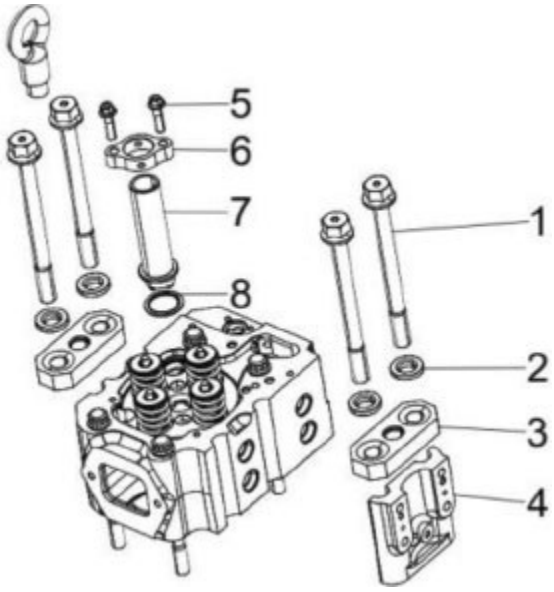


Figure 50. Cylinder Head Assembly

NO.	Name	NO.	Name
1	Bolt	5	Bolt
2	Gasket	6	Clamp
3	Clamping Block	7	Ignition Coil Bush
4	End Plate	8	Gasket

4. Loosen the bolts (Figure 50, Item 5) and remove tube clamp (Figure 50, Item 6).
5. Remove the ignition coil bush (Figure 50, Item 7) and the gasket (Figure 50, Item 8).
6. Remove the cylinder head main bolts in the following order 1-32 (Figure 51).

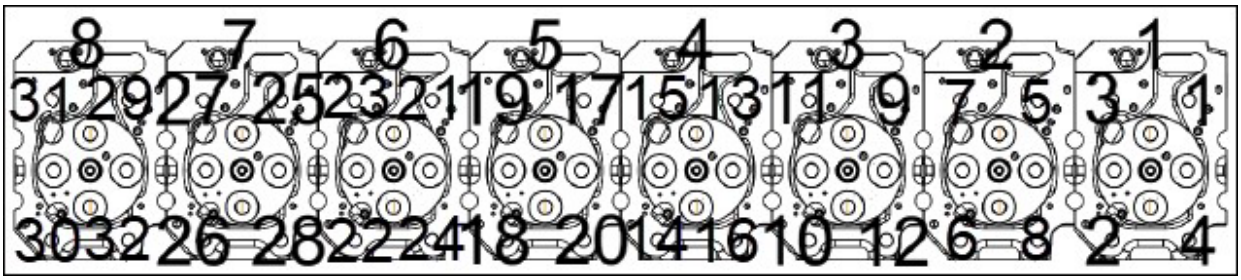


Figure 51.

7. Lift all cylinder heads away from the cylinder block (Figure 52, Item 2). Discard all cylinder head gaskets (Figure 52, Item 3)

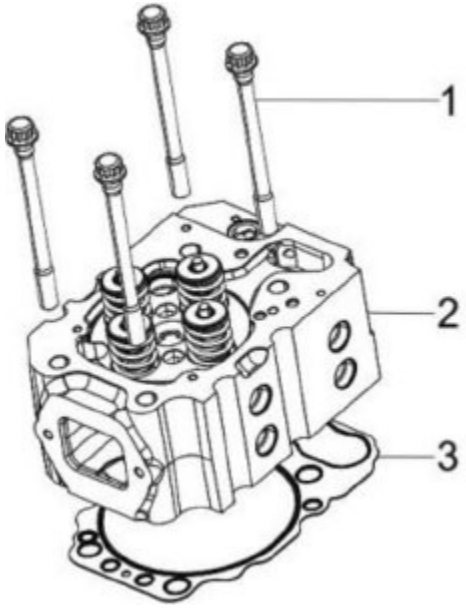


Figure 52. Cylinder Head Assembly

NO.	Name
1	Bolt
2	Cylinder Head
3	Cylinder Head Gasket

2. Place the cylinder head on the work bench with the combustion side down.
3. Using the valve spring compressor tool, compress the valve springs (Figure 53).

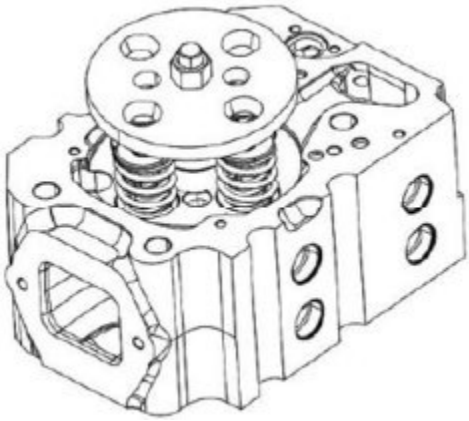


Figure 53. Valve Spring Compressor Assembly

4. Remove the valve keepers (Figure 54, Item 1).
5. Slowly release the tension on the valve spring.
6. Remove the spring top retainer (Figure 54, Item 2) and outer/inner valve spring (Figure 54, Items 3 & 4).
7. 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.

8. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves (Figure 54, Items 7 & 8) from the cylinder head.
9. Remove the valve stem seals (Figure 54, Item 5).
10. Remove the spring bottom retainer (Figure 54, Item 6).

Note:

- Using a magnet and a compressor line is the most efficient way to remove the spring bottom retainers.

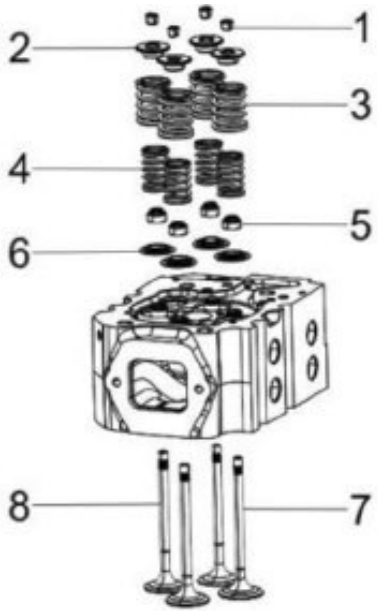


Figure 54. Cylinder Head Assembly

NO.	Name	NO.	Name
1	Valve Keeper	5	Valve Stem Seals
2	Spring Retainer	6	Spring Bottom Retainer
3	Outer Valve Spring	7	Valve
4	Inner Valve Spring	8	Valve

Note:

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

11. If the valve guides are not within specifications, use a hydraulic press to drive the valve guides (Figure 55, Item 1) out of the cylinder head.

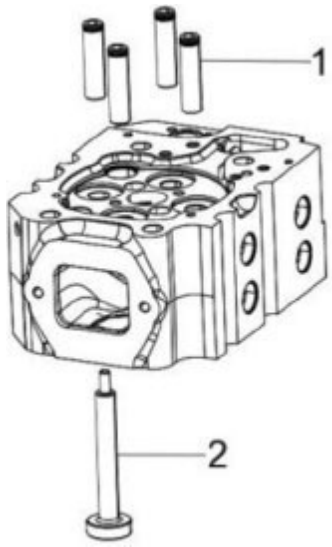


Figure 55. Cylinder Head Valve Guides

NO.	Name
1	Valve Guides
2	Press

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. Visually inspect all cylinder head components. 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 as a result 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 AND TAPPETS

Determine if the bend of the push rod is within the specified limit. Clean all push rods and tappets with compressed air. Replace tappets and push rods if necessary.

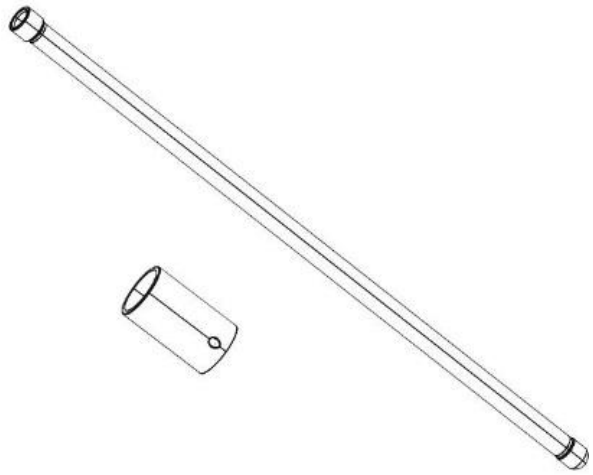


Figure 56. Push Rod and Tappet Assembly

Inspect all push rods and tappets for the following:

- Excessive wear
- Oil passages of the tappets and push rod blockage

INSPECTION OF ROCKER ARM ASSEMBLY

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

Inspect the contact areas for excessive wear or damage.

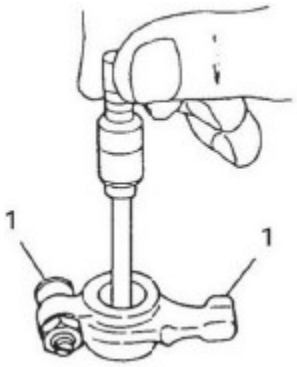


Figure 57. Rocker Arm Diameter Measurement

Use a micrometer to measure the rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart (Figure 57).

VALVE GUIDE INSPECTION

Visually inspect the valve guides for distortions, scoring or other damages. Replace guides if necessary.

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 58). See Intake / Exhaust Valve and Guide chart for the service limit. Replace valve guides if not within specification.

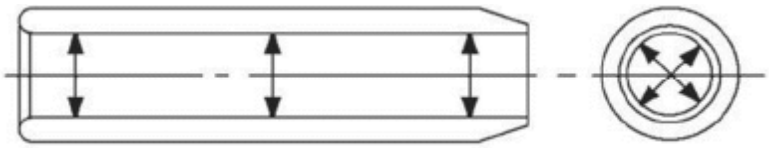


Figure 58. Valve Guide Measurement

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 cylinder head in a tank of water and increase pressure up to 73 PSI or 5 bar (Figure 59).
3. Check that there are no leaks in the intake ducts, exhaust ducts, spark plug sleeve, oil passages, cylinder combustion side or valve seat housings. Discard the cylinder head if necessary.

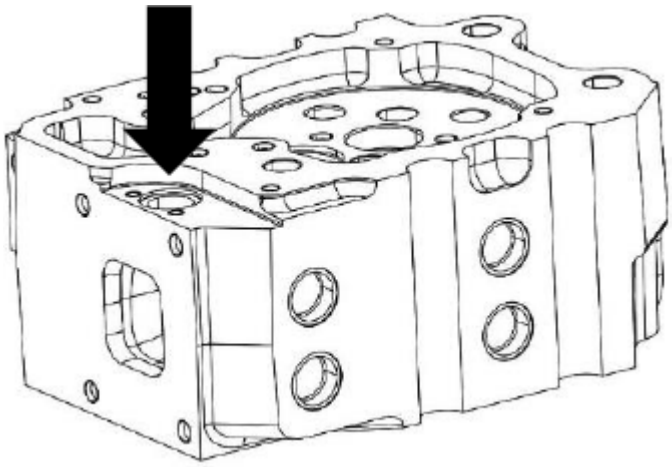


Figure 59. Cylinder Head outlet

INTAKE AND EXHAUST VALVE INSPECTION

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 60). See *Intake / Exhaust Valve and Guide chart* for the service limit.

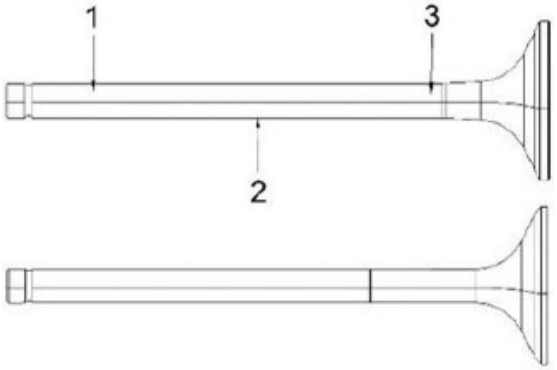


Figure 60. Valve Stem Diameter

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 61). See *Intake / Exhaust Valve and Guide chart* for the service limit.

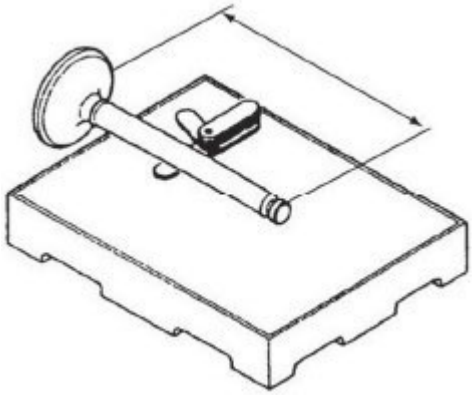


Figure 61. Valve Inspection Block

5. Insert the valves into their original locations and press them down until they are fully seated. Use a depth micrometer (Figure 62) 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.

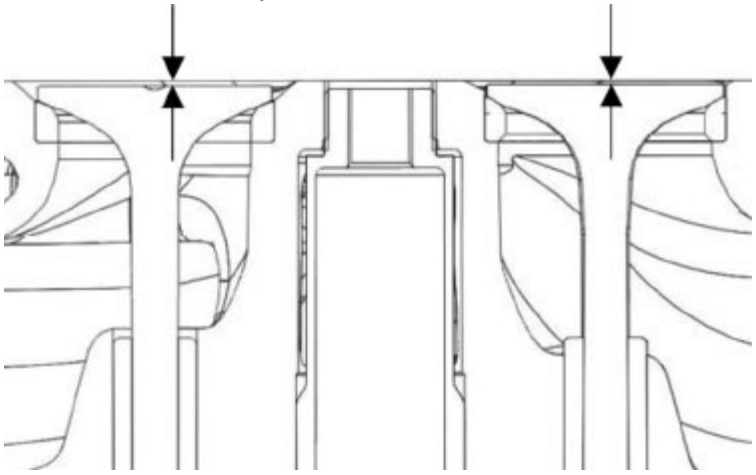


Figure 62. Valve Recession Check

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 63). See *Valve Spring specification chart* for the service limit.

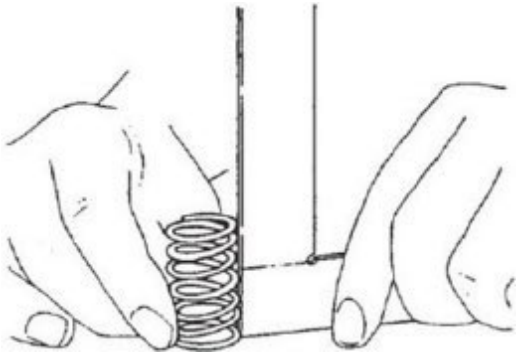


Figure 63. Valve Spring Squareness Measurement

5. Use a caliper to measure the length of the spring (Figure 64). See *Valve Spring Mechanical chart* for the service limit.

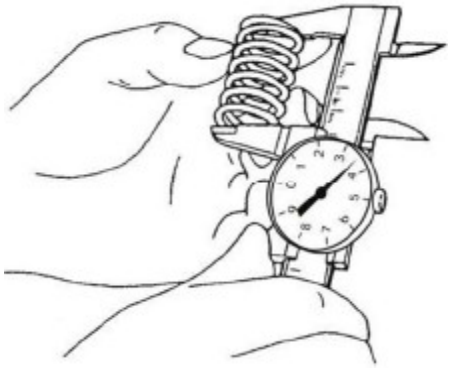


Figure 64. Valve Spring Measurement

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 65, Item 1) must be pre-approved by PSI manufacturing.

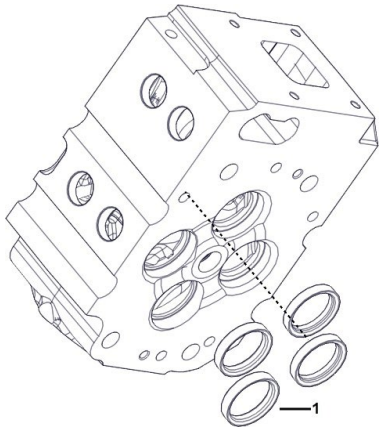


Figure 65. Valve Seat Assembly

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 66, Item 1) in their proper positions.

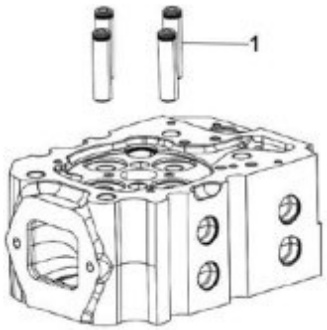


Figure 66. Valve Guide Assembly

NO.	Name
1	Valve Guides

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*.

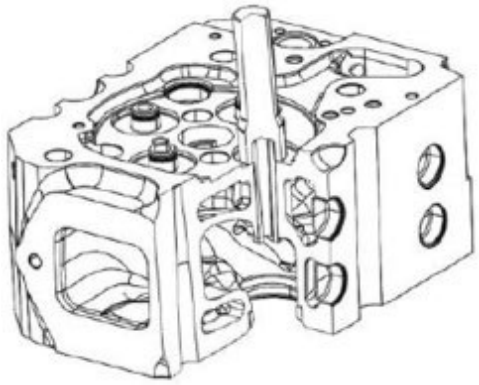


Figure 67. Valve Guide Installation Tool

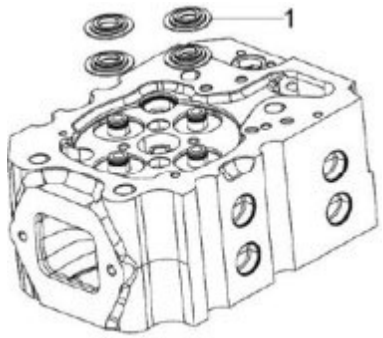
INTAKE AND EXHAUST VALVE INSTALLATION

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.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS chart* for any bolts without a specified torque value.

Engine Model	Marking	
	Intake	Exhaust
53L	Black	Brown

Figure 68. Valve Stem Seal Color Chart



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

Figure 69. Valve Spring Retainer

NO.	Name
1	Valve Spring Bottom Retainer

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

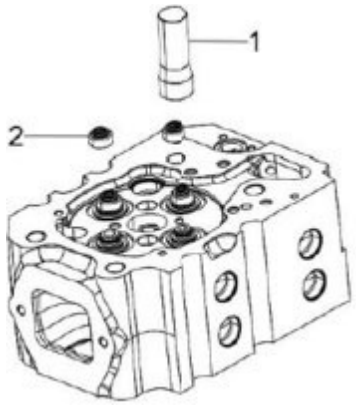


Figure 70. Valve Stem Seal Installation Tool

NO.	Name
1	Valve Stem Installation Tool
2	Valve Seal

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

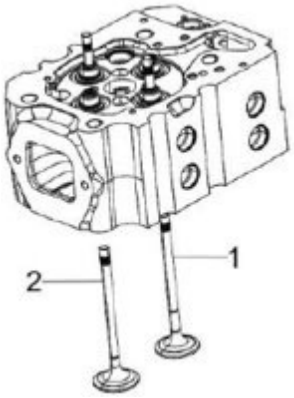


Figure 71. Valve Assembly

NO.	Name
1	Valve
2	Valve

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

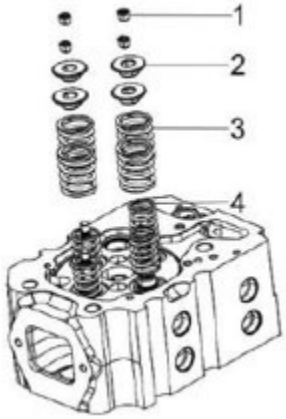


Figure 72. Valve Spring Assembly

NO.	Name
1	Keeper
2	Spring Retainer
3	Valve Spring
4	Valve Spring

6. Compress the valve springs.
7. Insert the valve keepers (Figure 72, Item 1) and slowly release the tension of the valve spring.
8. Repeat the steps on all the remaining cylinder head valves.

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, Item 7) on the cylinder block.
2. Position the cylinder head (Figure 73, Item 6) on the cylinder head gasket.

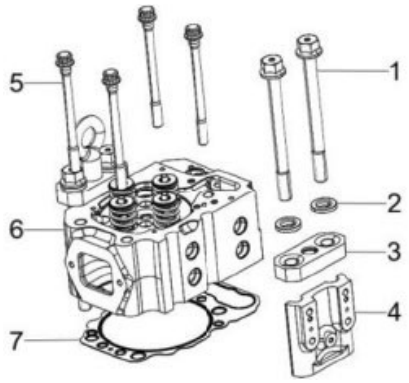


Figure 73. Cylinder Head Assembly

NO.	Name	NO.	Name
1	Bolt	5	Bolt
2	Gasket	6	Cylinder Head
3	Clamping Block	7	Gasket
4	End Plate		

3. Lightly oil the threads and shoulder of the cylinder head main bolts (Figure 73, Item 5) and cylinder head secondary bolts (Figure 73, Item 1). Lightly oil the clamping block (Figure 73, Item 3) and end plate (Figure 73, Item 4) and insert.
4. Repeat steps 1-3 for all remaining cylinder heads.
5. Tighten the main bolts in order (Figure 74) 1 through 32 to a torque of 59 ft/lbs.

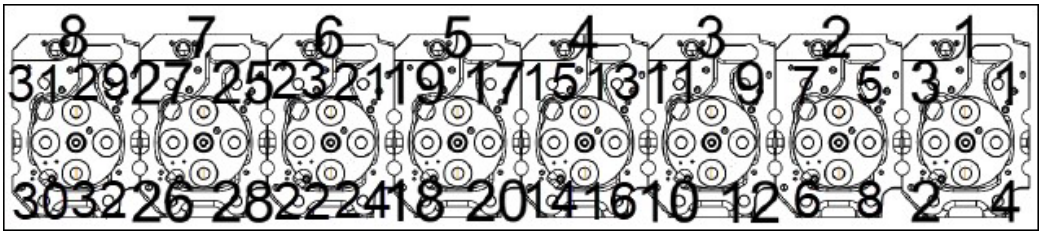


Figure 74. Main Bolt Torquing Order

6. Tighten the secondary bolts in order A through R (Figure 75) to 59 ft/lbs.

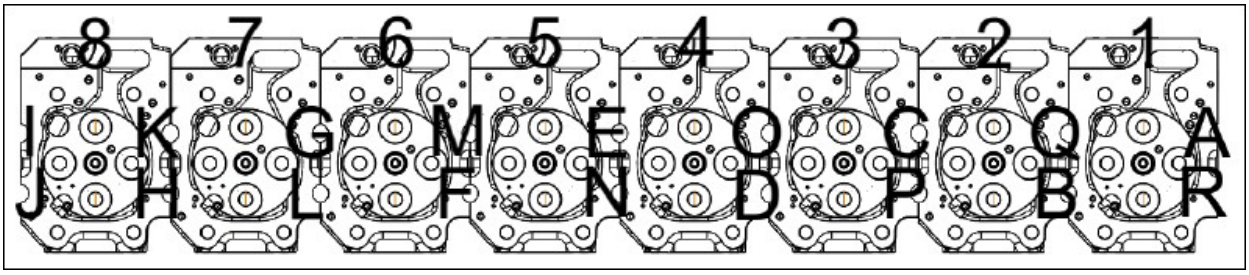


Figure 75. Secondary Bolt Torquing Order

7. Tighten the main bolts in order 1 through 32 to 59±10 ft/lbs, then to an angle of 60±5°
8. Tighten the secondary bolts in order A through R to 59±10 ft/lbs, then to an angle of 60±5°.
9. Tighten the main bolts to an angle of 60±5°.
10. Tighten the secondary bolts to an angle of 60±5°.
11. Tighten the secondary bolts to an angle of 60±5°.
12. Tighten the main bolts to an angle of 45±5°.
13. Reinstall the coolant pipe (Figure 76, Item 1) onto the cylinder head and torque down the two bolts (Figure 76, Item 2).

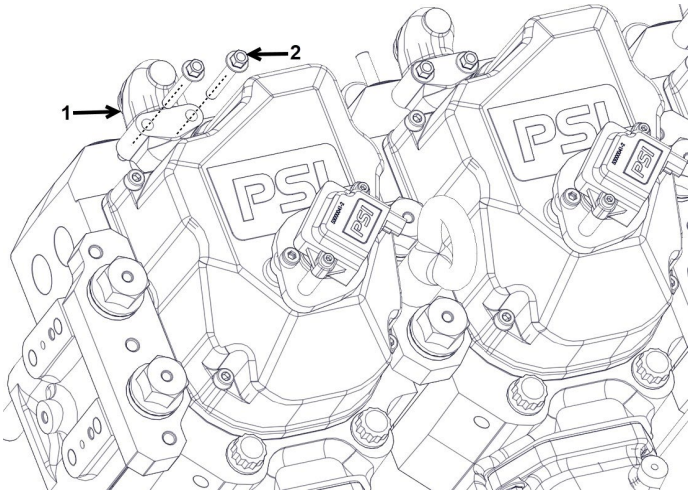


Figure 76.

Note:

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

ROCKER ARM INSTALLATION

Note:

- Ensure the lubrication holes (Figure 77, Item 1) in the rocker arm shaft are oriented correctly with respect to the rocker arms (Figure 77, Item 2).
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS chart* for any bolts without a specified torque value.

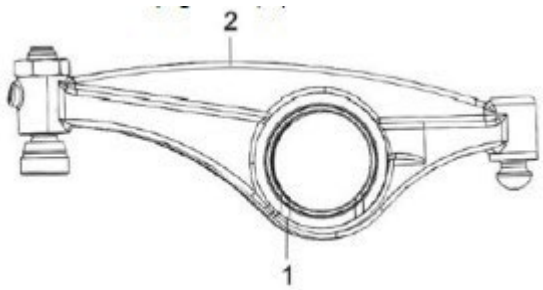


Figure 77. Rocker Arm

1. Lubricate the rocker arm shaft. Slide the rocker arm supports (Figure 78, Item 1), and rocker arms (Figure 78, Items 2 & 5) onto the shaft.

Note:

- Align the hole in the rocker arm shaft (Figure 78, Item 4) and the hole in the rocker arm support (Figure 78, Item 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.

