POWER SOLUTIONS INTERNATIONAL

20L SERVICE MANUAL

LARGE SPARK IGNITED CERTIFIED PRODUCT

PSI ENERGY

A Product by Power Solutions International
Wood Dale, IL

7610049-4

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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	09/21/2023	Initial Release
2	02/07/2024	Added mounting bolt torque specs
3	08/21/2025	Added note stating cylinder head bolts may be used a maximum of three times before needing to be replaced in Cylinder Head Removal/Installation and torques pec chart
4	12/04/2025	Updated valve lash specs and procedures to set engine to TDC

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.

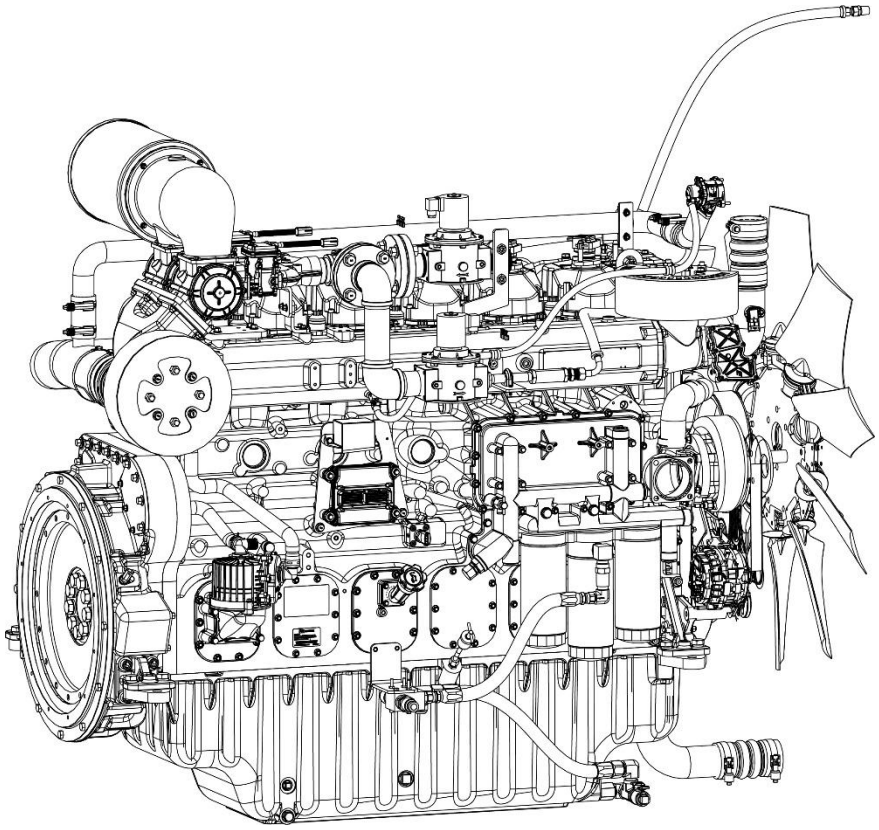
STARTER BATTERY

- 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. Ensure battery is a minimum of (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.

THEORY OF OPERATION AND ENGINE COMPONENTS



CYLINDER BLOCK

The cast iron cylinder block is configured as an in line with one bank of six integral cylinder bores at an included angle of 90 degrees. Coolant jackets surround each cylinder bore. Seven cast iron main bearing caps are each fastened by four bolts, with the crankshaft thrust taken up 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 20L engine uses a hardened steel forged crankshaft with seven hardened main bearing journals and six connecting rod journals oriented with 90-degree phasing. Eight counterweights to provide internal balance of the rotating assembly.

PISTON AND CONNECTING ROD

All six 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 six 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, cylinder head cover, cylinder head gasket, valves, and rocker assemblies.

CAMSHAFT

The camshaft utilizes seven cam journals and twelve 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.

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.

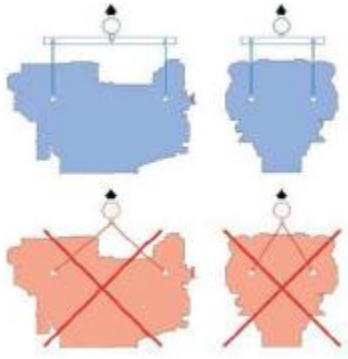


Figure 1. Hoisting Engine

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 BOLTS AND NUTS CHART.*

LIFTING EYES

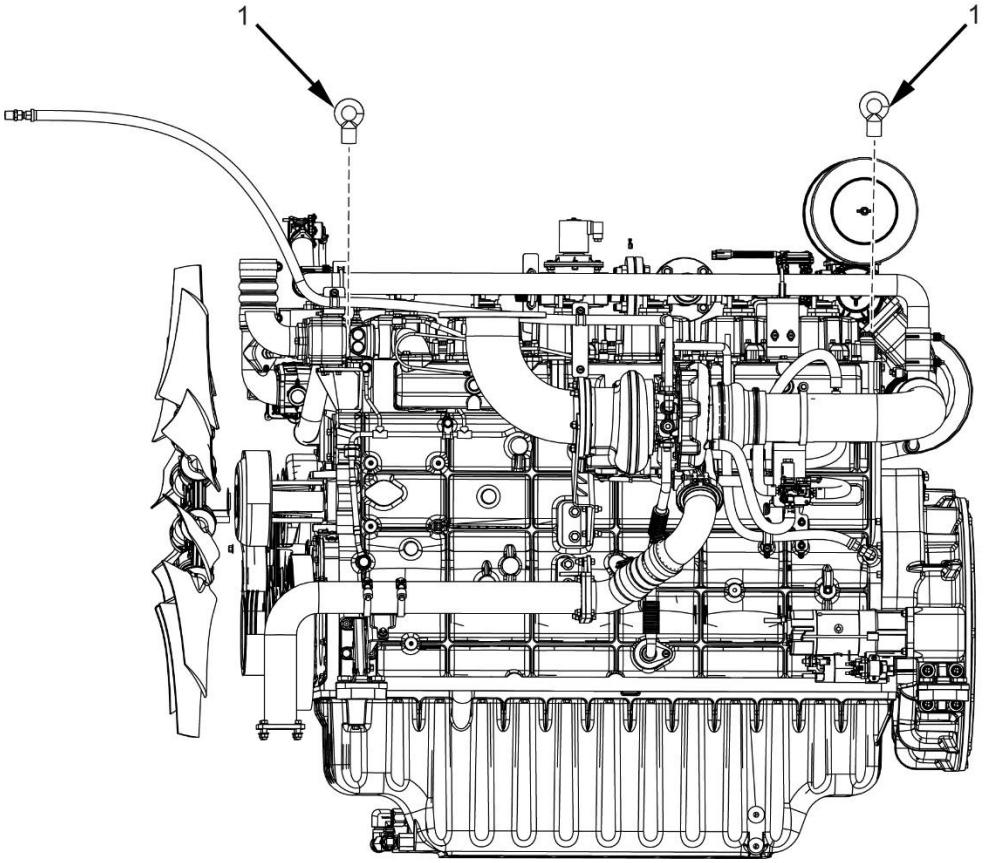


Figure 2. Lifting Eyes Assembly

NO.	Name
1	Lifting Eye

REMOVAL

1. Loosen and remove all four lifting eyes.

WARNING:

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

INSTALLATION

1. Insert and torque all four lifting eyes to 538 lb-ft.

ENGINE CONTROL MODULE (ECM)

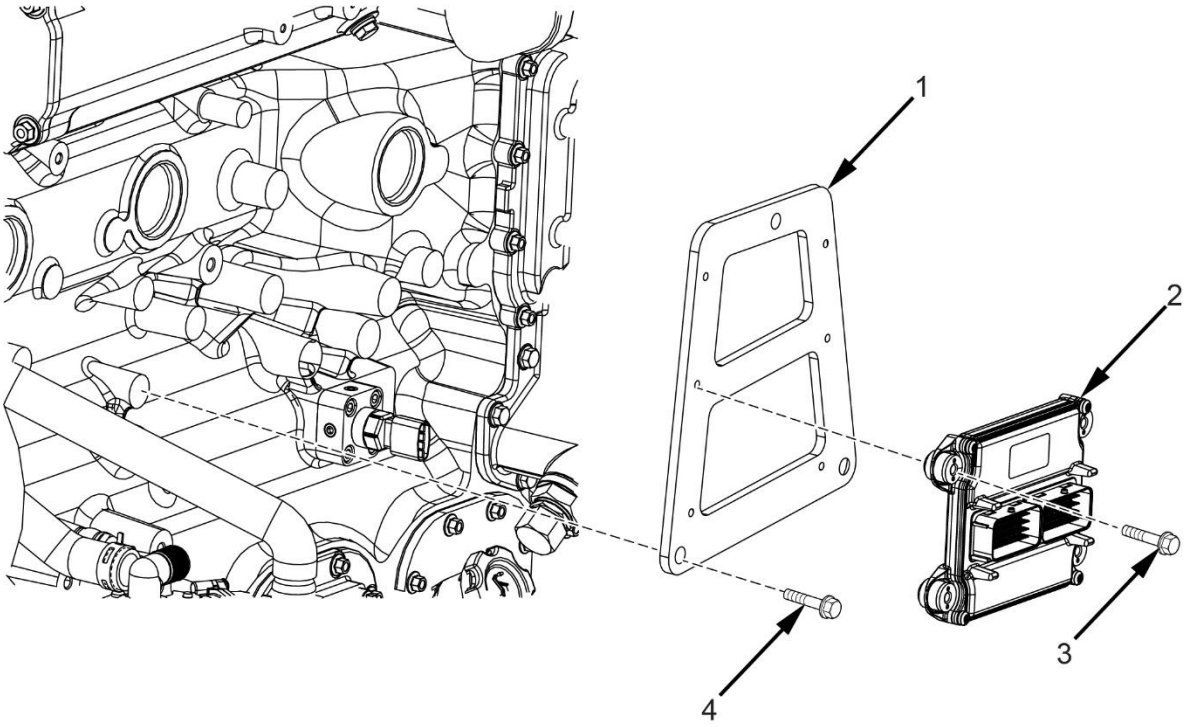


Figure 3. ECM Assembly

NO.	Name
1	Bracket
2	ECM
3	Bolt
4	Bolt

The 20L engine comes equipped with an Engine Control Module (ECM). The ECM monitors various engine sensors, this allows for optimal engine performance.

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Disconnect all batteries.
2. Disconnect all electrical harnesses coming from the ECM.
3. Remove the bolts (Figure 3, Item 3) from the ECM (Figure 3, Item 2).
4. Remove the ECM (Figure 3, Item 2).
5. Remove the mounting bracket bolts (Figure 3, Items 4).
6. Remove the mounting bracket (Figure 3, Item 1).

INSTALLATION

1. Place the ECM mounting bracket (Figure 3, Item 1) onto the engine block.
2. Insert and torque the mounting bracket bolts (Figure 3, Items 4).
3. Place the ECM (Figure 3, Item 2) onto the mounting bracket.
4. Insert and torque the bolts (Figure 3, Items 3) to 7 lb-ft.
5. Insert all electrical harness back into the ECM accordingly.
6. Reconnect all batteries.

ENGINE BRACKETS

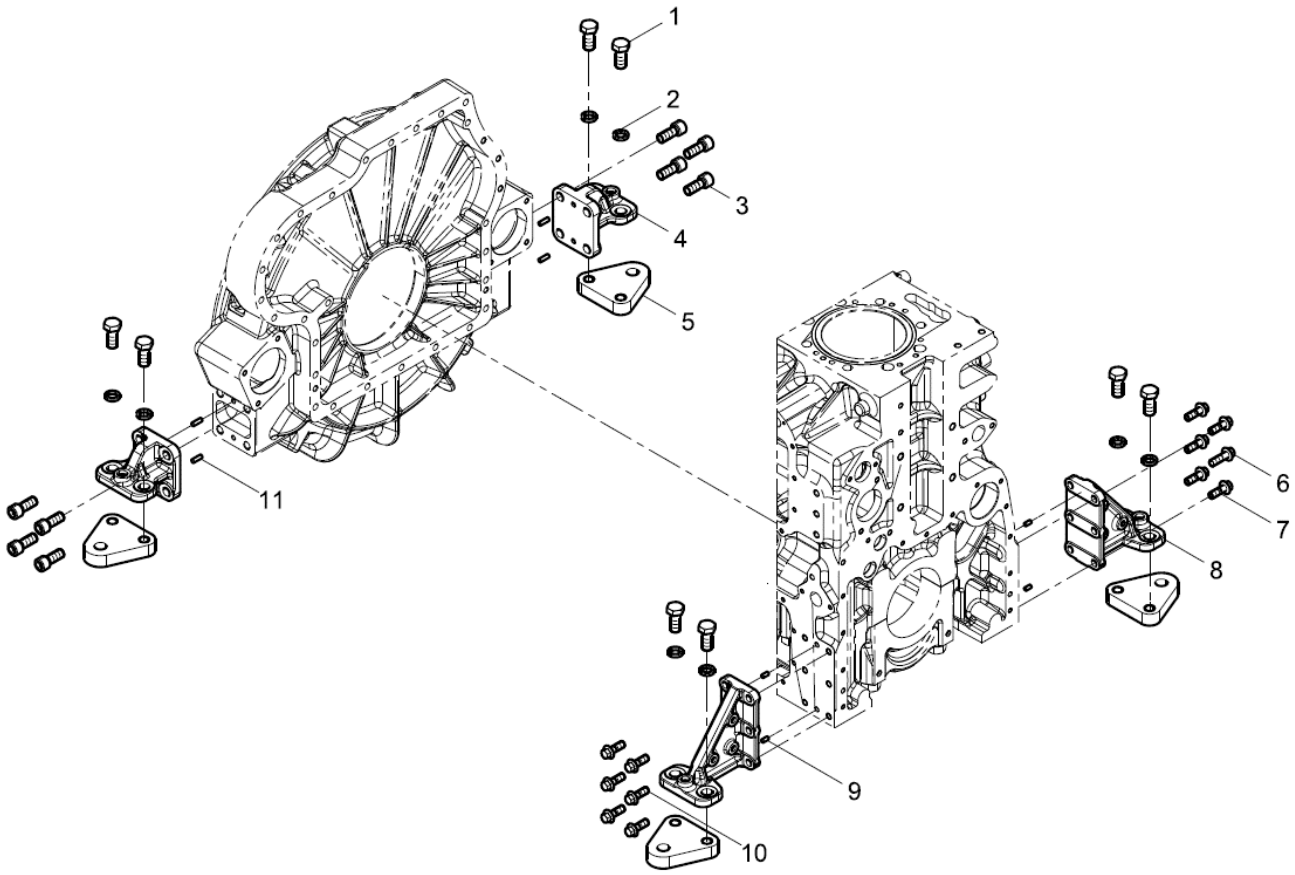


Figure 4. Engine Bracket Assembly

NO.	Name	NO.	Name	NO.	Name
1	Bolt	5	Bracket	9	Pin
2	Washer	6	Bolt	10	Bolt
3	Bolt	7	Bolt	11	Pin
4	Bracket	8	Bracket		

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 BOLTS AND NUTS CHART.*
- Before removing the engine brackets ensure the engine is supported securely.

REMOVAL

1. Remove the bolts and washers (Figure 4, Items 1, 2, 3, 6 & 7).
2. Remove the engine brackets (Figure 4, Items 4, 5 & 8).

INSTALLATION

1. Clean any debris from the front of the engine block and from the sides of the flywheel housing.
2. Install the pins (Figure 4, Items 9 & 11)
3. Place the engine brackets on the cylinder block and flywheel housing (Figure 4, Items 4, 5 & 8).
4. Install and tighten the bolts/washers to the standard torque (Figure 4, Item 1, 2, 3, 6 & 7).

CYLINDER BLOCK CLEANING AND INSPECTION

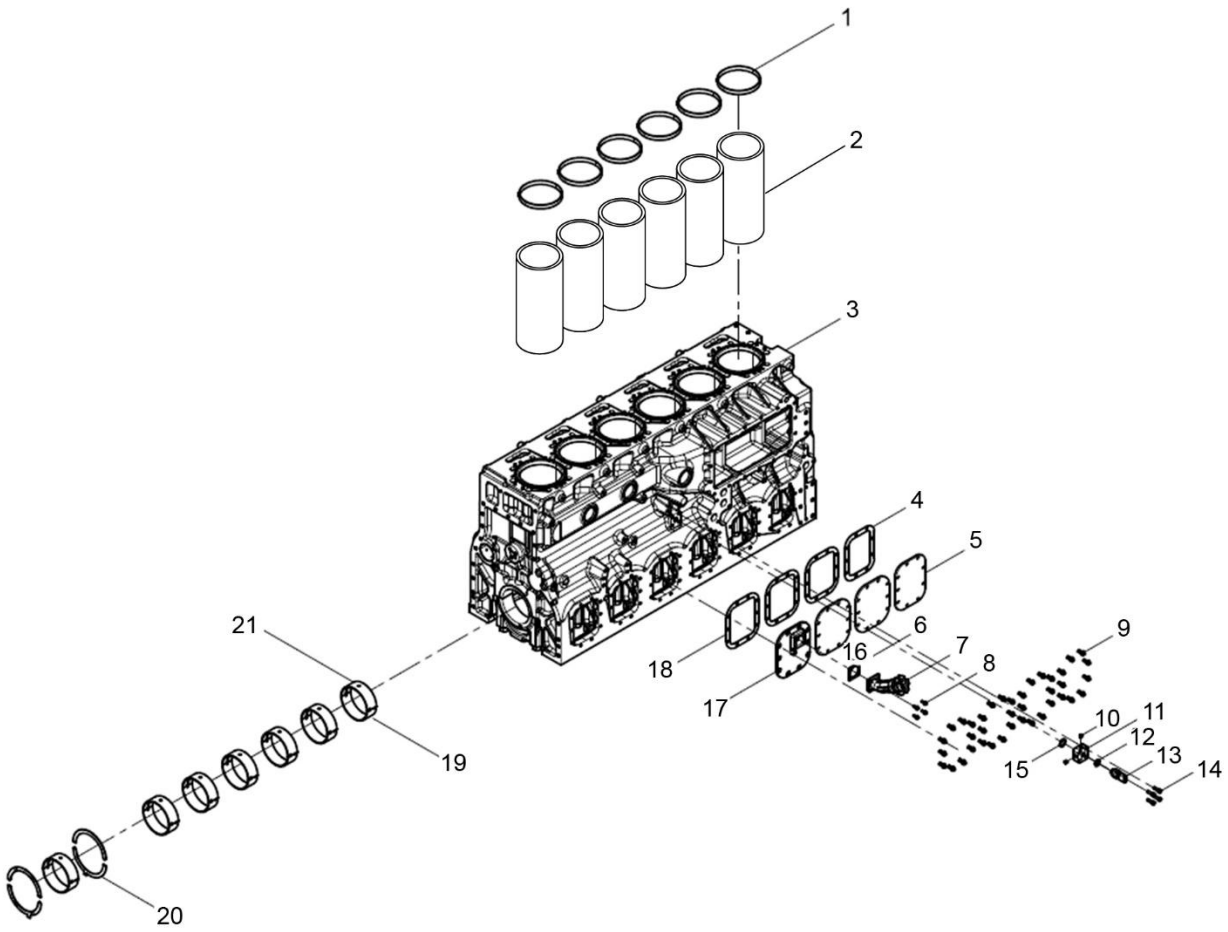


Figure 5. Cylinder Block Assembly

NO.	Name	NO.	Name	NO.	Name
1	Carbon Ring	8	Bolt	15	Plug
2	Cylinder Liners	9	Bolt	16	Cover
3	Crankcase	10	O-Ring	17	Cover
4	Gasket	11	Sensor Seat	18	Gasket
5	Cover	12	Washer	19	Lower Main Bearing
6	Gasket	13	Pressure/Temp Sensor	20	Plate
7	Oil Filling Tube	14	Bolt	21	Upper Main Bearing

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 BOLTS AND NUTS CHART.*

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

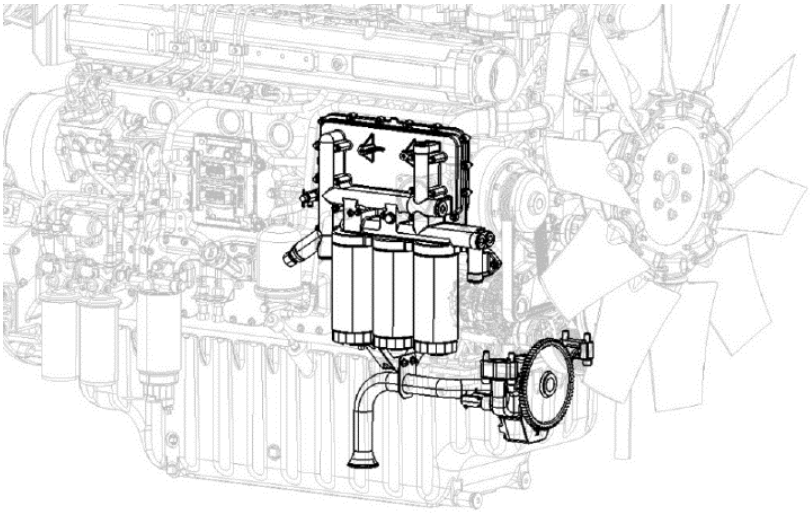


Figure 6. Lubrication System

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	Below 1400 RPM	Above 1400 RPM
20L	Warning 35 PSI (0.24 MPa)	Warning 50 PSI (0.34 MPa)
	Shutdown 29 PSI (0.20 MPa)	Shutdown 45 PSI (0.31 MPa)

Model	Oil Pressure at 1000 RPM (Idle)	
20L	Min	35 PSI
	Max	57 PSI)

LUBRICATION SYSTEM DIAGRAM

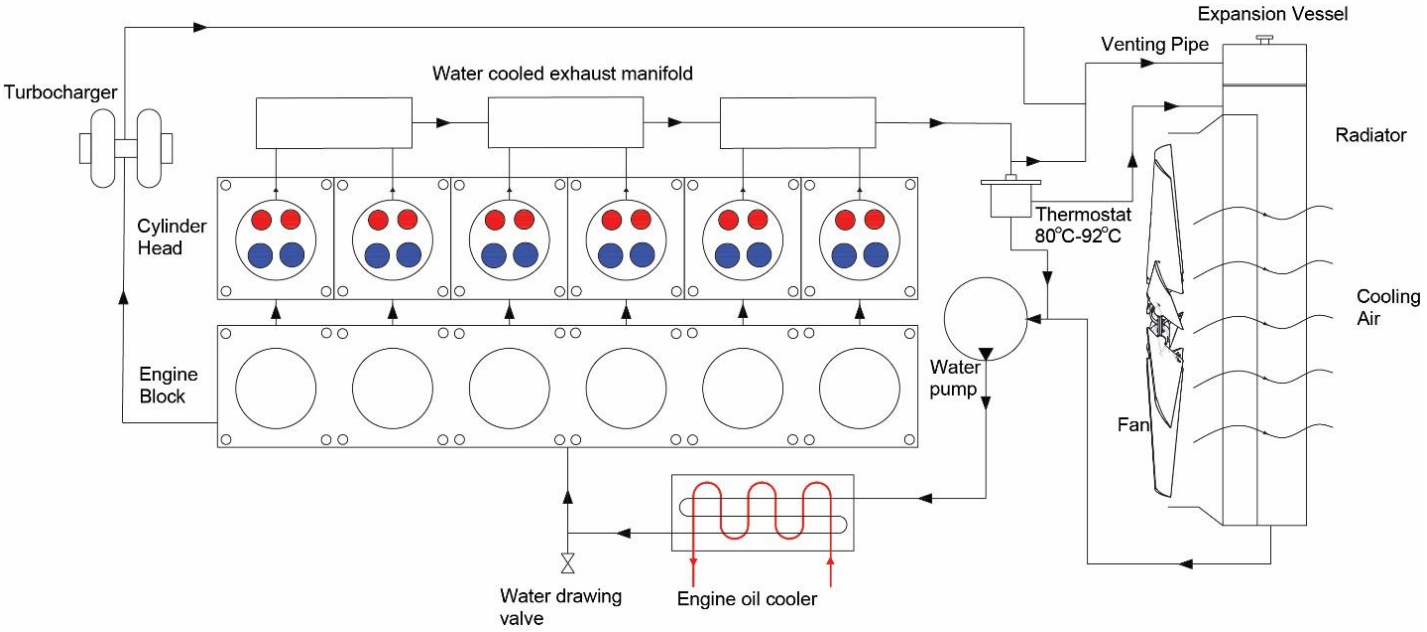


Figure 7. Lubrication System Diagram

OIL PUMP

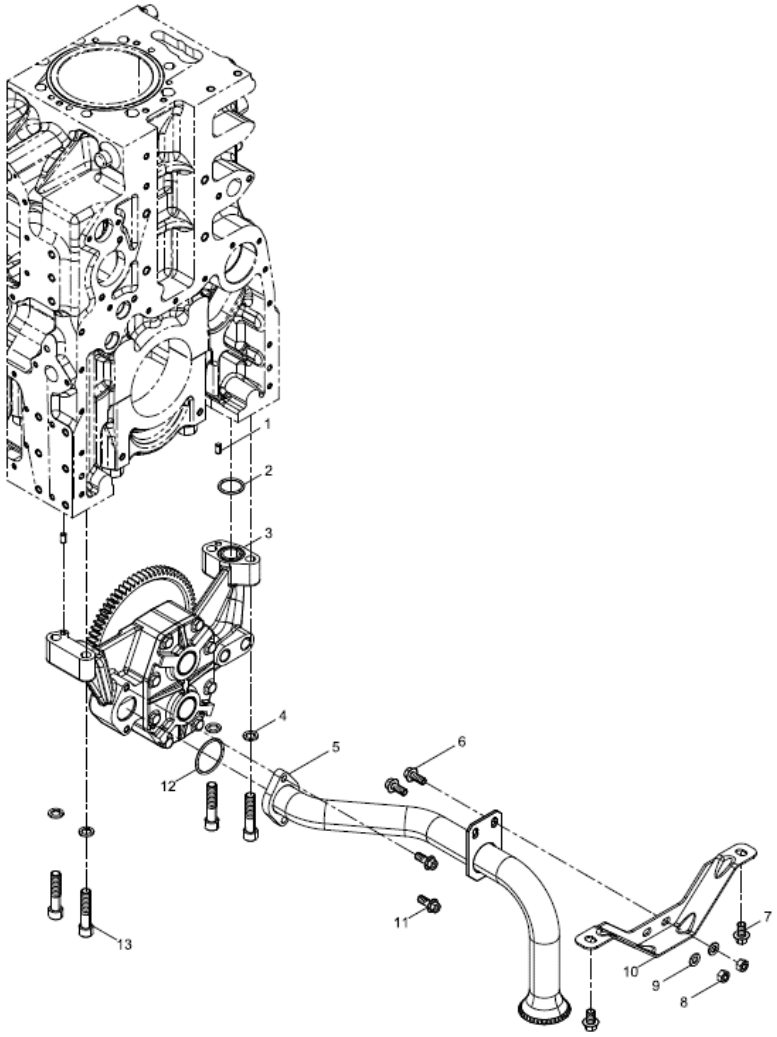


Figure 8. Oil Pump Assembly

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 BOLTS AND NUTS CHART.*

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

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 8, Items 13 & 4) from under the oil pump.
4. Remove the bolt (Figure 8, Item 11) from the rear of the oil pump and remove the O-ring (Figure 8, Item 12).
5. Remove the oil pump (Figure 8, Item 3).
6. Remove both bolts from the strainer bracket (Figure 8, Item 6).
7. Carefully remove the oil strainer (Figure 8, Item 5).

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.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

INSTALLATION

1. Insert oil strainer (Figure 8, Item 5) onto the oil strainer bracket (Figure 8, Item 10).
2. Insert and tighten both bolts (Figure 8, Item 6).
3. Install a new O-ring (Figure 8, Item 12) and tighten bolt (Figure 8, Item 11) on the oil pump.
4. Insert new O-rings (Figure 8, Item 2) on top of the oil pump.
5. Insert and tighten down the four bolt and washers (Figure 8, Items 13 & 4) from the bottom of the oil pump.

NOTE:

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

ENGINE OIL DIPSTICK

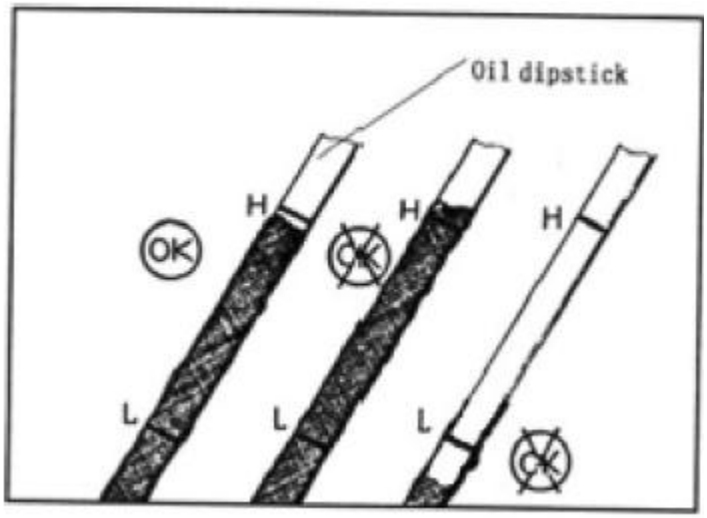


Figure 9. Engine Oil Dipstick

REMOVAL

1. Remove the engine oil dipstick from the engine oil dipstick tube.
   a. Check oil level. (Refer to Figure 9)
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

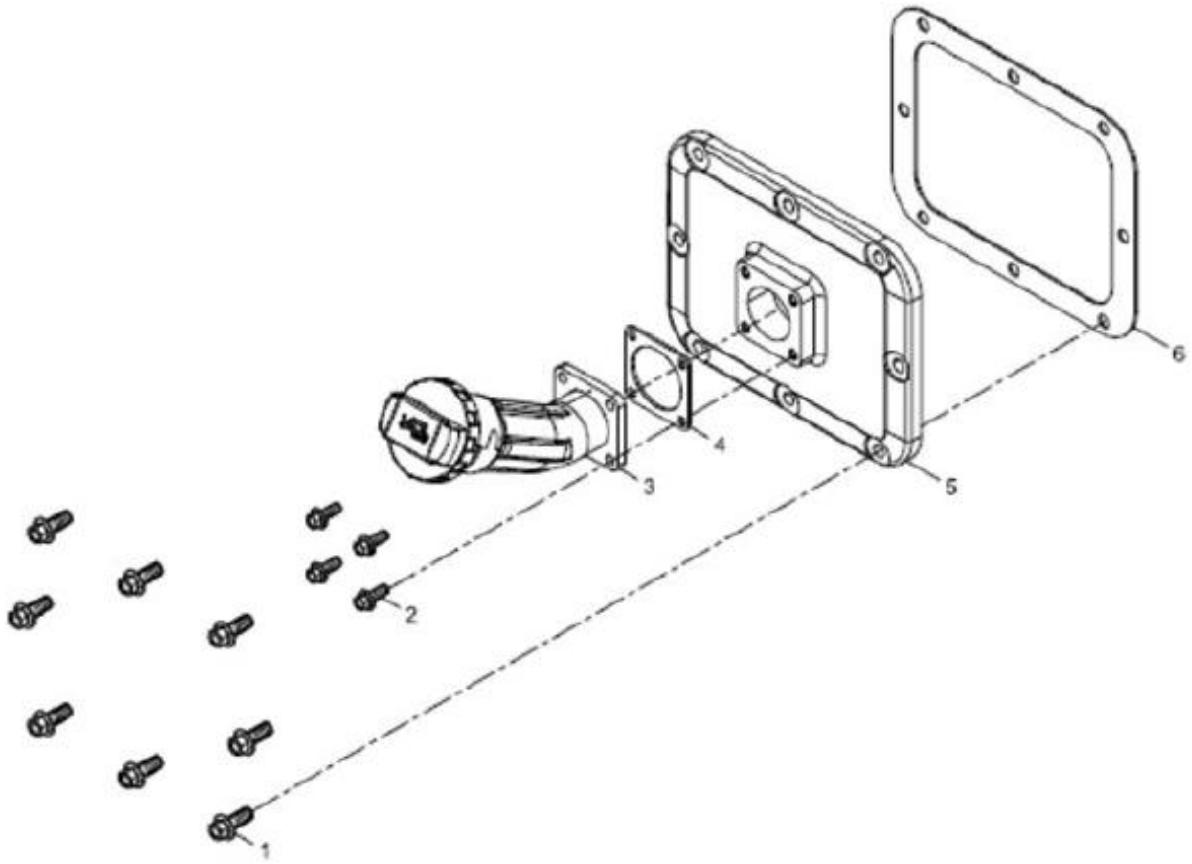


Figure 10. Oil Filling Tube Assembly

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

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Loosen and remove bolts (Figure 10, Items 1 & 2).
2. Remove oil fitting tube (Figure 10, Item 3).
3. Remove oil filler tube gasket (Figure 10, Item 4).

INSTALLATION

1. Place oil filler tube gasket (Figure 10, Item 4) on the cover (Figure 10, Item 5).
2. Place oil filling tube (Figure 10, Item 3) onto gasket (Figure 10, Item 4).
3. Insert and tighten bolts (Figure 10, Items 1 & 2).

ENGINE BELT ROUTING

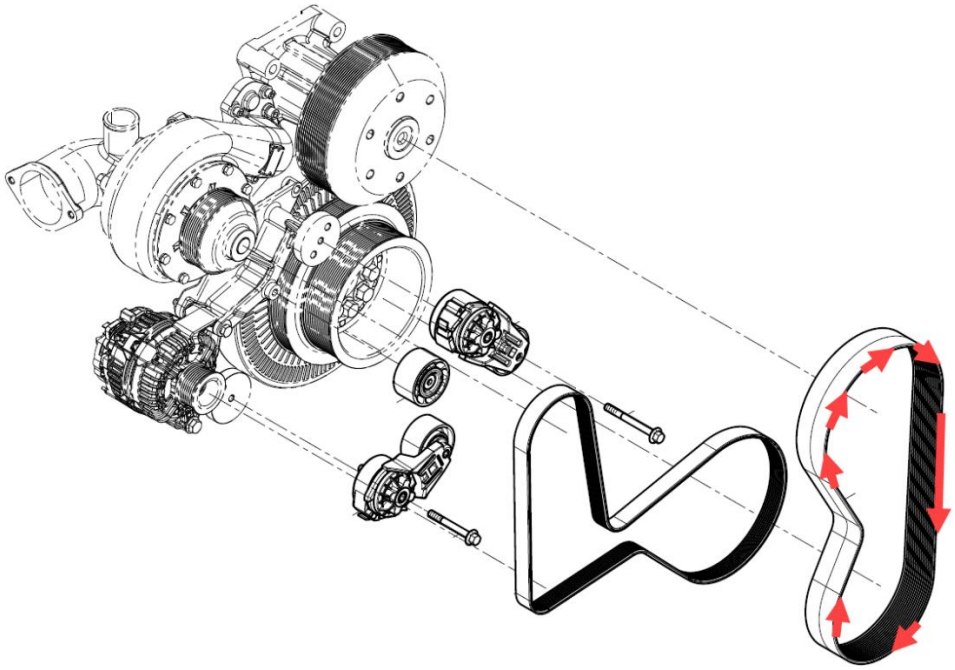


Figure 11. Serpentine Belt Routing

1. The grooved serpentine belt runs under the crankshaft pulley, to the right-hand automatic belt tensioner and over the fan pulley.

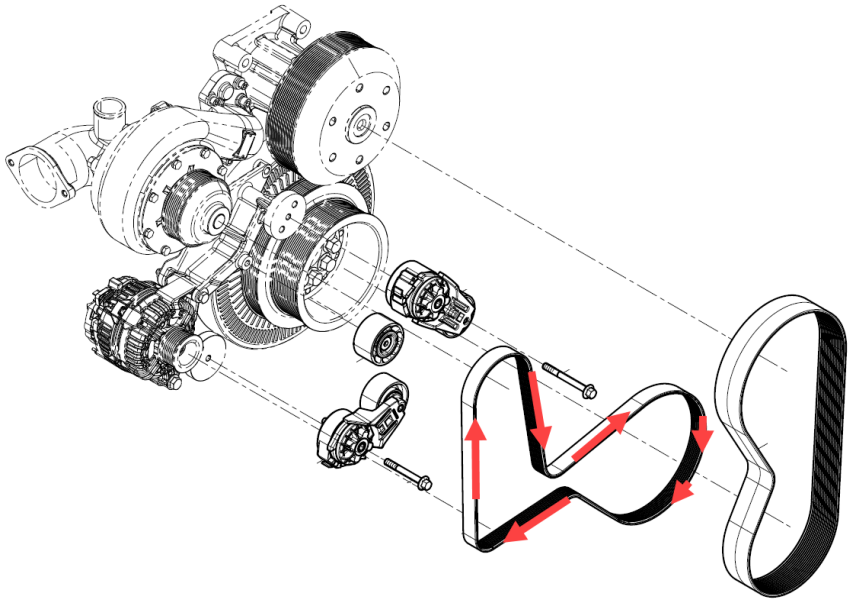


Figure 12. Right-Hand Belt Routing

2. The right-hand belt runs around the crankshaft pulley, above the automatic belt tensioner, around the alternator pulley and above the water pump pulley.

FRONT ENGINE ACCESSORY DRIVE (FEAD)

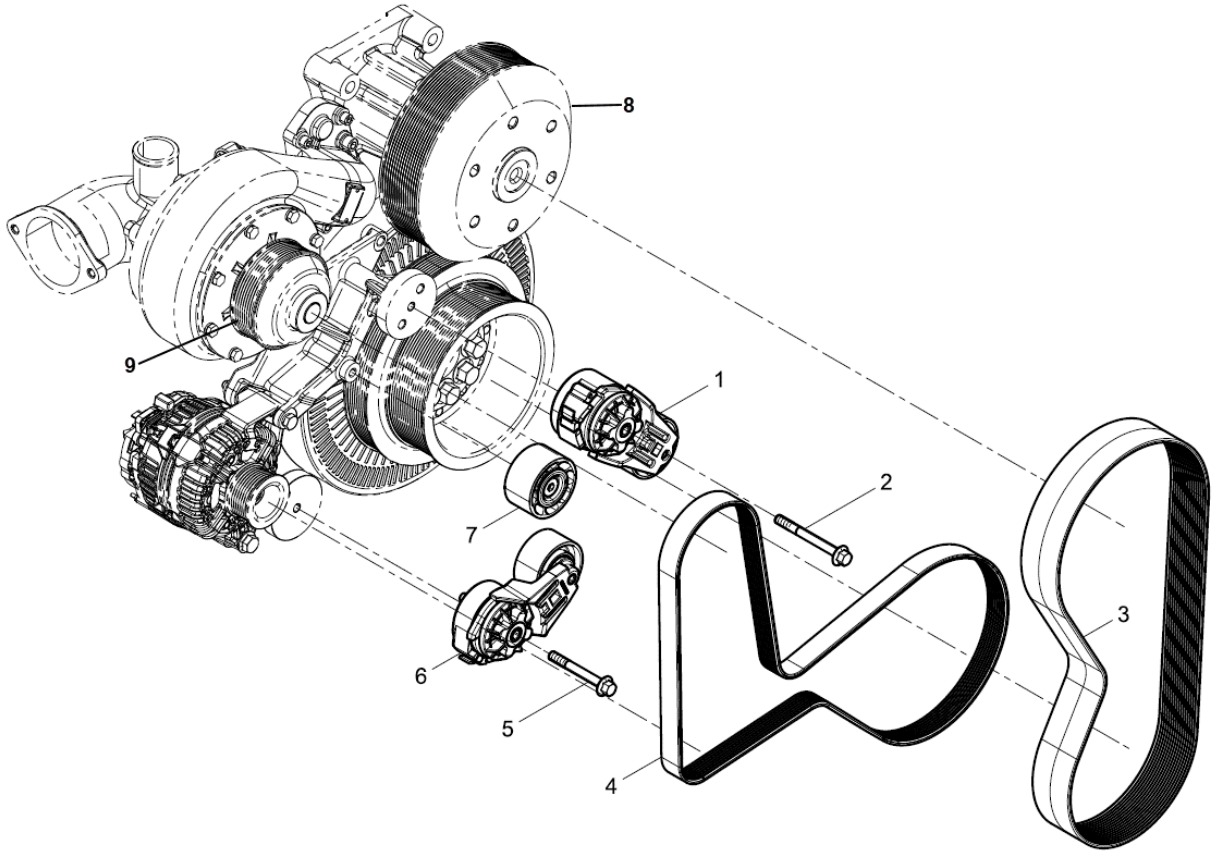


Figure 13. Front Engine Accessory Drive Assembly

NO.	Name	NO.	Name	NO.	Name
1	Automatic Belt Tensioner	4	Right-Hand Belt	7	Idler Pulley
2	Bolt	5	Bolt	8	Fan Pulley
3	Serpentine Belt	6	Automatic Belt Tensioner	9	Water Pump Pulley

ALTERNATOR PULLEY ASSEMBLY

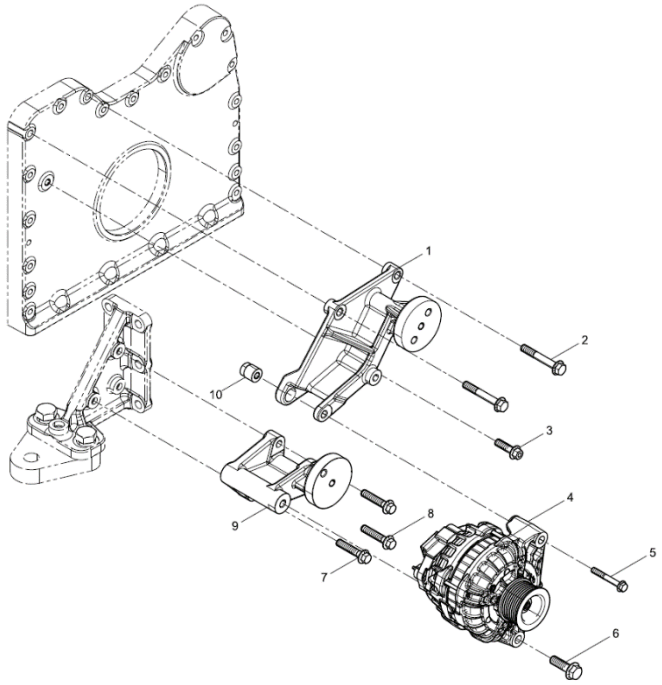


Figure 14. Alternator Pulley Assembly

NO.	Name	NO.	Name
1	Bracket	6	Bolt
2	Bolt	7	Bolt
3	Bolt	8	Bolt
4	Alternator	9	Bracket
5	Bolt	10	Nut

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 BOLTS AND NUTS CHART.*

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 right-hand belt.
2. Remove the bolts (Figure 14, Items 5 & 6).
3. Remove the alternator (Figure 14, Item 4).

INSTALLATION

1. Place the alternator (Figure 14, Item 4) onto the bracket (Figure 14, Item 9 & 1).
2. Insert and torque the bolts (Figure 14, Items 5 & 6).
3. Place the belt back onto the alternator pulley.

RIGHT-HAND IDLER PULLEY

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Remove the bolt (Figure 14, Item 3).
2. Remove the right-hand idler pulley (Figure 14, Item 7).

INSTALLATION

1. Place the right-hand idler pulley (Figure 14, Item 7) onto the bracket (Figure 14, Item 1).
2. Insert and torque the bolt (Figure 14, Item 3).

RIGHT-HAND AUTOMATIC BELT TENSIONER

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Remove bolt (Figure 13, Item 5).
2. Remove the right-hand automatic belt tensioner (Figure 13, Item 6).

INSTALLATION

1. Place the right-hand automatic belt tensioner (Figure 13, Item 6) onto the tensioner bracket.
2. Insert and torque the bolt (Figure 13, Item 5).

SERPENTINE AUTOMATIC BELT TENSIONER

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 BOLTS AND NUTS CHART.*

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 serpentine belt (Figure 13, Item 3).
2. Remove the bolt (Figure 13, Item 2).
3. Remove the serpentine automatic belt tensioner (Figure 13, Item 1).

INSTALLATION

1. Place the serpentine automatic belt tensioner (Figure 13, Item 1) onto the bracket.
2. Insert and torque the bolt (Figure 13, Item 2).

FAN PULLEY ASSEMBLY

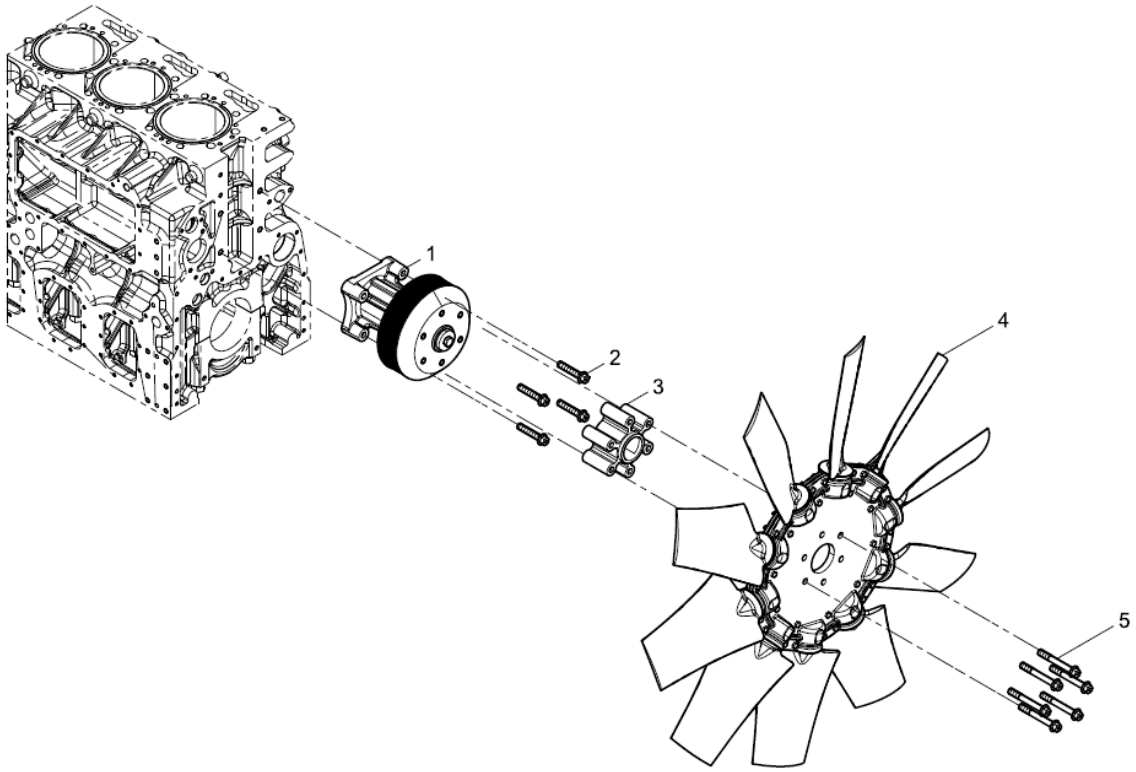


Figure 15. Fan Pulley Assembly

NO.	Name
1	Bracket
2	Bolt
3	Spacer
4	Fan
5	Bolt

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Remove the bolts (Figure 15, Item 5).
2. Remove the fan (Figure 15 Item 4) and the spacer (Figure 15, Item 3).
3. Remove the bolts (Figure 15, Item 2).
4. Remove the fan pulley bracket (Figure 15, Item 1).

INSTALLATION

1. Place the fan pulley bracket (Figure 15, Item 1) onto the front of the engine.
2. Insert and torque the bolts (Figure 15, Item 2).
3. Place the spacer (Figure 15, Item 3) onto the pulley and place the fan (Figure 15, Item 4) in front of the spacer.
4. Insert and torque the bolts (Figure 15, Item 5).

CRANKSHAFT PULLEY ASSEMBLY

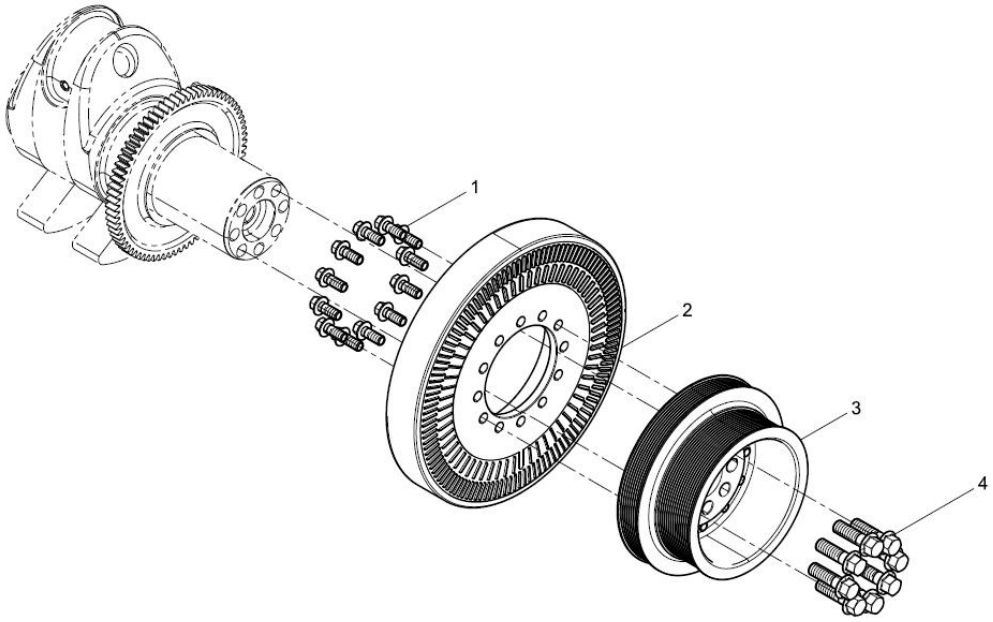


Figure 16. Crankshaft Pulley Assembly

NO.	Name	NO.	Name
1	Bolt	3	Pulley
2	Damper	4	Bolt

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Remove the bolts (Figure 16, Item 4).
2. Carefully remove the crankshaft pulley (Figure 16, Item 3).

INSTALLATION

1. Place the pulley (Figure 16, Item 3) onto the damper (Figure 16, Item 2).
2. Insert and torque the bolts (Figure 16, Item 4).

WATER PUMP

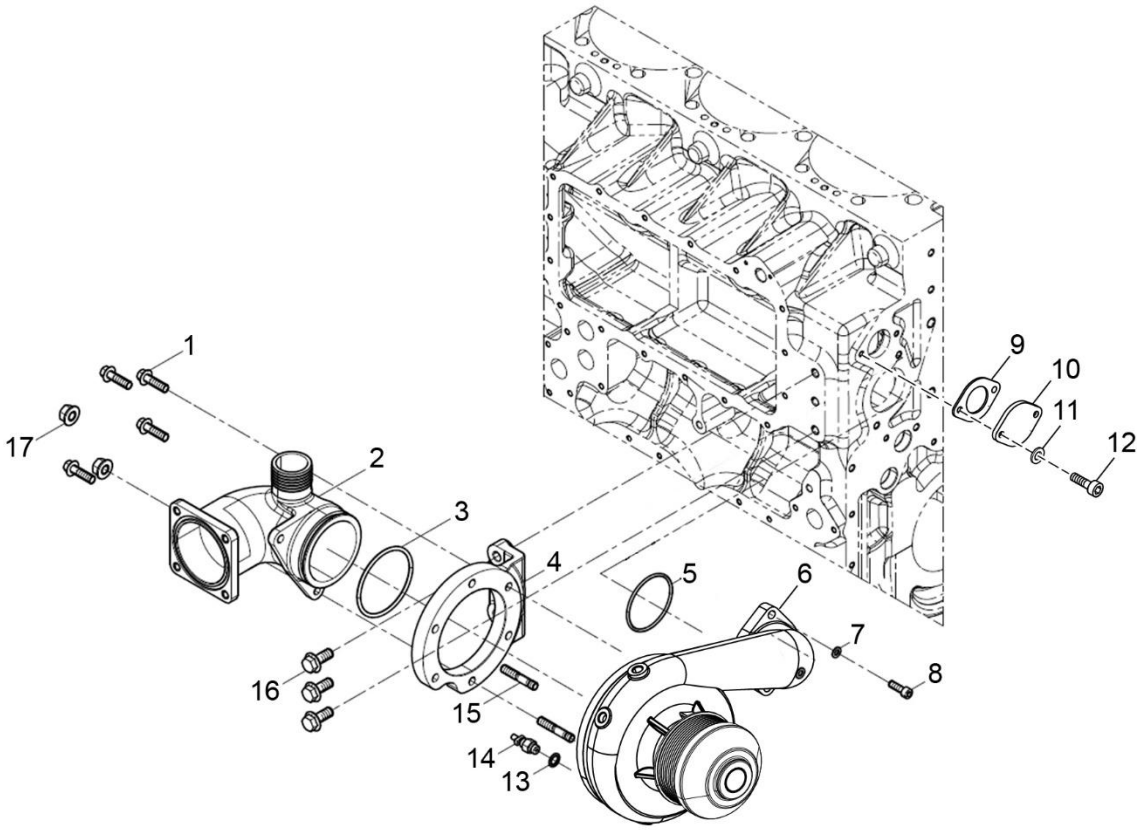


Figure 17. Water Pump Assembly Water Pump Assy

NO.	Name	NO.	Name	NO.	Name
1	Bolt	7	Washer	13	Washer
2	Pipe	8	Bolt	14	Valve
3	O-Ring	9	Gasket	15	Stud
4	Bracket	10	Cover Plate	16	Bolt
5	O-Ring	11	Washer	17	Nut
6	Water Pump	12	Bolt		

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Drain the coolant in the cooling system.
2. Remove the nuts (Figure 17, Item 17), then remove the pipe joint (Figure 17, Item 2), remove O-ring (Figure 17, Item 3).
3. Remove the bolts and washers (Figure 17, Items 7 and 8).
4. Remove the water pump (Figure 17, Item 6).
5. Remove O-ring (Figure 17, Items 5).
6. If required, remove bolts (Figure 17, Items 12), washers (Figure 17, Items 11), cover plate (Figure 17, Items 10) and gasket (Figure 17, Items 9).

INSTALLATION

1. If removed, install cover plate (Figure 17, Items 10) and gasket (Figure 17, Items 9) and install and torque two bolts (Figure 17, Items 12) and washers (Figure 17, Items 11).
2. Install new O-ring (Figure 17, Items 5).
3. Place the water pump (Figure 17, Item 6) onto the front of the engine.
4. Insert and torque the washers and bolts (Figure 17, Items 7 and 8).
5. Place a new O-Ring (Figure 17, Item 3) onto the back of the water pump (Figure 17, Item 6).
7. Place the pipe joint (Figure 17, Item 2) between the studs (Figure 17, Item 15).
8. Insert and torque the nuts (Figure 17, Item 17).