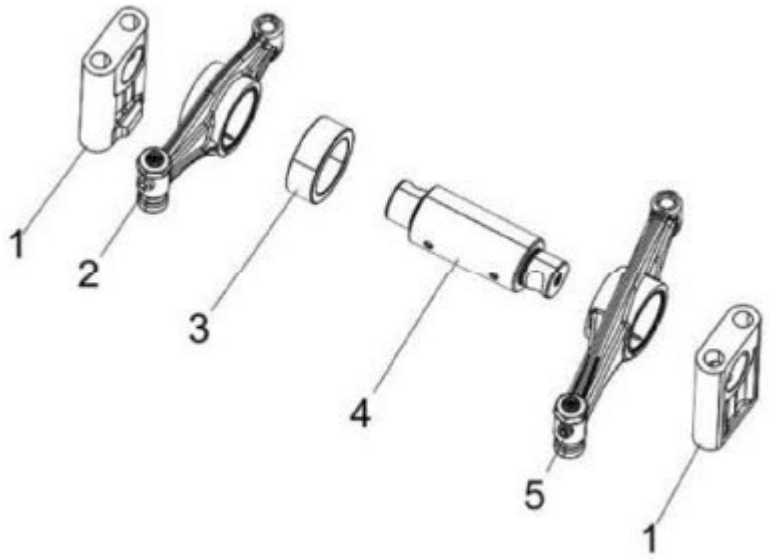


Figure 78. Rocker Arm Assembly

NO.	Name
1	Rocker Arm Support
2	Rocker Arm
3	Sleeve
4	Rocker Arm Shaft
5	Rocker Arm

2. Install the tube clamp with the gasket.
3. Oil and put the valve bridges on the valves.
4. If removed, reinstall the valve adjusting screws (Figure 79, Item 3) and the lock the nuts (Figure 79, Item 1).
5. Place the rocker arm shaft assembly onto the cylinder head.
6. Insert a 0.4~0.6 mm feeler gauge between rocker arm shaft sleeve (Figure 77, Item 3), and intake rocker arms assembly (Figure 77, Item 5). If outside of specifications replace rocker arms.
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*.

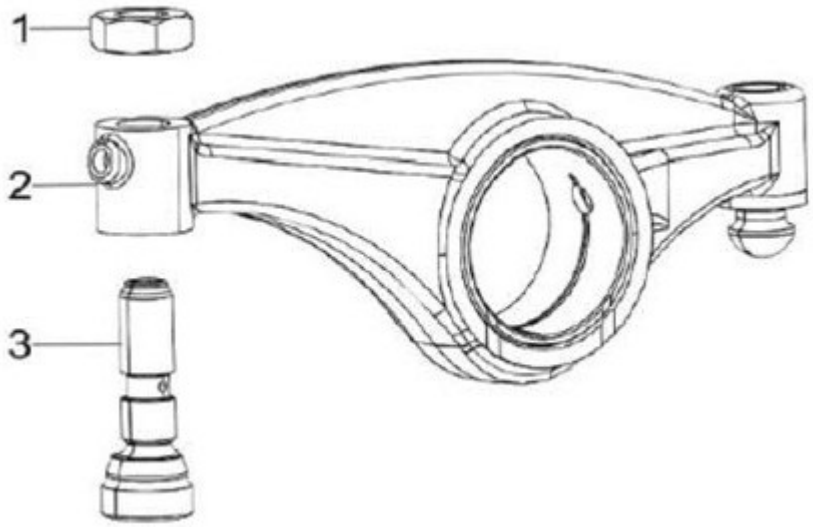


Figure 79. Rocker Arm Assembly

NO.	Name
1	Nut
2	Rocker Arm
3	Screw

TAPPET AND PUSHRODS

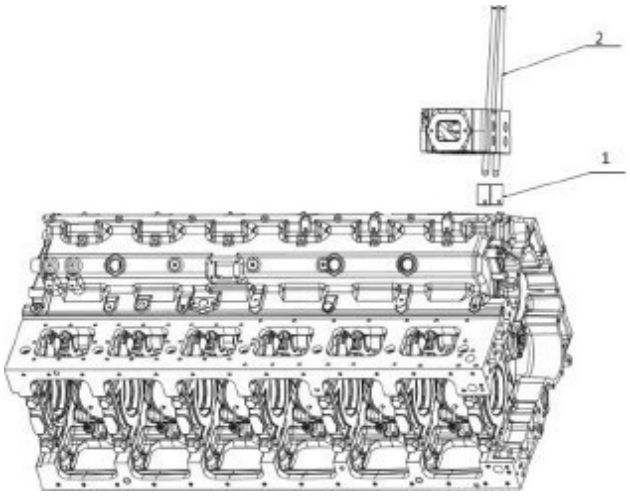


Figure 80. Tappet and Push Rod Assembly

NO.	Name
1	Tappet
2	Push Rod

REMOVAL

1. Once the rocker arm and rocker arm shaft are removed you may remove the push rod.
2. Remove cylinder head in order 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 installing 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. Carefully put the pushrod through the cylinder head and into the tappet socket end.

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 81). Remove all twelve valve covers from the engine.

Figure 81.

2. Rotate the engine until it is at TDC #1.
3. Check the rockers when cylinder 1 is at TDC (Left side of the engine closest to the rear (Flywheel) end of the engine). If cylinder 1 is at TDC the valves shown below in blue can be adjusted. If cylinder 11 is at TDC the valves shown below in red can be adjusted. (Refer to Figure 82)

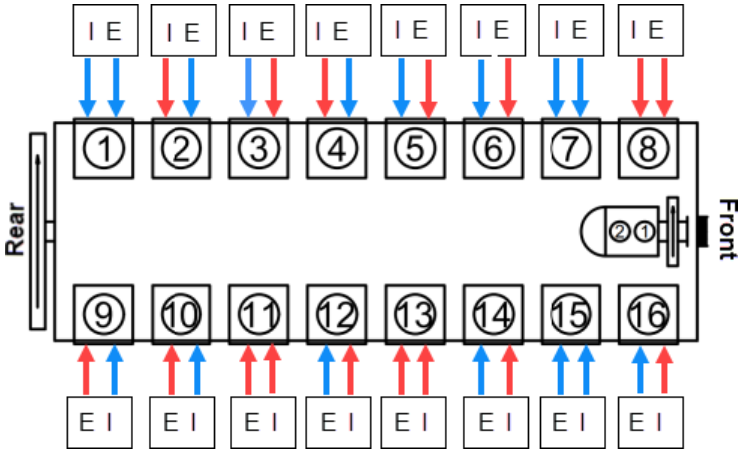


Figure 82.

4. Use a feeler gauge to check the clearance between the rocker arm and the valve bridge (Figure 83). Lash should be set to .022” (0.55 mm) for the intake and 0.039” (1.00 mm) for the exhaust. Repeat on all other valves with arrows of the same color as shown below.

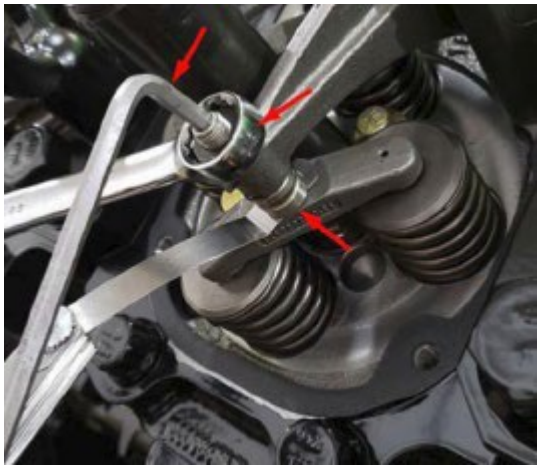


Figure 83.

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.

THROTTLE BODY

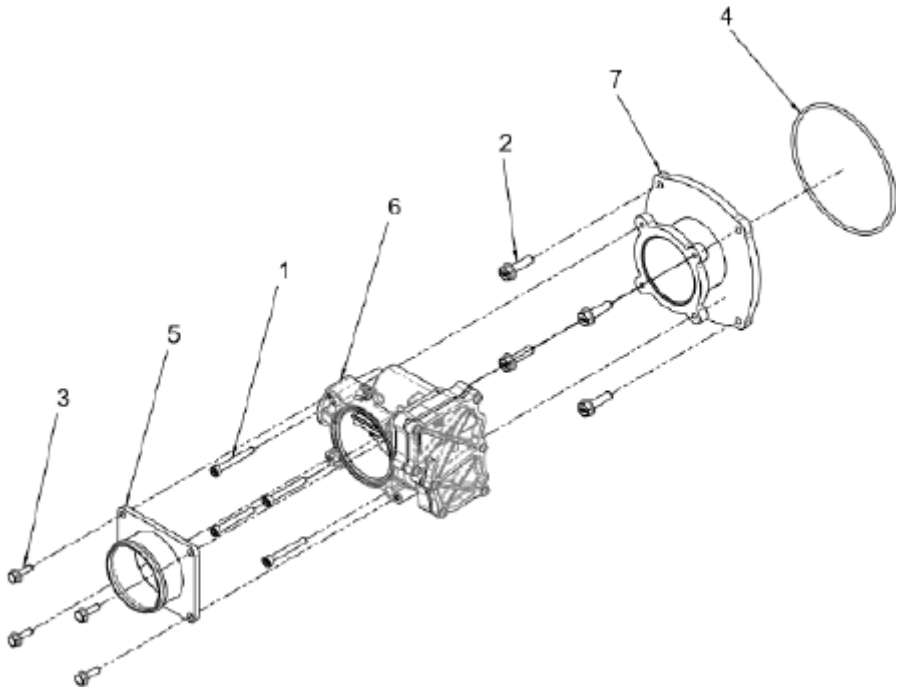


Figure 84. Throttle Body Assembly

NO.	Name
1	Bolt
2	Bolt
3	Bolt
4	O-Ring
5	Throttle Adapter
6	Throttle Body
7	Throttle Adapter

Note:

- All 53L engines are equipped with two throttle bodies, one on the end of each intake manifold.

REMOVAL

1. Remove the four flange bolts (Figure 84, Item 3).
2. Remove the throttle inlet adapter (Figure 84, Item 5).
3. Remove the four bolts (Figure 84, Item 1) from the throttle body (Figure 84, Item 6).
4. Carefully remove the throttle body (Figure 84, Item 6).
5. Remove the four throttle body adapter bolts (Figure 84, Item 2).
6. Remove the throttle body adapter (Figure 84, Item,7) and gasket (Figure 84, Item 4).

INSTALLATION

7. Clean any debris from the end of the intake manifold.
8. Clean the throttle body adapter from any debris and place the throttle adapter gasket (Figure 84, Item 4) onto the throttle body adapter (Figure 84, Item 7).
9. Place both the throttle body adapter and gasket onto the end of the intake manifold.
10. Insert and torque down the four throttle body adapter bolts (Figure 84, Item 2) to 22 ft/lbs.
11. Carefully install the throttle body (Figure 84, Item 6) onto the throttle body adapter (Figure 84, Item 7).
12. Apply PSI approved 242 Loctite to all four throttle body bolts (Figure 84, Item 1).
13. Insert and torque down the four throttle body bolts to 11 ft/lbs.
14. Place the throttle body inlet adapter (Figure 84, Item 5) onto the throttle body (Figure 84, Item 6).
15. Insert and torque down the four-throttle body inlet adapter bolts (Figure 84, Item 3) to 10 ft/lbs.

CYLINDER HEAD OIL PIPE

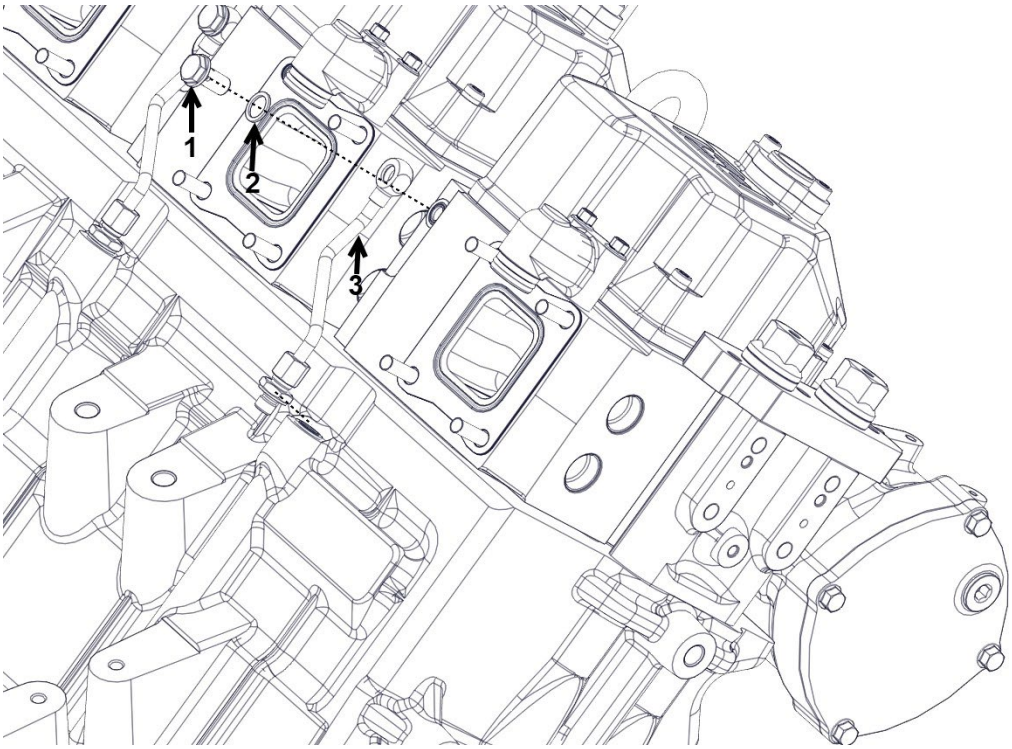


Figure 85. Cylinder Head Oil Pipe Assembly

NO.	Name
1	Bolt
2	Washer
3	Oil Pipe

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Loosen and remove the bolt and washer (Figure 85, Item 1 & 2).
2. Remove the oil pipe (Figure 85, Item 3)
3. Repeat steps 1-3 for all other cylinder head oil pipes.

INSTALLATION

1. Clean any debris on the port on the cylinder head and on the cylinder block.
2. Insert the oil pipe (Figure 85, Item 3).
3. Torque down the banjo bolt and washer to 15 ft/lb (Figure 85, Item 1 & 2).
4. Repeat steps 1-3 for all other cylinder head oil pipes.

TIMING GEARS

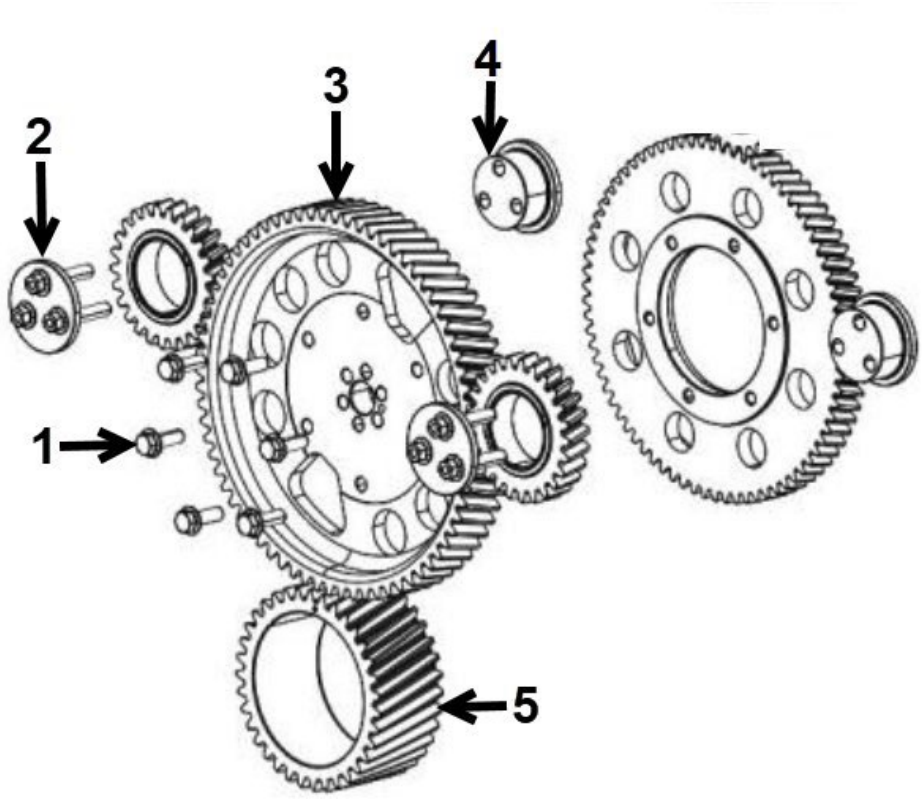


Figure 86. Timing Gears

NO.	Name
1	Bolt
2	Baffle
3	Camshaft Gear
4	Gear Shaft
5	Crankshaft Gear

Note:

- Refer to the INSTALLATION OF TIMING GEARS section of the manual for timing verification.

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 with a dial indicator.

CRANKSHAFT AND CAMSHAFT REMOVAL, CLEANING, INSPECTION, AND INSTALLATION

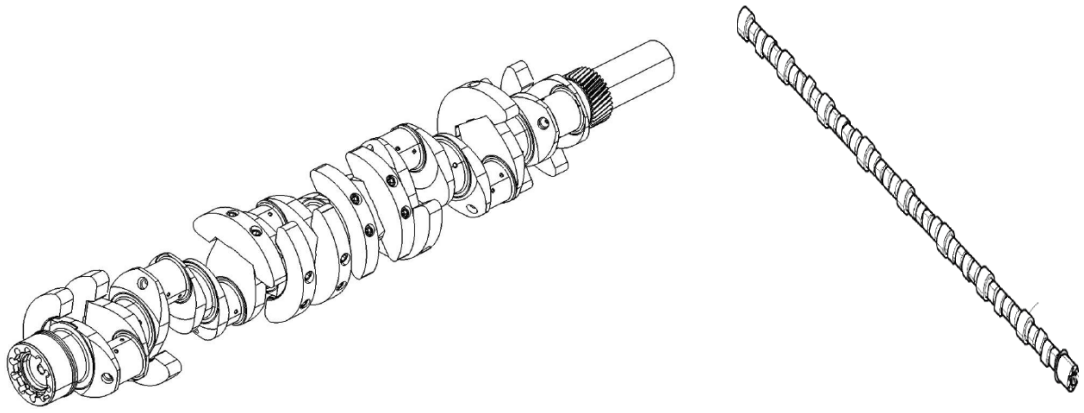


Figure 87. Crankshaft and Camshaft Assembly

Note:

- 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.
- 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. 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 to prevent injury or damage to parts due to engine falling during repairs.

6. Clean the engine by washing with solvent, air, or steam cleaning. Carefully operate 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 heads and related components.
9. Remove the starter motor.

DISASSEMBLY OF CAMSHAFT AND TIMING COMPONENTS

Note:

- Discard all gaskets, O-rings, and seals. Use new gaskets, O-rings, and seals on reassembly of the camshaft and timing components.
- Use care not to damage the threads in the end of the crankshaft when removing the crankshaft pulley.

1. Remove the thermostat assembly. (Refer to WATER CROSSOVER PIPE AND THERMOSTAT).
2. Remove the fan bracket assembly.
3. Remove the tensioner and belt assembly.
4. Remove the crankshaft pulley assembly.
5. Disconnect the connecting wiring harness of speed sensor (If necessary).
6. Remove the speed sensor (If necessary).
7. Remove the bolts that retain the gear case cover to the cylinder block and oil pan.
8. Remove the front cover.
9. Remove the rocker arm system and push rods.
10. Remove the cylinder heads.
11. Remove the tappets.

CHECKING TIMING GEAR BACKLASH

Prior to removing the timing gear, measure the backlash and determine the gear wear. Measure the backlash at four points at 90° to each pinion as well as the axial play of the camshaft with a dial indicator. See Timing Gear Backlash on specifications of service limits.

Note:

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

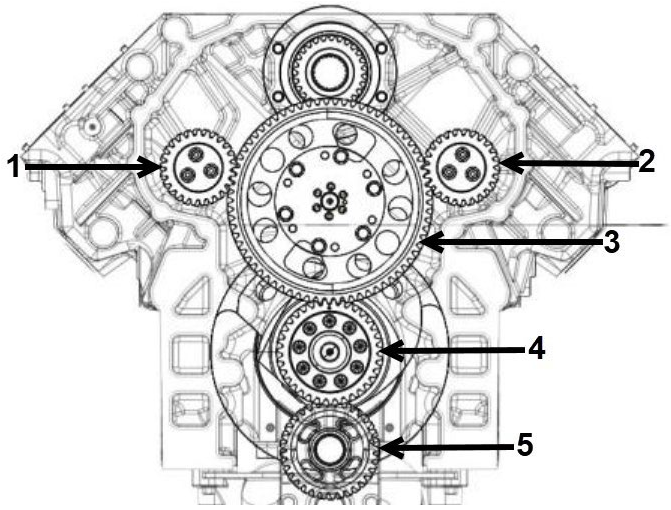


Figure 88.

NO.	Name
1	Water Pump Drive Gear
2	Water Pump Drive Gear
3	Camshaft Drive Gear
4	Crankshaft Drive Gear
5	Oil pump Drive Gear

MEASURING CAMSHAFT GEAR-TO-CRANKSHAFT GEAR BACKLASH

1. Install a dial indicator as shown in figure 1.
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.

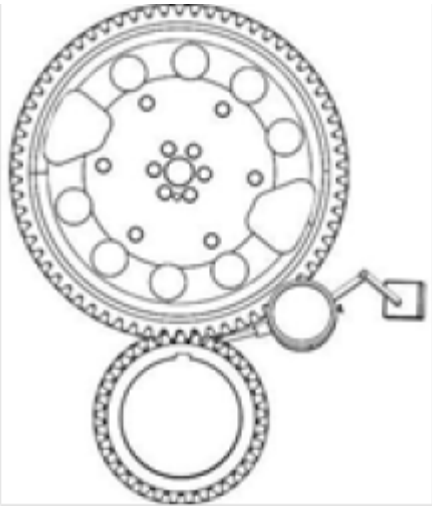


Figure 89.

REMOVAL OF CAMSHAFT

Note:

- Before removing the camshaft, check the camshaft end play.
- 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.
- Ensure to rotate the crankshaft to enable cylinder 1 is at TDC.

1. Install a dial indicator (Figure 90, item 1) on the cylinder block. Move the camshaft (Figure 90, item 2) back and forth to measure the end play. Record the measurement. See Camshaft specifications for the service limit.

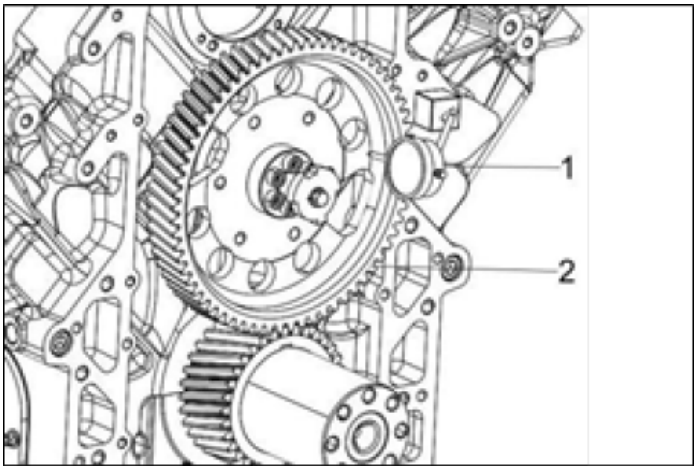


Figure 90.

NO.	Name
1	Dial Indicator
2	Camshaft

2. Loosen the tightening bolt (Figure 91, Item 5) and remove the trigger wheel (Figure 91, Item 4).
3. Remove the bolts (Figure 91, Item 3) from the connecting shaft (Figure 91, Item 2) of the trigger wheel. Remove the connecting shaft, and camshaft gear (Figure 91, Item 1).

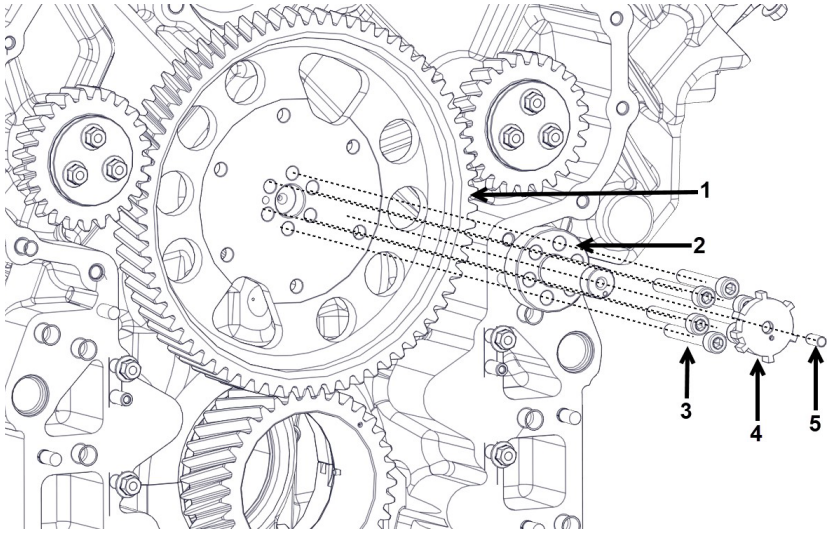


Figure 91.

NO.	Name
1	Camshaft Gear
2	Connecting Shaft
3	Bolt
4	Trigger Wheel
5	Bolt

4. Before removing the camshaft, take out the tappet first.
5. Remove the three bolts retaining the camshaft thrust bearing (use special tool 1002636760).
6. Slowly pull the camshaft assembly out of the engine being careful not to damage the camshaft bushings.