FRONT COVER

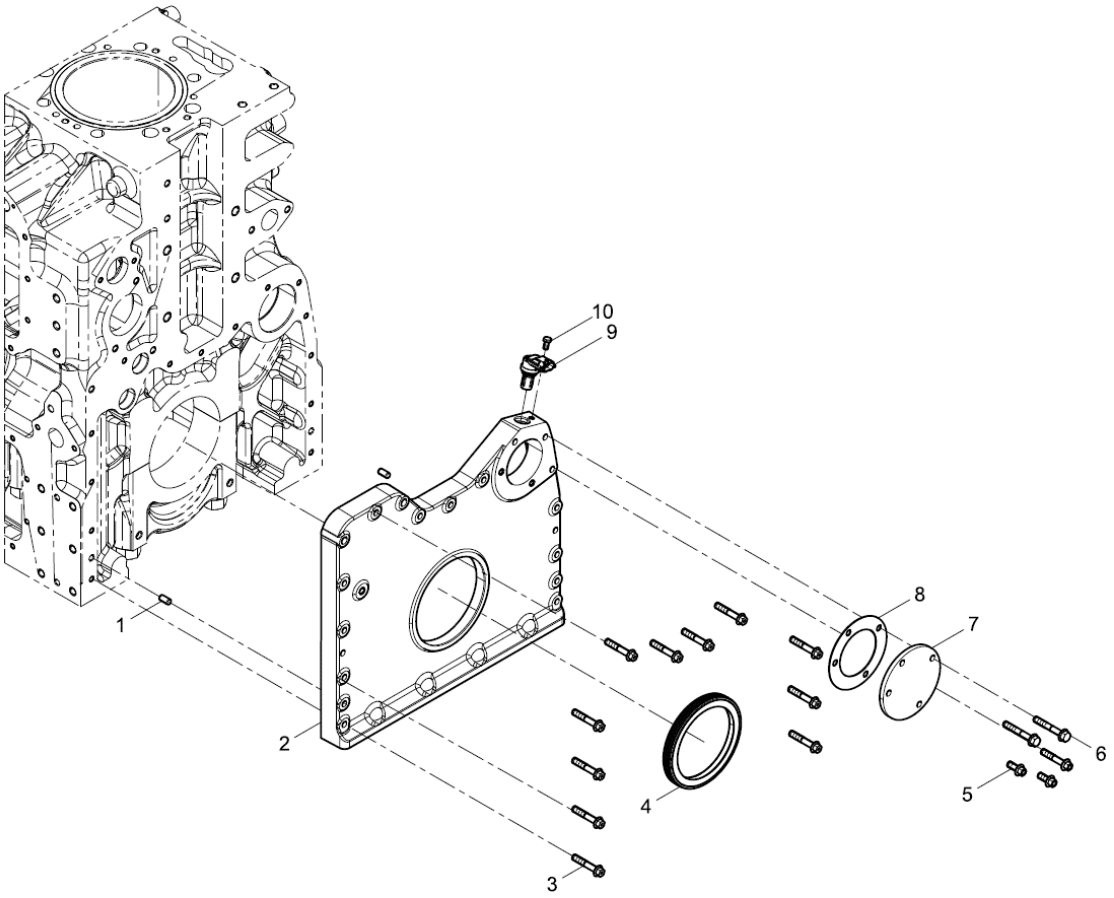


Figure 18. Front Cover Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Pin	4	Front Oil Seal	7	Cover	10	Bolt
2	Front Cover	5	Bolt	8	Gasket		
3	Bolt	6	Bolt	9	Sensor		

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 BOLTS AND NUTS CHART.*

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 the front cover bolts (Figure 18, Item 3).
4. Carefully remove the front cover (Figure 18, 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 18, Item 2).
3. Insert the two dowel pins (Figure 18, Item 1) if removed.
4. Apply Loctite 242 onto the threads of the bolts (Figure 18, Item 3).
   a. If removed oil the front oil seal (Figure 18, Item 4) and install using a front oil seal mounting tool.
5. Place the front cover (Figure 18, Item 2) onto the front of the cylinder block and torque the bolts (Figure 18, Items 3).
6. Install the entire FEAD on the engine. Refer to the *FEAD* section of the manual.

TURBOCHARGER

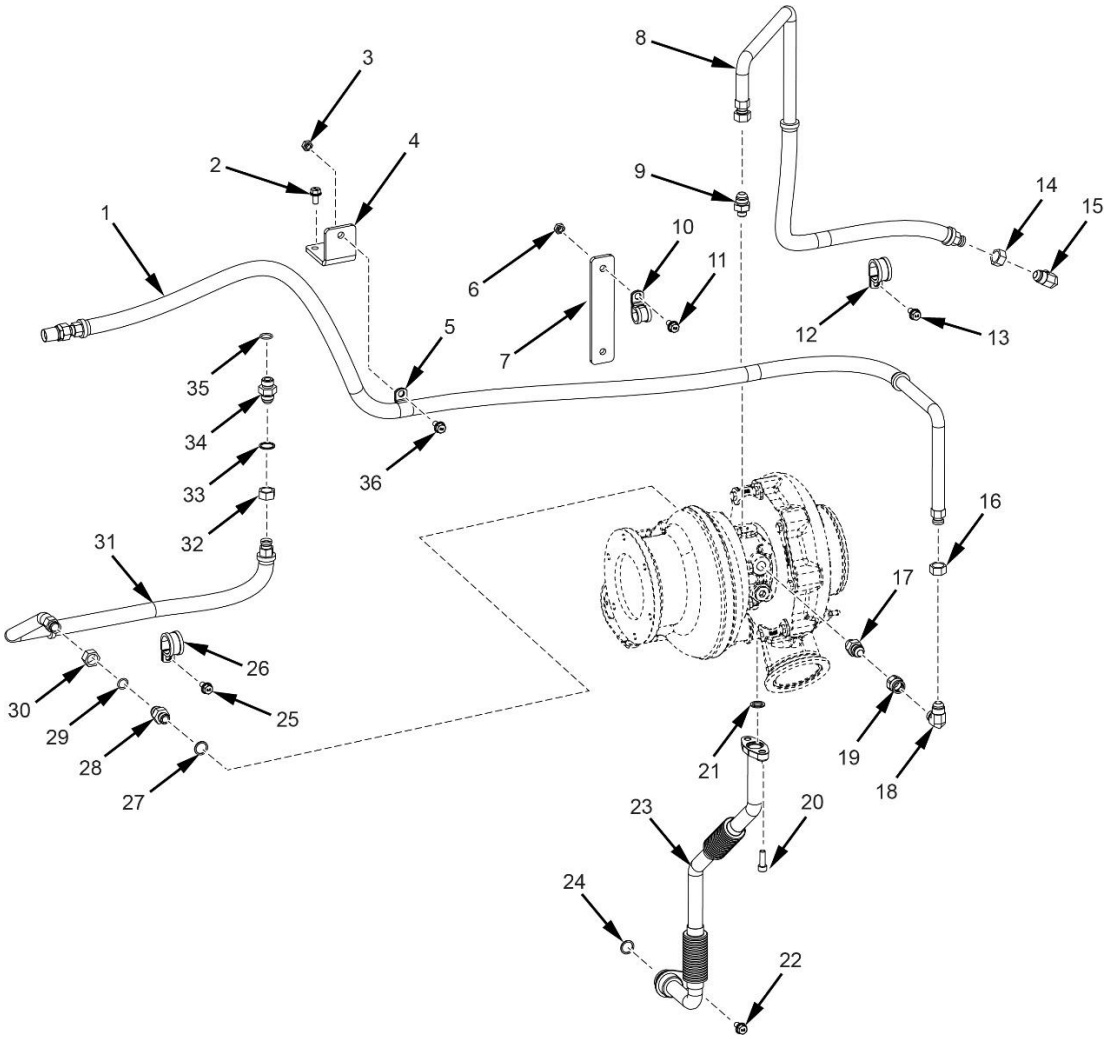


Figure 19. Turbocharger Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Coolant Outlet	10	Clamp	19	Fitting	28	Fitting
2	Bolt	11	Bolt	20	Bolt	29	O-Ring
3	Nut	12	Clamp	21	O-Ring	30	Fitting
4	Bracket	13	Bolt	22	Bolt	31	Coolant Inlet
5	Clamp	14	Fitting	23	Oil Tube Drain	32	Fitting
6	Nut	15	Elbow	24	O-Ring	33	O-Ring
7	Bracket	16	Fitting	25	Bolt	34	Fitting
8	Oil Inlet	17	Fitting	26	Clamp	35	O-Ring
9	Fitting	18	Elbow	27	O-Ring	36	Bolt

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Remove all outlet and inlet pipes leading into the turbo.
2. Remove bolt (Figure 19, Item 36), clamp (Figure 19, Item 5) and nut (Figure 19, Item 3) from bracket (Figure 19, Item 4).
3. Remove two bolts (Figure 19, Item 2) and bracket (Figure 19, Item 4).
4. Remove bolt (Figure 19, Item 11), clamp (Figure 19, Item 10) and nut (Figure 19, Item 6) from bracket (Figure 19, Item 7).
5. Remove fitting (Figure 19, Item 16) and coolant outlet (Figure 19, Item 1) from elbow (Figure 19, Item 18).
6. Remove elbow (Figure 19, Item 18) from fitting (Figure 19, Item 19) and fitting (Figure 19, Item 17). Remove fitting (Figure 19, Item 17).
7. Remove bolt (Figure 19, Item 13), clamp (Figure 19, Item 12).
8. Remove fitting (Figure 19, Item 14) and elbow (Figure 19, Item 15) from oil inlet (Figure 19, Item 8).
9. Remove oil inlet (Figure 19, Item 8) and fitting (Figure 19, Item 9).
10. Remove bolt (Figure 19, Item 25), clamp (Figure 19, Item 26) from coolant inlet (Figure 19, Item 31).
11. Remove fitting (Figure 19, Item 32) from fitting (Figure 19, Item 34) and coolant inlet (Figure 19, Item 31). Remove O-rings (Figure 19, Item 33 and 35). Discard O-rings.
12. Remove fitting (Figure 19, Item 30) from fitting (Figure 19, Item 28) and coolant inlet (Figure 19, Item 31). Remove O-rings (Figure 19, Item 27 and 29). Discard O-rings.
13. Remove bolt (Figure 19, Item 20) from oil tube drain (Figure 19, Item 23).
14. Remove bolt (Figure 19, Item 22) from oil tube drain (Figure 19, Item 23).
15. Carefully remove oil tube drain (Figure 19, Item 23) and two O-rings (Figure 19, Item 21 and 24).

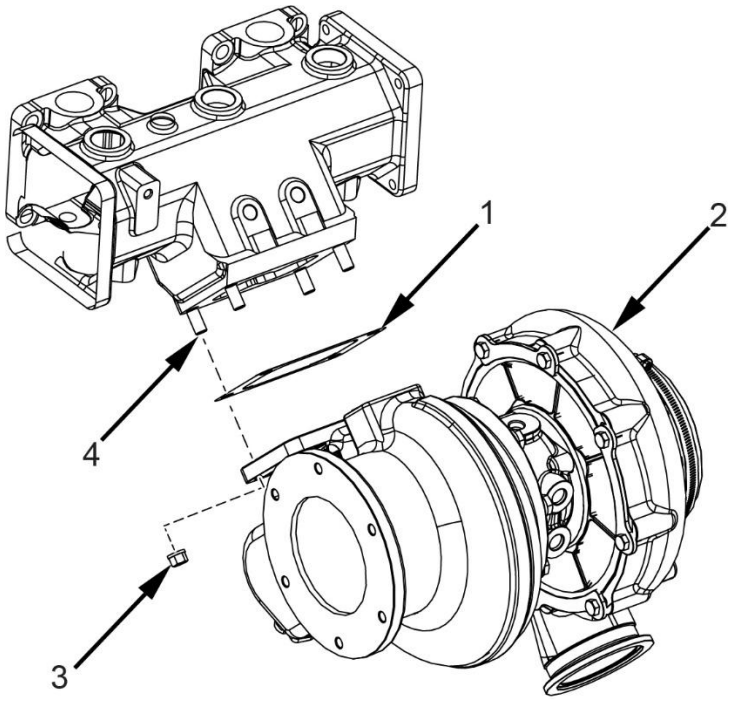


Figure 20. Turbocharger Assembly

NO.	Name	NO.	Name
1	Gasket	2	Turbocharger
3	Nut	4	Stud

16. Remove the four nuts (Figure 20, Item 3) and then carefully remove the turbocharger (Figure 20, Item 2).
17. Remove the gasket (Figure 20, Item 1).

INSTALLATION

1. Clean all debris from both ends of the turbocharger and hoses leading into the turbochargers.
2. Place a new gasket (Figure 20, Item 1) onto the turbocharger.

NOTE:

- All gaskets (Figure 20, Item 1) should be installed with the round edges facing up.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

3. Insert the turbo (Figure 20, Item 2) onto the four studs (Figure 20, Item 4) and torque the nuts (Figure 20, Item 3).
4. Place new O-rings (Figure 19, Items 21 and 24) and align the oil drain tube (Figure 19, Item 23) onto the turbo and cylinder block.
5. Install bolt (Figure 19, Item 22) and bolt (Figure 19, Item 20) to secure oil drain tube (Figure 19, Item 23). Torque the bolts.
6. Install new O-rings (Figure 19, Item 27 and 29) to fitting (Figure 19, Item 30) and install on turbocharger.
7. Install fitting (Figure 19, Item 30) and coolant inlet (Figure 19, Item 31) to fitting (Figure 19, Item 30).
8. Install new O-rings (Figure 19, Item 33 and 35) to fitting (Figure 19, Item 34) and install on manifold.
9. Install fitting (Figure 19, Item 32) and coolant inlet (Figure 19, Item 31) to fitting (Figure 19, Item 34).
10. Install clamp (Figure 19, Item 26) on coolant inlet (Figure 19, Item 31) and secure with bolt (Figure 19, Item 25).
11. Install fitting (Figure 19, Item 9) on turbocharger and install oil inlet (Figure 19, Item 8) on fitting (Figure 19, Item 9).
12. Install elbow (Figure 19, Item 15) to side of engine block and install fitting (Figure 19, Item 14) and oil inlet (Figure 19, Item 8).
13. Install clamp (Figure 19, Item 12) on oil inlet (Figure 19, Item 8) and secure with bolt (Figure 19, Item 13).
14. Install fitting (Figure 19, Item 17) on turbocharger and install fitting (Figure 19, Item 19) with elbow (Figure 19, Item 18).
15. Install coolant outlet (Figure 19, Item 1) to elbow (Figure 19, Item 18) and attach other end of coolant outlet to radiator.
16. Install bracket (Figure 19, Item 4) to thermostat housing and secure with two bolts (Figure 19, Item 2).
17. Install clamp (Figure 19, Item 5) on coolant outlet (Figure 19, Item 1) and secure to bracket (Figure 19, Item 4) with bolt (Figure 19, Item 36).
18. Install clamp (Figure 19, Item 10) to coolant outlet (Figure 19, Item 1) and secure to bracket (Figure 19, Item 7) with bolt (Figure 19, Item 11) and nut (Figure 19, Item 6).

AIR FILTER

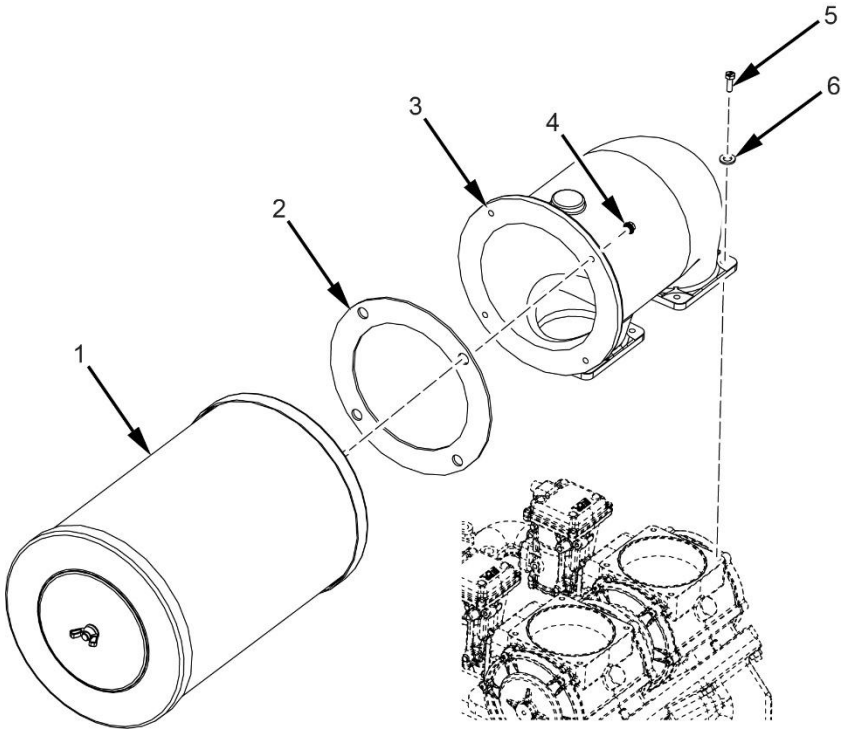


Figure 21. Air Filter Assembly

NO.	Name	NO.	Name
1	Air Filter	4	Nut
2	Gasket	5	Bolt
3	Housing	6	Washer

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Loosen and remove the nuts (Figure 21, Item 4).
2. Remove the air filter (Figure 21, Item 1) and gasket (Figure 21, Item 2).
3. Remove the bolts (Figure 21, Item 5) and washers (Figure 21, Item 6).
4. Remove the housing (Figure 22, Item 3).

NOTE:

- The air filter element (Figure 22, Item 4) can be found directly inside the air filter assembly.
- Maximum permissible intake resistance of the engine is 3.7 kPa.
- Only when the resistance of the intake air reaches 3.7 kPa or over does the air filter need to be replaced or cleaned.

5. Remove wing nut (Figure 22, Item 3), washer (Figure 22, Item 2) and air filter assembly cover (Figure 22, Item 3).
6. Remove filter element (Figure 22, Item 4) from air filter assembly housing bracket (Figure 22, Item 5).

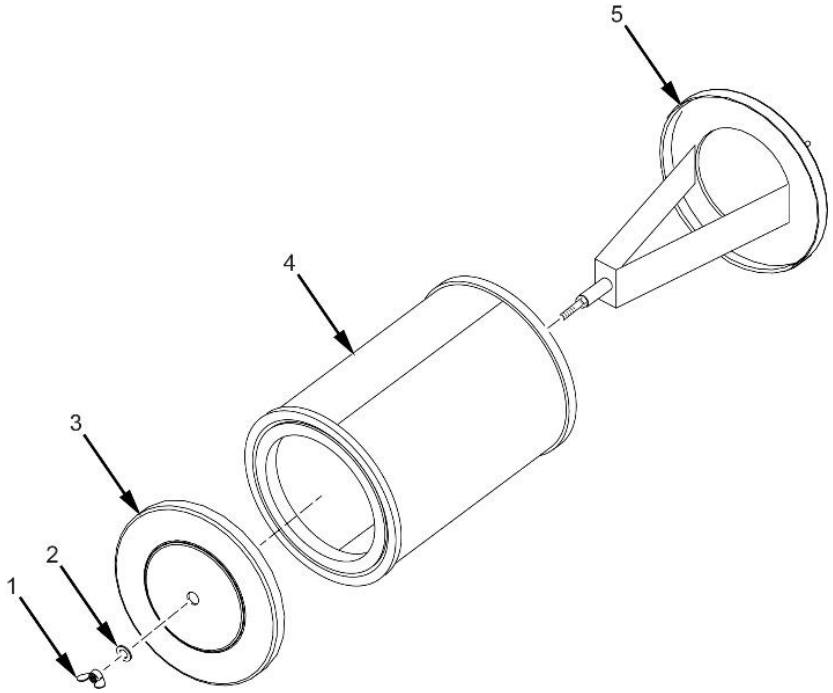


Figure 22. Air Filter Element

NO.	Name	NO.	Name
1	Wing Nut	4	Filter Element
2	Washer	5	Housing Bracket
3	Cover		

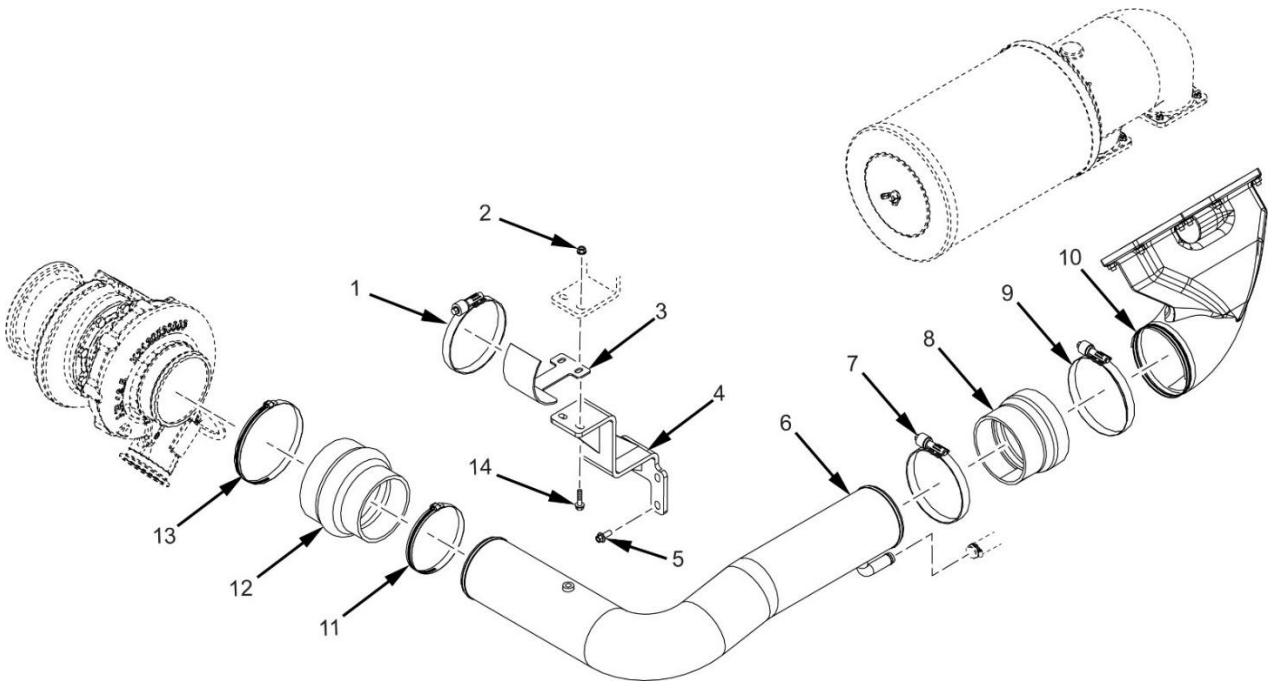


Figure 23. Air Filter Element

NO.	Name	NO.	Name	NO.	Name
1	Clamp	6	Turbocharger Inlet Tube	11	Clamp
2	Nut	7	Clamp	12	Air Connecting Rubber Pipe
3	Bracket	8	Air Connecting Rubber Pipe	13	Clamp
4	Bracket	9	Clamp	14	Bolt
5	Bolt	10	Mixer Intake Pipe		

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 BOLTS AND NUTS CHART.*

7. Remove hose from oil breather to turbocharger inlet tube (Figure 23, Item 6).
8. Remove clamp (Figure 23, Item 1) from bracket (Figure 23, Item 3) and turbocharger inlet tube (Figure 23, Item 6).
9. Remove clamps (Figure 23, Item 7 and 9) and air connecting rubber pipe (Figure 23, Item 8) from mixer intake pipe (Figure 23, Item 10) and turbocharger inlet tube (Figure 23, Item 6).
10. Remove clamps (Figure 23, Item 11 and 13) and air connecting rubber pipe (Figure 23, Item 12) from turbocharger inlet tube (Figure 23, Item 6) and turbocharger.
11. Remove bolts (Figure 23, Item 2) and nuts (Figure 23, Item 14) from bracket (Figure 23, Item 3) and bracket (Figure 23, Item 4).
12. Remove bolts (Figure 23, Item 5) and remove bracket (Figure 23, Item 4).

INSTALLATION

13. Install bracket (Figure 23, Item 4) with bolts (Figure 23, Item 5).
14. Install bracket (Figure 23, Item 3) and bracket (Figure 23, Item 4) with bolts (Figure 23, Item 2) and nuts (Figure 23, Item 14).
15. Install air connecting rubber pipe (Figure 23, Item 12) to turbocharger inlet tube (Figure 23, Item 6) and turbocharger with clamps (Figure 23, Item 11 and 13). Tighten clamps securely.
16. Install air connecting rubber pipe (Figure 23, Item 8) to mixer intake pipe (Figure 23, Item 10) and turbocharger inlet tube (Figure 23, Item 6) and secure with clamps (Figure 23, Item 7 and 9). Tighten clamps securely.
17. Install bracket (Figure 23, Item 3) to turbocharger inlet tube (Figure 23, Item 6) and secure with clamp (Figure 23, Item 1).
18. Install hose from oil breather to turbocharger inlet tube (Figure 23, Item 6).
19. Install new air filter (Figure 22, Item 4) into the air filter assembly housing bracket (Figure 22, Item 5).
20. Place air filter assembly cover (Figure 22, Item 3) onto air filter (Figure 22, Item 4) and secure with washer (Figure 22, Item 2) and wing nut (Figure 22, Item 3). Hand-tighten wing nut securely.
21. Install (Figure 22, Item 3) and secure with washers (Figure 21, Item 6) and bolts (Figure 21, Item 5).
22. Place the air filter assembly (Figure 21, Item 1) and gasket (Figure 21, Item 2) on housing (Figure 21, Item 3).
23. Secure the air filter assembly (Figure 21, Item 1) to housing (Figure 21, Item 3) with nuts (Figure 21, Item 4).

EXHAUST PIPE

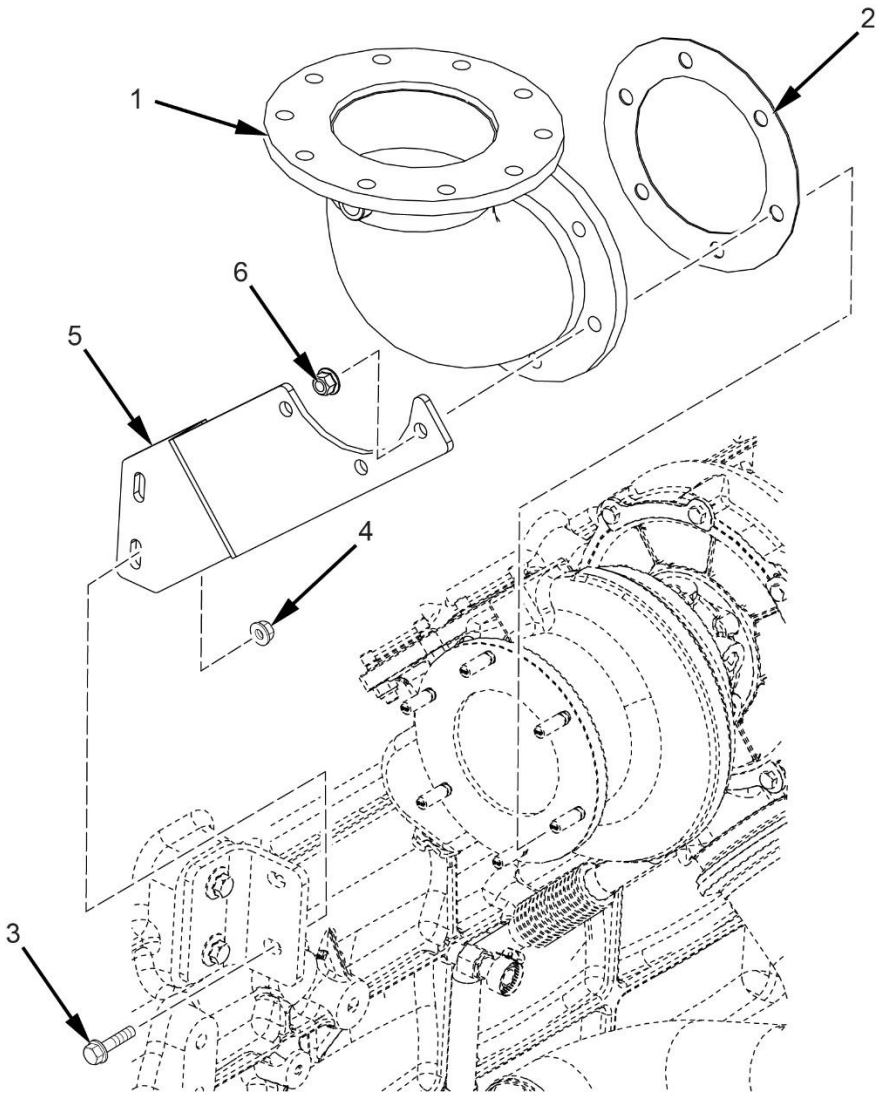


Figure 24. Exhaust Pipe Assembly

NO.	Name	NO.	Name
1	Exhaust Pipe	4	Nut
2	Gasket	5	Bracket
3	Bolt	6	Bolt

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Remove bolts (Figure 24, Item 3) and nuts (Figure 24, Item 4).
2. Remove three nuts (Figure 24, Item 6) securing plate (Figure 24, Item 5).
3. Remove plate (Figure 24, Item 5).
4. Remove three remaining nuts (Figure 24, Item 6) securing exhaust plate (Figure 24, Item 1).
5. Remove exhaust plate (Figure 24, Item 1) and gasket (Figure 24, Item 2) from turbocharger.

INSTALLATION

1. Install new gasket (Figure 24, Item 2) onto turbocharger and install exhaust plate (Figure 24, Item 1) and install three nuts (Figure 24, Item 6) to top three studs.
2. Install plate (Figure 24, Item 5) and install three remaining nuts (Figure 24, Item 6) to bottom studs of turbocharger and exhaust plate (Figure 24, Item 1).
3. Install bolts (Figure 23, Item 3) and nuts (Figure 23, Item 4) securing plate (Figure 23, Item 5) to engine block.

FUEL SYSTEM

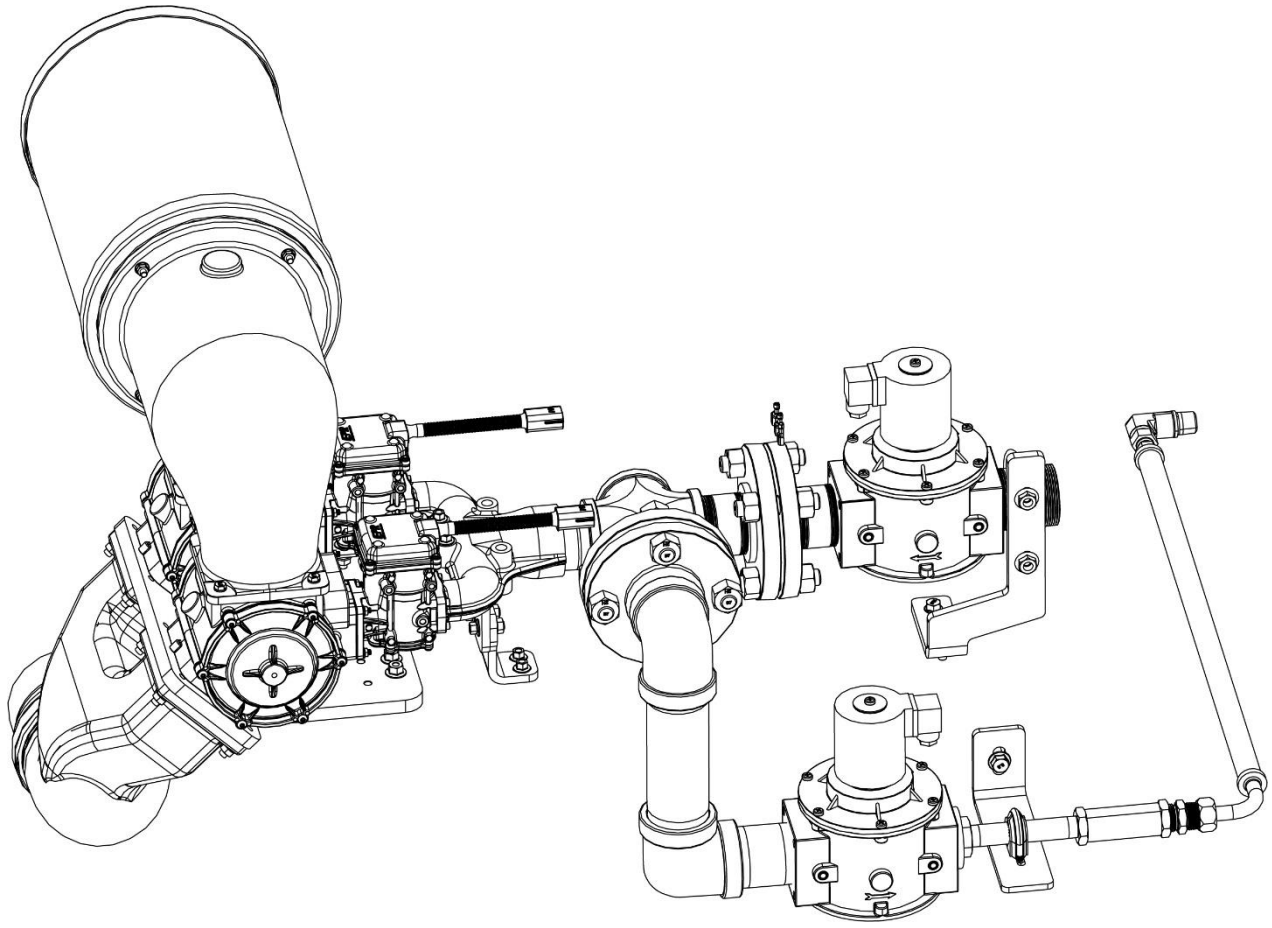


Figure 25. Fuel System Assembly

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

All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

DIRECT ELECTRONIC PRESSURE REGULATOR (DEPR) AND FUEL MIXER ASSEBMLY

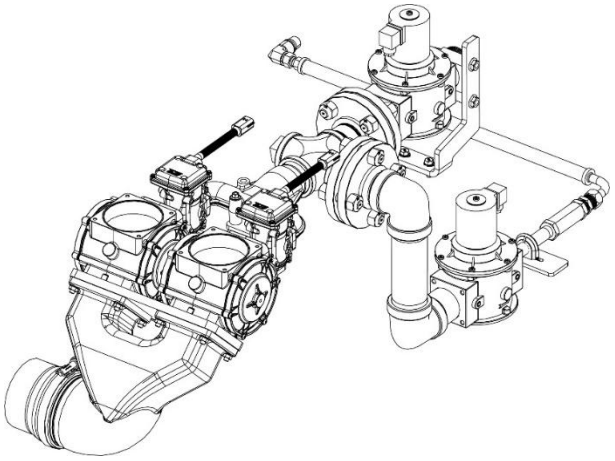


Figure 26. DEPR and Fuel Mixer Assembly

REMOVAL

1. Remove the air filter assembly. (Refer to the Air Filter Section)
2. Disconnect both clamps on the mixer to turbo adapter hose.

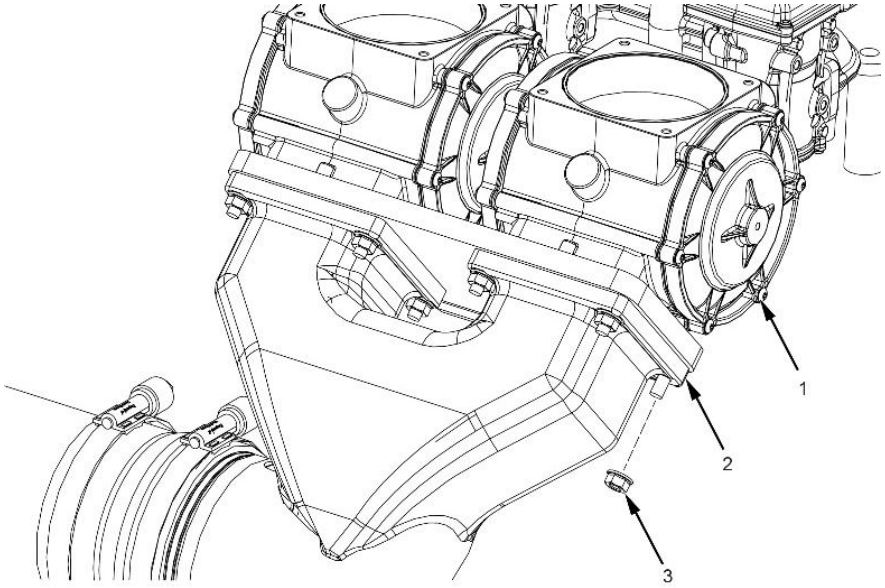


Figure 27. Dual Mixer Bracket Assembly

No.	Name	No.	Name	No.	Name
1	Fuel Mixers	2	Mixer Outlet Pipe	3	Nuts

3. Remove eight nuts (Figure 27, Item 3) from mixer outlet pipe (Figure 27, Item 2) and fuel mixers (Figure 27, Item 1).

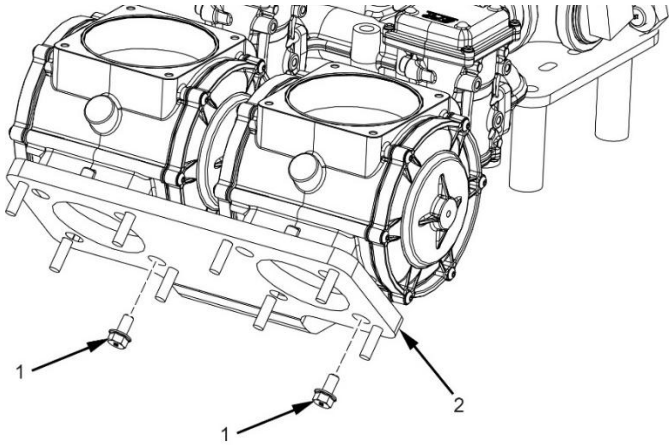


Figure 28. DEPR Bracket Assembly

No.	Name
1	Bolts
2	Dual Mixer Bracket

4. Remove eight bolts (Figure 28, Item 1) from dual mixer bracket (Figure 28, Item 2).

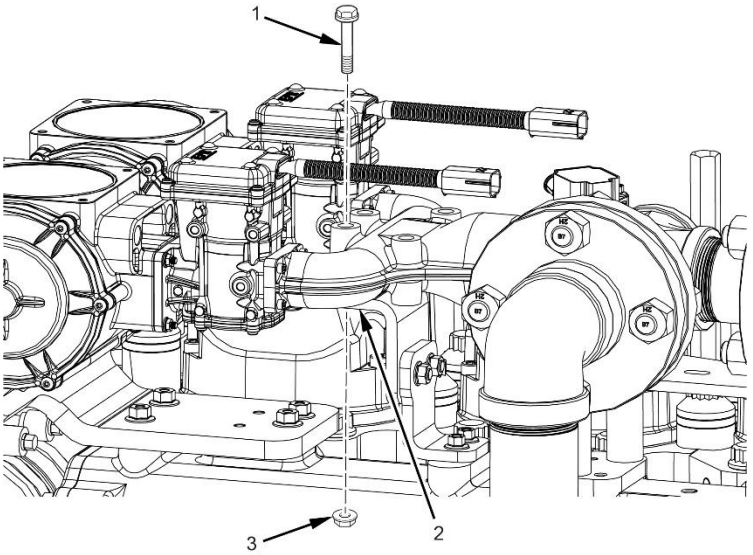


Figure 29. DEPR Bracket Assembly

No.	Name
1	Bolts
2	Dual DEPR Bracket
3	Nuts

5. Remove two bolts (Figure 29, Item 1) and two nuts (Figure 29, Item 3) from dual DEPR bracket (Figure 29, Item 2).

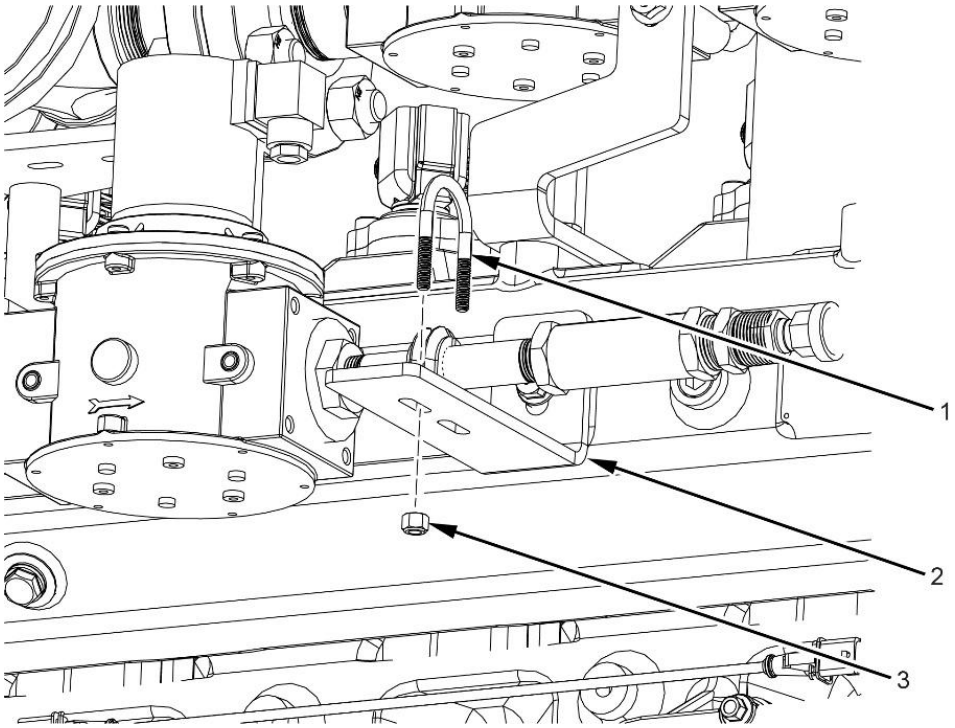


Figure 30. Fast Start Lockoff Assembly

No.	Name
1	“U” Clamp Bolt
2	Bracket
3	Nut

7. Remove two nuts (Figure 30, Item 3) from U-bolt (Figure 30, Item 1), remove U-bolt from bracket (Figure 30, Item 2).

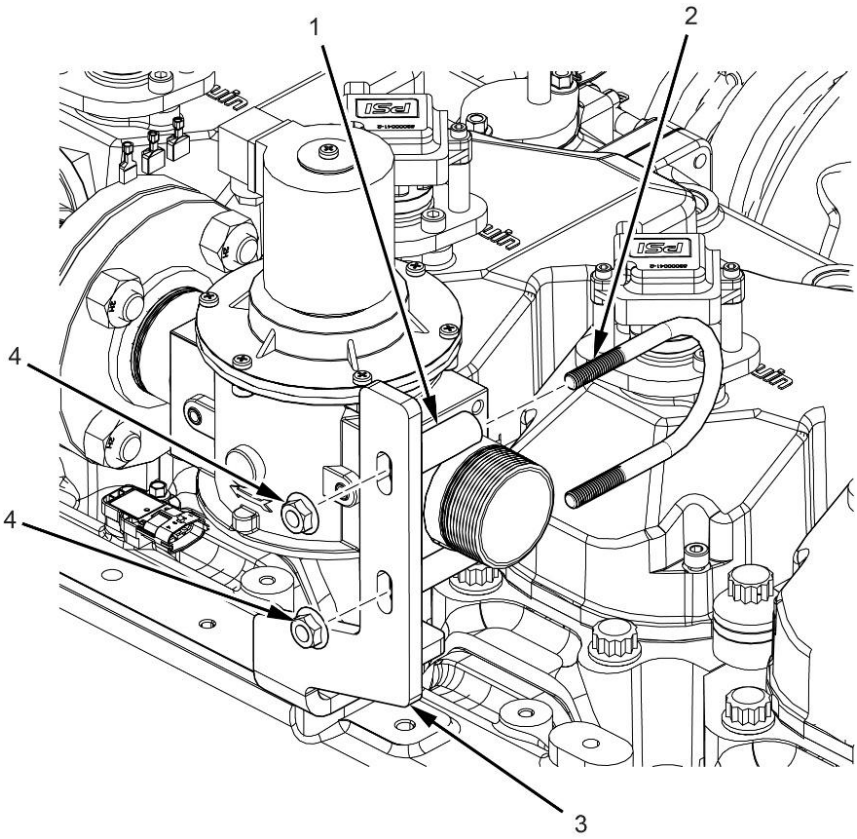


Figure 31. Upper Lock off Bracket Assembly

NO.	Name	NO.	Name
1	Saddle	3	Bracket
2	“U” Clamp Bolt	4	Nut

8. Remove nuts (Figure 31, Item 4) from U-bolt (Figure 31, Item 2). Remove U-bolt (Figure 31, Item 2) from bracket (Figure 31, Item 3).
9. Remove saddle (Figure 31, Item 1) from bracket (Figure 31, Item 3).
10. Carefully remove the entire DEPR and fuel mixer assembly.

INSTALLATION

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

NOTE:

- Loosening the fuel mounts may ease the DEPR and fuel mixer installation process.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

2. Carefully place the DEPR and fuel mixer assembly over the upper lock off bracket, DEPR bracket and dual mixer bracket.
3. Install saddle (Figure 31, Item 1) to bracket (Figure 31, Item 3).
4. Install U-bolt (Figure 31, Item 2) to saddle (Figure 31, Item 1) and bracket (Figure 31, Item 3) and nuts (Figure 31, Item 4).
5. Install U-bolt (Figure 30, Item 4) to bracket (Figure 30, Item 4). Apply PSI approved Loctite to the nuts (Figure 30, Item 4) and install to U-bolt.
6. Install two bolts (Figure 29, Item 1) and two nuts (Figure 29, Item 3) to dual DEPR bracket (Figure 29, Item 2).
7. Install eight bolts (Figure 28, Item 1) to dual DEPR bracket (Figure 28, Item 2).
8. Install mixer intake pipe (Figure 27, Item 2) to fuel mixers (Figure 27, Item 1) with eight nuts (Figure 27, Item 3).
9. Connect both clamps on the mixer to turbo adapter hose.
10. Connect both CCV vapor hoses to the back of mixer assembly.
11. Connect the air filter assembly. (Refer to the Air Filter Section)

FUEL MOUNTING BRACKETS

REMOVAL

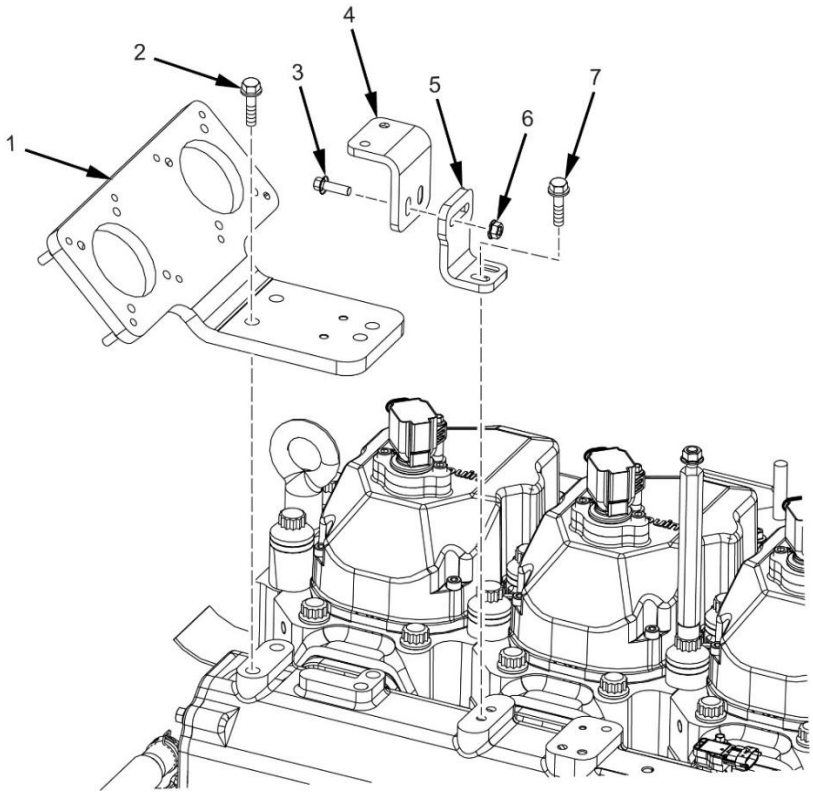


Figure 32. DEPR Bracket Assembly

NO.	Name	NO.	Name	NO.	Name
1	Bracket	4	Bracket	7	Bolt
2	Bolt	5	Bracket		
3	Bolt	6	Nut		

1. Remove the air filter assembly. (Refer to the Air Filter Section)
2. Remove DEPR and fuel mixer assembly. (Refer to the Direct Electronic Pressure Regulator (DEPR) And Fuel Mixer Assembly Section)
3. Remove the four bolts (Figure 32, Item 2) from the dual fuel mixer bracket (Figure 32, Item 1) and remove the dual fuel mixer bracket.
4. Remove the two bolts (Figure 32, Item 3) and nuts (Figure 32, Item 6) from the upper duel DEPR bracket (Figure 32, Item 4) and lower duel DEPR bracket (Figure 32, Item 5).
5. Remove the two bolts (Figure 32, Item 7) from the lower duel DEPR bracket (Figure 32, Item 5) and remove bracket.

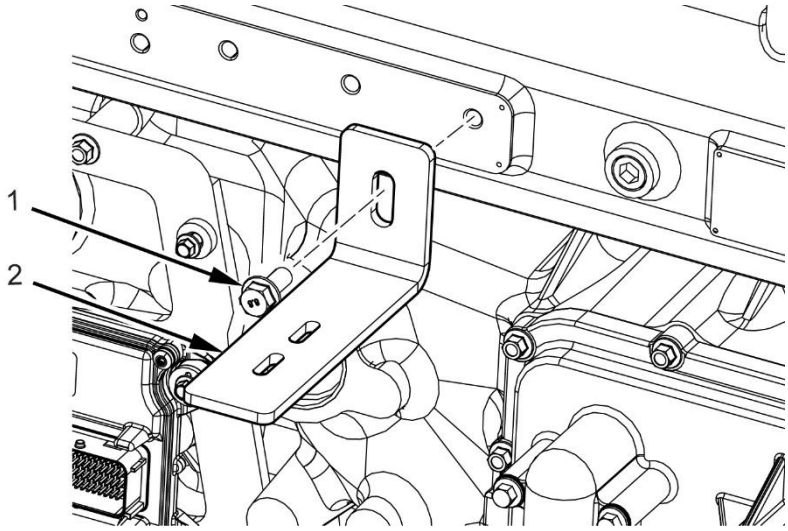


Figure 33. Lock Off Valve Bracket Assembly

NO.	Name
1	Bolt
2	Bracket

6. Remove bolt (Figure 33, Item 1) and bracket (Figure 33, Item 2) from intake manifold.

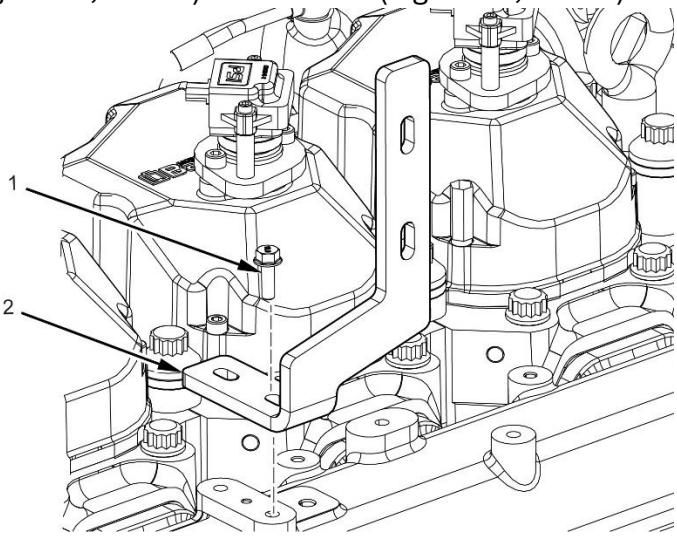


Figure 34. Lock Off Valve Bracket Assembly

NO.	Name
1	Bolt
2	Bracket

7. Remove two bolts (Figure 34, Item 1) from the lock off valve bracket (Figure 3, Item 2) and remove bracket.

INSTALLATION

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 BOLTS AND NUTS CHART.*

1. Install lock off valve bracket (Figure 34, Item 2) and two bolts (Figure 34, Item 1) to the intake manifold.
2. Install bracket (Figure 33, Item 2) to intake manifold with two bolts (Figure 33, Item 1).
3. Install the lower duel DEPR bracket (Figure 32, Item 5) two bolts (Figure 32, Item 7).
4. Install two bolts (Figure 32, Item 3) and nuts (Figure 32, Item 6) to the upper duel DEPR bracket (Figure 32, Item 4) and lower duel DEPR bracket (Figure 32, Item 5).
5. Install the dual fuel mixer bracket (Figure 32, Item 1) with four bolts (Figure 33, |Item 2) to the intake manifold.
6. Install the DEPR and fuel mixer assembly. (Refer to the Direct Electronic Pressure Regulator (DEPR) And Fuel Mixer Assembly Section)

EXHAUST MANIFOLD

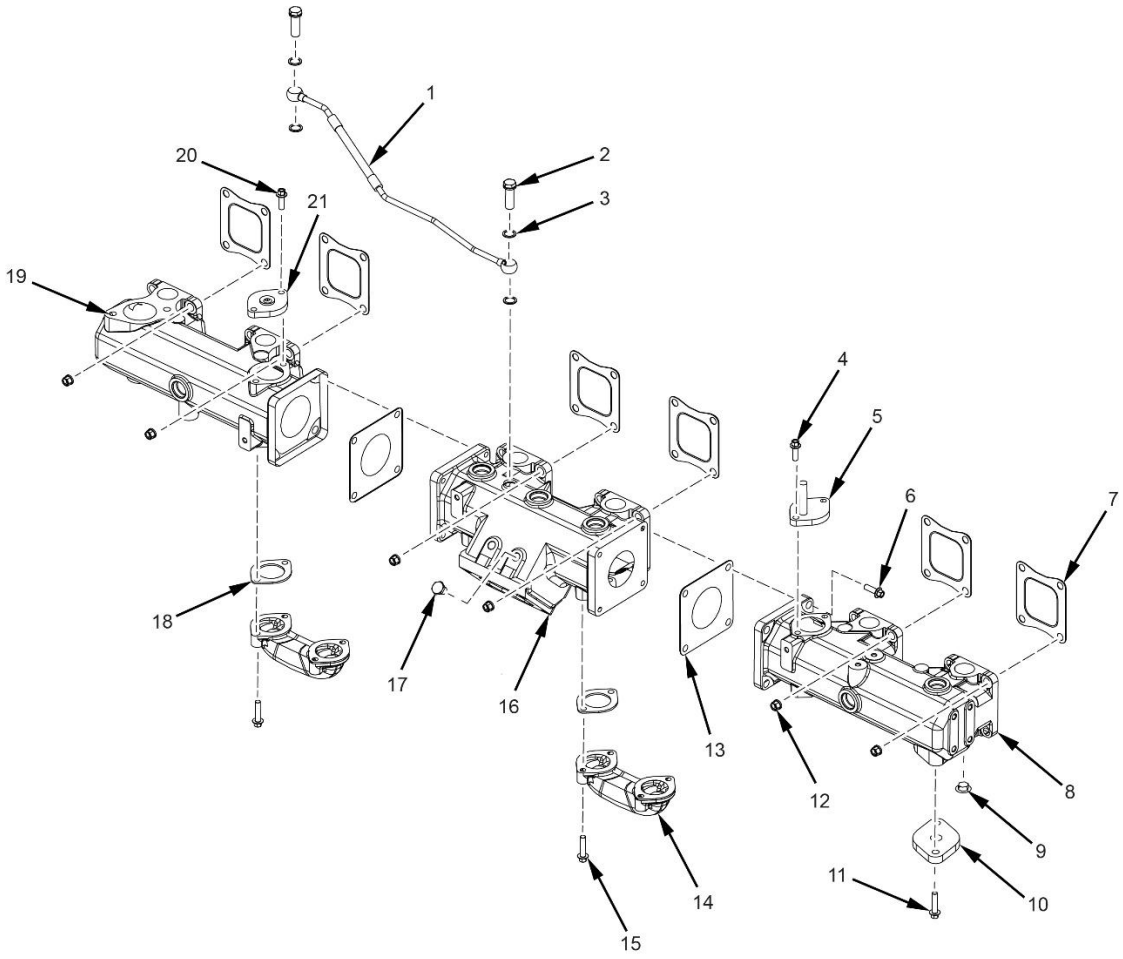


Figure 35. Exhaust Manifold Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Pipe	6	Bolt	11	Bolt	16	Exhaust Manifold Assembly
2	Bolt	7	Exhaust Manifold Gasket	12	Nut	17	Plug
3	Sealing Washer	8	Exhaust Manifold Assembly	13	Gasket	18	Gasket
4	Bolt	9	Taper Plug	14	Water Pipe	19	Exhaust Manifold Assembly
5	Flange	10	Flange	15	Bolt	20	

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 BOLTS AND NUTS CHART.*
- The exhaust manifold gaskets must be replaced when removed.
- The exhaust manifold bolts can only be reused twice.
- The turbocharger assembly and the compressor pipe assembly must be removed when servicing the exhaust manifold.
- Remove water outlet pipes, reference WATER OULET PIPE removal and installation.