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.
- 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.
- The connecting rod, cap and piston are stamped with the number of the corresponding cylinder.

1. Remove the oil cooler assembly.
2. Remove the water inlet assembly.
3. Remove the oil filter assembly.
4. Remove the cylinder heads.
5. Remove the oil filling pipe.
6. Remove the oil dipstick and dipstick upper pipe.
7. Remove the breather (If Necessary).
8. Remove the Inspection doors.
9. Bar over 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.
10. Remove the connecting rod cap with the lower half bearing.
11. Mark the connecting rod caps and connecting rods so the caps and connecting rods stay together.

Note:

- Do not allow the connecting rod to contract the crankshaft journal during piston removal.

12. Use a wooden dowel against the connecting rod and tap the piston / connecting rod assembly out of the cylinder.
13. Mark the cylinder number on the piston and connecting rod.
14. Remove the connecting rod bearings (Figure 92, Item 9).
15. Remove the compression rings (Figure 92, Item 1) from the piston using a piston ring expander.
16. Remove the oil ring (Figure 92, Item 2) from the piston using a piston ring expander.
17. Remove the circlips (Figure 92, Item 4) from the piston pin.

18. Remove the piston pin (Figure 92, Item 5) and connecting rod (Figure 92, Item 6) from the piston (Figure 92, Item 3).
19. Repeat the steps until all pistons are removed and dissembled.

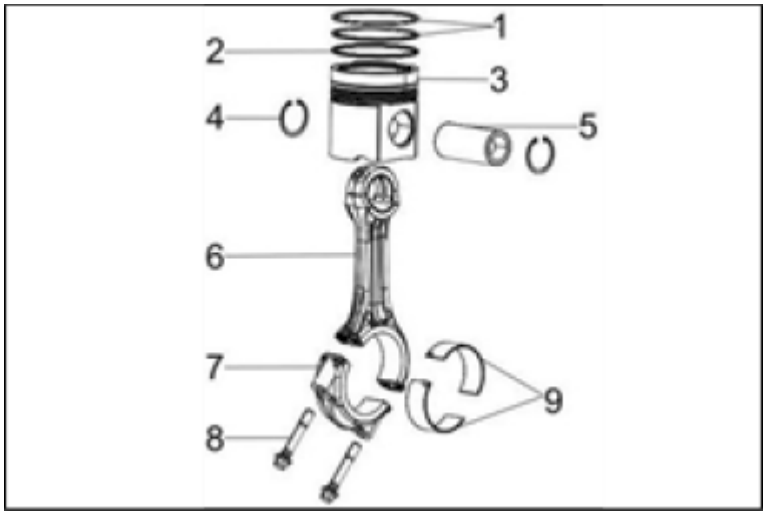


Figure 92.

NO.	Name	NO.	Name	NO.	Name
1	Compression Ring	4	Circlip	7	Connecting Rod Cap
2	Oil Ring	5	Piston Pin	8	Connecting Rod Bolt
3	Piston	6	Connecting Rod	9	Connecting Rod Bearing

REMOVAL OF CYLINDER LINER

Note:

- Take care not to damage the piston jet when removing and installing the mobile coupling to the cylinder block.
- Remove the carboned cord at the top of the liner before removal.
- Removal of the inspection door may be necessary when removing the liner.
- With the liner in place check the upper, middle, and lower working areas for any burnishing (Figure 93).

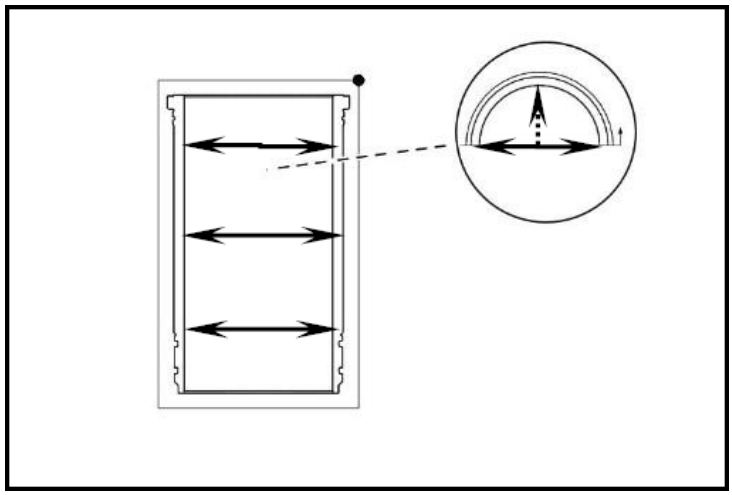


Figure 93.

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 94).
3. Slowly turn the nut and remove the cylinder liner and tool together.

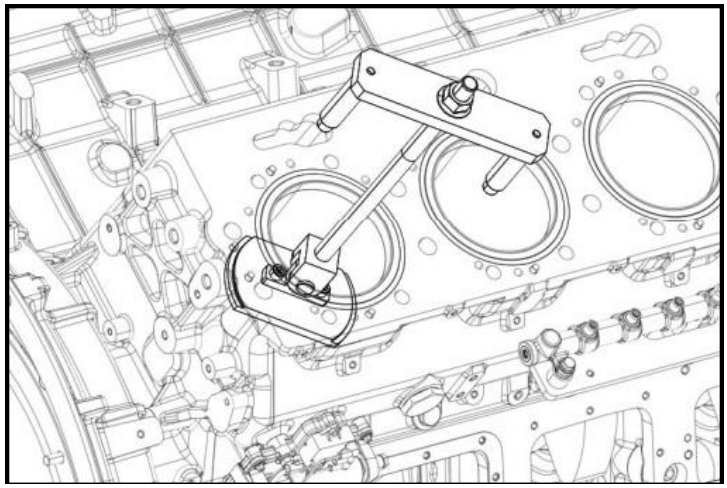


Figure 94.

4. Disassemble the O-rings from the cylinder liner (Figure 95).
5. Repeat the steps until all liners are removed.
6. Clean the inside of the oil sump. Remove the protection cloths.

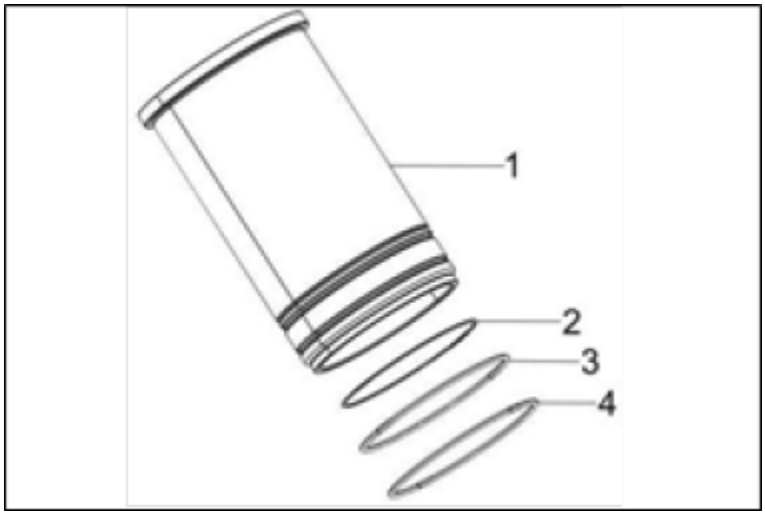


Figure 95.

NO.	Name	NO.	Name
1	Cylinder Liner	3	Oil Ring
2	Oil Ring	4	Oil Ring

REMOVAL OF OIL PAN

Note:

- Replace all O-rings if removed.
- Oil pan weighs 577 lb. use suitable lifting means when removing oil pan.
- Considerable force may be needed to separate the oil pan from the bottom of the block.

1. Remove the Oil dipstick.
2. Remove the CCV hose (If not already removed) from the right-hand side of the oil pan.
3. With a crane or any hosting assistance, remove the nine bolts from the front top.
4. of the oil pan and the thirty-eight bolts from the bottom of the oil pan.

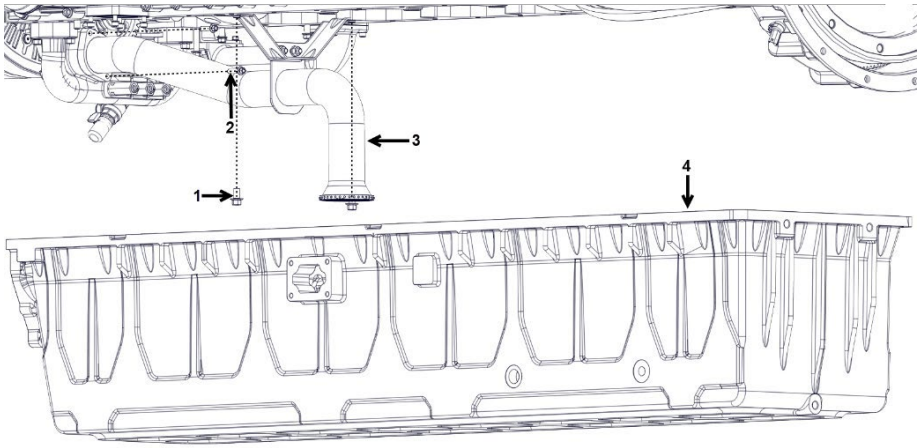


Figure 96. Oil Pan Assembly

NO.	Name	NO.	Name
1	Bolt	3	Oil Strainer
2	Bolt	4	Oil Pan

5. Remove the silicone from the bottom of the cylinder block and or the top of the oil pan.
6. Remove both bolts (Figure 96, Items 1 & 2) from the oil strainer (Figure 96, Item 3).
7. Carefully remove the oil strainer (Figure 96, Item 3)

REMOVAL OF FLYWHEEL

Note:

- Use caution when removing the flywheel. Flywheel weighs 180 lbs (81.67 kg).

1. Remove the starter assembly.
2. Remove the two diametrically opposed bolts from the engine flywheel.
3. Fit the flywheel guides (Figure 97, Item 1) into the opposed flywheel bolt holes.

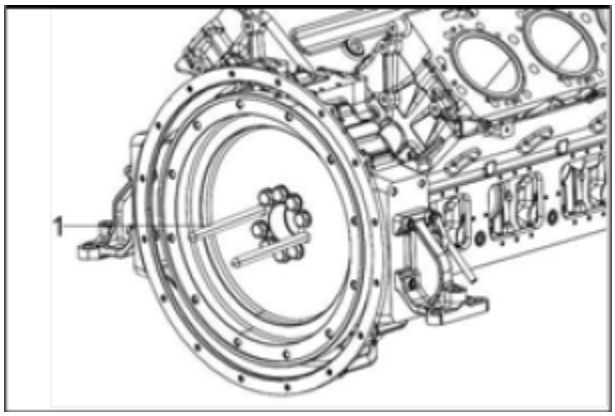


Figure 97.

NO.	Name
1	Flywheel Guides

4. Remove the remaining eight bolts from the flywheel.
5. Remove the flywheel from the crankshaft.
6. Disassemble the flywheel gear ring from flywheel if necessary.

REMOVAL OF CRANKSHAFT POSITION SENSOR

1. Remove bolt (Figure 98, Item 3) from flywheel housing.
2. Remove crankshaft sensor (Figure 98, Item 2) from flywheel housing.
3. Remove shim(s) (Figure 98, Item 1) from flywheel housing.

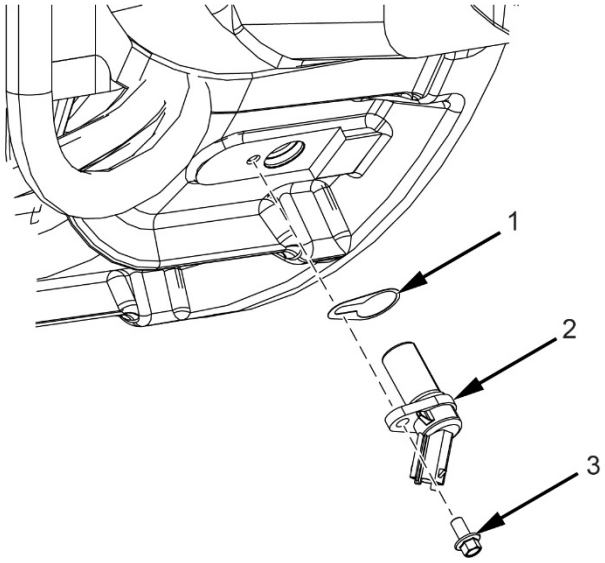


Figure 98.

NO.	Name
1	Shim
2	Crankshaft Sensor
3	Bolt

REMOVAL OF FLYWHEEL HOUSING

Note:

- Use caution when removing the flywheel housing. Flywheel housing weighs 280 lbs (126.6 kg).

1. Secure and support the engine block if not already supported.
2. Remove the engine support brackets.
3. Loosen and remove the flywheel housing bolts (Figure 99, Item 1).

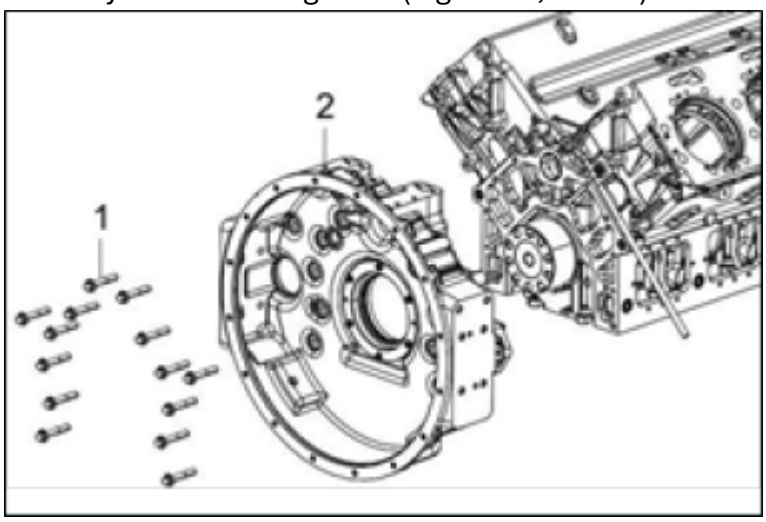


Figure 99.

NO.	Name
1	Flywheel Housing Bolts
2	Flywheel Housing

4. Remove the flywheel housing (Figure 99, Item 2).
5. Remove the Rear oil seal (Figure 100 Item 2) from the rear oil seal seat (Figure 100, Item 3).

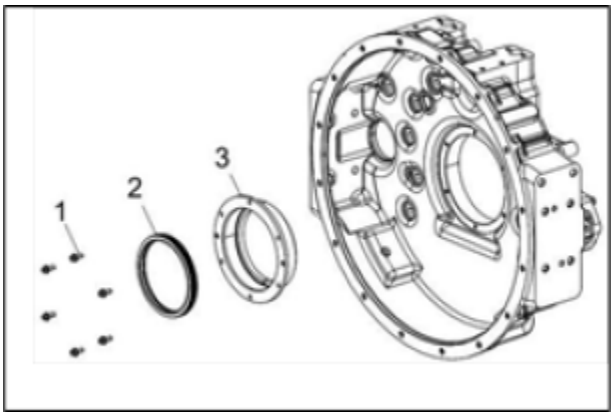


Figure 100.

NO.	Name
1	Bolt
2	Rear Oil Seal
3	Rear Oil Seal Seat

MEASURING CRANKSHAFT END PLAY

Before removing the main bearing caps, measure the crankshaft end play by using either of the below methods:

METHOD A: Install a dial gauge (Figure 101, Item 1) on the cylinder block. Move the crankshaft (Figure 101, Item 2) front to rear to measure the end play. Record the measurement.

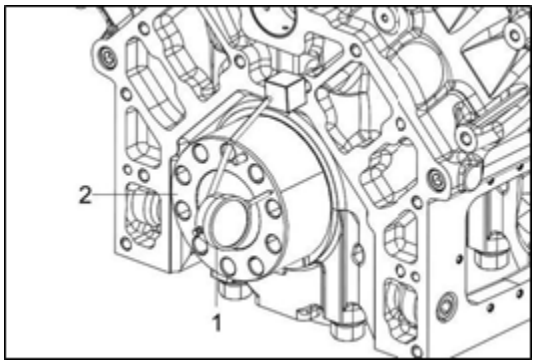


Figure 101.

NO.	Name
1	Dial Gauge
2	Crankshaft

METHOD B: Use a feeler gauge to measure the clearance (Figure 102, item 3) between the thrust bearing (Figure 102, item 1) and crankshaft (Figure 102, item 2). Record the measurement. See *Thrust Bearing specifications* for the service limit.

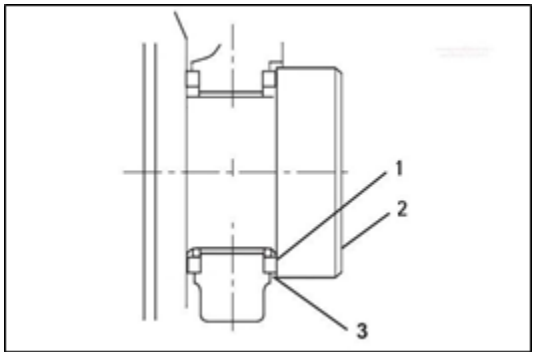


Figure 102.

REMOVAL OF CRANKSHAFT

Note:

- Do not remove the crankshaft gear unless the gear or crankshaft is damaged and requires replacement or unless specified by PSI.

1. Loosen and remove the main bearing cap auxiliary bolts (Figure 103, Item 1) and washers (Figure 103, Item 2).

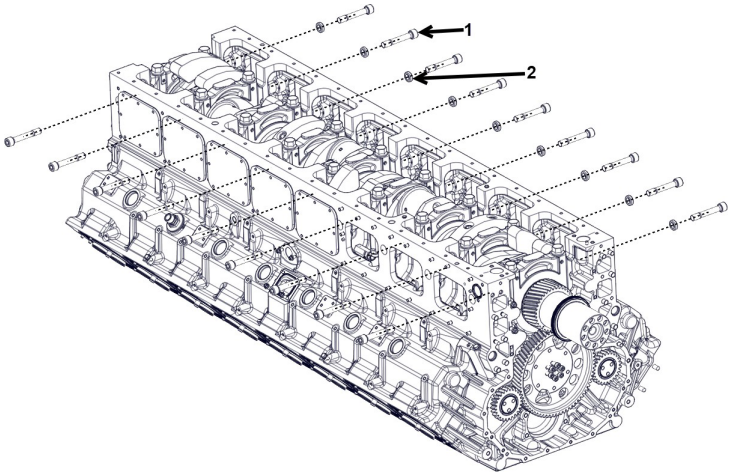


Figure 103.

NO.	Name
1	Bolt
2	Washer

2. Loosen and remove the main bearing cap bolts (Figure 104, Item 2).
3. Remove the main bearing caps (Figure 104, Item 3). 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**.
4. Remove the lower main bearings (Figure 104, Item 4) and thrust plates (Figure 104, Item 1).

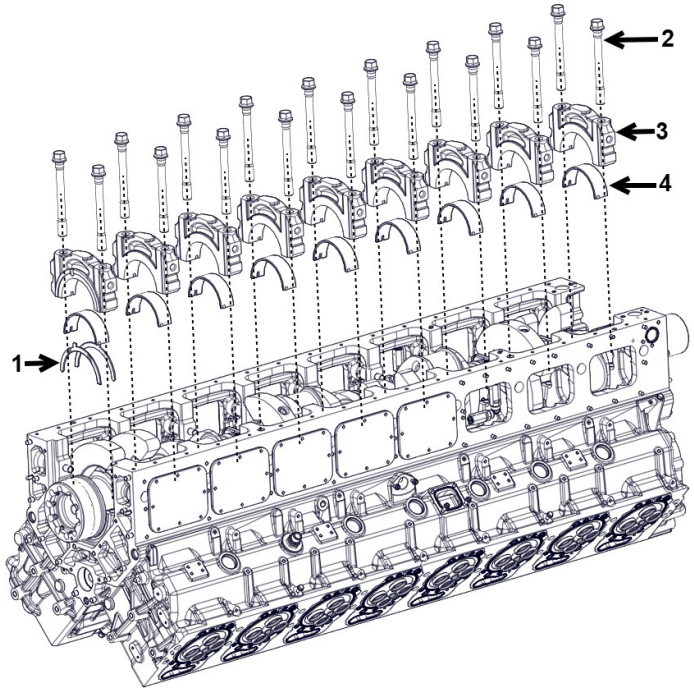


Figure 104.

NO.	Name
1	Lower Thrust Plates
2	Bolt
3	Main Bearing Cap
4	Lower Main Bearing

5. With proper hoisting assistance carefully remove the crankshaft (Figure 105, Item 2) from the engine.
6. Remove the upper bearings (Figure 105, Item 1) and the upper thrust plates (Figure 105, Item 3).

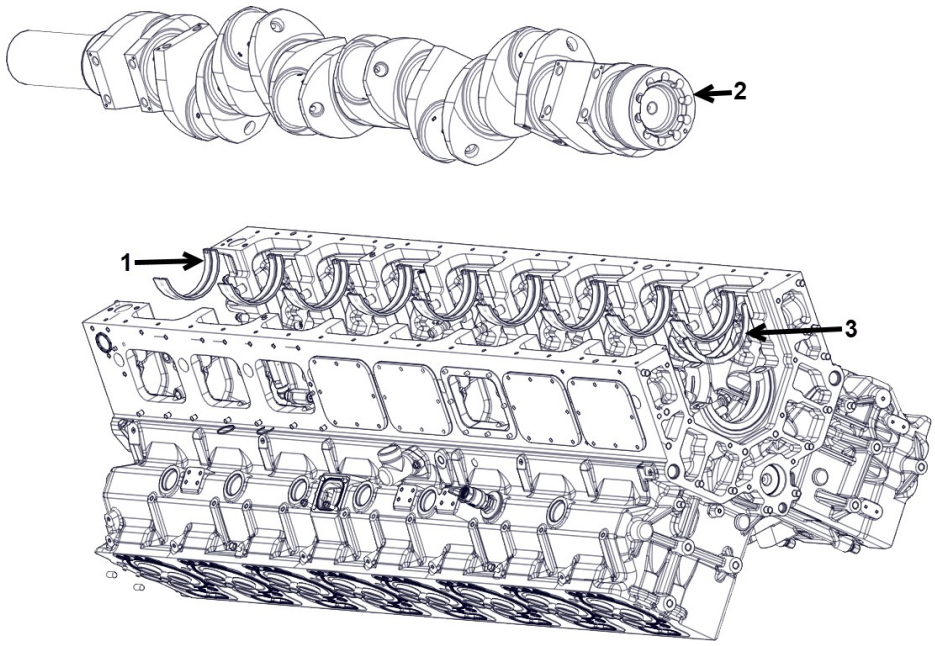


Figure 105.

NO.	Name
1	Upper Main Bearing
2	Crankshaft
3	Upper Thrust Plates

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.

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.
3. Take measurements at three places (Figure 106) (a, b, c), and in two directions (d and e) in each cylinder liner.

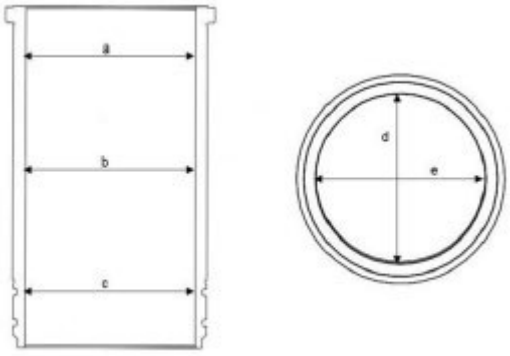


Figure 106.

INSPECTION OF PISTONS, RINGS AND PISTON PIN

Note:

- On an engine with low hours, the pistons and 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 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 107). Measurements must be taken at a specified distance (Figure 107, Item 1) from the bottom of the piston. Record measurements. See *Mechanical Specifications Chart*.

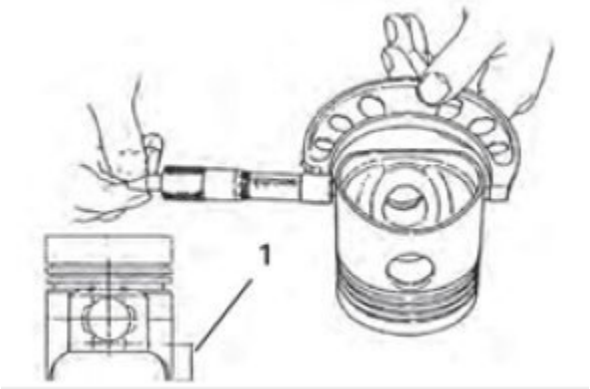


Figure 107.

5. Subtract the piston measurement from the greatest measurement acquired during cylinder inspection to obtain piston-to-cylinder clearance. Record the Measurement. Measure the diameter of the piston pin bore on both sides of the piston (Figure 108). See the *Mechanical Specifications Chart*. Record the measurements.

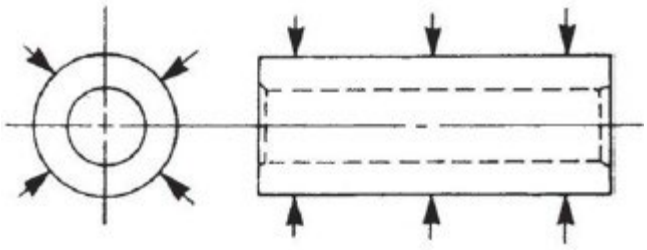


Figure 108.

6. Measure the outside diameter of the piston pin in three places and at 90° (Figure 109). See the *Mechanical Specifications Chart*. Record the measurements.

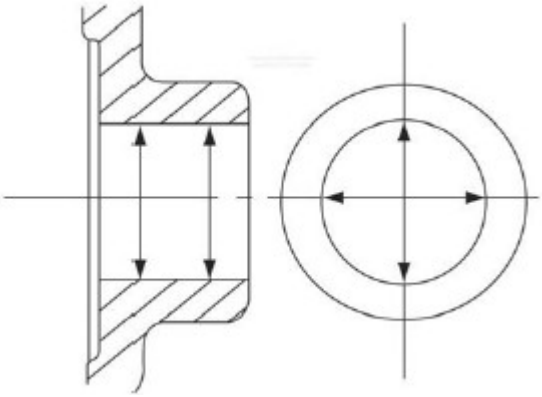


Figure 109.

7. Use a micrometer, measure the thickness of each piston ring. See the piston *Mechanical Specifications Chart*. Record the measurements.

8. Place each compression piston ring in the groove as shown (Figure 110). 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.

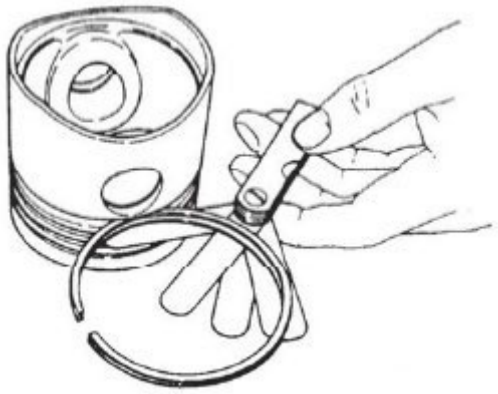


Figure 110.

9. To measure piston ring end gap, insert each compression piston ring (Figure 111, Item 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 111, Item 2) from the bottom of the bore. Remove the piston. Measure the end gap (Figure 111, Item 3) of each piston ring. Record the measurements. See *Piston Ring Mechanical Specifications Chart*.

Note:

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

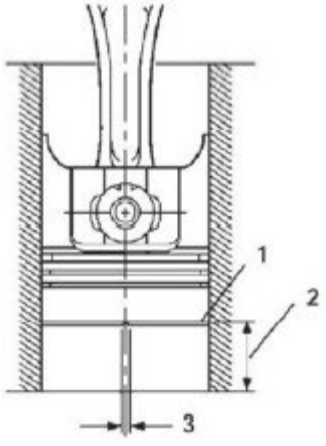


Figure 111.

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 112, Item 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 112, Item 2). See *Connecting Rod Mechanical Specifications Chart*.

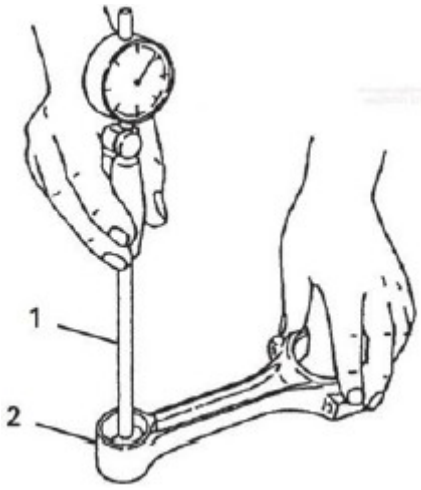


Figure 112.

NO.	Name
1	Bore Gauge
2	Connecting Rod

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 the *Crankshaft Mechanical Specification Chart*.

INSPECTION OF TAPPETS

1. Inspect the tappet contact surfaces for abnormal wear (Figure 113, Item 1).
2. Measure the outside diameter of the tappet stem (Figure 113, Item 2). See the *Mechanical Specifications chart* for the service limit.

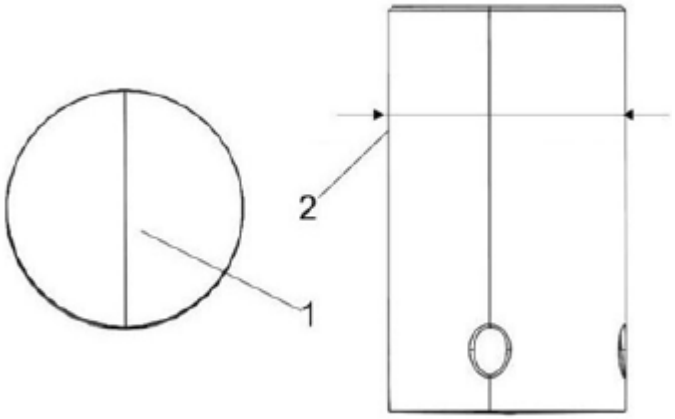


Figure 113.

3. Check the oil passage of the tappet for blockage.

INSPECTION OF CRANKSHAFT

Note:

- It is recommended that you have a specialized workshop to carry out a Magnaflux inspection of the crankshaft to ensure there are no metallurgical defects.
- If a defect is detected, it is imperative that the crankshaft be replaced.
- If a dynamic balancing test is performed, all counterweights must be fitted onto the crankshaft.

1. Place the crankshaft end journals (Figure 114, Item 4) on V-blocks.
2. Place a dial indicator (Figure 114, Item 3) on a center main bearing surface.

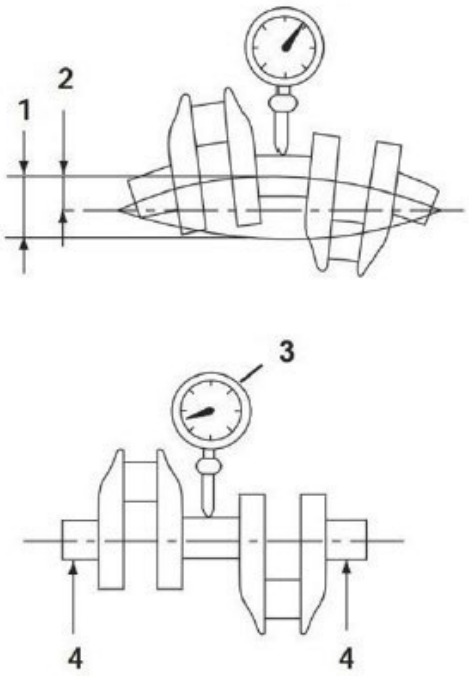


Figure 114.

NO.	Name	NO.	Name
1	Runout Measurement	3	Dial Indicator
2	Runout Measurement	4	End Journal

3. Rotate the crankshaft and observe runout. See *Crankshaft Mechanical Specifications Chart*.

4. Use a Magnaflux® to inspect the crankshaft for cracks. Replace the crankshaft if fractures are found. Measure the outside diameter of each crankpin (Figure 115, Item 2) and main bearing journal (Figure 115, Item 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.

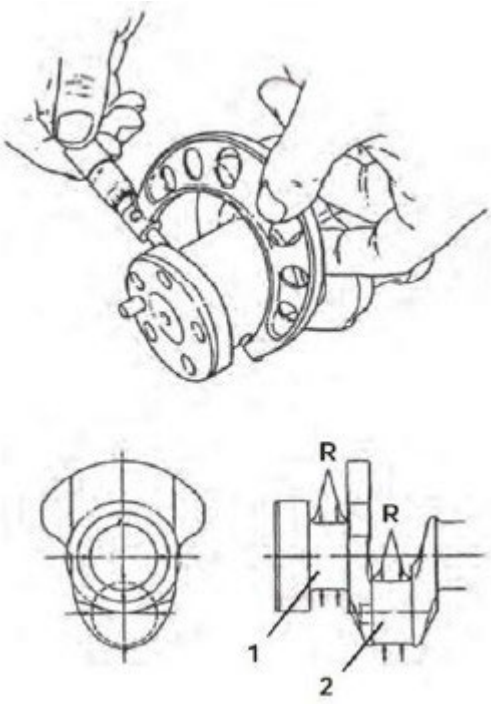


Figure 115.

INSPECTION OF CAMSHAFT

1. Use V-blocks and a dial indicator to check camshaft bend (Figure 116). Place the indicator on the center bearing journal.

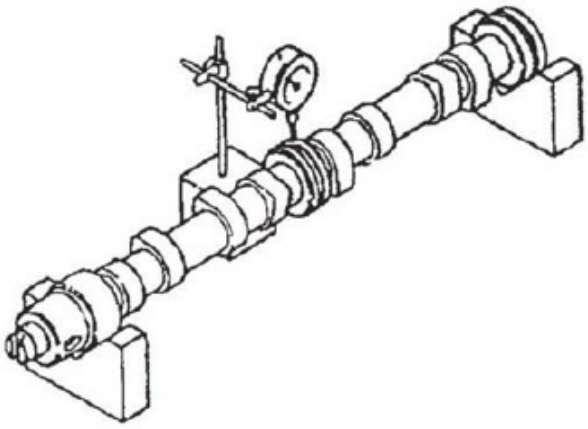


Figure 116.

2. Rotate the camshaft and observe the runout. See the *Camshaft Specifications Chart*.
3. Measure the height of each lobe (Figure 117, Item 1). See the *Camshaft Specifications Chart*.

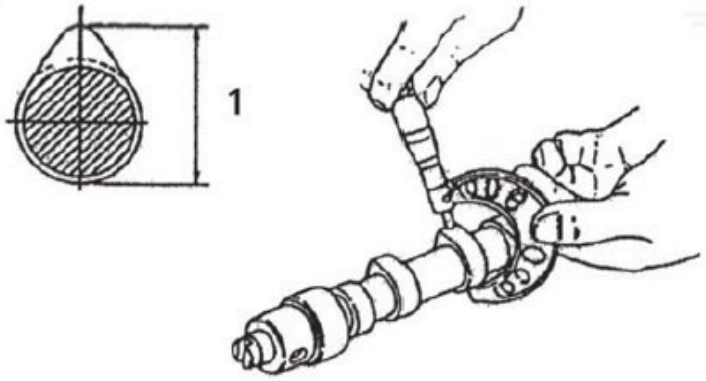


Figure 117.

4. Measure the diameter of the gear end, intermediate, and flywheel end bearing journals. See the Camshaft Specifications Chart.
5. Measure the I.D. of the front bushing and the remaining bores in the cylinder block. See the Camshaft Specifications Chart.
6. 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.

INSTALLATION OF CYLINDER LINER

Note:

- Proceed slowly. Make no forced assemblies unless a pressing operation is called for. All parts must be perfectly clean and lightly lubricated when assembled.
- 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.
- The O-rings can be used only once.

1. Equip the liner with new seals (Figure 118) coated with grease or clean oil.

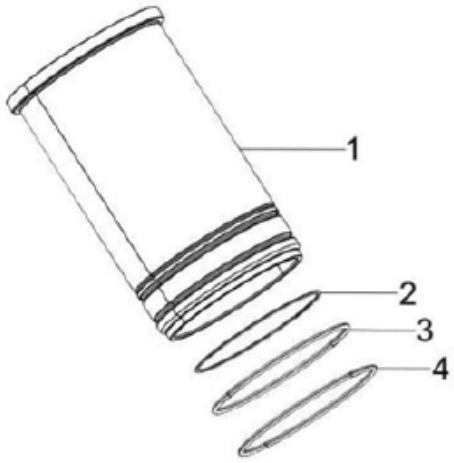


Figure 118.

NO.	Name	NO.	Name
1	Cylinder Liner	3	Oil Ring
2	Oil Ring	4	Oil Ring

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 119, Item 1) on the engine block and nest the liner (Figure 119, Item 2) using the special tool.
6. Install 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.

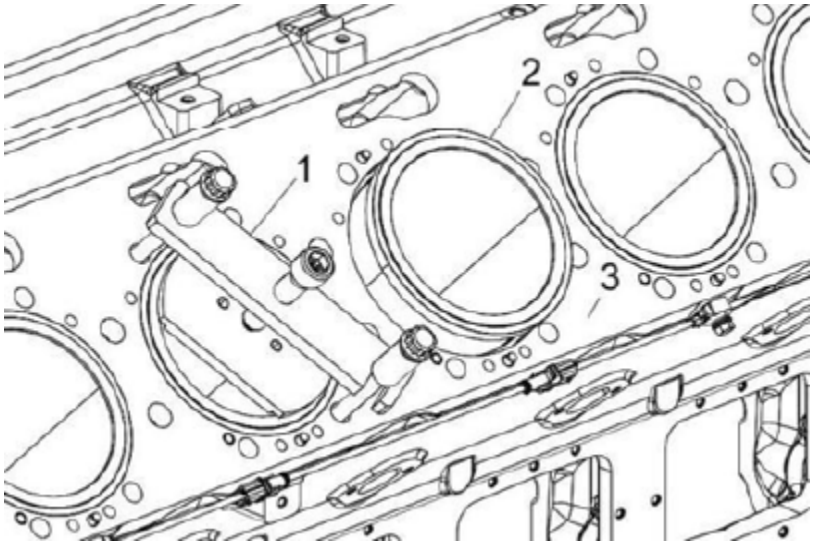


Figure 119.

NO.	Name
1	Cylinder Liner Installer
2	Liner
3	Cylinder Block

REASSEMBLY OF PISTONS

Note:

- The rings must always be replaced when installing new liners.
- The gaps of the inner spring and external ring of the scraper are diametrically opposed.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

1. Select the parts needed to reassemble the piston and connecting rod for one cylinder.
2. Carefully clean the ring grooves of the piston (Figure 120, Item 3). Fit the piston rings (Figure 120, Items 1 & 2) with the special tool.
3. After fitting the rings, check the rings move easily and do not catch on the grooves. Make sure the marking faces to 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 "TOP" must face the top of the piston.
- **3rd groove**: Scraper ring – No marking. Does not matter which way it is fitted.

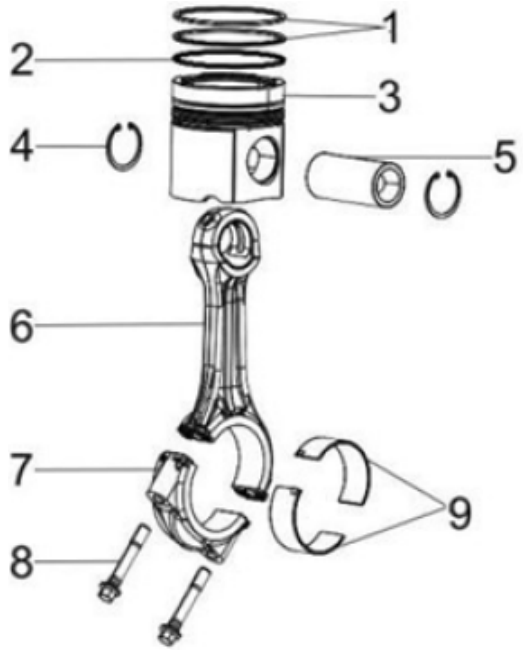


Figure 120.

NO.	Name	NO.	Name	NO.	Name
1	Compression Ring	4	Circlip	7	Connecting Rod Cap
2	Oil Ring	5	Piston Pin	8	Connecting Rod Bolt
3	Piston	6	Connecting Rod	9	Connecting Rod Bearing

4. Check all the connecting rods (Figure 121, Item 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.
- In case of difficulty inserting the piston pin, you can heat the piston in an oven to a temperature of about 43°F.

5. Fit the 1st circlip (Figure 120, Item 4) onto one end of the piston.
6. Lightly oil the bore openings and insert the piston pin (Figure 120, Item 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.
9. Stagger the piston ring end gaps at 120° intervals (Figure 121). Do not position the top piston ring end gap in line with the piston pin.
10. Repeat steps 1-9 for the remaining pistons and connecting rods.

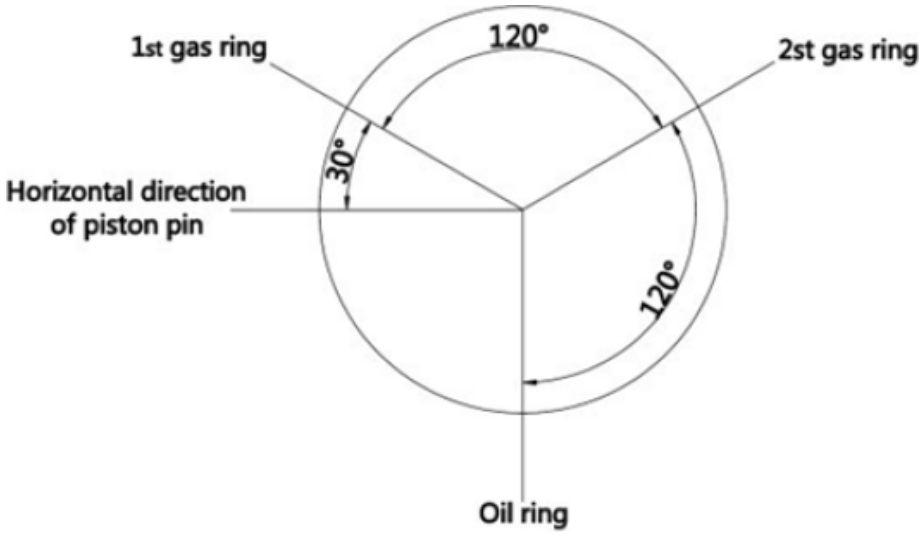


Figure 121.

INSTALLATION OF CRANKSHAFT

Note:

- Ensure all crankshaft assembly components are clean and clean motor oil has been applied.
- Ensure the lubrication grooves face the area of friction.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

1. Install the piston cooling jets.
2. If removed, reinstall the timing gear on the crankshaft.
3. Reinstall new main bearing (Figure 122, Item 1) and thrust plate (Figure 122, Item 3) in the cylinder block and main bearing caps.

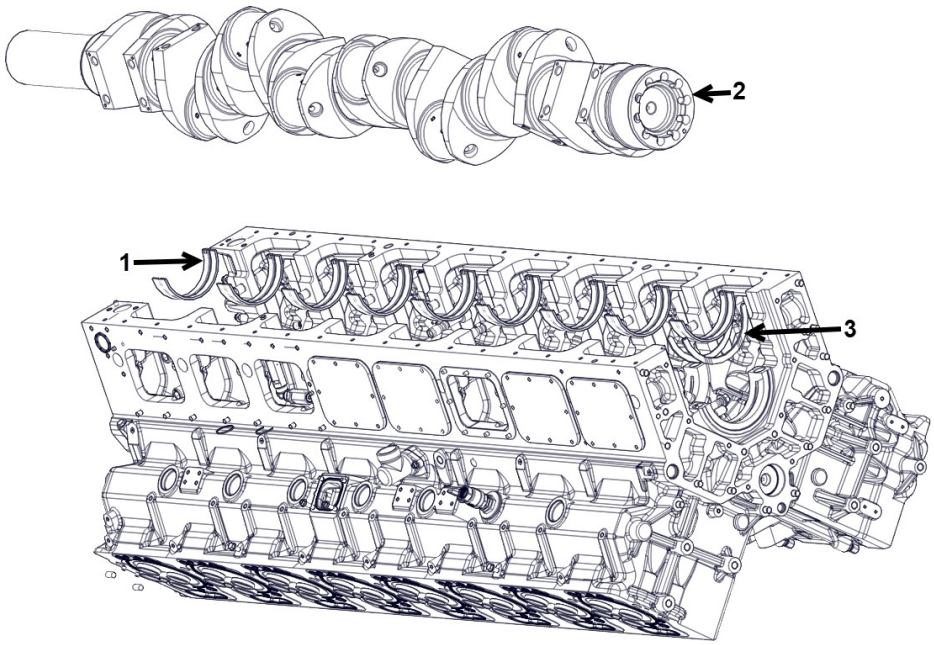


Figure 122.

NO.	Name
1	Upper Main Bearing
2	Crankshaft
3	Upper Thrust Plates

4. Apply a coat of clean engine oil to the bearings and crankshaft journals.
5. With proper hoisting assistance place the crankshaft (Figure 122, Item 2) into the engine.

Note:

- Ensure the end counterweights when initially placing the crankshaft into the engine are facing up.

- Once the crankshaft is properly placed orient the crankshaft, so the end counterweights are facing down.
- Make sure the lubrication grooves face the area of friction.
- If it is difficult to install the main bearing caps, put a wall spreader between the wall of the two rear bearings. Perform stressing of the cylinder block (max. 0.25mm).
- The original main bearing bolts can be reused at most 4 times.

6. Reinstall new main bearing (Figure 123, Item 4) and thrust plate (Figure 123, Item 3) in the main bearing caps (Figure 123, Item 2).

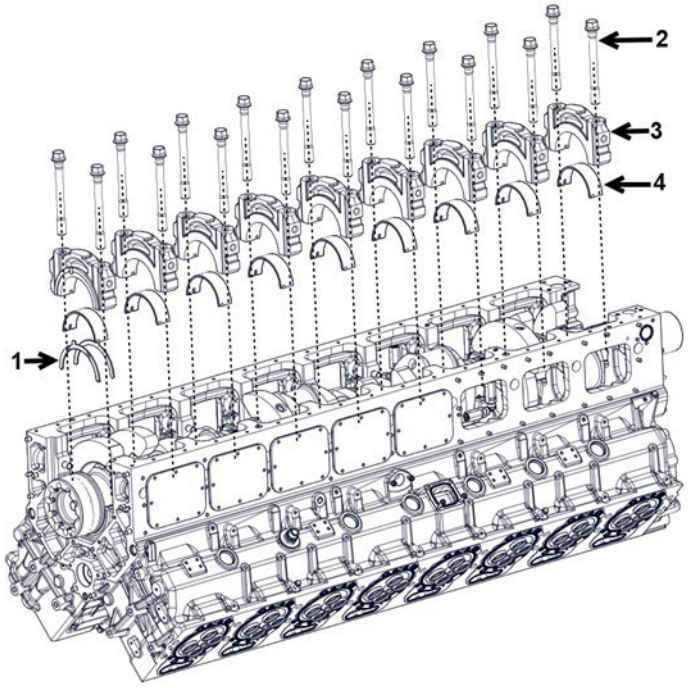


Figure 123.

NO.	Name
1	Lower Thrust Plates
2	Bolt
3	Main Bearing Cap
4	Lower Main Bearing

7. Reinstall the main bearing caps (Figure 123, Item 2).
8. Apply a light coat of clean engine oil to the bearing cap main bolts (Figure 123, Item 2) and auxiliary bolts (Figure 124, Item 1) with washer (Figure 124, Item 2).

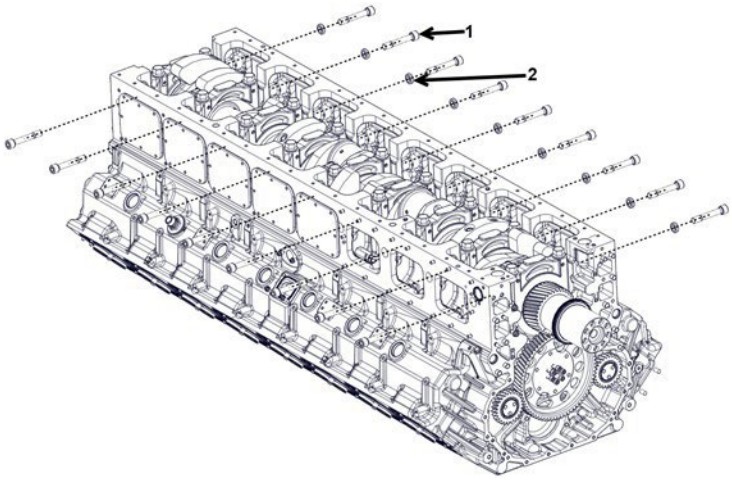


Figure 124.

NO.	Name
1	Bolt
2	Washer

9. Tighten the main bearing bolts and the side auxiliary bolts in the following sequence (Figure 125 & 126):
    i. Tighten the main bearing bolts (Figure 123, Item 2) in alphabetic order (A – R) to 133 ft/lb.
    ii. Tighten both sides of the auxiliary bolts (1-9) to 59 ft/lb (Figure 126).
    iii. Tighten the main bearing bolts (Figure 123, Item 2) in alphabetic order (A – R) to an angle of 60°.
    iv. Tighten the main bearing bolts (Figure 123, Item 2) in alphabetic order (A – R) to an angle of 60°.
    v. Tighten both sides of the auxiliary bolts (1-9) to 199 ft/lb (Figure 126).
10. Rotate the crankshaft to assure it turns freely.

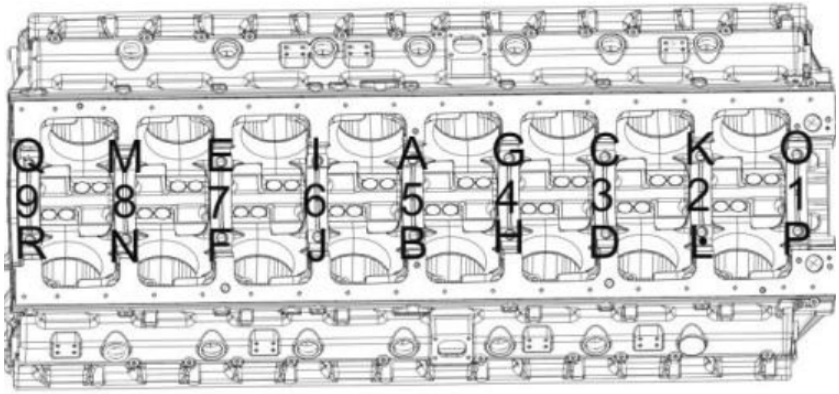


Figure 125.

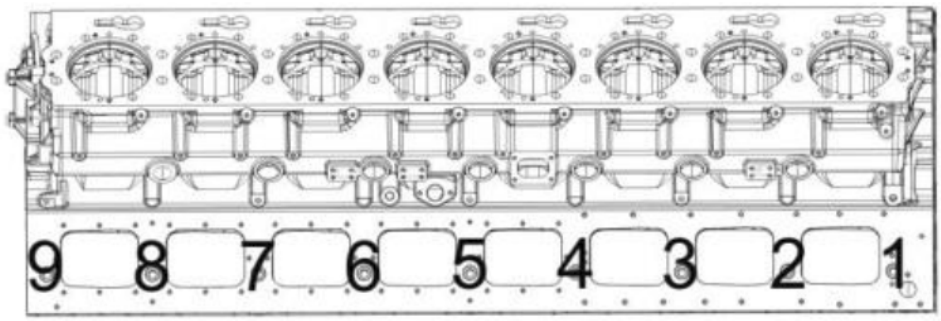


Figure 126.