REMOVAL

1. Drain the coolant from the engine into a suitable container.
2. Remove bolt (Figure 35, Item 2), washers (Figure 35, Item 3) and pipe (Figure 35, Item 1) from exhaust manifold assembly.
3. Remove 34 nuts (Figure 35, Item 12) securing the from exhaust manifold assembly.
4. Remove the exhaust manifold assembly from engine and remove six exhaust gaskets (Figure 35, Item 7). Discard gaskets.
5. Remove the bolts (Figure 35, Item 15), gaskets (Figure 34, Item 18) and water pipes (Figure 35, Item 15) from the exhaust manifolds.
6. Remove bolts (Figure 35, Item 4) and flange (Figure 35, Item 5).
7. Remove bolts (Figure 35, Item 11) and flange (Figure 35, Item 10).
8. Remove bolts (Figure 35, Item 20) and flange (Figure 35, Item 21).
9. Remove taper plug (Figure 35, Item 9) if required.
10. Remove plugs (Figure 35, Item 17) if required.
11. Remove bolts (Figure 35, Item 6) and Exhaust Manifold Assemblies (Figure 35, Item 8 and 19) and gaskets (Figure 35, Item 13) from Exhaust Manifold Assembly (Figure 35, Item 16). Discard gaskets.

INSTALLATION

1. Clean any debris from the mounting flanges of the exhaust manifold assemblies.
2. Install new gaskets (Figure 35, Item 13) between the three sections of the exhaust manifolds (Figure 35, Item 18, 16 & 8).
3. Place the three sections of the exhaust manifold assembly on a clean flat surface, exhaust flange facing the table.
4. Apply molybdenum disulfide onto the threads of all bolts (Figure 35, Item 6).
5. Install bolts (Figure 35, Item 6) and tighten.
6. Torque all bolts (Figure 35, Item 7).
7. Install taper plug (Figure 35, Item 9) if removed.
8. Install plugs (Figure 35, Item 17) if removed.
9. Install bolts (Figure 35, Item 4) and flange (Figure 35, Item 5).
10. Install bolts (Figure 35, Item 11) and flange (Figure 35, Item 10).
11. Install water pipes (Figure 35, Item 15) and gaskets (Figure 35, Item 18) to the exhaust manifolds and secure with bolts (Figure 35, Item 15).
12. Clean any debris from the side of the cylinder heads.
13. Install new gaskets (Figure 35, Item 7) onto the cylinder heads and between the exhaust manifold assembly.
14. Install and torque the 24 nuts (Figure 35, Item 12).
15. Install bolt (Figure 35, Item 2), washers (Figure 35, Item 3) and pipe (Figure 35, Item 1) to the exhaust manifold assembly.

INTAKE MANIFOLD

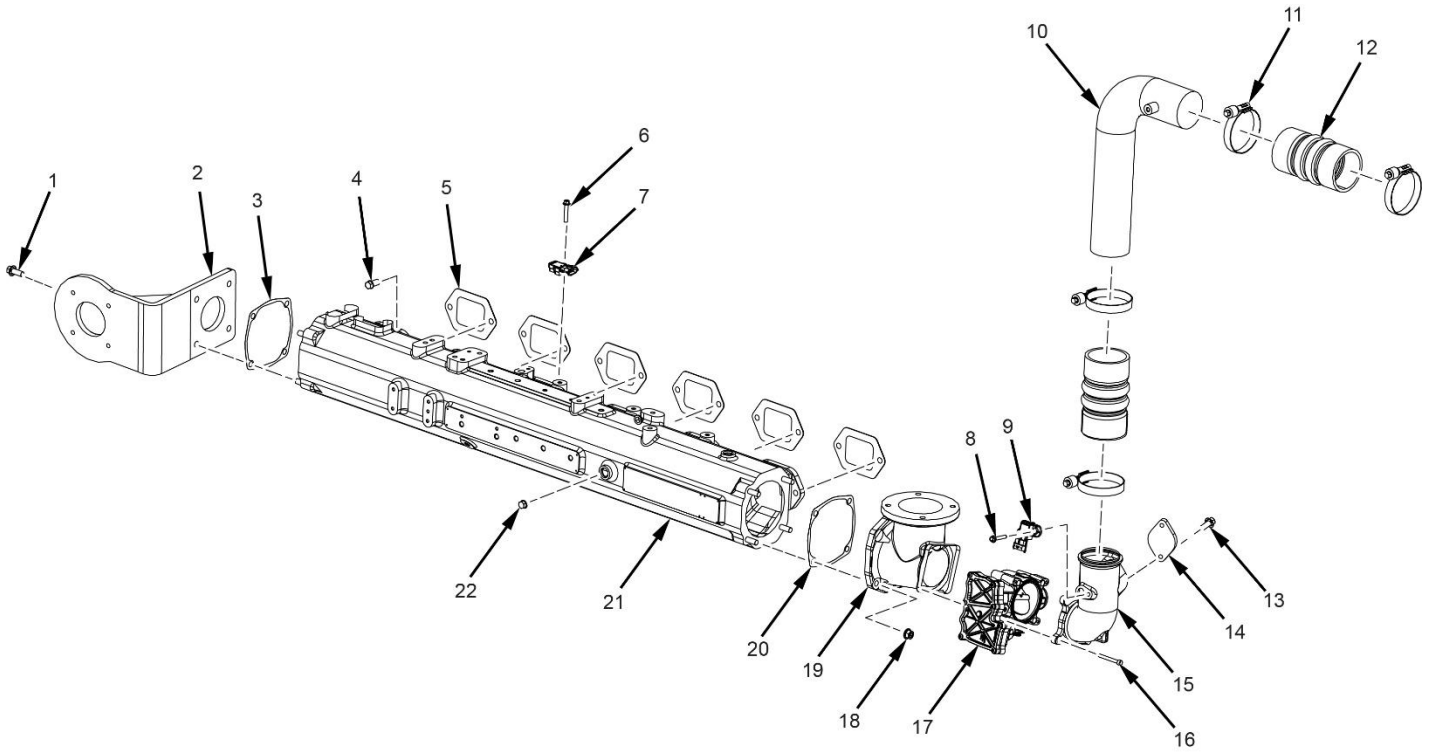


Figure 36. Intake Manifold Assembly

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 BOLTS AND NUTS CHART.*
- High Pressure fuel lines must be removed before servicing the intake manifold.

NO.	Name	NO.	Name	NO.	Name
1	Bolt	9	Throttle Inlet Pressure and Temperature Sensor	17	Electronic Throttle
2	Pressure Relief Bracket	10	Charge Air Cooler Outlet Pipe	18	Nut
3	Gasket	11	Clamp	19	Manifold Inlet Pipe
4	Bolt	12	Pipe Coupler	20	Gasket
5	Gasket	13	Bolt	21	Intake Manifold
6	Bolt	14	Flange	22	Hexagon Taper Screw Plug
7	Manifold Pressure and Temperature Sensor	15	Throttle Inlet Pipe		
8	Bolt	16	Bolt		

REMOVAL

1. Loosen clamps (Figure 36, Item 11) and remove Pipe Coupler (Figure 36, Item 12) from Charge Air Cooler Outlet Pipe (Figure 36, Item 10).
2. Remove the two bolts (Figure 36Item 13) from flange (Figure 36, Item 14).
3. Remove bolt (Figure 36 Item 8) and Throttle Inlet Pressure and Temperature Sensor (Figure 36, Item 9) from Throttle Inlet Pipe (Figure 36, Item 15).
4. Remove four bolts (Figure 36, Item 16), electronic throttle (Figure 36, Item 17) and Mixer Intake Pipe (Figure 36, Item 15) from Mixer Intake Pipe (Figure 36, Item 19).
5. Remove four nuts (Figure 36, Item 18) from Manifold Inlet Pipe (Figure 36, Item 19) and gasket (Figure 36, Item 20) from Intake Manifold (Figure 36, Item 21).
6. Remove Hexagon Taper Screw Pug (Figure 36, Item 22) from Intake Manifold (Figure 36, Item 21).
7. Remove four bolts (Figure 35, Item 1), pressure relief bracket (Figure 36, Item 2) and gasket (Figure 36, Item 3) from Intake Manifold (Figure 36, Item 21).
8. Remove bolt (Figure 36, Item 6) and Manifold Pressure and Temperature Sensor (Figure 36, Item 7) from Intake Manifold (Figure 36, Item 21).
9. Remove bolts (Figure 36, Item 4) and gaskets (Figure 36, Item 5) from Intake Manifold (Figure 36, Item 21) and remove from cylinder heads.

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 36, Item 5) onto each end of the intake manifold.
3. Place the intake manifold (Figure 36, Item 21) onto the cylinder heads.
4. Insert and torque the bolts (Figure 36, Item 4).
5. Install new gasket (Figure 36, Item 3) and pressure relief bracket (Figure 36, Item 2) and secure with bolts gasket (Figure 36, Item 1).
6. Install bolt (Figure 36, Item 6) and Manifold Pressure and Temperature Sensor (Figure 36, Item 7) to Intake Manifold (Figure 36, Item 21).
7. Install Hexagon Taper Screw Pug (Figure 36, Item 22) to Intake Manifold (Figure 36, Item 21).
8. Install new gasket (Figure 36, Item 20) and Mixer Intake Pipe (Figure 36, Item 19) to Intake Manifold (Figure 36, Item 21) and secure with four nuts (Figure 36, Item 18).
9. Install Throttle Inlet Pipe (Figure 36, Item 15) to Manifold Inlet Pipe (Figure 36, Item 19) and secure with four bolts (Figure 36, Item 16).
10. Install Throttle Inlet Pipe (Figure 36 Item 15) and electronic throttle (Figure 36, Item 17) to Mixer Intake Pipe (Figure 36, Item 19) and secure with four bolts (Figure 36, Item 16).
11. Install Boost Pressure and 36 Sensor (Figure 36, Item 9) to Mixer Intake Pipe (Figure 36, Item 15) with bolt (Figure 36, Item 8).
12. Install flange (Figure 36, Item 14) with two bolts (Figure 36, Item 13).
13. Install Pipe Coupler (Figure 36, Item 12) to Throttle Inlet Pipe (Figure 36, Item 15) and Charge Air Cooler Outlet Pipe (Figure 36, Item 10). with clamps (Figure 36, Item 11).

PRESSURE RELIEF VALVE

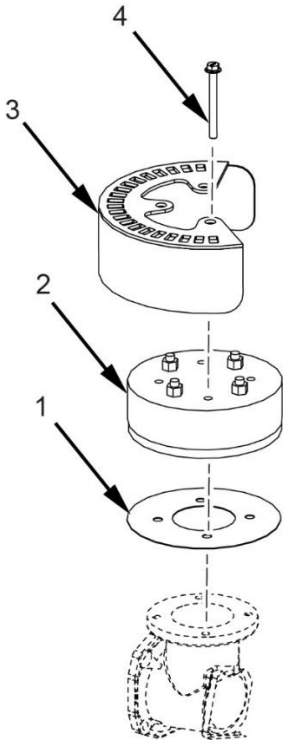


Figure 37. Pressure Relief Valve Assembly

NO.	Name
1	Relief Valve Gasket
2	Relief Valve
3	Pressure Relief Shield
4	Bolt

NOTE:

There are two pressure relief valves installed on the engine in different locations with slightly different configurations, the assembly sequence is the same for both.

CAUTION:

Do not remove valve unless specifically requested by PSI.

REMOVAL

1. Remove the four bolts from the pressure relief valve and pressure relief shield.

CAUTION:

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

2. Remove the pressure relief valve.
3. Remove the relief valve gasket from the mixer intake pipe.

INSTALLATION

1. Clean any debris from the surface of the relief valve.
2. Place the pressure relief shield on the back of the relief valve and ensure the shield is pointed out and away from the engine.
3. Place the pressure relief valve on the mixer intake pipe.
4. Insert and torque down four bolts to 27 ft/lbs.

IGNITION COIL

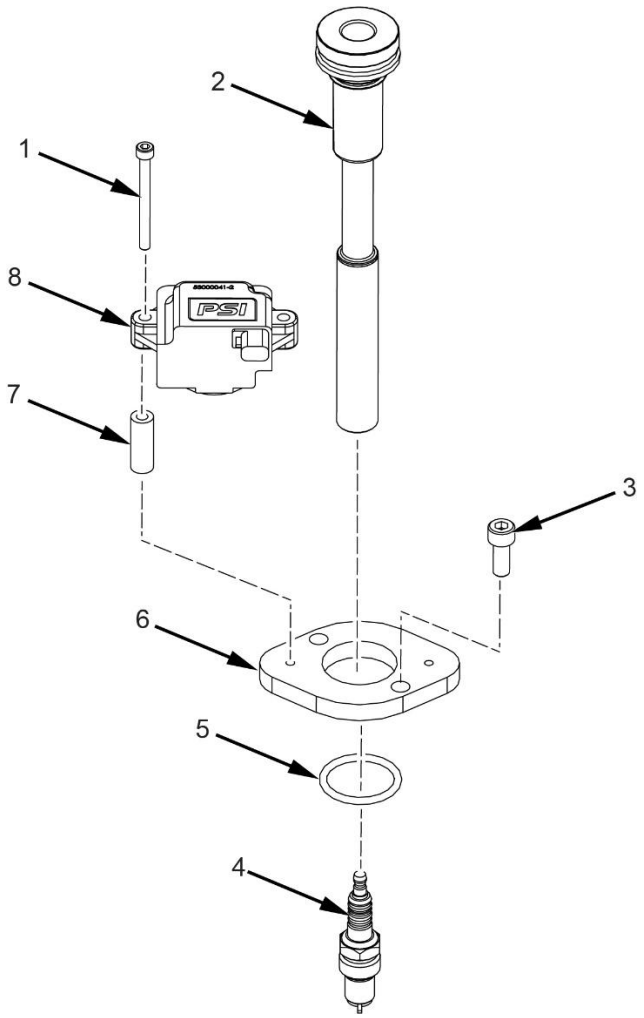


Figure 38. Explosion Relief Valve Assembly

NO.	Name	NO.	Name
1	Bolt	5	O-Ring
2	Ignition Coil Boot	6	Ignition Coil Bracket
3	Bolt	7	Spacer
4	Spark Plug	8	Ignition Coil

REMOVAL

1. Remove the two bolts (Figure 38, Item 1) on the ignition coil (Figure 38, Item 8).
2. Remove the ignition coil. (Figure 38, Item 8).
3. Remove the two spacers (Figure 38, Item 7) directly below the ignition coil (Figure 38, Item 8).
4. Remove the two bolts (Figure 38, Item 3) on the ignition coil bracket (Figure 38, Item 6).
5. Remove the ignition coil bracket (Figure 38, Item 6).
6. Remove ignition coil boot (Figure 38, Item 2) and O-ring (Figure 38, Item 5) if necessary.

INSTALLATION

1. Apply dielectric grease (Permatex Dielectric grease #81150 or equivalent) to each coil as shown in figure 39.
2. Install ignition coil boot (Figure 38, Item 2) and O-ring (Figure 38, Item 5) if removed.
3. Install ignition coil bracket (Figure 38, Item 6) and torque down the two ignition coil bracket bolts (Figure 38, Item 3) to 17 lb-ft.
4. Install the two spacers (Figure 38, Item 7) and place the ignition coil (Figure 38, Item 8) over the spacers.
5. Insert and torque down the two ignition coil bolts (Figure 38, Item 1) to 80 lb-in.

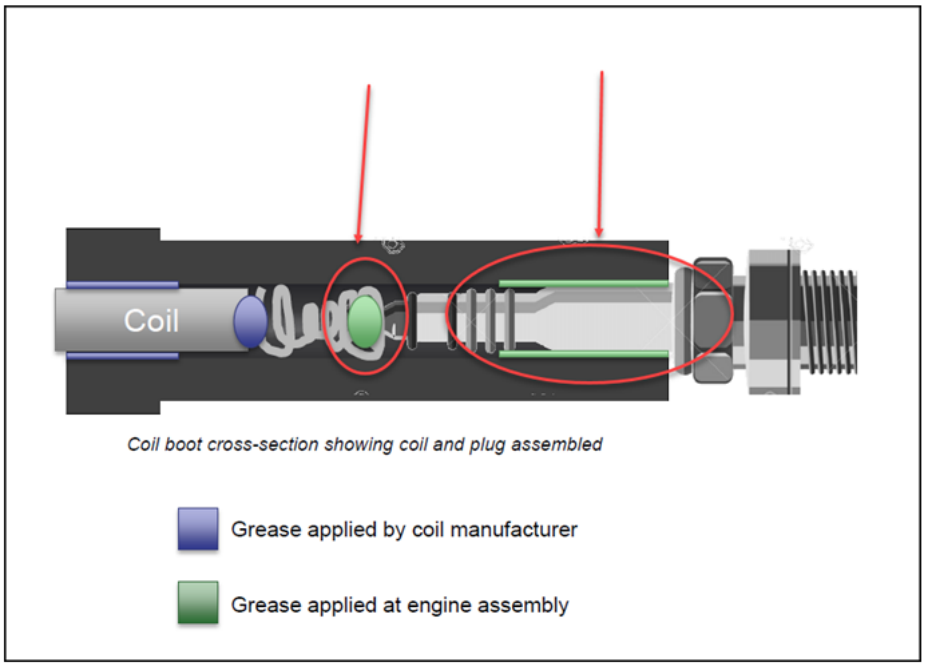


Figure 39. Dielectric Grease applied to ignition coil boots

CYLINDER HEAD COVER

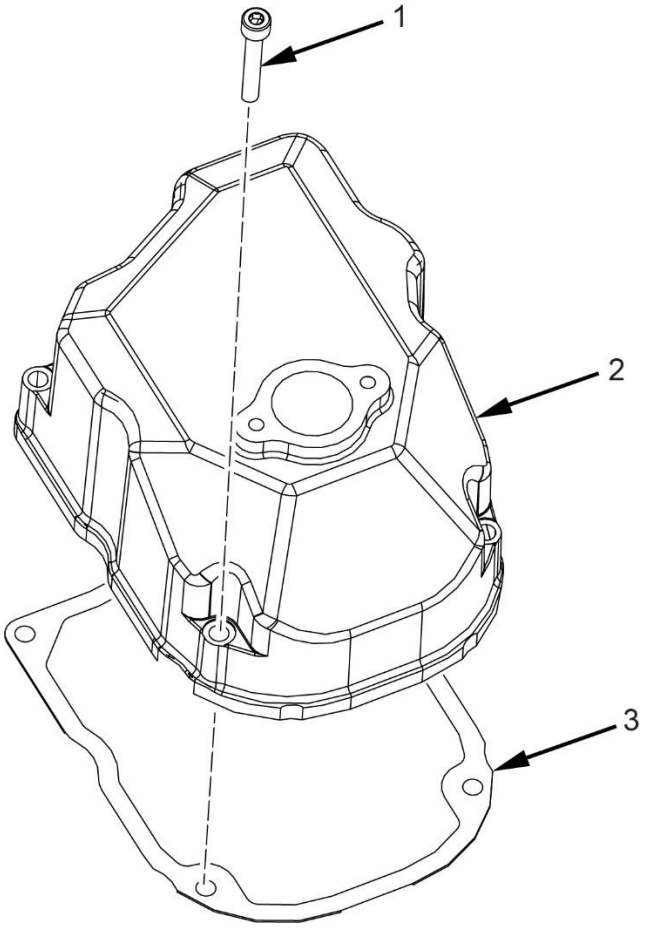


Figure 40. Cylinder Head Cover Assembly

NO.	Name
1	Bolt
2	Cover
3	Gasket

NOTE:

All cylinder head gaskets are not reusable. Once removed the cylinder head gasket must be replaced.

REMOVAL

1. Remove all four-cylinder head cover bolts (Figure 40, Item 1).
2. Remove the cylinder head cover (Figure 40, Item 2) and gasket (Figure 40, Item 3).

INSTALLATION

1. Clean top of cylinder head of any debris.
2. Install gasket (Figure 40, Item 3) onto cylinder head.
3. Install cylinder head cover (Figure 40, Item 2) and torque all four bolts (Figure 40, Item 1) to 20 lb-ft.

ROCKER ARMS

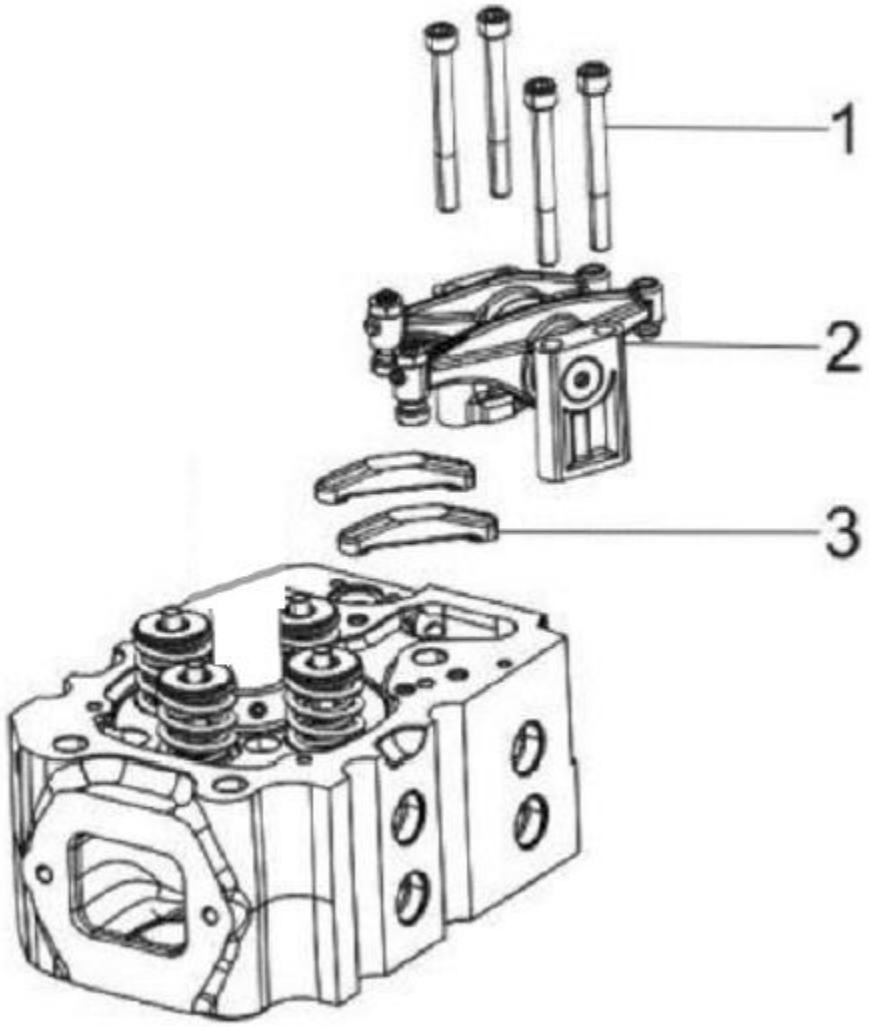


Figure 41. Rocker Arm Assembly

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

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Remove the bolts (Figure 41, Item 1) that retain the rocker arm shaft support.
2. Remove the rocker arm shaft assembly (Figure 41, Item 2) from the cylinder head.
3. Remove the valve bridge (Figure 41, Item 3).

NOTE:

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

1. Remove the push rods and identify for installation.
2. Remove the rocker arm support (Figure 42, Item 1).
3. Slide the exhaust rocker arm assembly (Figure 42, Item 2) out of the rocker arm shaft assembly (Figure 42, Item 4), rocker arm shaft sleeve (Figure 42, Item 3), and intake rocker arms assembly (Figure 42, Item 5).