INSTALLATION OF FLYWHEEL HOUSING AND FLYWHEEL

Note:

- The flywheel cover bolts can be reused at most two times.
- It is better to install the camshaft before installing the flywheel housing and flywheel.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

1. If removed, install the camshaft first.
2. Install the rear oil seal group on the flywheel housing (Figure 127).

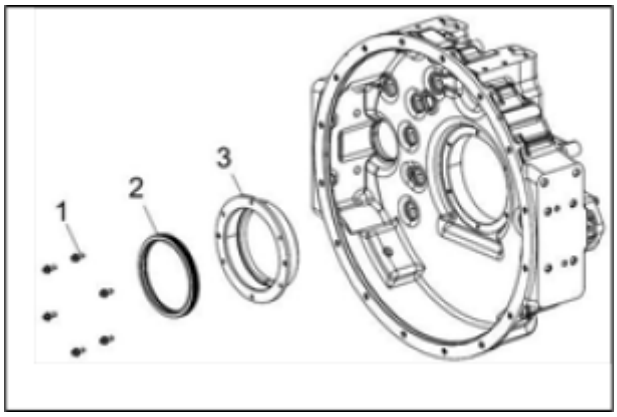


Figure 127.

NO.	Name
1	Bolt
2	Rear Oil Seal
3	Rear Oil Seal Seat

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 128, Item 2) to the rear end of engine block by using the guide rods.

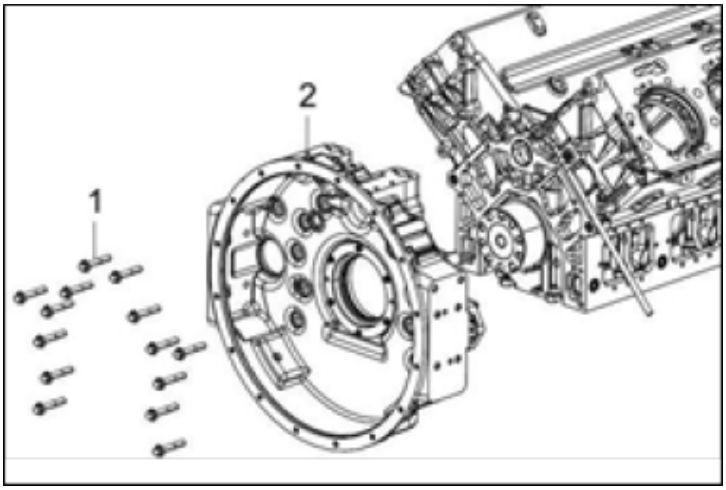


Figure 128.

NO.	Name
1	Flywheel Housing Bolts
2	Flywheel Housing

6. Apply Loctite 242 sealant coated at the threads of the flywheel housing bolts (Figure 128, Item 1).
7. Tighten the bolts in two steps in the following sequence (Figure 129):
    i. Tighten the bolts (1-14) to 59 ft/lb.
    ii. Tighten the bolts (1-14) to 133 ft/lb.

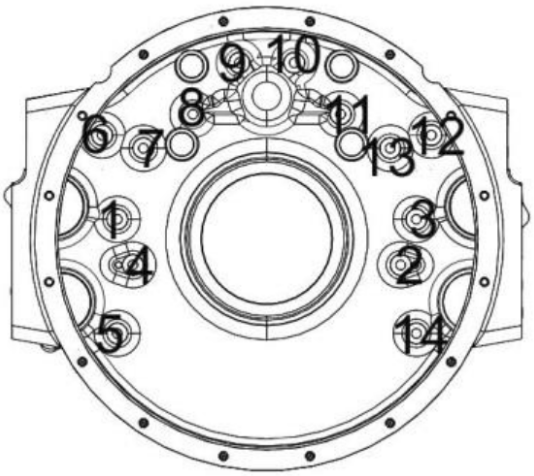


Figure 129.

Note:

- The flywheel cover bolts can be reused at most two times.
- When installing the flywheel ring, heat the ring gear to 482°F.
- If the ring gear is removed, the engagement chamfer must be oriented towards the engine side (Figure 130).

Figure 130.

8. Assemble the flywheel ring to the flywheel if removed.
9. Fit the flywheel guide rods on the crankshaft.
10. Apply a film of oil to the threads and under the head of the flywheel fixing bolts (Figure 131, Item 1).
11. Using suitable handling, install the flywheel (Figure 131, Item 2) on the crankshaft.
12. Remove the guide rods.

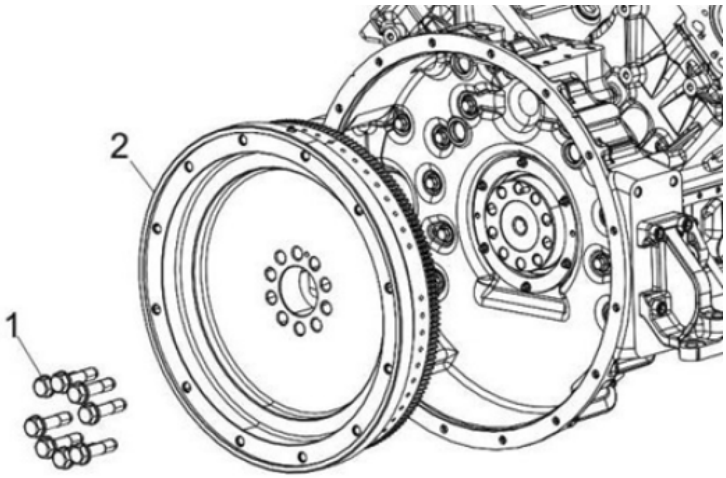


Figure 131.

NO.	Name
1	Bolt
2	Flywheel

13. Tighten the bolts in three steps in the following sequence (Figure 132):
    i. Tighten the bolts (1-10) to 66 ft/lb.
    ii. Tighten the bolts (1-10) to 133 ft/lb.
    iii. Then rotate an angle of 90°, and then apply paint to the bolts.

Figure 132.

14. Install the engine bracket group.
15. Install the starter assembly.

CRANKSHAFT POSITION SENSOR GAP

Correct crankshaft position sensor (“CKP”) gap is critical for proper engine performance. The gap between the sensor and reluctor is adjusted by adding or removing the sensor shim.

In cases where the gap is not correct utilize the 0.010” shim(s) to obtain the desired gap.
If the gap is not within the specification the ECM may lose the crank/cam sync which can lead to an unintended backfire condition.

Tools Required:

Digital measuring tool or dial indicator (as shown in images B, C, D, E, and F)
0.01-inch shims (as shown in Image G)
Impact wrench with extended 8mm socket

Tolerance:

Crank sensor gap tolerance: 0.110 ± 0.005 in.

Step-by-Step Instructions

1. Remove the Crank Sensor
(Refer to Image A)
Use an impact wrench with an extended 8mm socket to remove the bolt holding the crank sensor in place. Pull the crank sensor out by wiggling it back and forth.
Reason: The crank sensor needs to be removed to measure and adjust the gap.

2. Zero Out the Tool
(Refer to Image B and D)
Zero out the crank sensor gap tool by pressing the ZERO button on the tool.
Key Point: Ensure the tool is accurate before proceeding to the next steps.
Reason: This step ensures the tool is ready to measure correctly.

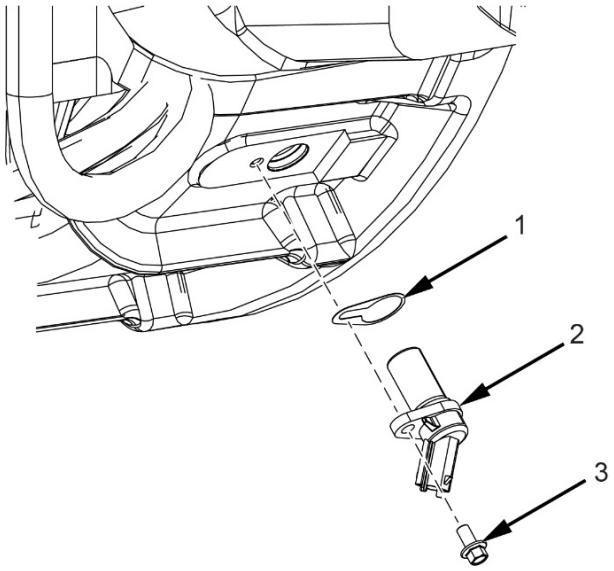
3. Measure the Crank Sensor Gap
(Refer to Image C)
Line the crank sensor up with the measuring tool so that the sensor sits securely in the adapter. Hold the tool with the crank sensor upside down, and press the ZERO button. Ensure the tool is set to measure in inches.
Key Point: The measuring tool will now register the crank sensor gap.
Reason: This step sets the tool for measuring the correct gap between the sensor and flywheel.

4. Measure the Crank Sensor Gap
(Refer to Images E and F)
Insert the measuring tool so that the tip of the adapter you measured the crank sensor from sits flush with the flywheel housing.
Target Gap: The gap should measure 0.110 ± 0.005 in.

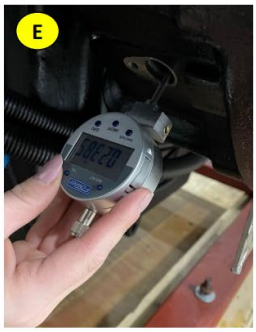
5. Install Shim(s) if Necessary
(Refer to Image G)
If the measured gap is below 0.105 in., place one or more 0.01 in. shim(s) over the crank sensor to adjust the gap to the required specification.
Key Point: Ensure the shims are placed properly to adjust the gap within the acceptable range.

6. Reinstall the Crank Sensor
(Refer to Image H)
Reinstall the crank sensor into its position in the engine. Tighten the bolt to secure the crank sensor in place.
Reason: Proper installation of the crank sensor ensures the engine runs efficiently and the sensor functions correctly.

NO.	Name
1	Shim
2	Crankshaft Sensor
3	Bolt



SEQ	STEP (What)	SYM	KEY POINT (How)	REF	REASON (Why)
1	Remove crank sensor.		Remove the bolt holding the crank sensor in place. Use an impact wrench with an extended 8mm socket. Pull the crank sensor out by wiggling it back an d forth.	A	The crank sensor needs to be removed in order to be measured and for the gap to be measured.
2	Zero out the tool	C	Zero out the crank sensor gap tool by pressing the ZERO button in face off the tool.	B	This needs to be done to make sure the tools reading is accurate for the next step.
3	Measure the Crank Sensor	C	Line the crank sensor up with the measuring tool so that the sensor sits nicely in the adapter. It helps if you hold the tool and crank sensor upside down. Press "ZERO". Make sure you are measuring in inches.	C,D	This sets the measuring tool up to measure the gap relative to the crank sensor. Whatever distance is registered by the tool will be the size of the gap.



SEQ	STEP (What)	SYM	KEY POINT (How)	REF	REASON (Why)
4	Measure the crank sensor gap.	C	Insert the measuring tool so that the end of the adapter you measured the crank sensor from sits flush with the flywheel housing.	E,F	The gap needs to be .110 ± .005 in. If the gap is measured to be below this range, then insert one or more .01 in. shim(s) so that the gap is within range.
5	Install shim(s) if needed	C	Place one or more 0.01 in. shim(s) over the crank sensor	G	By inserting one or more .01 in. shim(s) will make the gap within range
6	Reinstall crank sensor	C	Reinstall the crank sensor into the engine. Reinstall the bolt to hold the crank sensor in place	H	The crank sensor needs to be installed to allow the engine to run properly.

Example Measurement Shown Below

Sensor	1.363”
Depth (flywheel hsg. to flywheel)	1.408”
Sensor Gap	0.035”
Target Gap (+/- .015”)	0.110”
Difference	0.075”

Add 7 .010” shims to achieve target gap of .110” +/- 0.015”

INSTALLATION OF CONNECTING ROD AND PISTON

Note:

- Do not allow the connecting rod to contact the crankshaft journal during piston installation.
- Apply a film of oil onto the ring set before compressing.
- Ensure the piston ring gaps are located correctly (Figure 134).
- The manufacturing marking on the top of the piston will be oriented towards the flywheel side.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

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.

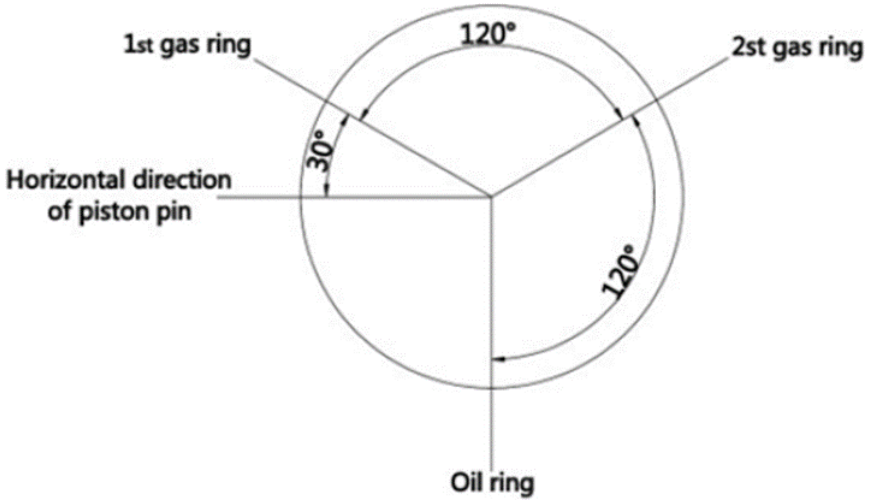


Figure 134.

3. Using a piston ring compressor (Figure 134, Item 1), compress the piston rings.
4. Apply a film of oil to the liner, crank pin, rod bearings and the connecting rod bolts.
5. Lower the mobile coupling (Figure 134, Item 2) until the connecting rod big end and its half bearing are in place on the crank pin.
6. Reinstall the connecting rod cap (Figure 134, Item 3). Fit the connecting rod bolts (Figure 134, Item 4) and fully engage the cap (turn the crankshaft to facilitate fitting of bolts).
7. Tighten the connecting rod bolts (Figure 134, Item 4) in following sequence:
    i. Pre-tighten bolts to 74 ft/lb.
    ii. Tighten the bolts to 147 ft/lb.
    iii. Tighten to an angle of 60°.
    iv. Tighten to an angle of 45°.

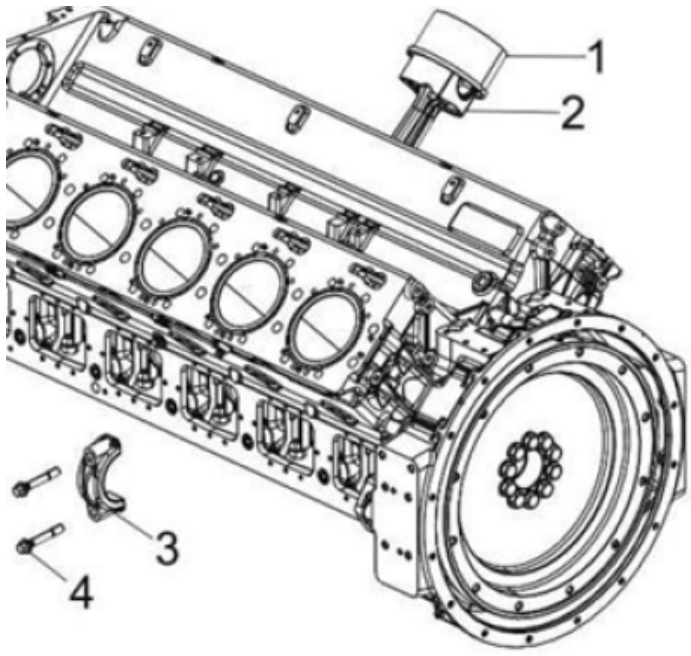


Figure 135.

NO.	Name	NO.	Name
1	Piston Ring Compressor	3	Connecting Rod Cap
2	Mobile Coupling	4	Bolt

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

INSTALLATION OF CAMSHAFT

Note:

- It is better to install the camshaft before installing the flywheel housing and flywheel.
- Apply clean oil to the camshaft bushing, bearings, bearing bore and all contact surfaces.
- Use the camshaft installation tool (Figure 134, Item 1) if necessary.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

1. If removed, install a new camshaft bushing using the appropriate service tool.
2. Use the camshaft installation tool to assist in installing the camshaft if necessary.
3. Apply a film of oil to the camshaft and the camshaft bushing.
4. Apply 1 mm (.040") of CASTROL MOLUB-ALLOY™ 6040/460-1.5 grease onto **ALL** camshaft lobes, spread evenly throughout the entire lobe surface with a plastic brush or gloved finger.
5. Install the camshaft (Figure 136, Item 2), gradually rotate it as you insert it.
6. Apply a film of oil to the bearing bore. Fit the bearing (Figure 136, Item 3), taking care to position the lubrication groove at the top at 12 o'clock.
7. Apply a film of Loctite 242 to the fastened bolts (Figure 136, Item 4) and tighten to a torque of 29 ft/lb.

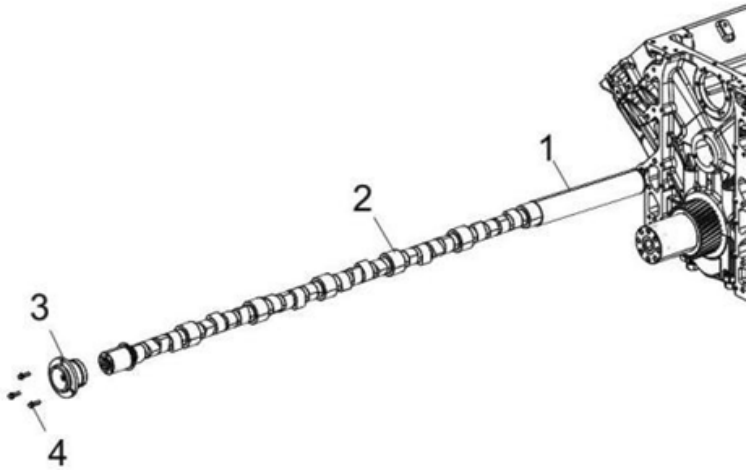


Figure 136.

NO.	Name	NO.	Name
1	Camshaft Installation Tool	3	Bearing
2	Camshaft	4	Bolt

INSTALLATION OF TIMING GEARS

Note:

- The oil hole of the bearing seats should be facing upward.
- The “N” mark on the camshaft gear must be facing the marking on the crankshaft timing gear (Figure 3).
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

1. Turn the crankshaft so that the engraved marking on the pinion is at 12 o’clock.
2. Install the camshaft gear (Figure 137, Item 1) and the connecting shaft (Figure 137, Item 2) of the trigger wheel.

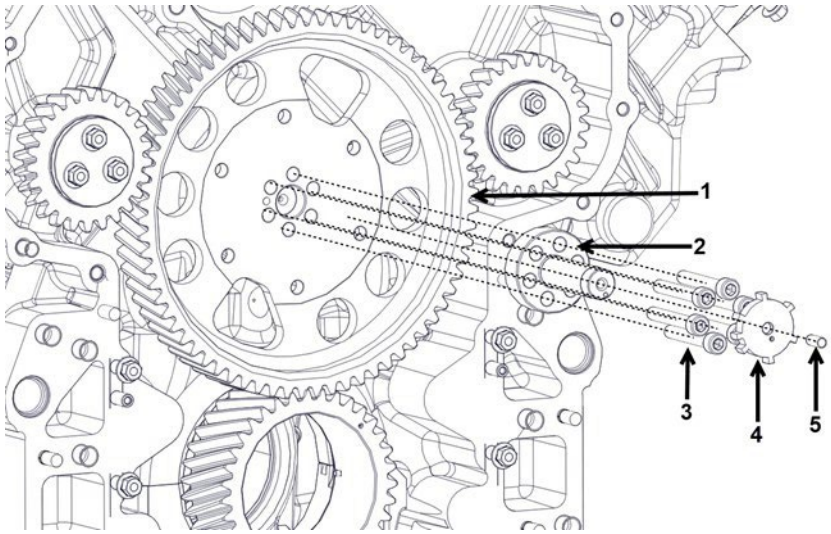


Figure 137.

NO.	Name
1	Camshaft Gear
2	Connecting Shaft
3	Bolt
4	Trigger Wheel
5	Bolt

3. Apply a film of Loctite 242 to the bolts (Figure 137, Item 3) and tighten the bolts.
4. Install the trigger wheel (Figure 137, Item 4).
5. Install the two intermediate gears (Figure 138, Item 2) next to the camshaft gear and torque the bolts of the intermediate gears to 52 ft/lb.

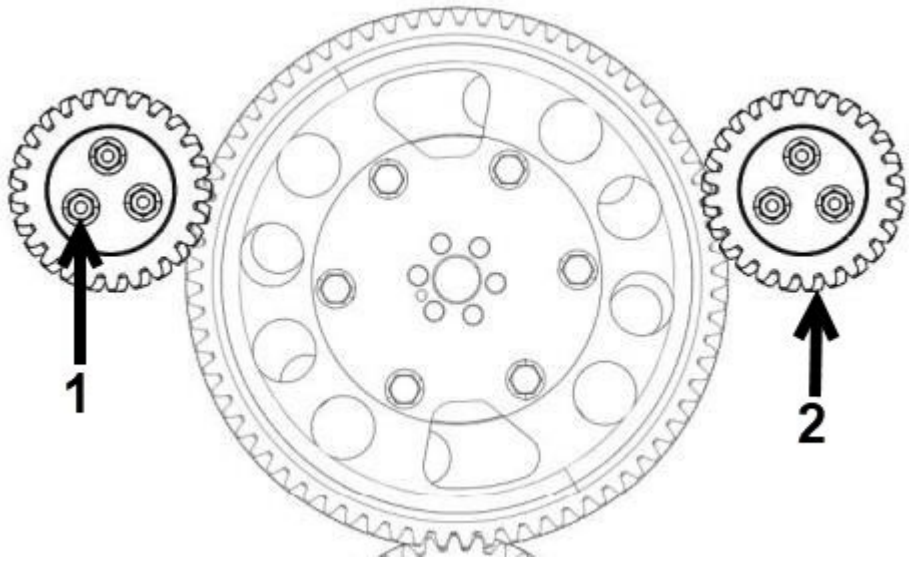


Figure 138.

NO.	Name
1	Bolt
2	Intermediate Gear

6. If necessary, rotate the camshaft gear and align the “N” mark with the crankshaft gear mark (Figure 139).

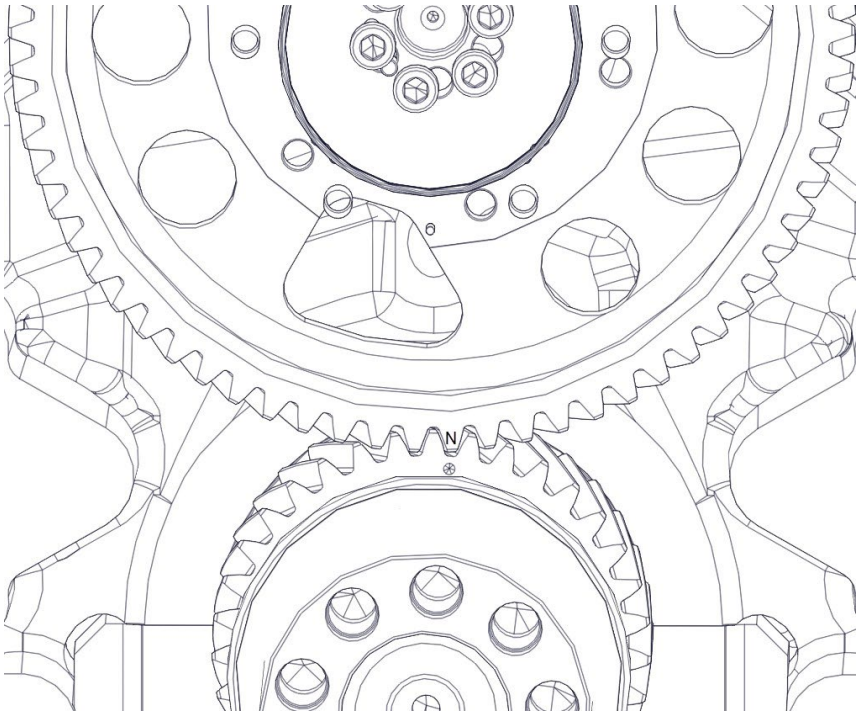


Figure 139.

INSTALLATION OF OIL PAN

Note:

- Replace all O-rings once removed.
- Oil pan weighs 577 lbs. use suitable lifting means when installing oil pan.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

1. Install the oil strainer by tightening both bolts (Figure 140, Items 1 & 2).

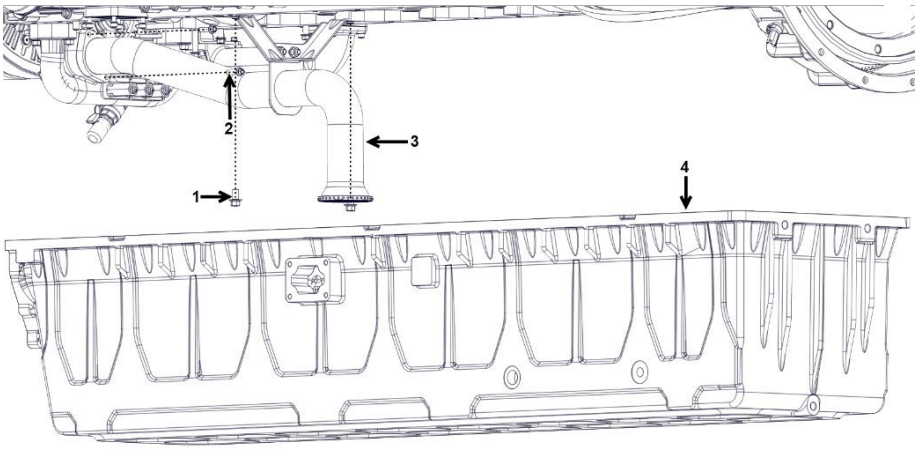


Figure 140.

NO.	Name	NO.	Name
1	Bolt	3	Oil Strainer
2	Bolt	4	Oil Pan

2. Apply silicone to the mating face of the oil pan evenly.
3. With a crane or any hosting assistance, place the oil pan onto the bottom of the engine block.
4. Apply Loctite 242 to all the threads of the oil pan bolts.
5. Tighten the bolts and wipe off the excessive silicone.
6. Reinstall the CCV hose on the right-hand side of the oil pan.
7. Reinstall the oil dipstick.

INSTALLATION OF FRONT COVER

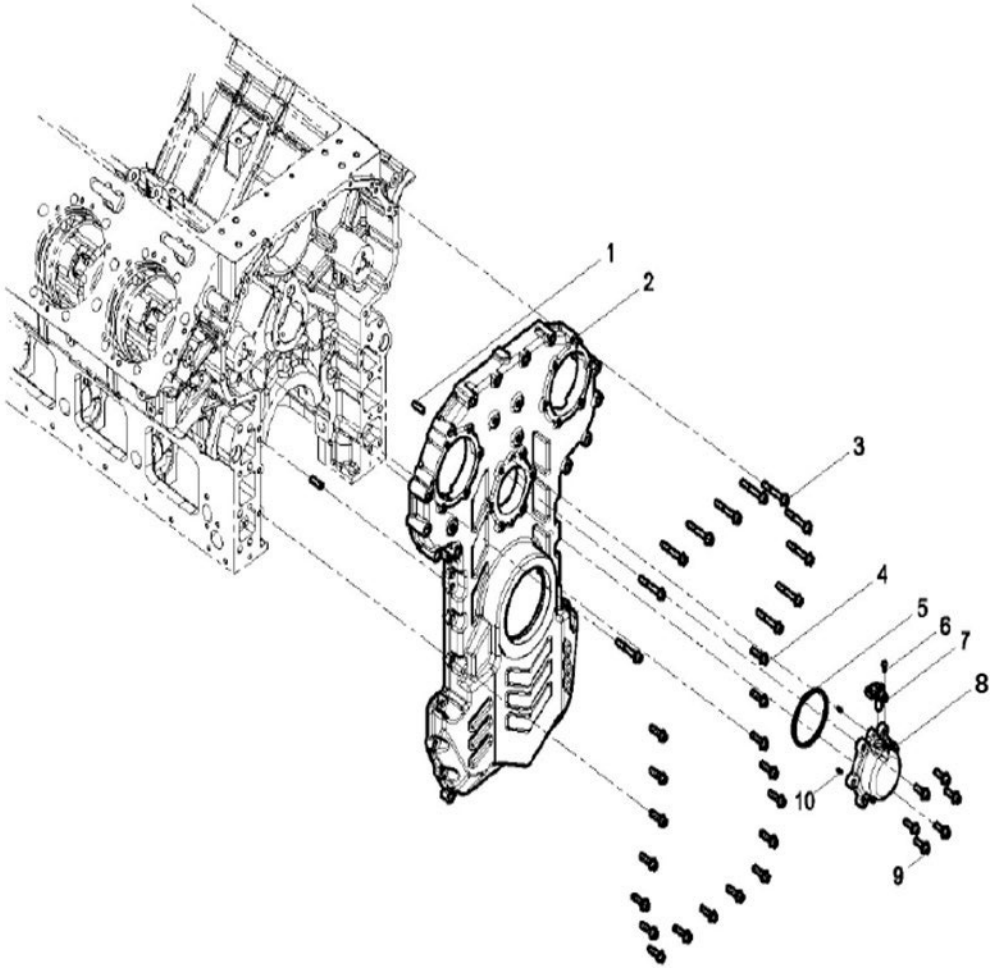


Figure 141.

NO.	Name	NO.	Name
1	Dowel Pin	6	Bolt
2	Front Cover	7	Speed Sensor
3	Bolt	8	Sensor Seat
4	Bolt	9	Bolt
5	O-Ring	10	Dowel Pin

Note:

- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

1. Clean the entire front surface of the cylinder block and back surfaces of the front cover of any debris.
2. Apply PSI approved silicone sealant on the back of the front cover (Figure 141, Item 2).
3. Insert the two dowel pins (Figure 141, Item 2) if removed.
4. Place the front cover (Figure 141, Item 2) onto the front of the cylinder block and torque down all thirty-nine bolts (Figure 141, Item 3).
5. Reinstall the speed sensor (Figure 142, item 2).
6. Loctite sealant 242 to the threads and install bolt (Figure 142, item 1) and secure speed sensor (Figure 142, item 2) to speed sensor seat (Figure 142, item 3). Tighten the bolt to recommended torque.
7. Connect the connecting wring when the engine harness is installed.

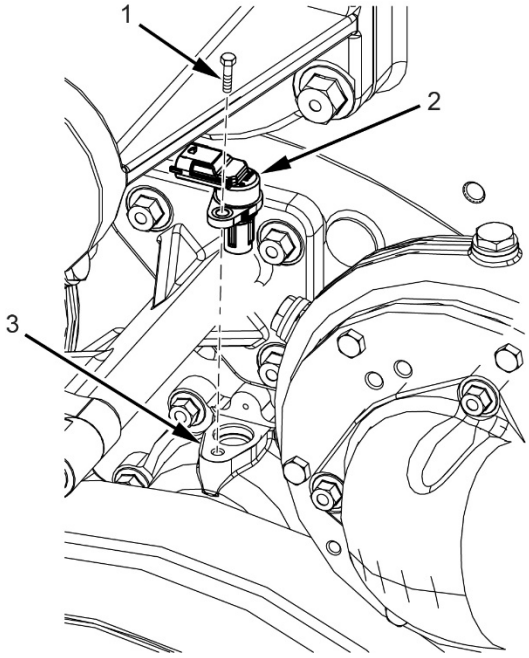


Figure 142.

8. Insert both water pumps. Refer to the WATER PUMP section of the manual.
9. Install the entire FEAD on the engine. Refer to the FEAD section of the manual.

OIL PAN

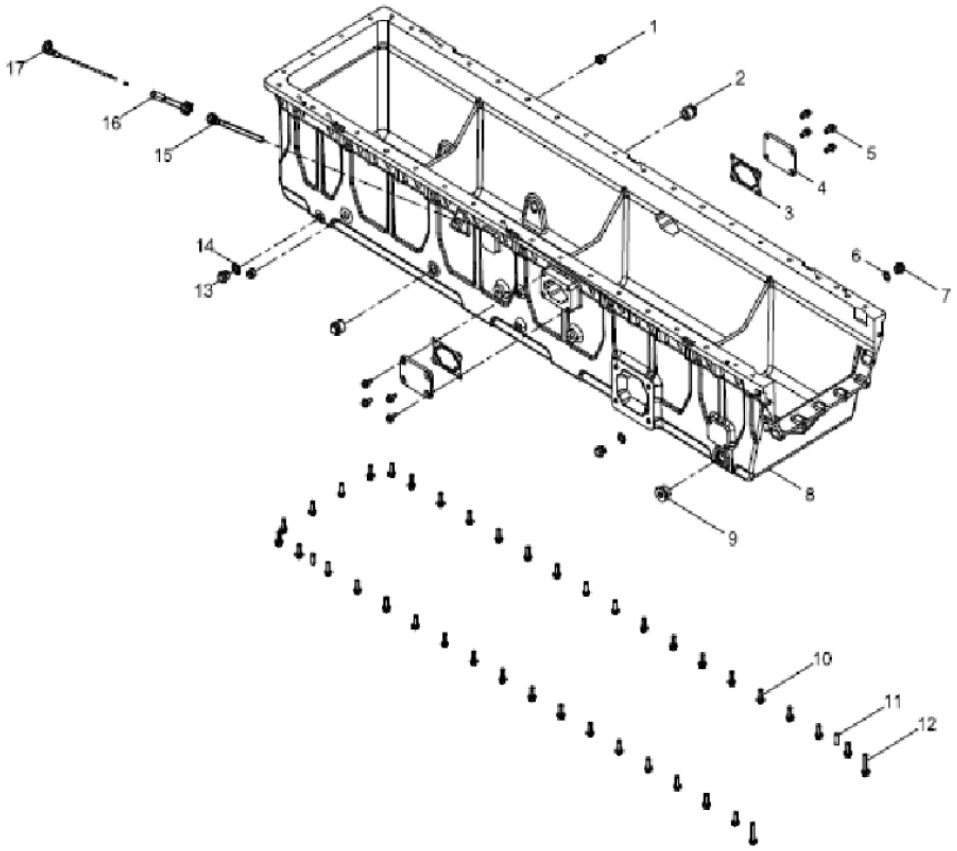


Figure 143. Oil Pan Assembly

NO.	Name	NO.	Name	NO.	Name
1	Plug	7	Plug	13	Plug
2	Plug	8	Oil Pan	14	Washer
3	Gasket	9	Plug	15	Oil Tube
4	Cover	10	Bolt	16	Dipstick Tube
5	Bolt	11	Dowel Pin	17	Dipstick
6	Washer	12	Bolt		

Note:

- Replace all O-rings once removed.
- Oil pan weighs 577 lbs. Use suitable lifting means when installing oil pan.
- See the *TIGHTENING TORQUES FOR STANDARD BOLTS* chart for any bolts without a specified torque value.

REMOVAL

1. Drain oil and remove the CCV hose on the right-hand side of the oil pan.
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.

INSTALLATION

1. Clean the surface of the oil pan and underneath the cylinder block from any debris.
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 the oil pan bolts, tighten the bolts, and wipe off the excessive silicone.

OIL TEMPERATURE/PRESSURE SENSOR

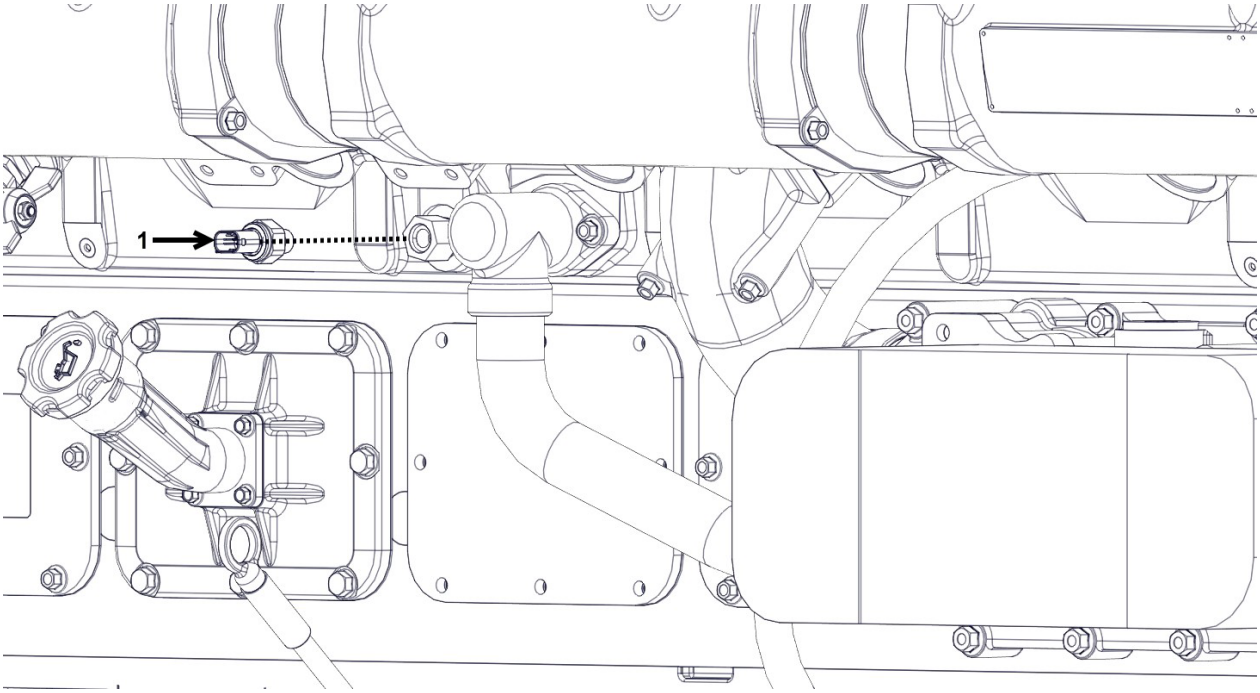


Figure 144. Oil Temperature/Pressure Sensor Assembly

NO.	Name
1	Oil Temperature/Pressure Sensor

Note:

- There are two oil temperature/pressure sensors, next to the oil coolers on each side of the cylinder block.

REMOVAL

1. Disconnect both oil temperature/pressure sensor harnesses.
2. Remove each oil temperature/pressure sensor from the cylinder block above the oil coolers.

INSTALLATION

1. Insert and torque down both oil temperature/pressure sensors to 65 ft/lb. if equipped with adapter, if only installing the sensor torque down to 25 ft/lb.
2. Reconnect both oil temperature/pressure sensor harnesses.

COOLING SYSTEM DIAGRAM

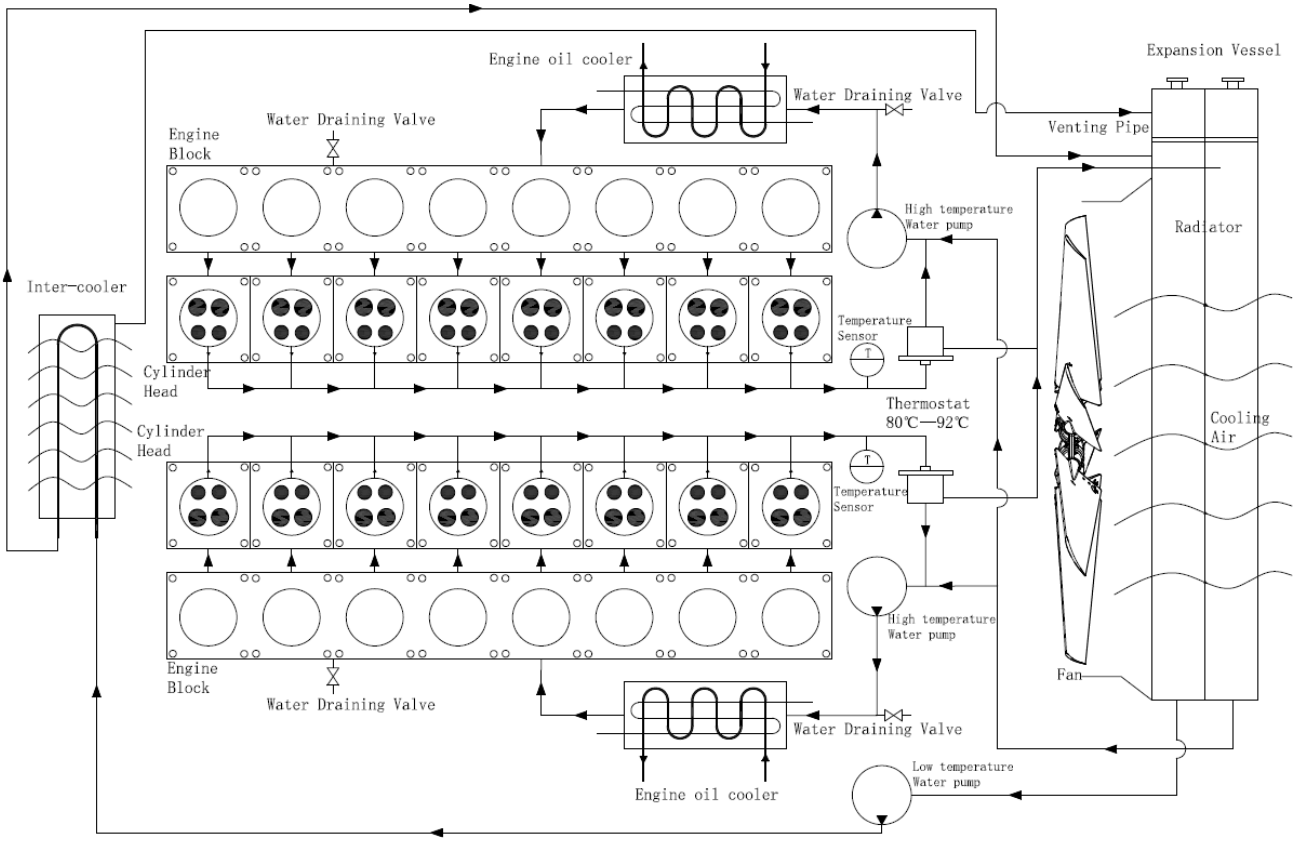


Figure 145. Cooling System Diagram

WATER OUTLET PIPE AND THERMOSTAT

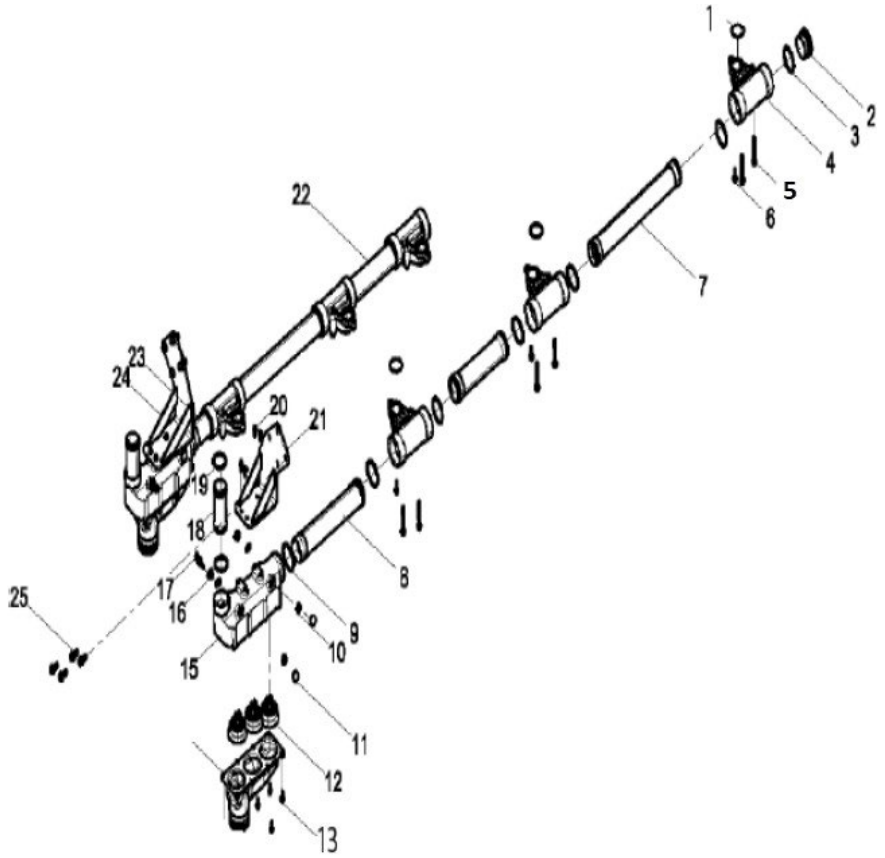


Figure 146. Thermostat Assembly

NO.	Name	NO.	Name	NO.	Name
1	Seal	10	Washer	19	O-Ring
2	Plug	11	Plug	20	Bolt
3	Seal	12	Thermostat	21	Support
4	Pipe Connector	13	Bolt	22	Water Pipe
5	Bolt	14	Thermostat Cover	23	Water Pipe
6	Bolt	15	Thermostat Housing	24	Support
7	Water Pipe	16	Seal	25	Bolt
8	Water Pipe	17	Temperature Sensor		
9	Seal	18	Pipe Connector		

REMOVAL

1. Drain coolant into suitable container.
2. Remove the sensor harness coming from the temperature sensor.
3. Remove the four bolts (Figure 146, Item 13) from the bottom of the thermostat housing (Figure 146, Item 15).

4. Remove the three bolts (Figure 146, Item 6) from each section of the water pipes (Figure 146, Item 7).
5. Remove the eight bolts (Figure 146, Item 20) from the top of the thermostat housing (Figure 146, Item 15).
6. Remove the thermostats (Figure 146, Item 12).

Note:

- Inspect O-Rings and pipes for any damages.
- Inspect the thermostat, opening temperature is 171°F (77°C)
- Lifting height at full opening for all thermostat is ≥10.7MM (198°F or 92°C).

INSTALLATION

1. Install the thermostats (Figure 146, Item 12) onto the thermostat housing (Figure 146, Item 15).
2. Insert all new O-rings and gaskets if any were removed during the removal process.
3. Place the thermostat housing (Figure 146, Item 15) onto the bracket and tighten the bottom four thermostat housing bolts (Figure 146, Item 13).
4. Tighten the eight bolts (Figure 146, Item 20) from the top of the thermostat housing (Figure 146, Item 15).
5. Wipe down all ends of each section of the water pipes from any debris.
6. Connecting all water pipes (Figure 146, Item 7) with new seals (Figure 146, Item 3) and torque down the three bolts (Figure 146, Item 6) from each section of the water pipes (Figure 146, Item 7).
7. Reconnect the sensor harness coming from the temperature sensor.

OIL COOLER

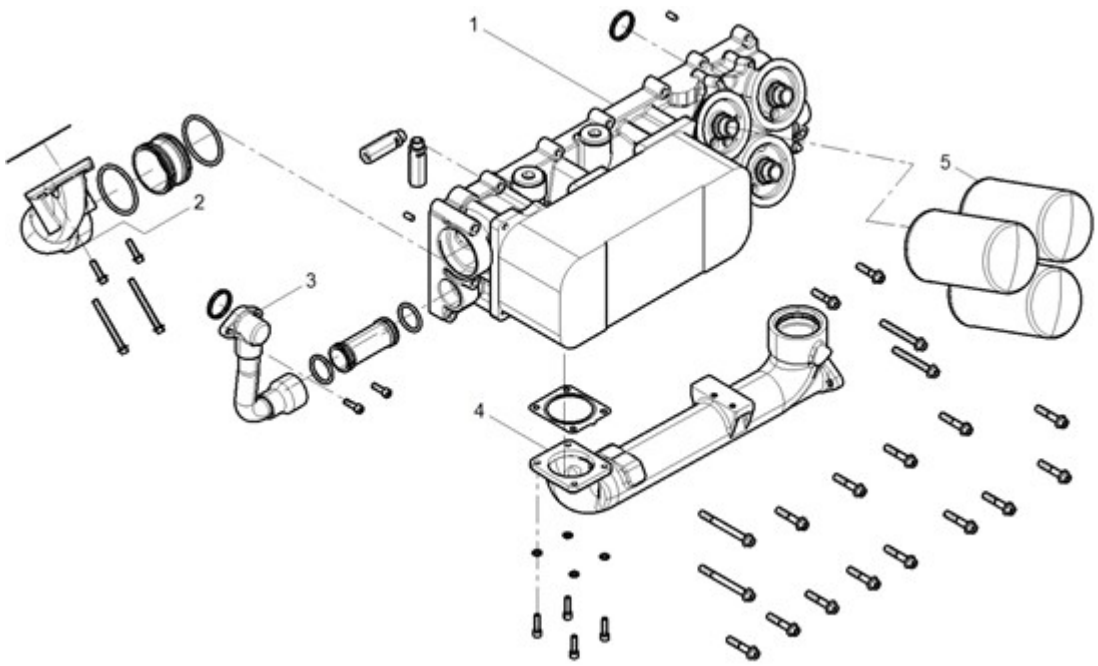


Figure 147. Oil Cooler

S.N.	Name	S.N.	Name	S.N.	Name
1	Oil Cooler	2	Oil Cooler Water Outlet Pipe	3	Oil Cooler Oil Outlet Pipe
4	Oil Cooler Water Inlet Pipe	5	Oil Filter		

Removal of Oil Cooler Assembly

Note!

Prior installation, the adhesive residue must be scraped and cleaned.

Use new seals and gaskets whenever oil cooler in replaced.

Note!

The outlet pipe is connected with the oil cooler as plug type, and there is an O-ring (at each end of the pipe joint.

1. Remove the oil cooler oil outlet pipe (Fig 148, item 2), loosen the fixed bolts (Fig 2, item 3) take the oil outlet pipe, pay attention to the seal ring (Fig 2, item 1).

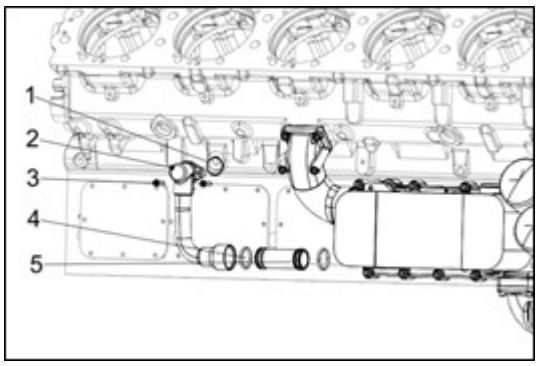


Figure 148

2. Remove the oil cooler water outlet pipe (Fig 149, item 2), loosen the fixed bolts (Fig 3, items 3,4) take the water outlet pipe, pay attention to the gasket (Fig 3, item 1).

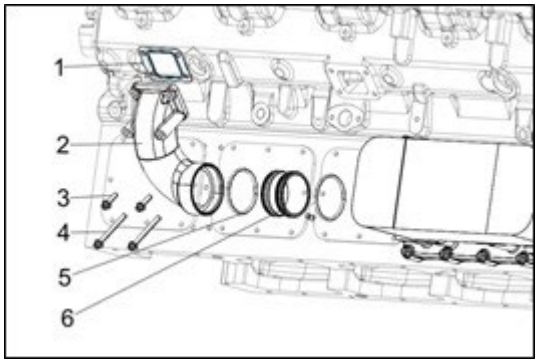


Figure 149

3. Remove the oil cooler inlet pipe, loosen the fixed bolts (Fig 150, item 4) and take the washer (Fig 150, item 3), remove the water inlet pipe, pay attention to the gasket (Fig 150, item 1).