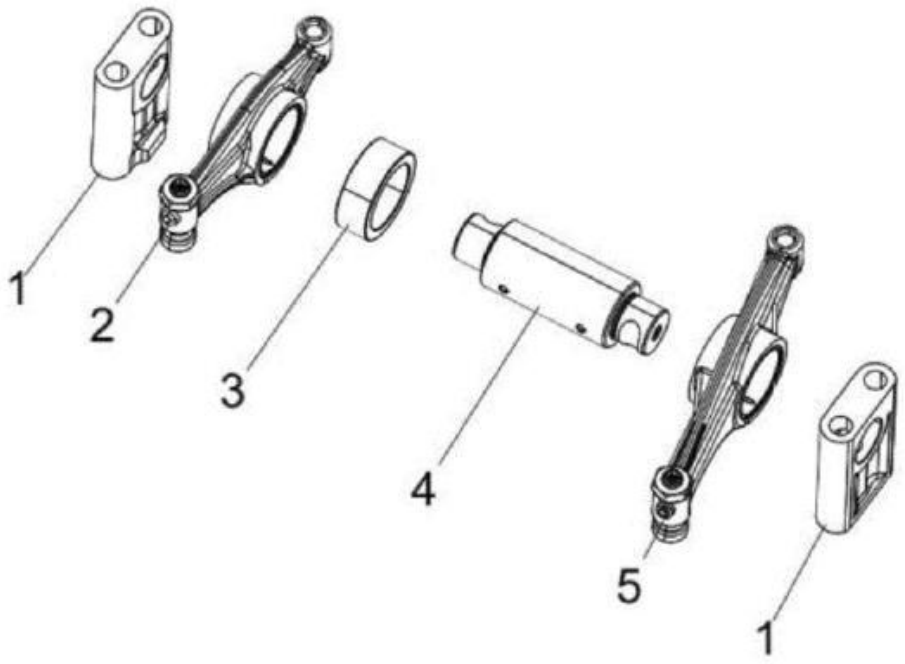


Figure 42. Rocker Arm Assembly

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

CYLINDER HEAD REMOVAL

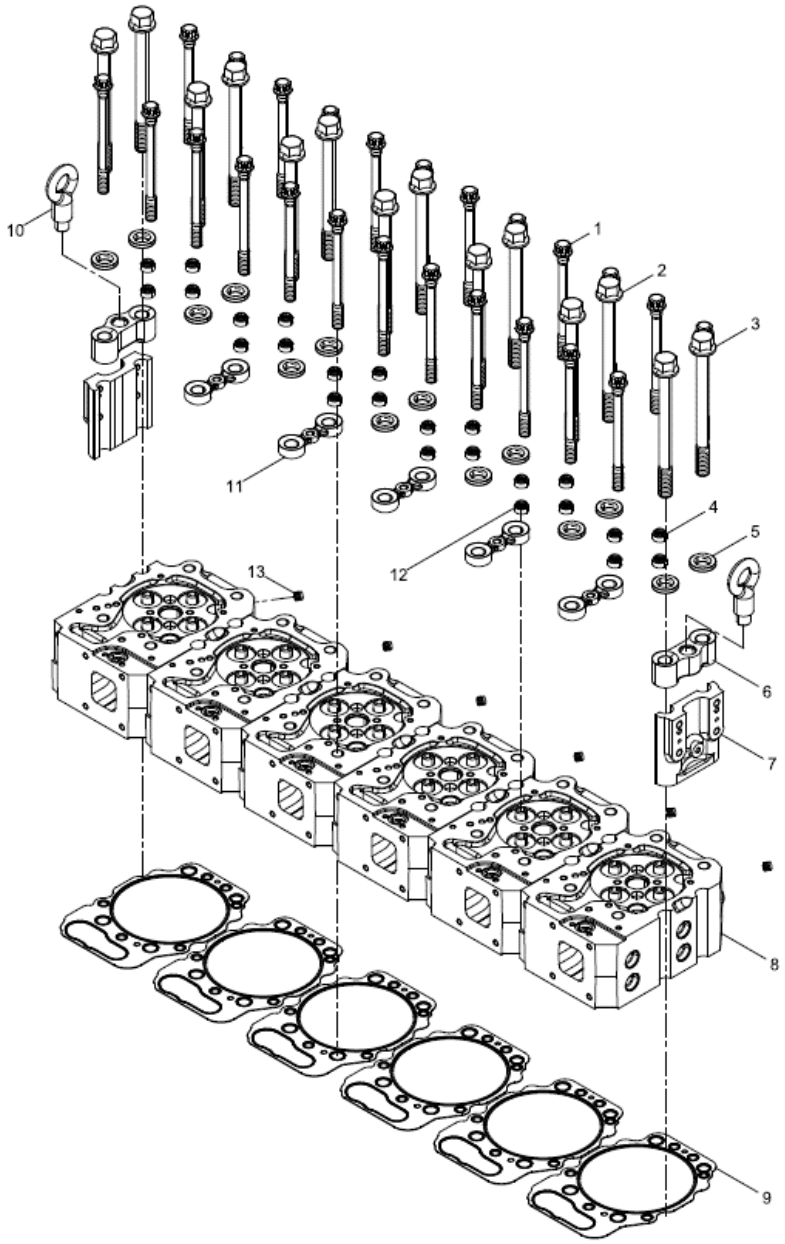


Figure 43. Cylinder Head Assembly

NO.	Name	NO.	Name	NO.	Name
1	Main Bolt	6	Clamp Block	11	Clamping Block
2	Secondary Bolt	7	End Plate	12	Valve Stem Seal
3	Secondary Bolt	8	Cylinder Head	13	Plug
4	Valve Stem Seal	9	Gasket		
5	Washer	10	Lifting Eye		

REMOVAL

1. Remove the two bolts (Figure 44, Item 2) from the pipe and remove the pipe (Figure 44, Item 1) from the cylinder head.

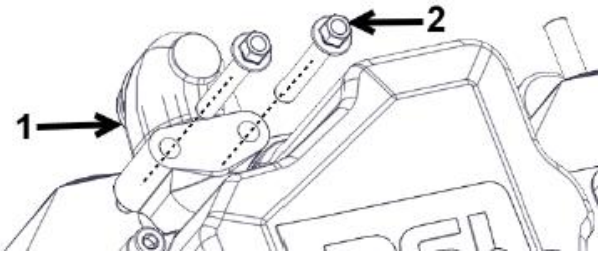


Figure 44.

NO.	Name
1	Pipe
2	Bolt

NOTE:

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

2. Loosen the cylinder secondary bolts in the following order A-N (Refer to figure 45).

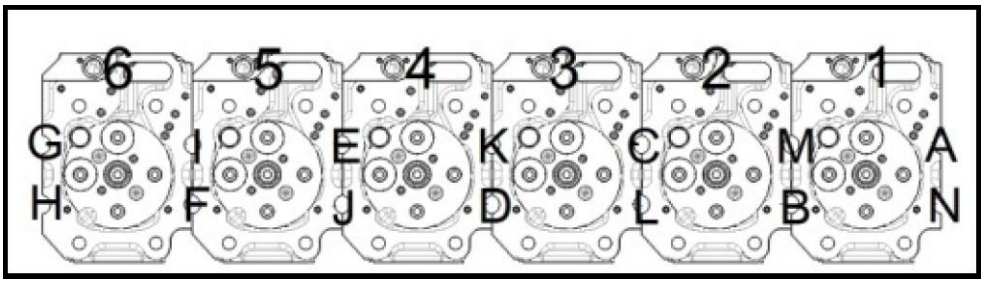


Figure 45.

3. Remove the cylinder secondary bolts (Figure 46, Item 3). Remove the washer (Figure 46, Item 5), Clamping blocks (Figure 46, Item 6 & 11) and end plate (Figure 46, Item 7).
4. Loosen and remove the cylinder head main bolts in the following order 1-24 (Figure 46).

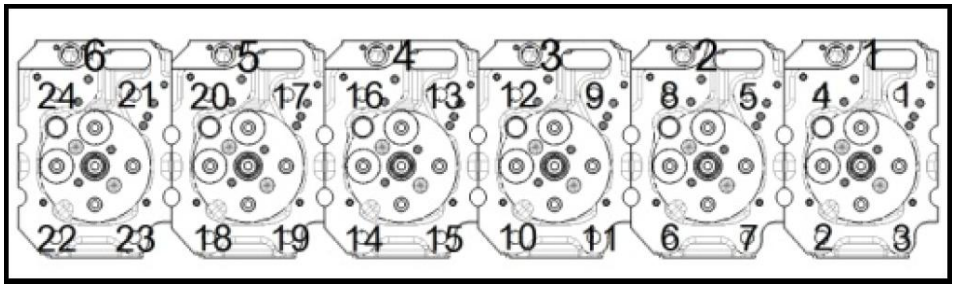


Figure 46.

5. Lift all cylinder heads away from the cylinder block (Figure 47, Item 8). Discard all cylinder head gaskets (Figure 47, Item 9).
6. Remove spark plugs from cylinder head.
7. Place the cylinder head on the work bench with the combustion side down.

8. Using a valve spring compressor tool, compress the valve springs (Figure 47).

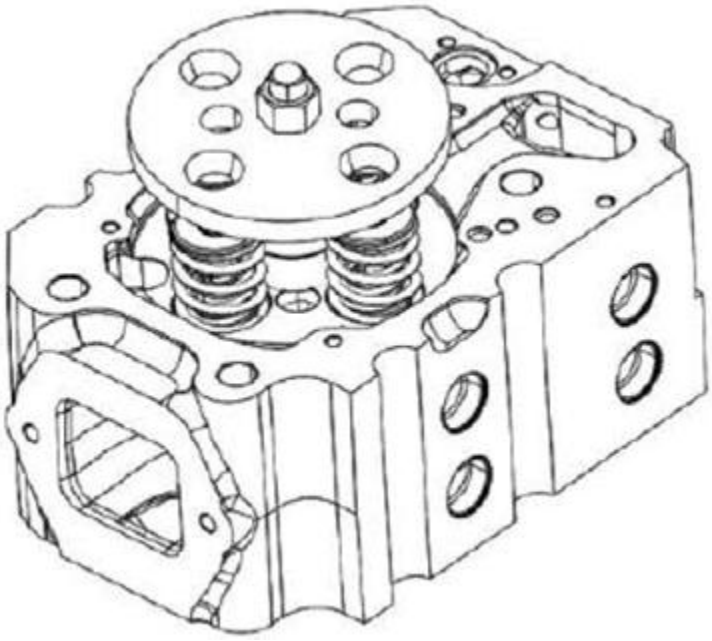


Figure 47. Valve Spring Compressor Assembly

9. Remove the valve keeper (Figure 48, Item 1).
10. Slowly release the tension on the valve spring.
11. Remove the spring top retainer (Figure 48, Item 2) and outer/inner valve spring (Figure 48, Items 3 & 4).
12. Repeat the procedure with all remaining valves.

NOTE:

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

13. Turn the cylinder head so the exhaust port side faces down. Remove the intake and exhaust valves (Figure 48, Items 7 & 8) from the cylinder head.
14. Remove the valve stem seals (Figure 48, Item 5).
15. Remove the spring bottom retainer (Figure 48, Item 6).

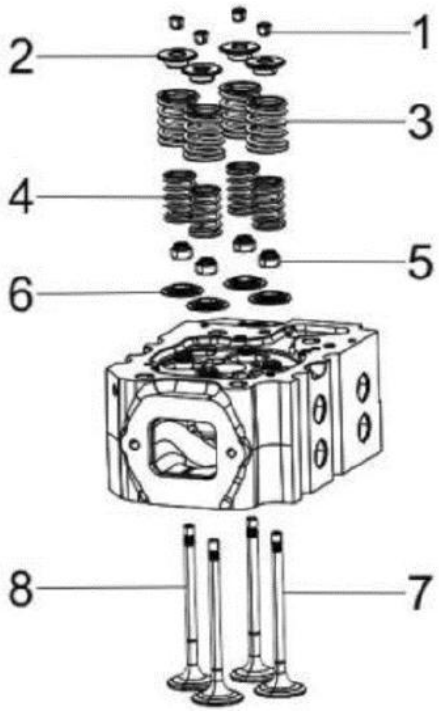


Figure 48. Cylinder Head Assembly

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.

16. If the valve guides are not within specifications, use a hydraulic press to drive the valve guides (Figure 49, Item 1) out of the cylinder head.

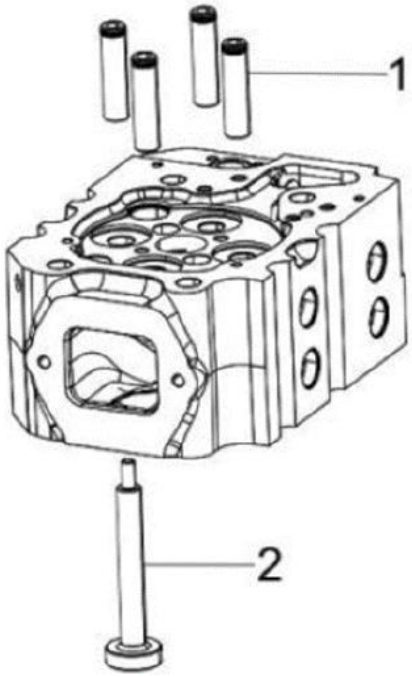


Figure 49. Cylinder Head Valve Guides

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. Inspection of Cylinder Head Components Visually inspect the parts. Replace any parts that are obviously discolored, heavily pitted, or otherwise damaged. Discard any parts that do not meet its specified limit.

NOTE:

- Any part which is found defective because of inspection or any part whose measured value does not satisfy the standard or limit must be replaced.
- Any part determined to not meet the service standard or limit before the next service, as determined from the state of current rate of wear, should be replaced even though the part currently meets the service standard limit.

INSPECTION OF PUSH RODS 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.

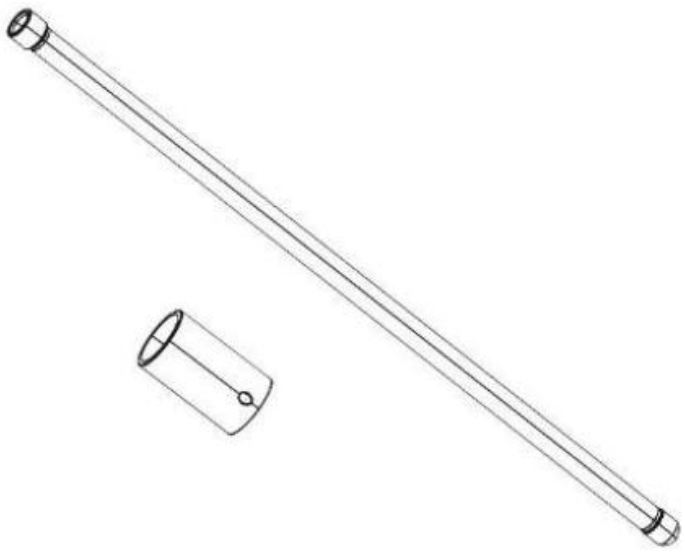


Figure 50. Push Rod and Tapper Assembly

Inspect all push rods and tappets for the following:

- Excessive Wear
- Oil passages of the tappers and push rod blockage

INSPECTION OF ROCKER ARM ASSEMBLY

1. Use a test indicator and micrometer to determine if the inside diameter of all the rocker arm support brackets and the rocker arms are within the specified limits.
2. Inspect the contact areas for excessive wear or damage.

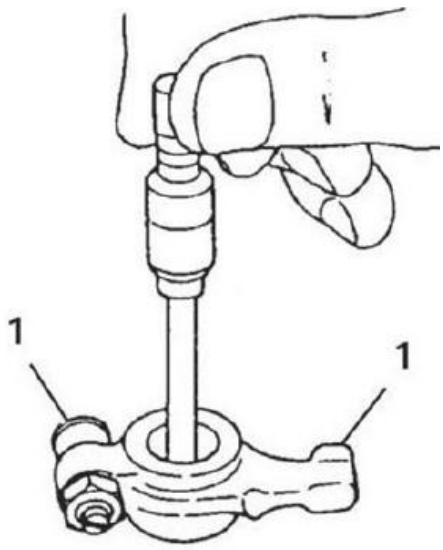


Figure 51. Rocker Arm Diameter Measurement

3. Use a micrometer to measure the rocker arm shaft diameter. Measure at each rocker arm location in two directions 90° apart (Figure 51). Allowable spec should be between 35.017mm - 35.030mm.

VALVE GUIDE INSPECTION

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

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

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

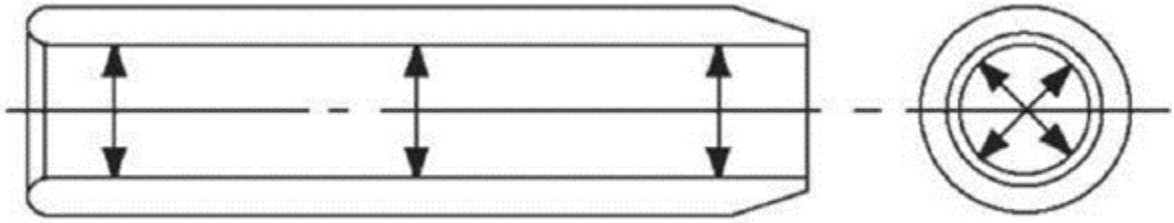


Figure 52. Valve Guide Measurement

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 53).
3. Check that there are no leaks in the intake ducts (ducts should be 100% sealed), exhaust ducts, sleeve, oil passages, cylinder combustion side, valve seat housings, discard the cylinder head if necessary.

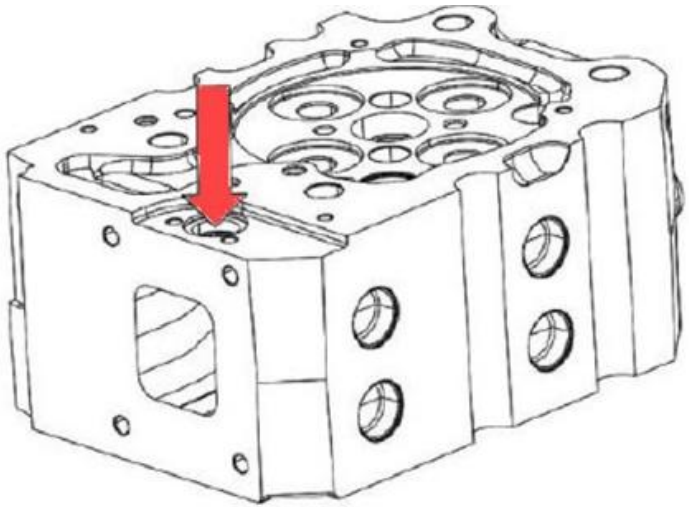


Figure 53. Cylinder Head Outlet

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

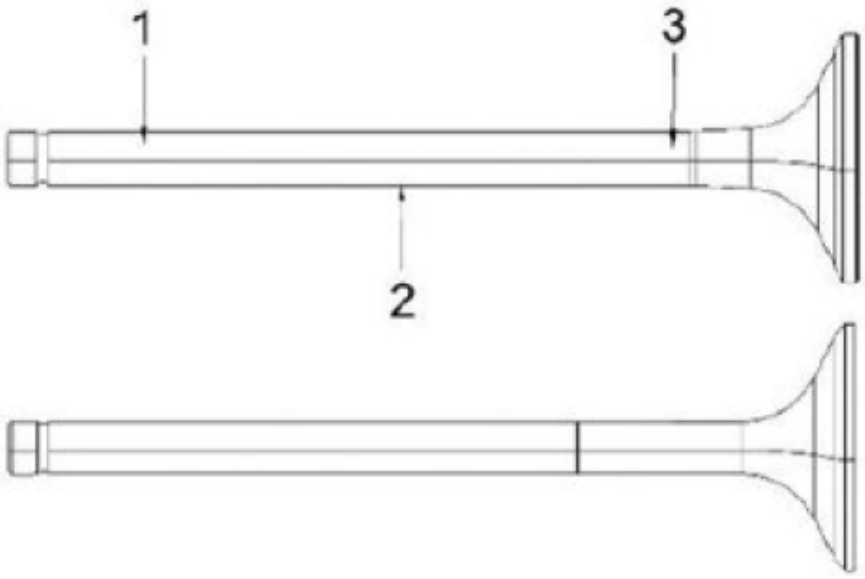


Figure 54. Valve Stem Diameter

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

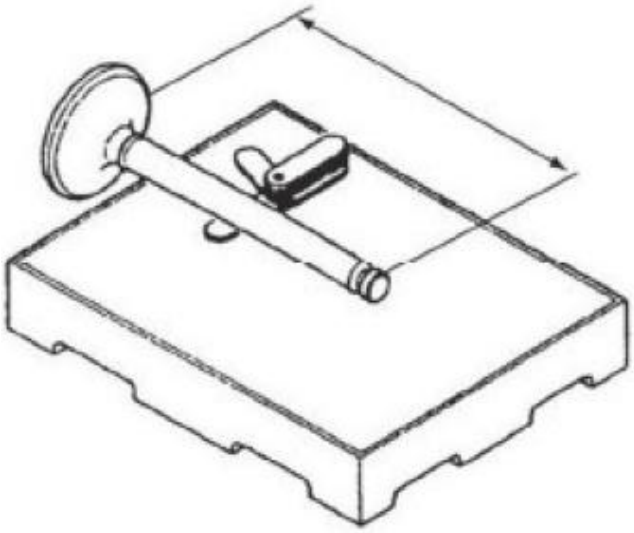


Figure 55. Valve Inspection Block

5. Insert the valves into their original locations and press them down until they are fully seated. Use a depth micrometer (Figure 56) 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.

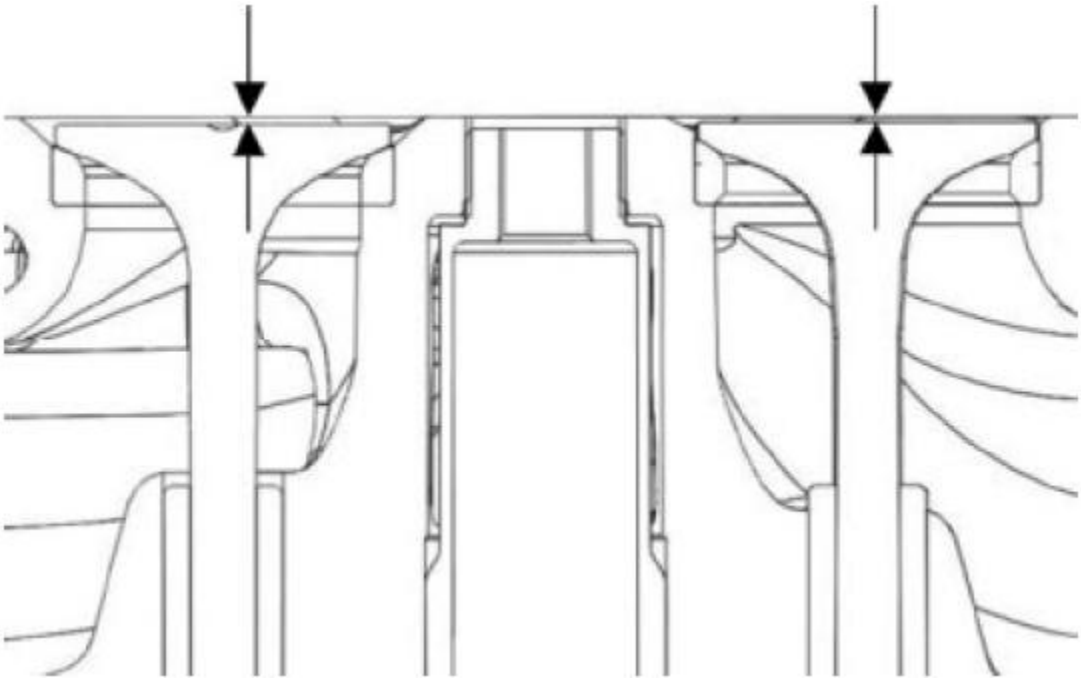


Figure 56. Valve Recession Check

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 57). See Valve Spring specification chart for the service limit.

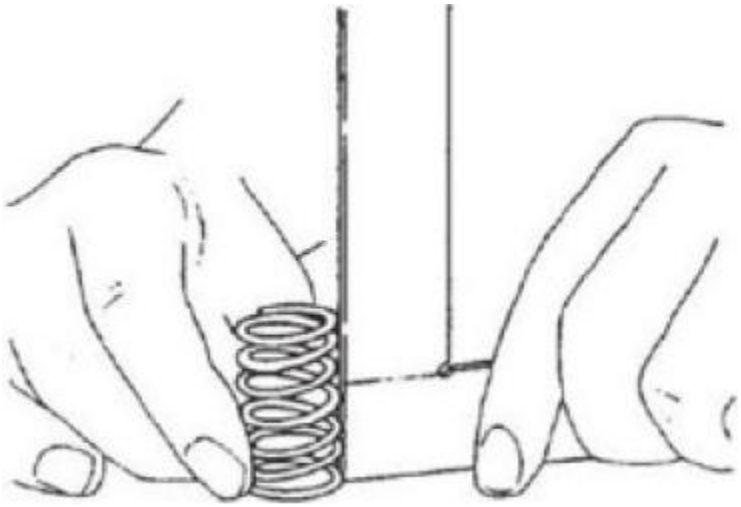


Figure 57. Valve Spring Squareness Measurement

5. Use a caliper to measure the length of the spring (Figure 58). See Valve Spring Mechanical chart for the service limit.

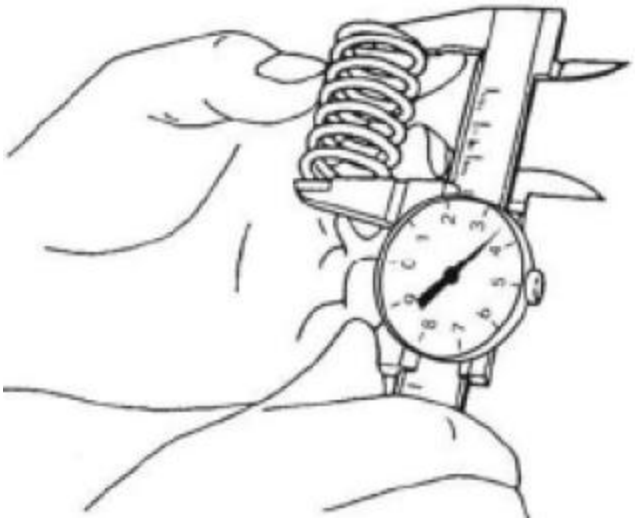


Figure 58. Valve Spring Measurement

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.

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.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

Engine Model	Marking	
20L	Intake	Exhaust
	Black	Brown

Figure 59. Valve Stem Seal Color Chart

1. Install the valve spring bottom retainers (Figure 59, Item 1).

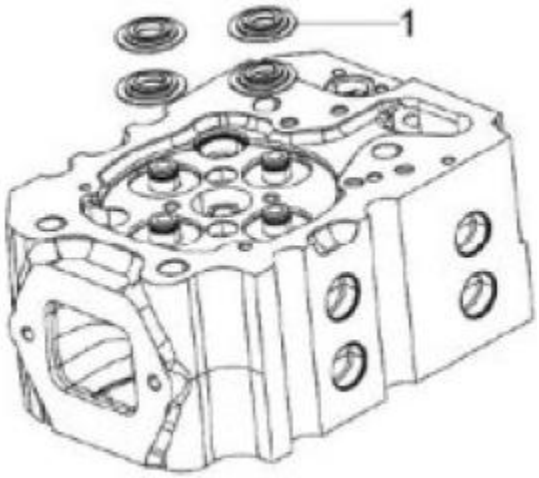


Figure 60. Valve Spring Retainer

NO.	Name
1	Valve Spring Bottom Retainer

2. Oil the lip of the valve stem seal (Figure 60, Item 2). Using the valve stem seal installation tool (Figure 60, Item 1), install a new valve stem seal on each of the valve guides.

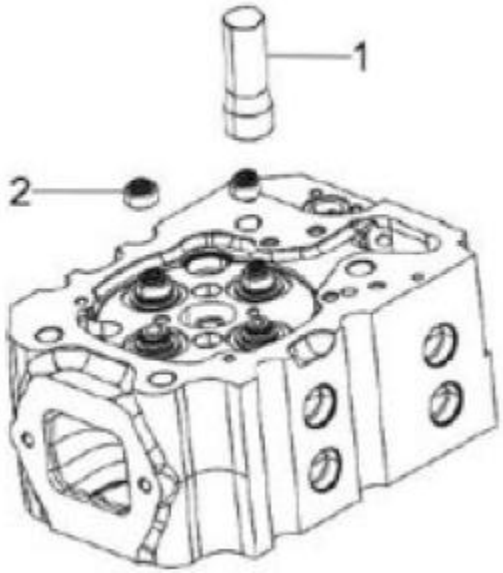


Figure 61. Valve Stem Seal Installation Tool

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 61, Items 1 & 2) in their proper location in the cylinder head.

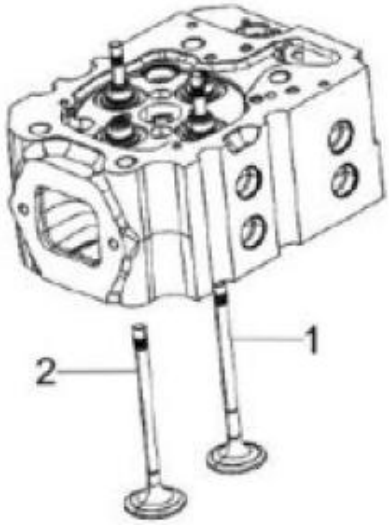


Figure 62. Valve Assembly

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 62, Items 3 & 4) and the spring retainers (Figure 62, Item 2).