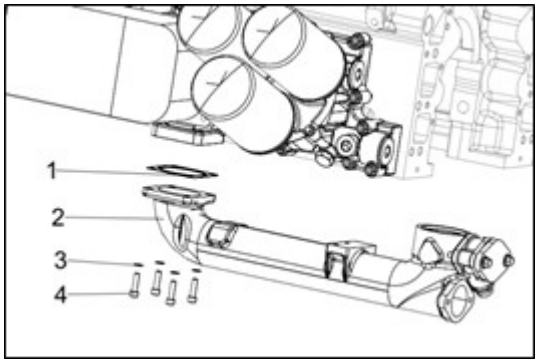


Figure 150

4. Remove the oil filter (Fig 151, item 1) with the special tool.

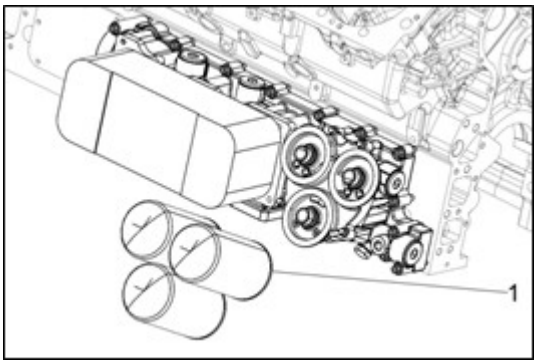


Figure 151

5. Remove the oil cooler seat (Fig 152, item 3), loosen the fixed bolts (Fig 152, item 4), remove the oil cooler seat, pay attention to the O-ring (Fig 152, item 2), remove the locating pins (Fig 152, item 1) if necessary.

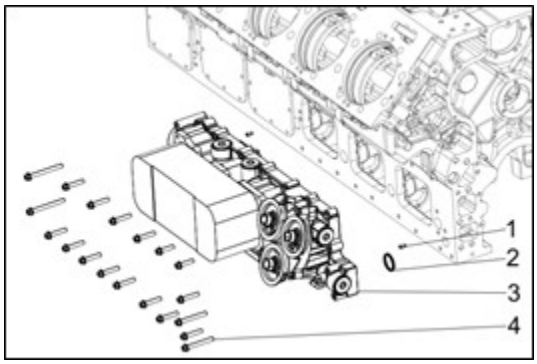


Figure 152

Removal of Pressure-limiting Valve of Main Oil Passage

1. Remove the pressure-limiting valve (Fig 153, item 1) of the main oil passage.

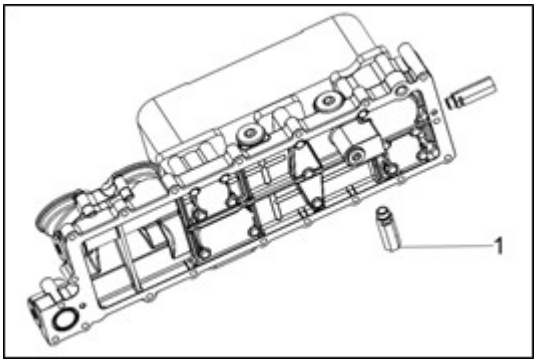


Figure 153

Clean and Inspect Oil Cooler Assembly

1. Check the inner cavity of the main oil gallery pressure relief valve for cleanliness, touch by hand to check for burrs, iron swarf, etc., if present, replace valve.

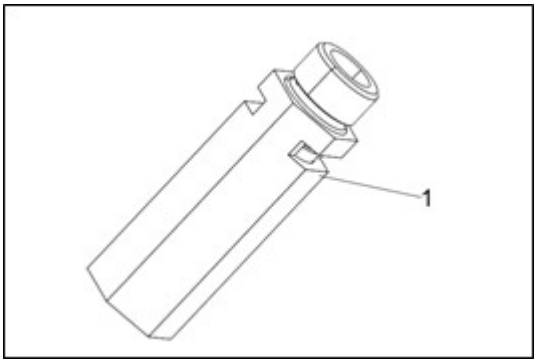


Figure 154

2. Inspect the oil filter, when the oil temperature is 80 ±3℃ and the rated flow is 90L/Min, the original resistance of the assembly is ≤35Kpa.

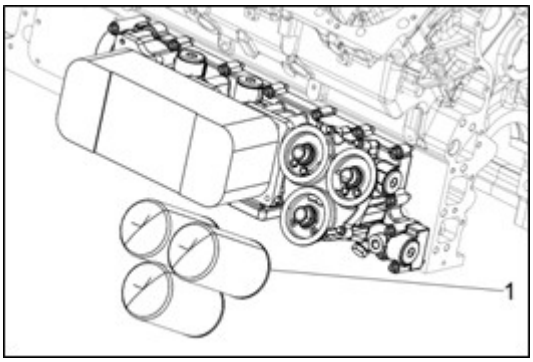


Figure 155

3. Check the condition of the oil cooler assembly, the parts must not be damaged or corroded. Check the oil cooler oil holes and the cleanliness inside the water channel. Metal and other impurities are not allowed in the cavity.

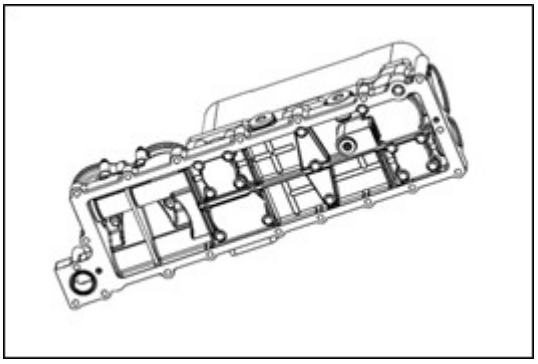


Figure 156

Assembly of Oil Cooler Assembly

1. At the end face of the orifice (1～2) mm and width (3～5) mm, apply 242 sealant to the half-turn thread range, install the pressure- limiting valve of the main oil passage.
2. Tighten the main oil gallery pressure relief valve to the oil cooler assembly, with the following tightening torque: M24 tightening torque (80±5) N.m, paint mark after tightening.

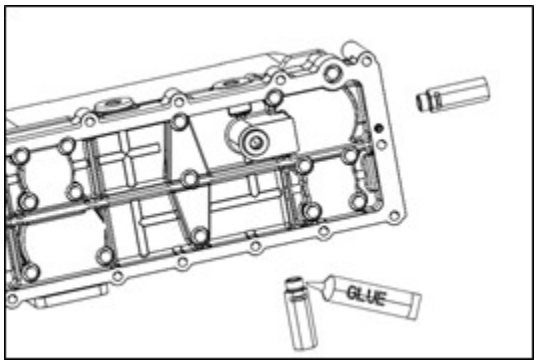


Figure 157

Installation of Oil Cooler Assembly

1. Apply a film of sealant to the oil cooler seat, it is recommended that apply sealant uniformly and continuously without fracture.

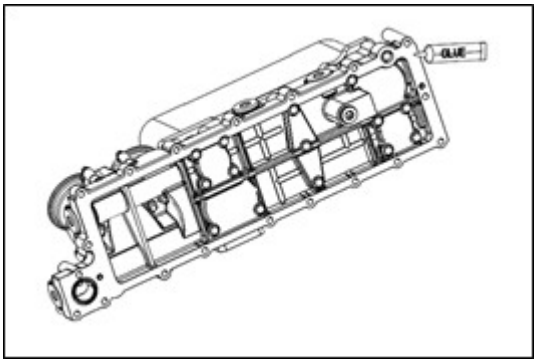


Figure 158

2. Install the two threaded alignment rods (Figure 159, item 1) into any two of the holes that will be used for the fixed bolts (Figure 160, item 4).

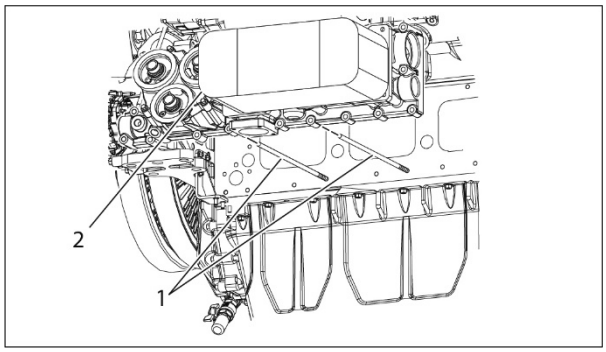


Figure 159

NOTE

Apply sealant 242 to threads of the lower bolts and sealant 567 to threads of upper bolts

3. Install the oil cooler seat (Fig 160, item 3), install the locating pin (Fig 160, item 1) firstly, pay attention to the O-ring (Fig 160, item 2). Install and tighten the fixed bolts (Fig 160, item 4), except the remaining two where the two threaded alignment rods are installed. After the bolts are tightened, remove the two threaded alignment rods and install and tighten the remaining fixed bolts.
4. Tightening torque: Flange head bolts M10: Class 10.9 (70 ± 5) N·m, Grade 12.9 (82 ± 5) N·m; Flange head bolts M8: Class 10.9 (35 ± 5) N·m, Hexagon socket bolt M8: Class 10.9 (33 ± 5) N·m, Class 12.9 (39 ± 3) N·m; the bolt tightening sequence is to tighten the four diagonal bolts first, then the remaining bolts in a clockwise direction. Two of the M10 bolts for the pipe clamp are left loose and will be tightened after installing oil cooler water outlet pipe during step 8.

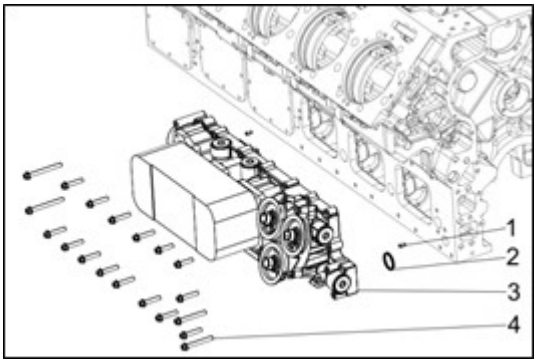


Figure 160

5. Apply a film of oil to the sealing gasket.


Figure 161

6. Install the oil filter, tighten the oil filter by hand and rotate by approximately 1/2 turn.

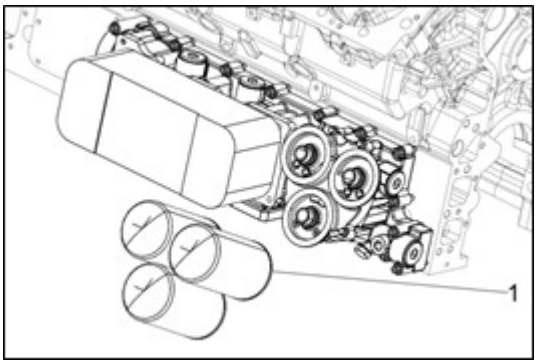


Figure 162

7. Install the water inlet pipe, fit the gasket (Fig 163, item 1) firstly, tighten the fixed bolts (Fig 163, item 4) with the washer (Fig 163, item 3). Torque bolts to 37 N·m.

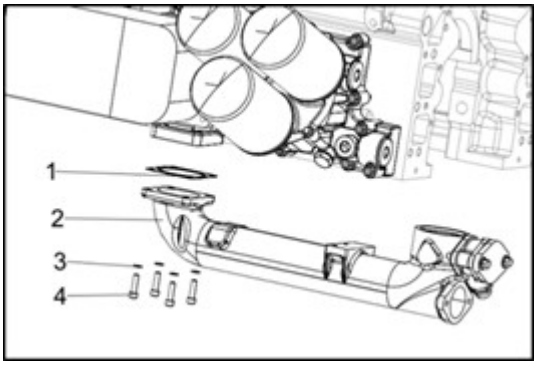


Figure 163

8. Install the oil cooler water outlet pipe (Fig 164, item 2), fit the O-ring (Fig 164, item 5) to the joint pipe (Fig 164, item 6), connect the water outlet pipe with the oil cooler, tighten the fixed bolts (Fig 164, item 3) with washers (Fig 164, item 1). Torque bolts to 35 N·m. Tighten remaining fixed bolts (Fig 164, item 7) left loose in Figure 160.

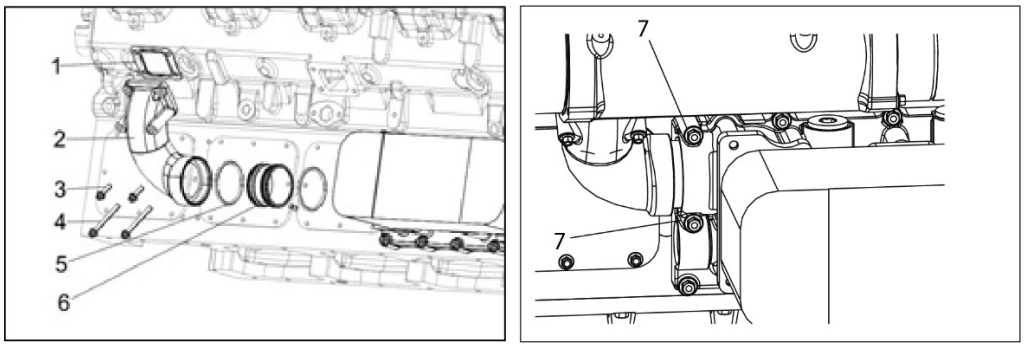


Figure 164

9. Install the oil cooler oil outlet pipe (Fig 165, item 20), fit the O-ring (Fig 165, item 4) to the joint pipe (Fig 165, item 5), connect the oil outlet pipe with the oil cooler, tighten the fixed bolts (Fig 165, item 3) with O-ring (Fig 165, item 1). Torque bolts to 35 N·m.

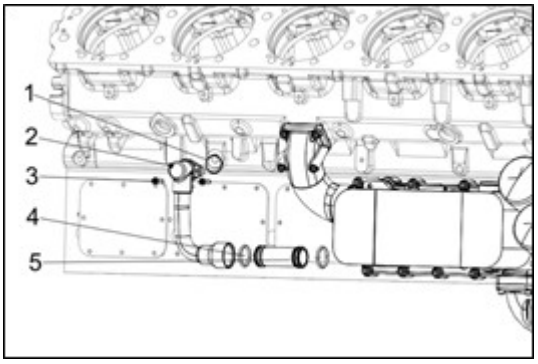


Figure 165

OIL RECOMMENDATION

When the 53L engine is being filled for the first time, oil should be filled to the max scale of 171 liters.

53L engine oil should be determined according to the temperature (Figure 166).

SAE Viscosity Level	Applicable Ambient Temperature (°F)
15w-40	-4-107

Figure 166. Oil Recommendation Chart

ENGINE OIL FILTER AND OIL REPLACEMENT

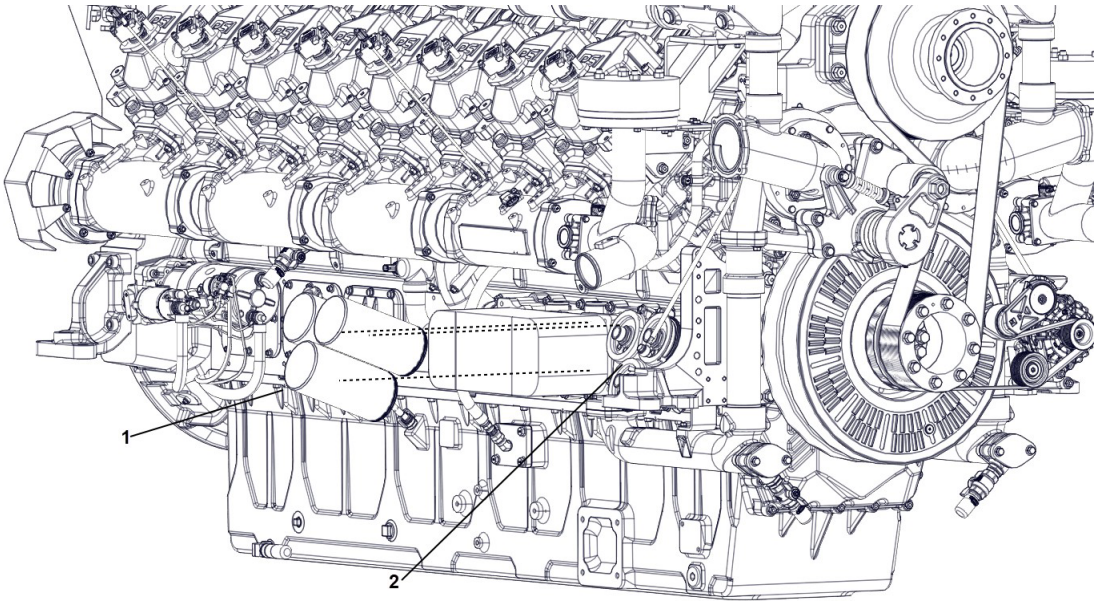


Figure 167. Engine Oil Filter Assembly

NO.	Name
1	Oil Filters
2	Oil Filter Seat

REMOVAL

1. Separate the oil filters (Figure 167, Item 1) from the oil filter seat (Figure 167, Item 2).

INSTALLATION

1. Apply clean oil on all filter rings (Figure 168).

Figure 168.

2. Hand tighten all oil filters (Figure 168, Item 1) onto the oil filter seat (Figure 168, Item 2).
3. Tighten all oil filters (Figure 168, Item 1) a 1/2 turn past hand tighten.

OIL DRAIN AND OIL SAMPLE VALVE

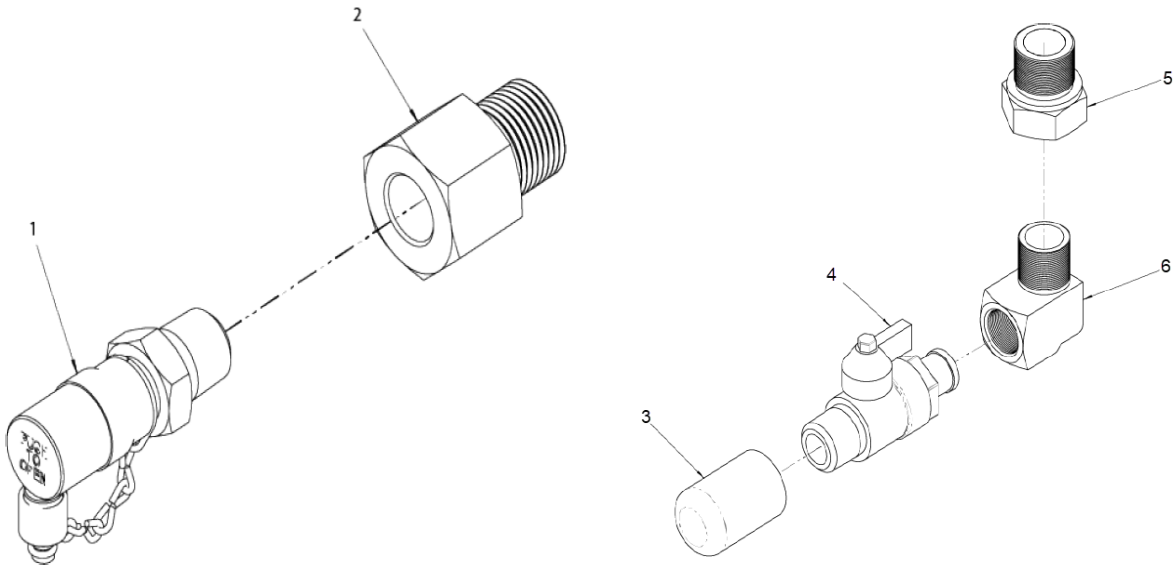


Figure 169. Oil Drain and Oil Sample Valve Assembly

NO.	Name
1	Oil Sample Valve
2	Bushing
3	Rubber Cap
4	Oil Drain Valve
5	Adapter
6	Elbow

1. If the engine is cold, start it and allow it to run for a few minutes to get the oil warm and circulating. Shut the engine down and disconnect the negative battery cable from the battery.
2. Attach a collection hose to the fitting (Figure 169, Item 4). Drain the oil into a suitable container. When the oil has completely drained, close the valve, remove the hose, and reinstall the rubber cap. Dispose of the drained oil in accordance with environmental regulations.
3. Open the filler cap and add engine oil 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 loads 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.

ALTERNATOR

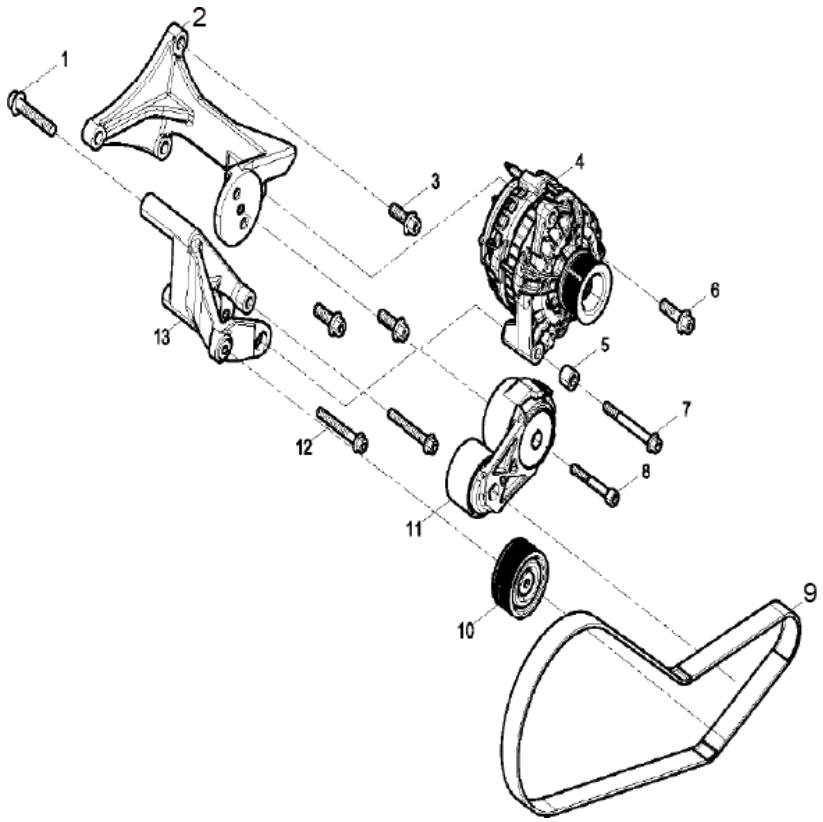


Figure 170. Alternator Assembly

NO.	Name	NO.	Name
1	Bolt	8	Screw
2	Alternator Bracket	9	Belt
3	Bolt	10	Idler
4	Alternator	11	Tensioner
5	Sleeve	12	Alternator Bracket
6	Bolt	13	Alternator Bracket
7	Bolt		

REMOVAL

1. Disconnect all battery power.
2. Disconnect the wires from the back of the alternator.
3. Insert a ½" ratchet or breaker bar into the belt tensioner hole (Figure 170, Item 11) and pull to relieve the bolt tension. Slip the belt (Figure 170, Item 9) off the tensioner pulley and remove from the engine.

4. Loosen and remove both bolts (Figure 170, Items 6 & 7) and remove the sleeve (Figure 170, Item 5) if necessary.
5. Remove the alternator (Figure 170, Item 4).

INSTALLATION

1. Place the alternator (Figure 170, Item 4) onto the bracket (Figure 170, Item 13).
2. Insert the sleeve (Figure 170, Item 5) and insert and torque down the two bolts (Figure 170, Items 6 & 7).
3. Insert a ½" ratchet or breaker bar into the hole on the 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 and reconnect all battery power.

STARTER MOTOR

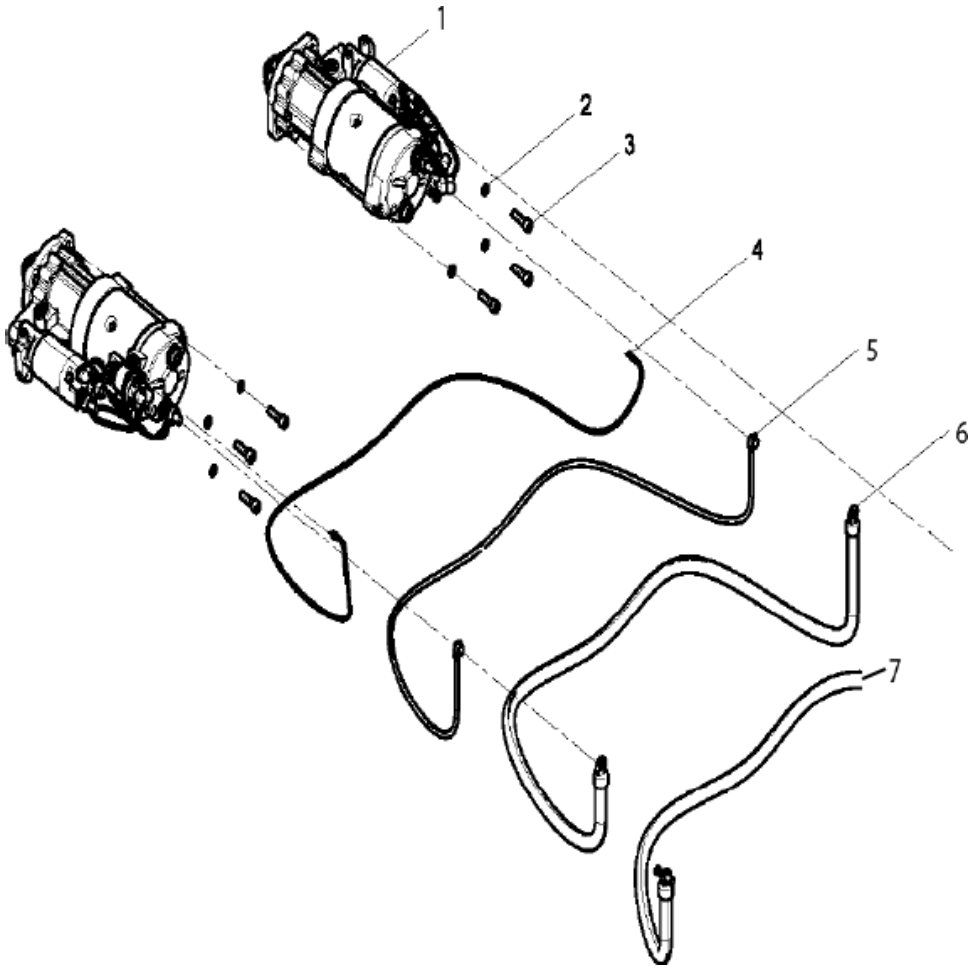


Figure 171. Starter Motor Assembly

NO.	Name
1	Starter
2	Washer
3	Stud
4	Wire
5	Wire
6	Wire
7	Wire

Note:

- 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 to prevent contact with other metal surfaces.