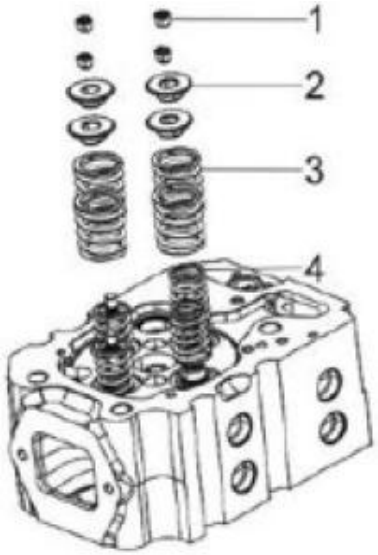


Figure 63. Valve Spring Assembly

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

6. Compress the valve springs.
7. Insert the valve keepers (Figure 63, 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

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 64, Item 7) on the cylinder block.
2. Position the cylinder head (Figure 64, Item 6) on the cylinder head gasket.

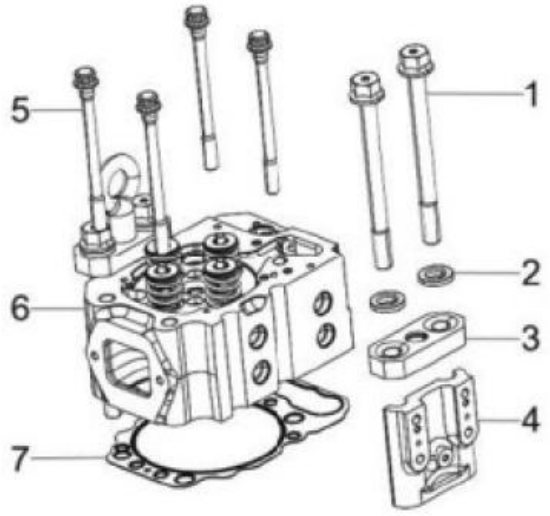


Figure 64. Cylinder Head Assembly

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

NOTE:

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

3. Lightly oil the threads and shoulder of the cylinder head main bolts (Figure 65, Item 5) and cylinder head secondary bolts (Figure 65, Item 1). Lightly oil the clamping block (Figure 65, Item 3) and end plate (Figure 65, Item 4) and insert.
4. Repeat steps 1-3 for all remaining cylinder heads.
5. Tighten the main bolts in order (Figure 65) 1 through 24 to a torque of 59 lb-ft.

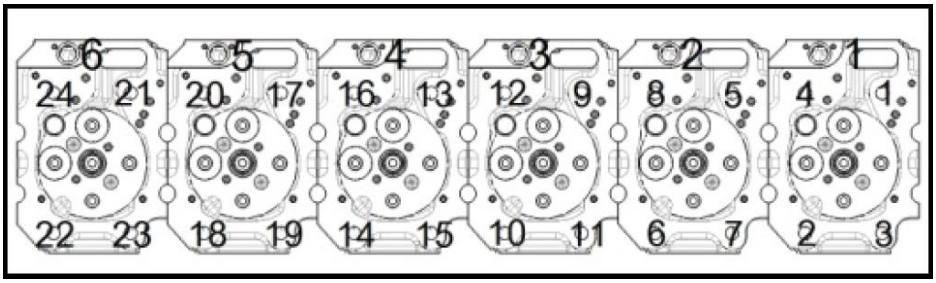


Figure 65. Main Bolt Torquing Order

1. Tighten the secondary bolts in order A through N (Figure 66) to 59 lb-ft.

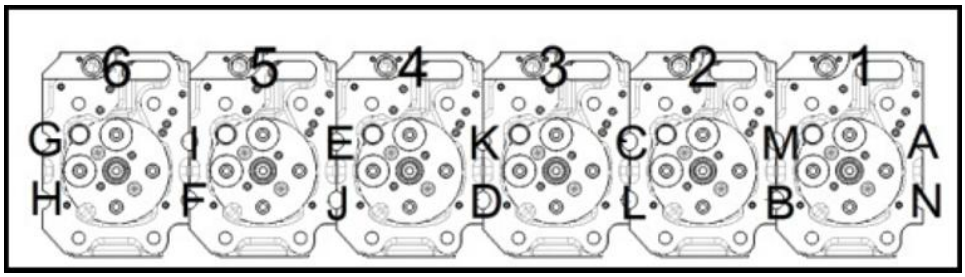


Figure 66. Secondary Bolt Torquing Order

2. Tighten the main bolts in order 1 through 32 to an angle of 60±5°
3. Tighten the secondary bolts in order A through R to an angle of 60±5°.
4. Tighten the main bolts to an angle of 60±5°.
5. Tighten the secondary bolts to an angle of 60±5°.
6. Tighten the secondary bolts to an angle of 60±5°.
7. Tighten the main bolts to an angle of 45±5°.
8. Reinstall spark plugs. Torque the spark plug to 28 ft/lbs.
9. Reinstall the coolant pipe (Figure 66, Item 1) onto the cylinder head and torque down the two bolts (Figure 66, Item 2).

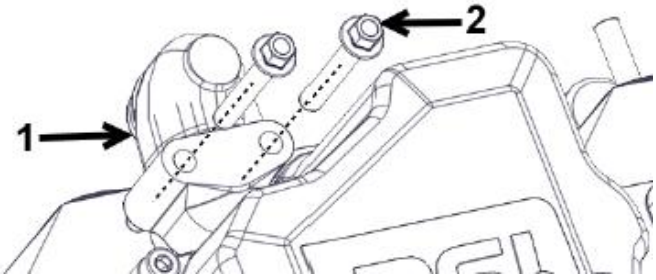


Figure 67.

NO.	Name
1	Pipe
2	Bolt

ROCKER ARM INSTALLATION

NOTE:

- Ensure the lubrication holes (Figure 68, Item 1) in the rocker arm shaft are oriented correctly with respect to the rocker arms (Figure 68, Item 2).
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

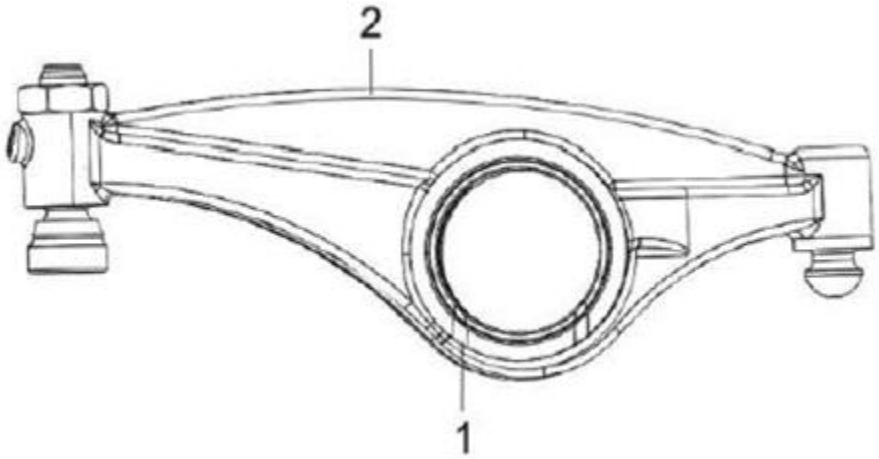


Figure 68. Rocker Arm

NO.	Name
1	Lubrication Hole
2	Rocker Arm

1. Lubricate the rocker arm shaft. Slide the rocker arm supports (Figure 69, Item 1), and rocker arms (Figure 69, Items 2 & 5) onto the shaft.

NOTE:

- Align the hole in the rocker arm shaft (Figure 69, Item 4) and the hole in the rocker arm support (Figure 69, Item 1).
- 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.

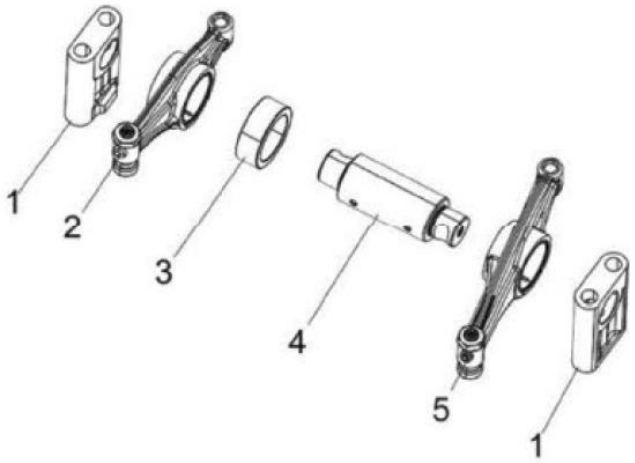


Figure 69. Rocker Arm Assembly

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

2. Oil and put the valve bridges on the valves.
3. If removed, reinstall the valve adjusting screws (Figure 69, Item 3) and the lock nuts (Figure 69, Item 1).
4. Place the rocker arm shaft assembly onto the cylinder head.
5. Insert a 0.4~0.6 mm feeler gauge between rocker arm shaft sleeve (Figure 70, Item 3), and intake rocker arms assembly (Figure 70, Item 5). If outside of specifications replace rocker arms.
6. Align the push rods with their respective rocker arms.
7. Reinstall and tighten the rocker arm shaft retaining bolts to the specified torque.
8. Adjust the valve clearance. See Measuring and Adjusting Valve Clearance Chart.

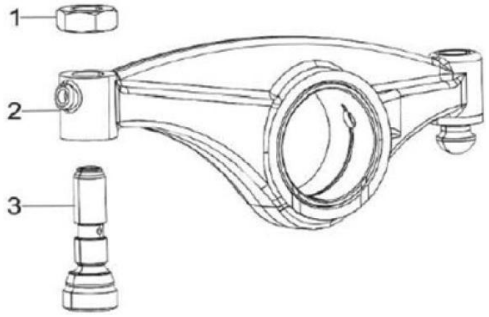


Figure 70. Rocker Arm Assembly

NO.	Name	NO.	Name
1	Nut	3	Screw
2	Rocker Arm		

TAPPET AND PUSHRODS

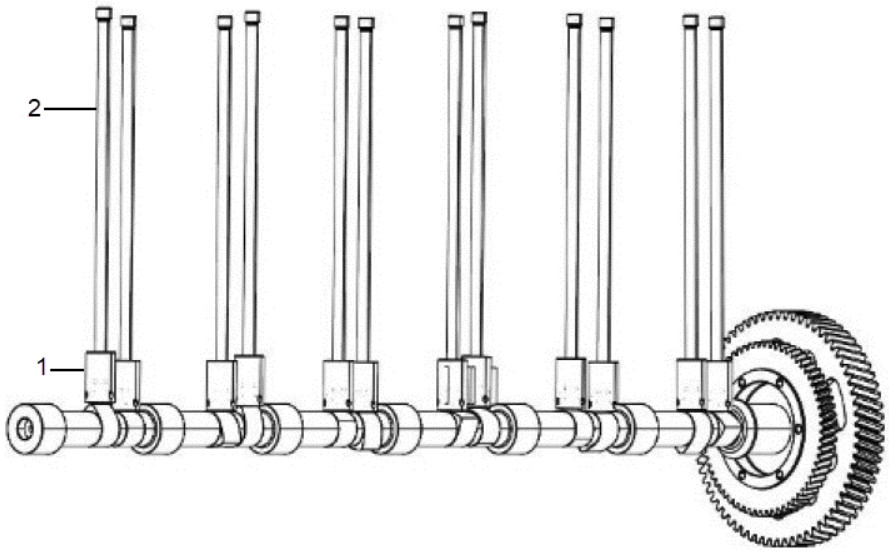


Figure 71. Tappet and Push Rod Assembly

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 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 valve lash while engine is cold.

1. Remove ignition coil covers, ignition coils, and valve covers from the engine.
2. TDC determination method is based on starter location:
    a. If starter is on left side of engine (exhaust side, per Figure 72 below), TDC determination done with paint mark on flywheel and crankshaft position sensor port – Figure 73.
    b. If starter has been relocated to right side of engine (intake side, per Figure 73 below), TDC determination done through pin-hole method – Figure 76.

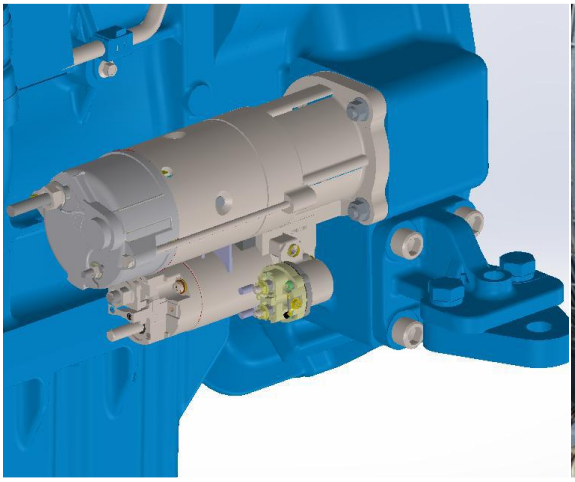


Figure 72.

Figure 73.

3. Remove cover on flywheel housing (shown below) and insert barring over tool.
    c. The barring over tool procedure is identical on either side of the engine. Housing cover removal will depend on starter location (per Step 2).

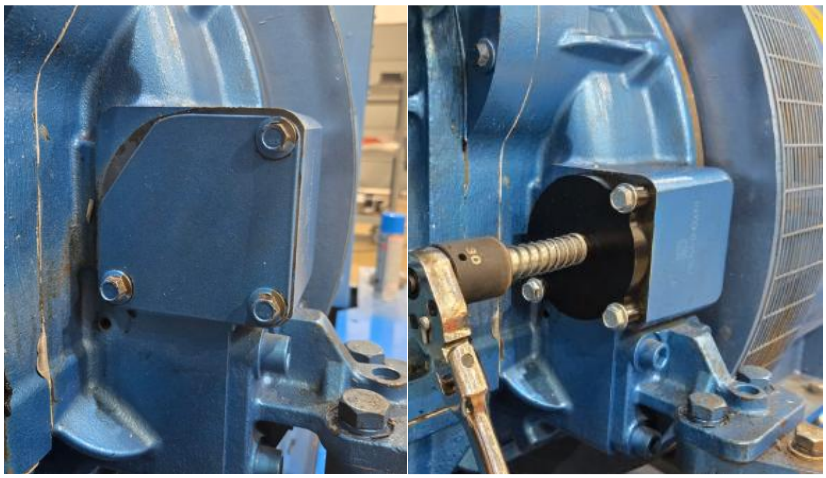


Figure 74.

4a. Standard Starter Location (Exhaust Side)

4. Remove the crankshaft position sensor on the flywheel to expose the flywheel (as below). Keep all shims together with crank sensor.

Figure 75.

5. Bar engine over until the TDC indication paint mark on the flywheel lines up with the paint mark on the housing. These paint markings are already set on the unit. Continue to Step 6.

4b. Relocated Starter Location (Intake Side)

4. Locate pin-hole under cover on flywheel housing as circled below. Insert a small Allen key, screwdriver, or other tool into the pinhole and hold against the flywheel (as below).

Figure 76.

5. Bar engine slowly over while simultaneously holding tool against the flywheel. While barring over, the tool will slide into a bore on the flywheel (shown below). The engine is now at the TDC compression stroke.

6. Check the rockers when cylinder 1 is at TDC (closest to the rear (Flywheel) end of the engine). If cylinder 1 is at TDC the valves shown below in can be adjusted. If cylinder 6 is at TDC the valves shown below can be adjusted. (Refer to Figure 77)

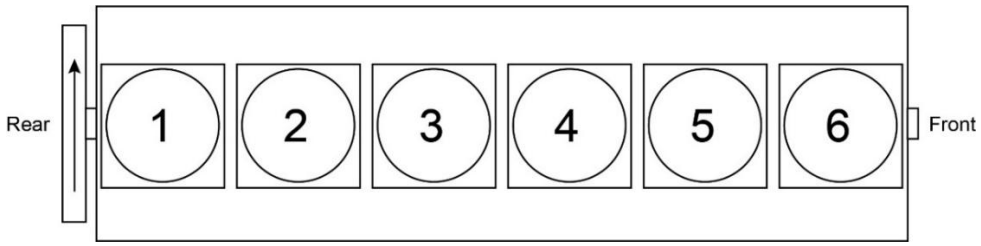


Figure 77.

Adjust Valve Clearance		
	Intake Valves	**Exhaust Valves**
Clearance Specification	0.021”	0.039”
Cylinder 1 @ TDC	1-2-4	1-3-5
Cylinder 6 @ TDC	3-5-6	2-4-6

Figure 78. Valve Clearance Adjustment Chart

7. Use a feeler gauge to check the clearance between the rocker arm and the valve bridge (Figure 79). Lash should be set to 0.021” (0.533 mm) for the intake and 0.039” (0.990 mm) for the exhaust.
8. If lash needs to be adjusted, loosen nut and adjust to the specs listed above. Tighten nuts to a torque of 15 +/- 3.5 ft-lbs (20 +/- 5 Nm).
9. Re-check rocker and valve bridge clearance with appropriate feeler gauge.
10. Repeat on all other valves at the same TDC.
11. Bar engine over 360 degrees until the timing mark is at TDC #1 again. Repeat steps 5-9 for other set of valves now at TDC.
12. Remove barring over tool and reinstall flywheel housing cover
13. Reinstall valve covers, ignition coils, and ignition coil covers.
14. IF CRANKSHAFT POSITION SENSOR REMOVED: Reinstall crankshaft position sensor. If any shims were damaged during removal, replace and maintain the same number of total shims.

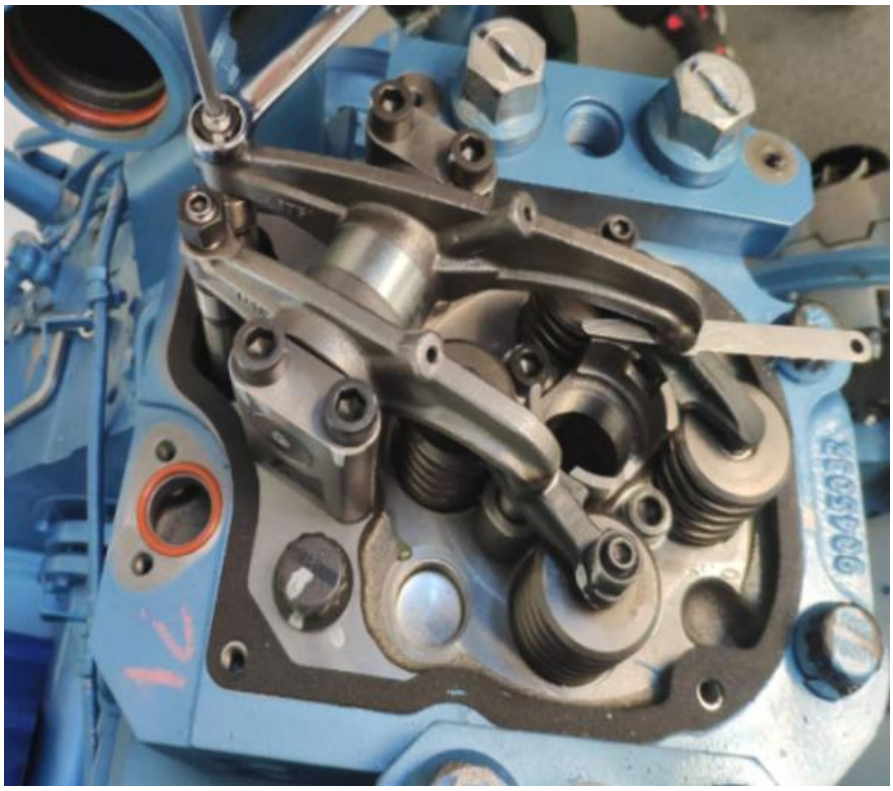


Figure 79.

16. Rotate the crankshaft 360 degrees until the timing mark is back at TDC #1 again. If the valves with cylinder #1 at TDC were checked first, the valves with cylinder 6 at TDC may now be checked. If the valves with cylinder 6 at TDC were checked first, the valves with cylinder 1 at TDC may now be checked.
17. Check lash on all rockers that were not previously checked. Adjust as necessary.
18. Reinstall valve covers.

TIMING GEARS

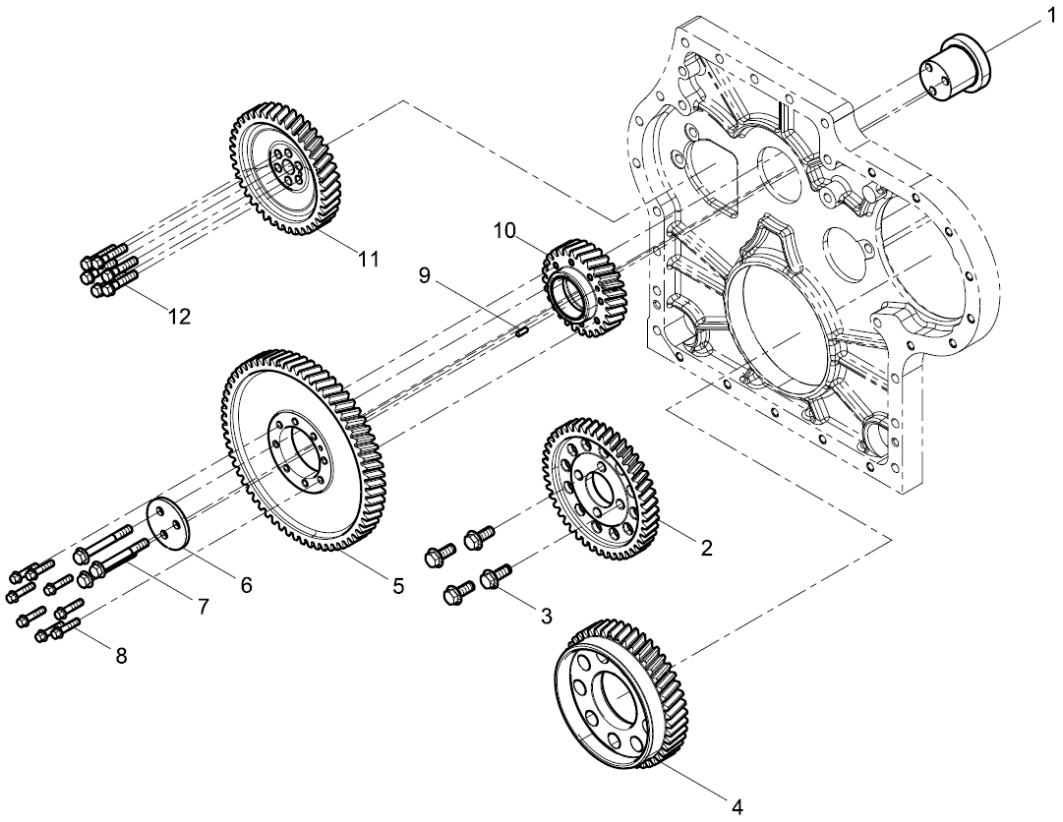


Figure 80. Timing Gear Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Idler Gear Shaft	4	Crankshaft Timing Gear	7	Bolt	10	Idler Gear
2	Injection Pump Gear	5	Idler Gear	8	Bolt	11	Camshaft Timing Gear
3	Bolt	6	Board	9	Pin	12	Bolt

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

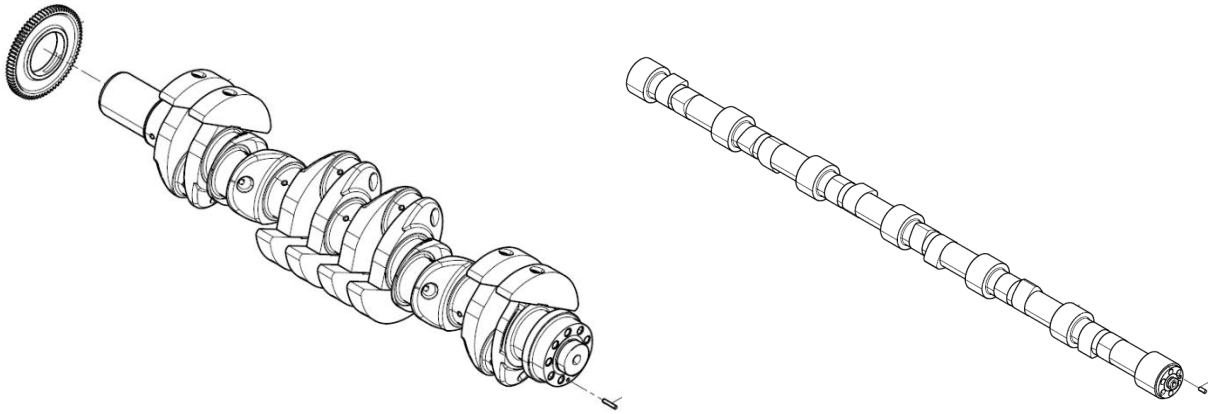


Figure 81. Crankshaft and Camshaft Assembly

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 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 *THERMOSTAT* section of the manual).
2. Remove the tensioner and belt assembly.
3. Remove the crankshaft pulley assembly.
4. Disconnect the connecting wiring harness of speed sensor (If necessary).
5. Remove the speed sensor (If necessary).
6. Remove the bolts that retain the gear case cover to the cylinder block and oil pan.
7. Remove the front cover.
8. Remove the rocker arm system and push rods.
9. Remove the cylinder heads.
10. Remove the tappets.

CHECKING TIMING GEAR BACKLASH

Prior to removing the timing gears, measure the gear backlash and determine the gear wear. Check the backlash between each pair of mating gears (Figure 77). If not within specification, replace both mating gears. See Timing Gear Backlash on specifications for service limits.

NOTE:

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

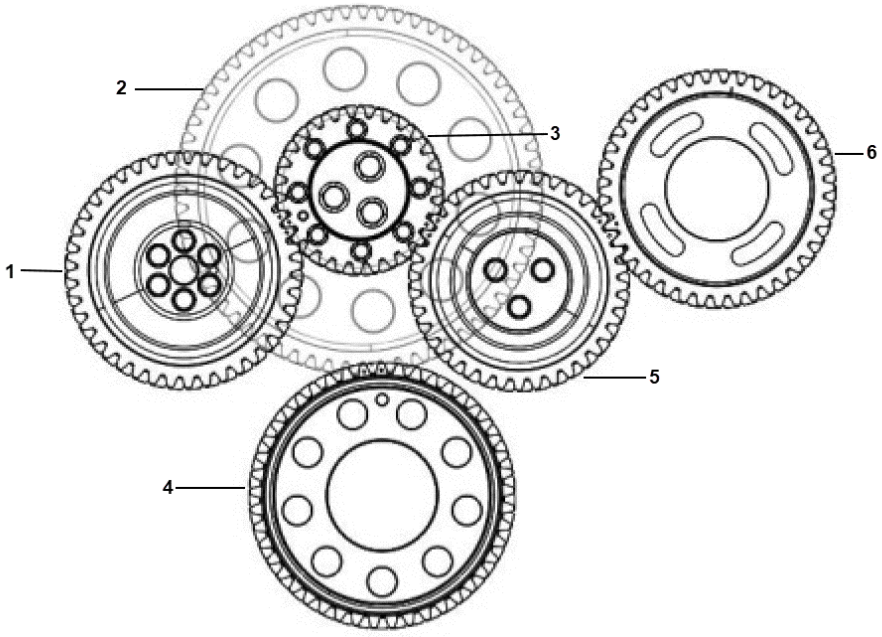


Figure 82.

NO.	Name	NO.	Name
1	Camshaft Timing Gear	4	Crankshaft Drive Gear
2	Big Idler Gear	5	Idler Gear
3	Idler Gear	6	Injection Drive Gear

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.
- Remove all rocker arm systems, injector holders, push rods, tappets, cylinder heads and flywheel housing before removing the camshaft.