REMOVAL

1. Loosen and remove the starter wires (Figure 171, Items 4-7).
2. With a 16mm wrench remove the bolts and washers (Figure 171, Item 3 & 2).
3. Remove the starter (Figure 171, Item 1).
4. Repeat steps 1-3 for the opposite starter.

INSTALLATION

1. Apply grease to the gear of the starters.
2. Place the starter motor into the flywheel cover and ensure it is engaged correctly.
3. Insert and torque down the washer and bolts (Figure 171, Item 2 & 3).
4. Repeat steps 1-3 for the opposite starter motor.
5. Reconnect the four starter wires (Figure 172).
    a. Connect the red wire onto both solenoids.
    b. Connect the yellow wire onto both starters.
    c. Connect the green wire onto both starters.
    d. Connect the blue wire onto both starters.

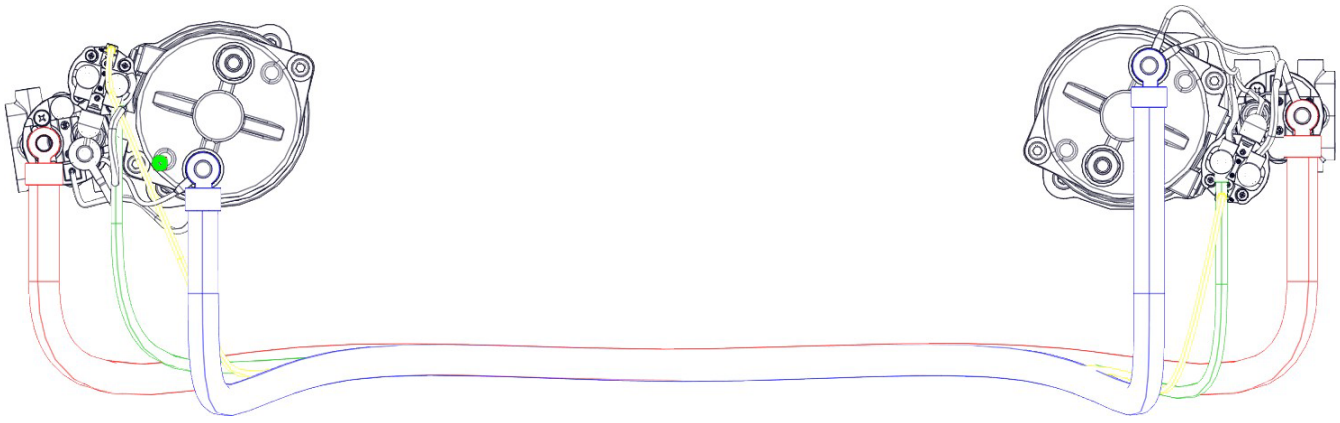


Figure 172. Starter Motor Wire Assembly

PRE-LUBE ASSEMBLY

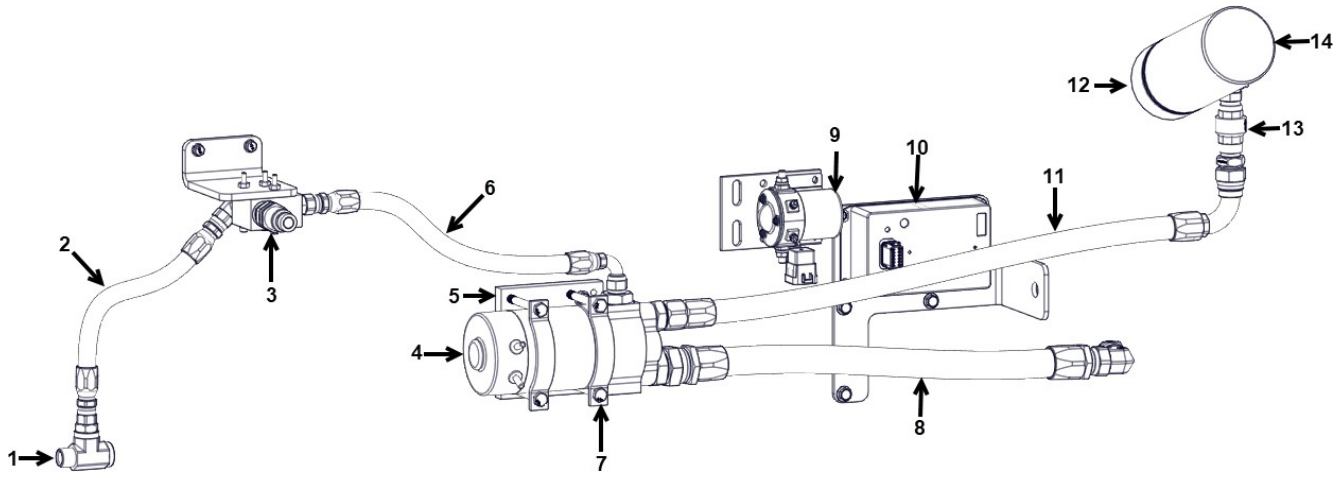


Figure 173. Pre-Lube Pump Assembly

NO.	Name	NO.	Name
1	NPT Tee Adapter	8	Hose
2	Hose	9	Magnetic Switch
3	Quick Fix Valve	10	Pre-Lube Module (Standby Applications Only)
4	Pre-Lube Pump	11	Hose
5	Pump Bracket	12	Filter Ring
6	Hose	13	Check Valve
7	Bracket Bolts	14	Lower Oil Filter

Note:

- The Pre-Lube assembly switches, module and pump are the only items that need to be serviced, unless specified directly by PSI.
- See the TIGHTENING TORQUES FOR STANDARD BOLTS chart for
- any bolts without a specified torque value.
- 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.
- The pre-lube assembly kit must be obtained in order to purge, evacuate and refill the pre-lube pump assembly (Reference the *SPECIAL TOOLS* section of the manual).

PRE-LUBE PUMP

REMOVAL

1. Purge engine oil through the oil filter and into the engine sump by attaching a compressed air line to the filter purge tool, then attached the purge tool to the male quick disconnect on the Quick fix valve. Hold lever on purge tool for 10 seconds (Refer to Figure 174).

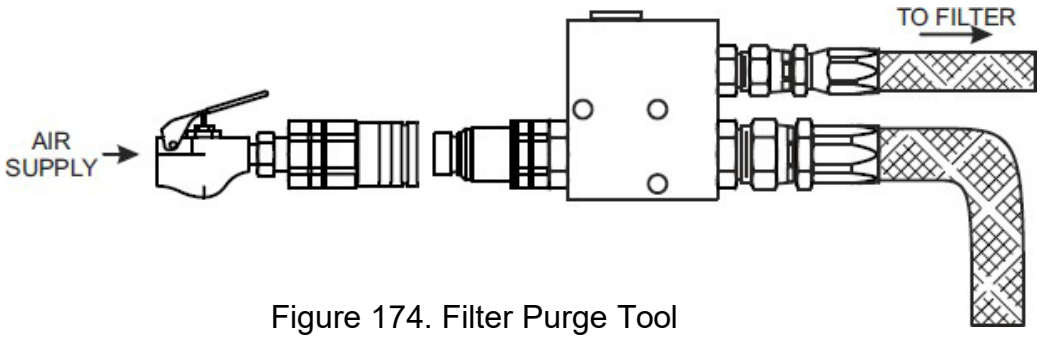


Figure 174. Filter Purge Tool

2. Evacuate the oil from the engine sump by attaching the female quick disconnect from the waste oil reel to the male quick disconnect on quick fix valve. Then turn the waste oil pump on to remove oil from the engine sump, remove the waste oil line once all oil is removed from the engine sump (Refer to Figure 175).

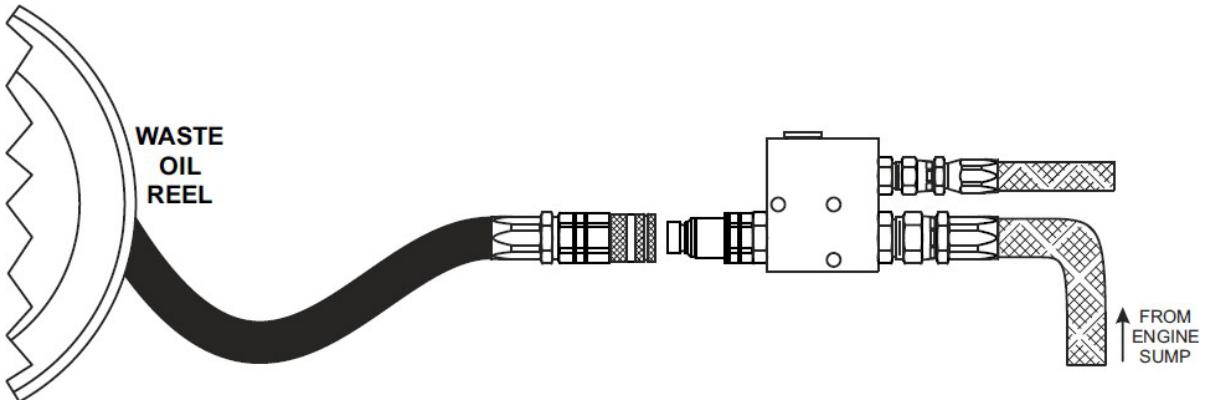


Figure 175. Waste Oil Reel Line

3. Disconnect both pressure hoses (Figure 175, Item 6 & 11) and disconnect the suction hose (Figure 175, Item 8) from the pump (Figure 175, Item 4).
4. Remove the four bracket bolts (Figure 175, Item 7) from the pump bracket (Figure 175, Item 5).
5. Remove the pump (Figure 175, Item 4).

PRE-LUBE PUMP

Note:

- Pressure switch can be found above the cylinder block on prime engines only (Figure 156), if replacing.

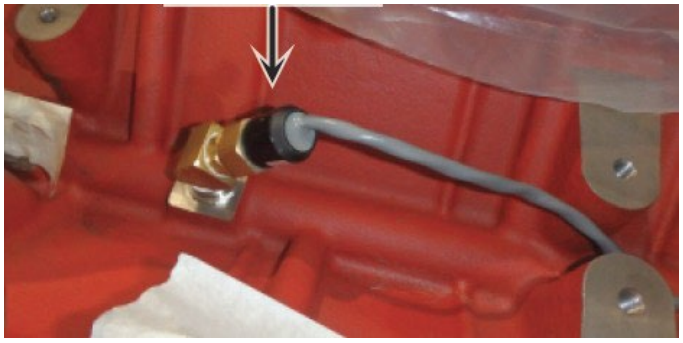


Figure 176. Pre-Lube Pressure Switch

INSTALLATION

1. Place new pump (Figure 176, Item 4) onto the pump bracket (Figure 176, Item 5).
2. Insert the four bracket bolts (Figure 176, Item 7) onto the pump bracket (Figure 176, Item 5) and torque the four bolts to 7 ft/lbs.
3. Insert and torque the pressure hose (Figure 176, Item 6) onto the top of the pump to 30 ft/lbs.
4. Insert and torque the pressure hose (Figure 176, Item 11) onto the pump to 30 ft/ lbs.
5. Insert and torque the suction hose (Figure 176, Item 8) onto the pump to 30 ft/lbs.
6. To refill the system attached the female quick disconnect from the clean oil reel to the male quick disconnect on the Quick fix valve. Turn the clean oil pump on to refill oil through the new oil filter, when the clean oil pump has finished refilling the oil to refill capacity, remove the clean oil line (Refer to Figure 177).

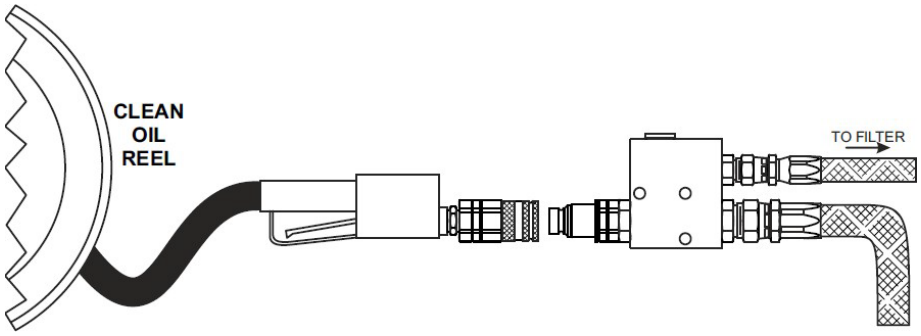


Figure 177. Clean Oil Reel Line

7. Reconnect all battery terminals.

TORQUE SPECIFICATIONS

Data for Tightening Torque			
Tightening of Screws and Nuts	**Thread**	**Assembly**	**Recommended Tightening Torque (ft/lb)**
Injector Pipe Nut	M14×1.5	Lub. oil	30±2
	M16×1.5	Lub. oil	
Bolt for Return Pipe of Injector	M8×1	Lub. oil	6
Bolt for Adjust Plate of Alternator	M8 (10.9)	Lub. oil	26±2
Bolt for Fixing Bracket Rod of Alternator	M10 (10.9)	Lub. oil	48±4
Exhaust Manifold Bolt	M10 (10.9)	Loctite 242	48±4
Banjo Bolt (Between exhaust elbow/pipe)			52±5
Intake Manifold Bolt	M10 (10.9)	Loctite 242	48±4
Engine Hanger Plate Bolt	M12 (10.9)	Lub. oil	81±4
Bolt for Fixing Turbocharger Oil Outlet Pipe	M10 (10.9)	Loctite 242	48±4
Bolt for Fixing Fuel Injection Pump Bracket	M10 (10.9)	Lub. oil	33±2
Nut for Fixing Fuel Injection Pump Bracket	M8 (12.9)	Lub. oil	30±2
Fuel Injection Pump Inter Gear Bolt	M10 (10.9)	Loctite 242	48±4
Fuel Injection Pump Gearing Bolt	M10 (12.9)	Loctite 242	52±4
Injection Pump Camshaft Nut	M24×1.5	Loctite	236±7
Oil Cooler Bolt	M8 (10.9)	Loctite 242	26±2
Oil Pump Bolt	M14 (10.9)	Loctite 242	133±7
Valve Bridge Adjusting Nut	M10 (10.9)	Loctite 242	33±2

Data for Tightening Torque			
Tightening of Screws and Nuts	**Thread**	**Assembly**	**Recommended Tightening Torque (ft/lb)**
Connecting Rod Bolt	M16×1.5	Loctite 242	Tighten to 74 then 147
			Tighten to an angle of 60°
			Tighten to an angle of 45°
Main Bearing Bolt	M24×2	Lub. oil	Tighten to 133 ±7
			Tighten to an angle of 60°
			Tighten to an angle of 60°
Cylinder Head Bolt	M16 (Main Bolt) M20 (Secondary Bolt)	Lub. oil	Tighten M16 bolts to 59. Tighten the M20 bolts to 59.
			Tighten the M16 and M20 bolts to 59±10, then to an angle of 60±5°.
			Tighten M16 & M20 bolts to an angle of 60±5°.
			Tighten the M20 bolts to an angle of 60°±5°. Tighten the M16 bolts to an angle of 45°±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.
Bolt for fixing rocker arm bracket onto cylinder head	M10 (10.9)	Lub. oil	48±4
Crankshaft Damper Bolt	M14 (10.9)	Loctite 242	Tighten the bolts to a torque of 59
			Tighten the bolts to a torque of 151±7
Flywheel Bolt	M20×2.0	Lub. oil	Tighten the bolts to a torque of 140±7
			Tighten the bolts to a torque of 55±4
Screw for Fixing Camshaft Thrust Plate	M8 (12.9)	Loctite 242	Tighten the bolts to a torque of 15
			Tighten the bolts to a torque of 29
Camshaft Timing Gear Bolt	M10 (10.9)	Loctite 242	52±4
Bolt for Fixing Oil Pan onto Block	M10 (10.9)	Loctite 242	55±4
Bolt for Adjusting Rocker Arm	M10 (10.9)	Lub. oil	33±2
Flywheel Housing Bolt	M14 (10.9)	Lub. oil	Tighten the bolts to a torque of 59
			Tighten the bolts to a torque of 133±7

Data for Tightening Torque			
Tightening of Screws and Nuts	**Thread**	**Assembly**	**Recommended Tightening Torque (ft/lb)**
Nut for fixing starter	M10 (10.9)	Loctite 242	48±4
Valve Bridge Bolt	M10 (10.9)	Loctite 242	33±4
Water Pump Bolt	M8 (10.9)	Loctite 242	26±2
Bolt	M14 (10.9)	Loctite 242	133±7
Front Cover Bolt	M10 (10.9)	Loctite 242	48±4
Injector Holder Nut	M32×1.5	Lub. oil	89±4
Oil Supply line to water pump bolt (Banjo bolt)	M10x1 (10.9)		20
Oil Supply line to water pump bolt (Banjo bolt)	M12×1.5		23

MECHANICAL SPECIFICATIONS

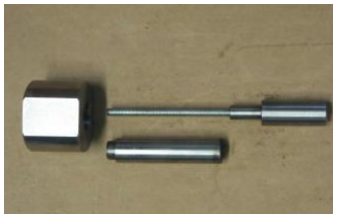
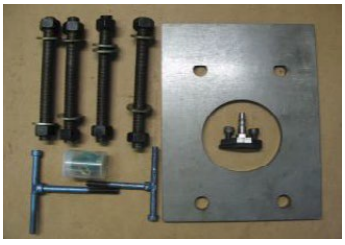
SN	Item		Unit	53L
1	Intake Mode		-	Inter-Cooling
2	Cylinders		-	16
3	Bore/Stroke		mm	150/185
4	Displacement		L	52.3
5	Compression Ratio		-	15:1
6	Operating Oil Pressure		MPa	0.40-0.65 (rated power)
7	Oil Temp after Cooling		°F	185-221
8	Thermostat Opening Temperature		°F	176
9	Exhaust Temperature after Turbine		°F	≤1022
10	Opening of Intake Valve		°CA	34±5 °CA before TDC
11	Closing of Intake Valve		°CA	40±5 °CA after BDC
12	Opening of Exhaust Valve		°CA	47±5 °CA before BDC
13	Closing of Exhaust Valve		°CA	13±5 °CA after TDC
14	Firing Order		-	1-7-12-14-4-16-2-8-11-13-3-5-10-6-9-15
15	Rotation Direction		-	Counter-clockwise (facing towards flywheel)
16	Starting Method		-	Electric Starter Motor
17	Lubrication Method			Forced Lubrication
18	Cooling Method			Water Cooling Forced Circulation
19	Intake/Exhaust Valve Gap (cold state)		mm	Intake: 0.022" (0.55 mm) Exhaust: 0.039" (1.00 mm)
20	Oil capacity		L	171
21	Dimensions (with radiator)	Length	mm	2875
		Width		1542
		Height		1746
22	Net Weight		lb.	11,299
23	Main Bearing Clearance		mm	0.116～0.196
24	Connecting Rod Bearing Clearance		mm	0.08-0.15
25	Crankshaft Axial Clearance		mm	0.15～0.346
26	Connecting Rod Axial Clearance		mm	0.20～0.65
27	Clearance Between Connecting Rod Small end Bush and Piston Pin		mm	0.031～0.081
28	Piston 1 ring gap working clearance at cold state		mm	0.45～0.6
29	Piston 2 ring gap working clearance at cold state		mm	0.75～1.0
30	Oil control ring gap working clearance at cold state		mm	0.45～0.7

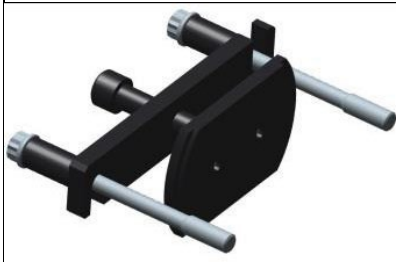
SN	Item	Unit	53L
31	Clearance Between Piston Pin and Pin Seat	mm	0.015~0.03
32	Clearance Between Intake Valve Stem and Valve Guide	mm	0.035～0.065
33	Clearance Between Exhaust Valve Stem and Valve Guide	mm	0.055～0.085
34	Intake Valve Sinkage from Cylinder Head Bottom Plane	mm	0.60～1.10
35	Exhaust Valve Sinkage from Cylinder Head Bottom Plane	mm	1.20～1.70
36	Upper plane of cylinder liner support shoulder above the engine body upper plane (integral cylinder gasket, at compacted state)	mm	0.07～0.13
37	Camshaft Axial Clearance	mm	0.10～0.25
38	Camshaft Bearing Clearance	mm	0.055～0.128
39	Camshaft Bearing Clearance (thrust bearing)	mm	0.06～0.12
40	Clearance Between Tappet and Hole	mm	0.025～0.080
41	Clearance between the outer diameter of cylinder liner and the cylinder hole of engine body (upper part)	mm	0.014～0.079
42	Clearance between the outer diameter of cylinder liner and the cylinder hole of engine body (lower part)	mm	0.03～0.095
43	Intake Valve Gap (cold state)	mm	0.55
44	Exhaust Valve Gap (cold state)	mm	1.0
45	Rocker Arm Axial Clearance	mm	0.4～0.6
46	Clearance Between Crankshaft Gear and Camshaft Gear	mm	0.07-0.25

PRE-LUBE PUMP

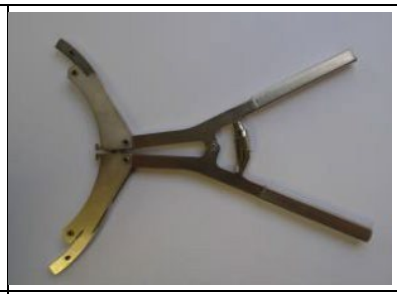
Note:

- All parts cannot be individually purchased, all parts must be purchased as an entire kit.

Description	PSI P/N	OEM P/N	Illustration
Valve Guide Remover	Z799002	1002777012	
Valve Guide Installer	Z799002	1002777012	
Intake Valve Insert Installer	Z799002	1002777012	
Exhaust Valve Insert Installer	Z799002	1002777012	
Cylinder Head Hydraulic Test Plate	Z799002	1002777012	

Valve Remover	Z799002	1002777012	
30mm Socket	Z799002	1002777012	
Flywheel Locating Pin	Z799002	1002777012	
Liner Remover	Z799002	1002777012	
Liner Installer	Z799002	1002777012	

Rear Seal Installer	Z799003	1002813557	
Flywheel Guide Rods	Z799003	1002813557	
Front Oil Seal Installer	Z799003	1002813557	
Wall Spreader for Crankshaft Bearing	Z799003	1002813557	
Piston Handle	Z799002	1002777012	

Piston Ring Pliers	Z799002	1002777012	
Piston Guide Cylinder	Z799002	1002777012	
Camshaft Fitting Guide	Z799003	1002813557	
Tappet Tool	Z799002	1002777012	
Camshaft Bearing Fitting/Removal Tool	Z799003	1002813557	

Turning Tool	Z799002	1002777012	
21mm Socket	Z799002	1002777012	
Vibration Damper Guide Rod	Z799003	1002813557	
Injector Busing Removal Tool	Z799003	1002813557	
Valve Keeper Remover	Z799004	N/A	

Pre-Lube Assembly Kit	Z52500416 (Standby)	N/A	
Pre-Lube Assembly Kit	Z52500419 (Prime)	N/A	

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 loose, 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 242	Applied onto outer threads for locking, sealing, preventing vibration from causing looseness	Auxiliary bolt, cylinder head	
Loctite 242	Preventing looseness, fixing	Cup plug, oil drain hole	N/A
Loctite 242	For sealing between element and bore	Other cup plugs	N/A

Loctite 242	Sealing cylinder head top	Push rod, cylinder head	N/A

Grey Loctite RTV Silicone Note: • Silicone should not be used on <u>ANY</u> coolant or pressurized oil joints.	It's applied onto shining metal surfaces for sealing purpose.	Interface between cylinder block.	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 water pump rear cover and engine body front end face.	
		Interface between flywheel cover and its connecting	
		Interface between cylinder block and engine oil filler pipe.	
CASTROL MOLUB-ALLOY™ 6040/460-1.5	It's applied onto the camshaft lobes and lifters	Camshaft lobes and lifters.	N/A

TIGHTENING 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 (ft/lb.)							
M4	2	2	3	3	2	2	3	4
M5	3	4	6	7	4	4	6	7
M6	6	7	10	12	6	7	10	13
M8	14	17	24	29	15	18	26	30
M10	29	34	47	57	30	36	51	61
M12	49	59	81	96	53	63	87	107
M14	77	92	133	159	85	100	140	170
M16	122	144	203	243	133	155	218	262
M18	166	199	288	336	181	214	299	358
M20	240	284	398	479	254	302	428	509
M22	321	376	531	642	343	406	575	686
M24	413	487	686	811	443	524	738	885
M27	612	723	1033	1217	656	774	1106	1328
M30	811	996	1364	1660	885	1069	1475	1770
M8X1	15	18	26	31	17	20	28	33
M10X1.25	30	36	49	60	32	38	54	65
M12X1.25	55	65	92	111	59	70	100	114
M12X1.5	52	61	85	103	56	66	92	111
M14X1.5	85	103	144	173	92	111	155	184
M16X1.5	129	155	218	258	140	166	232	280
M18X1.5	188	225	313	376	203	240	339	406
M20X1.5	266	313	442	531	284	339	472	568
M22X1.5	354	420	590	708	384	450	634	774
M24X1.5	450	531	738	885	479	575	811	959
M27X1.5	656	774	1106	1328	715	848	1180	1438
M30X1.5	922	1069	1512	1844	996	1180	1660	1991

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