1. Install a dial indicator on the cylinder block. Move the camshaft back and forth to measure the end play. Record the measurement. See Camshaft specifications for the service limit.
2. Loosen the tightening bolt (Figure 83, Item 5) and remove the trigger wheel (Figure 83, Item 4).
3. Remove the bolts (Figure 83, Item 3) from the connecting shaft (Figure 83, Item 2) of the trigger wheel. Remove the connecting shaft, and camshaft gear (Figure 83, Item 1).

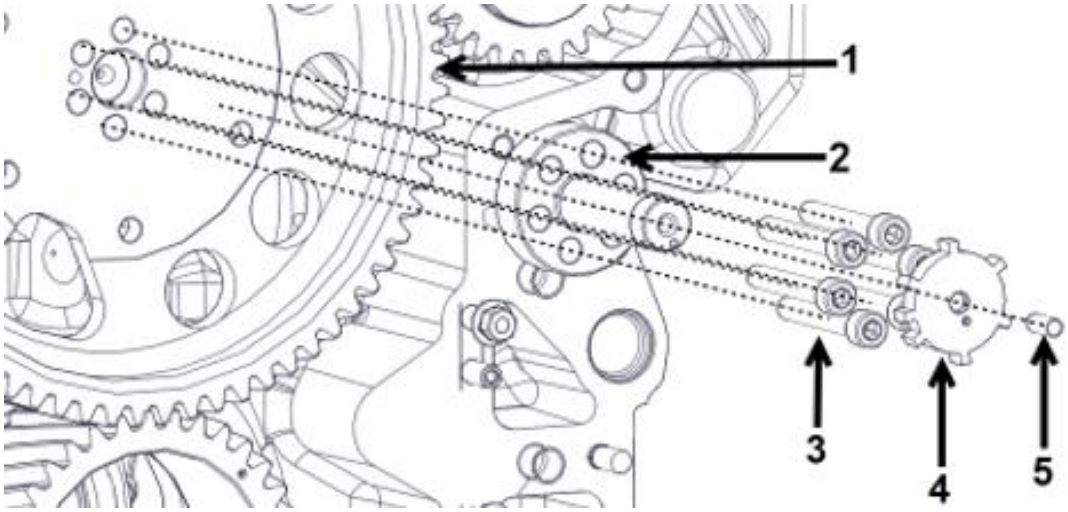


Figure 83.

NO.	Name	NO.	Name
1	Camshaft Gear	4	Trigger Wheel
2	Connecting Shaft	5	Bolt
3	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 contact 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 84, Item 9).
15. Remove the compression rings (Figure 84, Item 1) from the piston using a piston ring expander.
16. Remove the oil ring (Figure 84, Item 2) from the piston using a piston ring expander.
17. Remove the circlips (Figure 84, Item 4) from the piston pin.
18. Remove the piston pin (Figure 84, Item 5) and connecting rod (Figure 84, Item 6) from the piston (Figure 84, Item 3).
19. Repeat the steps until all pistons are removed and disassembled.

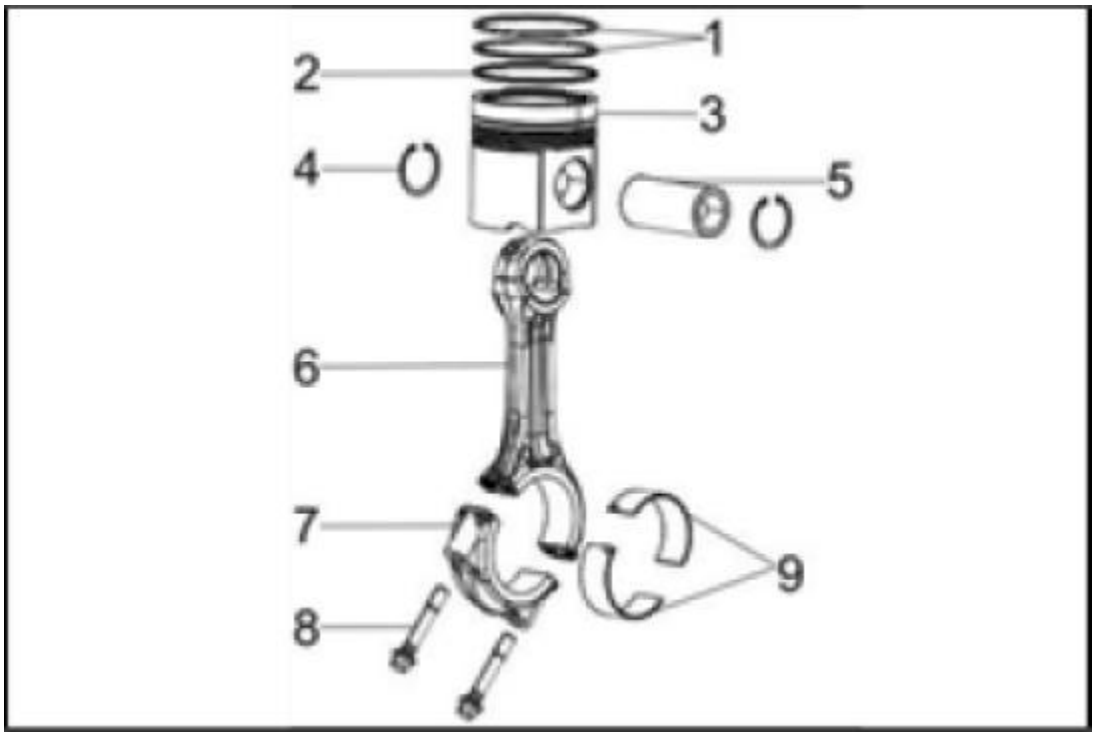


Figure 84.

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 carbon 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 85).

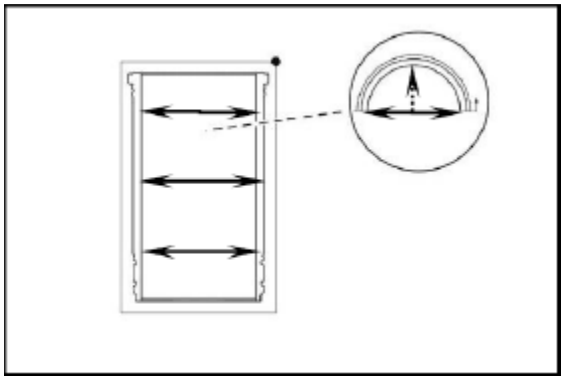


Figure 85.

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 86).
3. Slowly turn the nut and remove the cylinder liner and tool together.

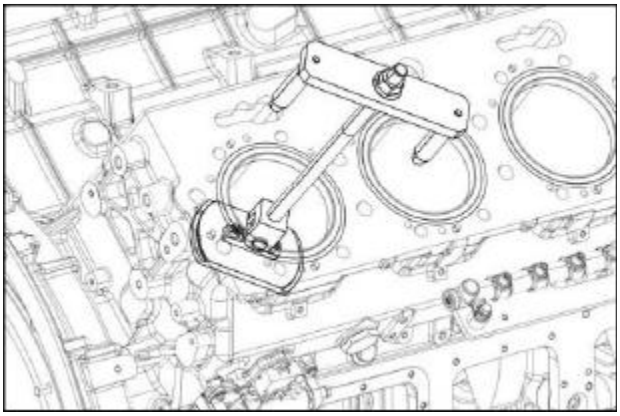


Figure 86.

4. Disassemble the O-rings from the cylinder liner (Figure 87).
5. Repeat the steps until all liners are removed.
6. Clean the inside of the oil sump. Remove the protective clothes.

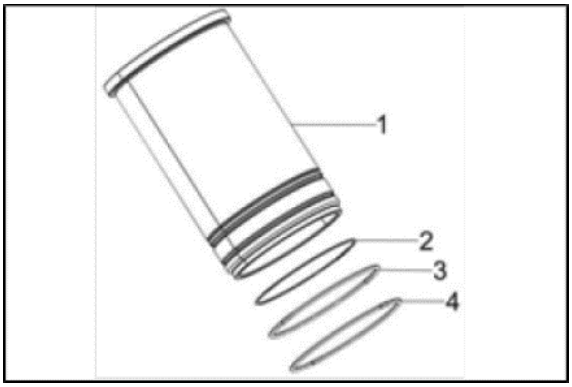


Figure 87.

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

REMOVAL OF OIL PAN

NOTE:

Oil pan weighs 142 kg (313 lbs). 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 (Figure 88, Items 11, 12 & 13).
2. With a crane or any hosting assistance, remove the thirty-four bolts (Figure 88, Items 5 & 6).

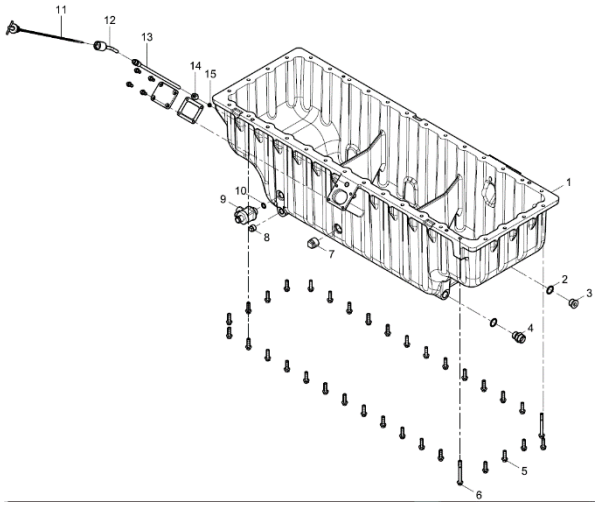


Figure 88. Oil Pan Assembly

NO.	Name	NO.	Name	NO.	Name
1	Oil Pan	6	Bolt	11	Dipstick
2	Washer	7	Plug	12	Dipstick Tube
3	Plug	8	Plug	13	Dipstick Tube
4	Pipe	9	Oil Drain Valve	14	Cap
5	Bolt	10	Washer	15	Washer

3. Remove the silicone from the bottom of the cylinder block and or the top of the oil pan.

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 89, Item 1) into the opposed flywheel bolt holes.

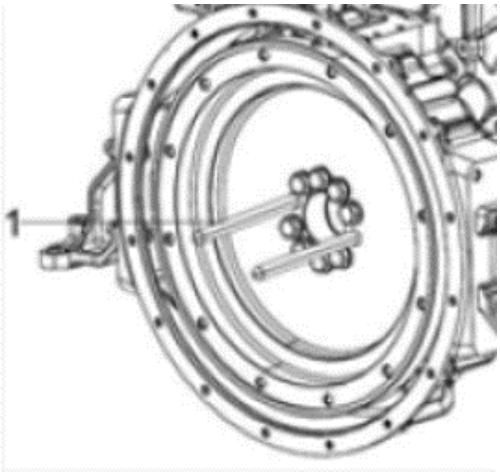


Figure 89.

NO.	Name
1	Flywheel Guides

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

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 90, Item 1).

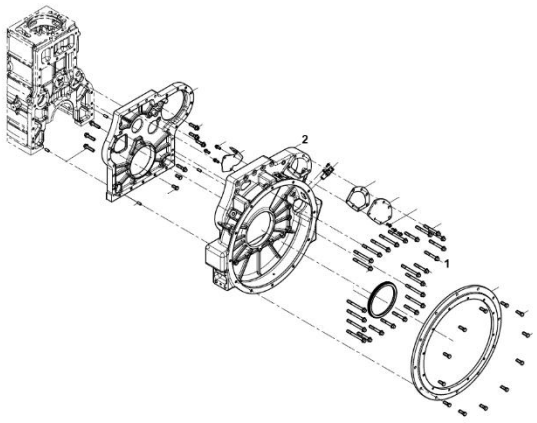


Figure 90.

NO.	Name
1	Flywheel Housing Bolts
2	Flywheel Housing
3	Rear Oil Seal

4. Remove the flywheel housing (Figure 90, Item 2).
5. Remove the Rear oil seal (Figure 90, Item 3) from the 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 93, Item 1) on the cylinder block. Move the crankshaft (Figure 91, Item 2) front to rear to measure the end play. Record the measurement.

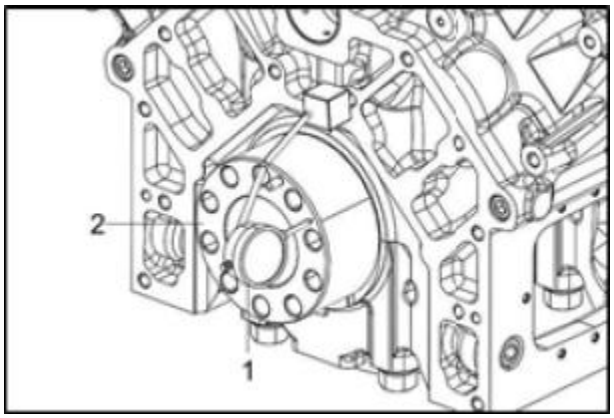


Figure 91.

NO.	Name
1	Dial Gauge
2	Crankshaft

METHOD B: Use a feeler gauge to measure the clearance (Figure 92, Item 3) between the thrust bearing (Figure 92, Item 1) and crankshaft (Figure 92, Item 2). Record the measurement. See Thrust Bearing specifications for the service limit.

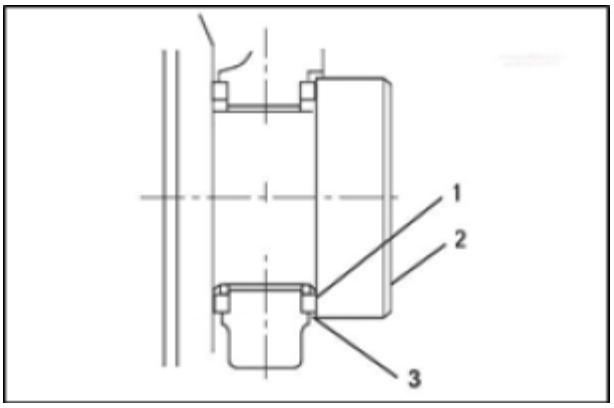


Figure 92.

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 bolts (Figure 93, Item 1).
2. Remove the main bearing caps (Figure 93, Item 2). Be sure to note the markings on the main bearing caps, or mark them yourself, so they can be reinstalled in the same order as they were removed. **DO NOT REMOVE THE BEARING INSERTS AT THIS TIME.**
3. Remove the lower main bearings and thrust plates.

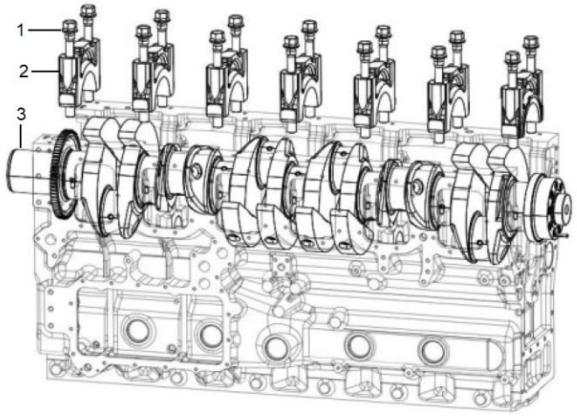


Figure 93.

NO.	Name
1	Main Bearing Cap Bolts
2	Main Bearing Caps
3	Crankshaft

4. With proper hoisting assistance carefully remove the crankshaft (Figure 93, Item 3) from the engine.
5. Remove the upper bearings and the 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 94) (a, b, c), and in two directions (d and e) in each cylinder liner.

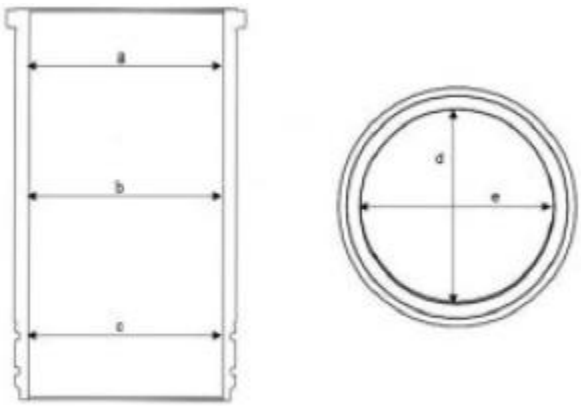


Figure 94.

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 95). Measurements must be taken at a specified distance (Figure 95, Item 1) from the bottom of the piston. Record measurements. See *Mechanical Specifications Chart*.

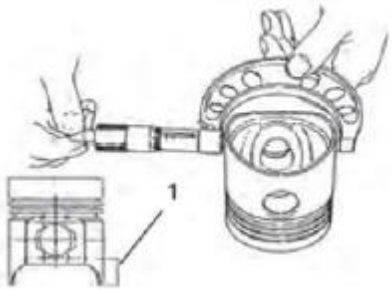


Figure 95.

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 96). See the *Mechanical Specifications Chart*. Record the measurements.

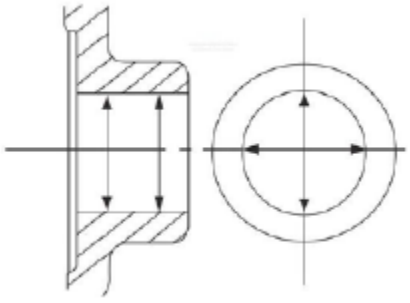


Figure 96.

6. Measure the outside diameter of the piston pin in three places and at 90° (Figure 97). See the *Mechanical Specifications Chart*. Record the measurements.

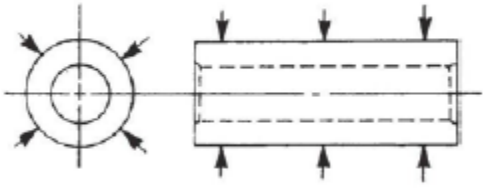


Figure 97.

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 98). 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.

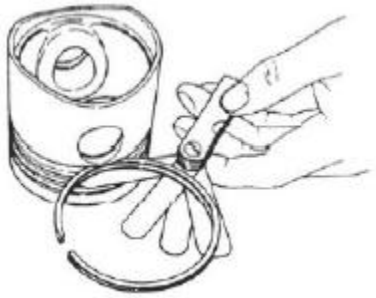


Figure 98.

9. To measure piston ring end gap, insert each compression piston ring (Figure 99, 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 99, Item 2) from the bottom of the bore. Remove the piston. Measure the end gap (Figure 99, 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.

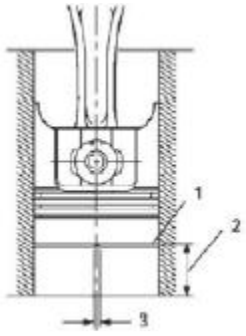


Figure 99.

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 100, 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 100, Item 2). See *Connecting Rod Mechanical Specifications Chart*.

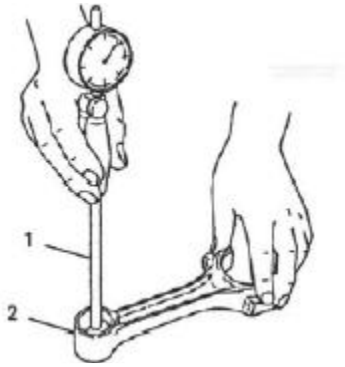


Figure 100.

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 101, Item 1).
2. Measure the outside diameter of the tappet stem (Figure 101, Item 2). See the *Mechanical Specifications Chart* for the service limit.

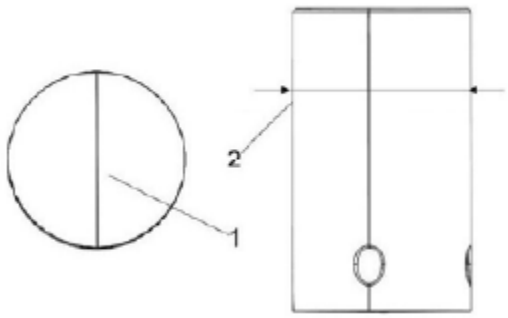


Figure 101.

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 102, Item 4) on V-blocks.
2. Place a dial indicator (Figure 102, Item 3) on a center main bearing surface.

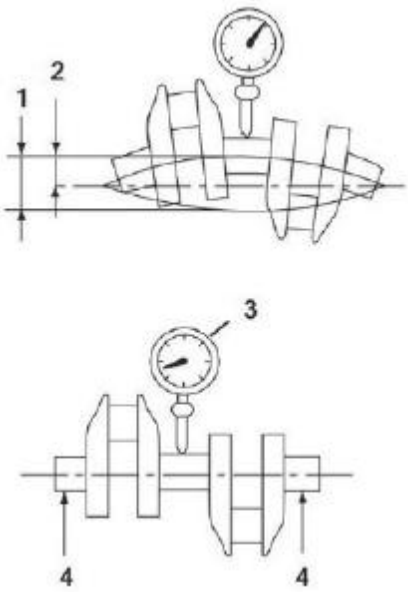


Figure 102.

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 103, Item 2) and main bearing journal (Figure 103, 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.

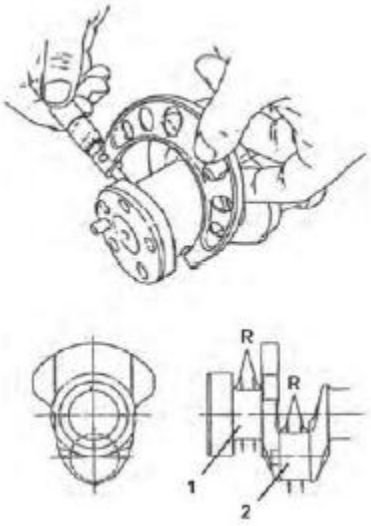


Figure 103.

INSPECTION OF CAMSHAFT

1. Use V-blocks and a dial indicator to check camshaft bend (Figure 104). Place the indicator on the center bearing journal.

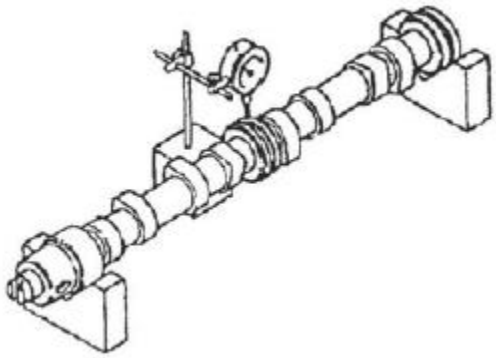


Figure 104.

2. Rotate the camshaft and observe the runout. See the *Camshaft Specifications Chart*.
3. Measure the height of each lobe (Figure 105, Item 1). See the *Camshaft Specifications Chart*.

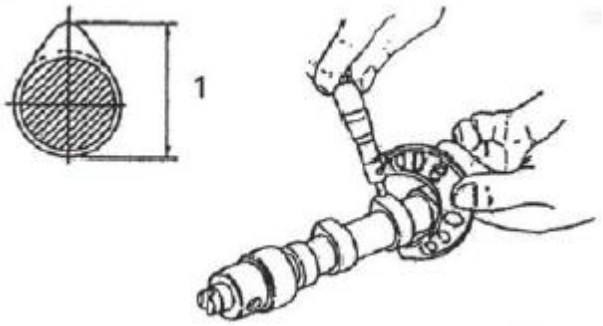


Figure 105.

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 end cap is not within specification, replace it using the appropriate service tool. If the remaining bores are not within specification, the journal bearings will require replacement.

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 and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*
- The O-rings can be used only once.

1. Equip the liner with new seals (Figure 106) coated with grease or clean oil.

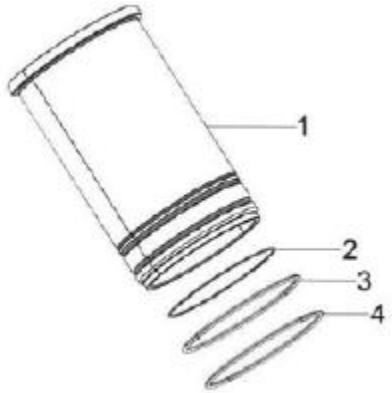


Figure 106.

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 107, Item 1) on the engine block and nest the liner (Figure 102, 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.

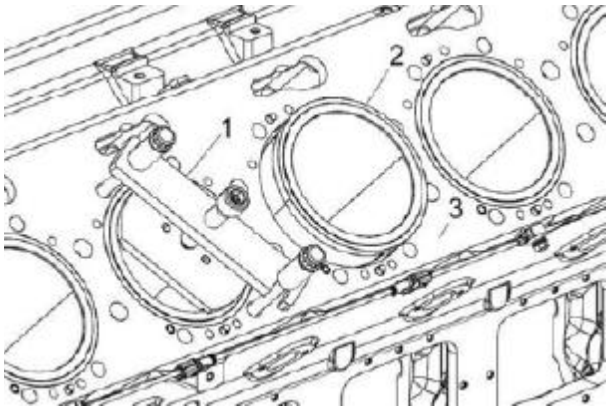


Figure 107

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.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

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 108, Item 3). Fit the piston rings (Figure 108, 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

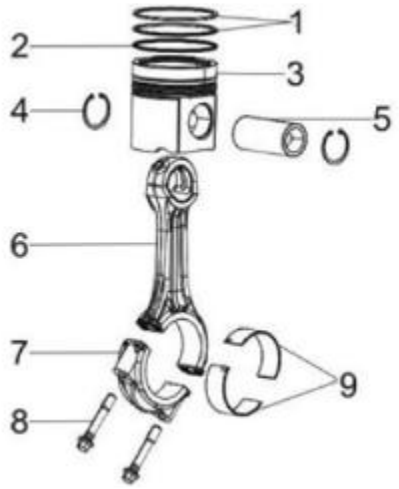


Figure 108.

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 103, 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 109, Item 4) onto one end of the piston.
6. Lightly oil the bore openings and insert the piston pin (Figure 109, 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 104). 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.

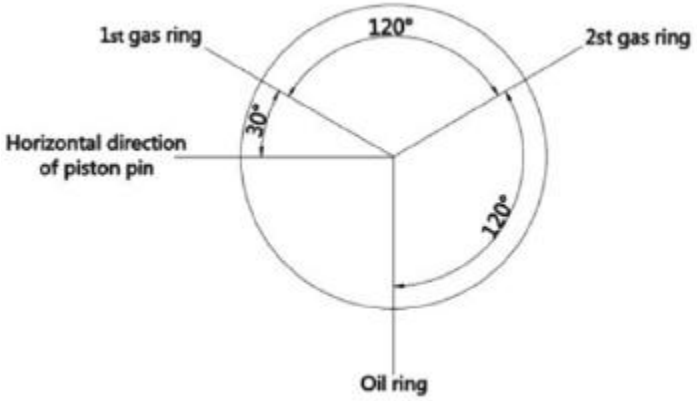


Figure 109.

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.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

1. Install the piston cooling jets.
2. If removed, reinstall the timing gear on the crankshaft.
3. Reinstall new main bearing (Figure 110, Item 1) and thrust plate (Figure 110, Item 3) in the cylinder block and main bearing caps.

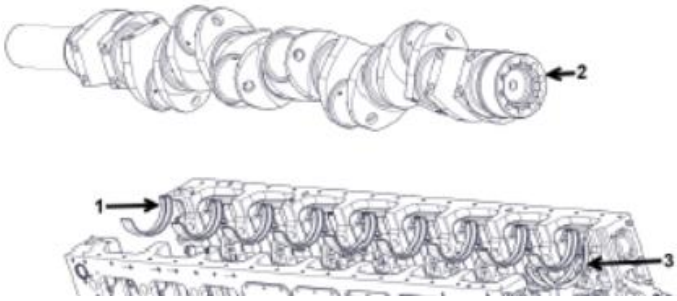


Figure 110.

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 110, 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 and thrust plates in the main bearing caps (Figure 111, Item 2).

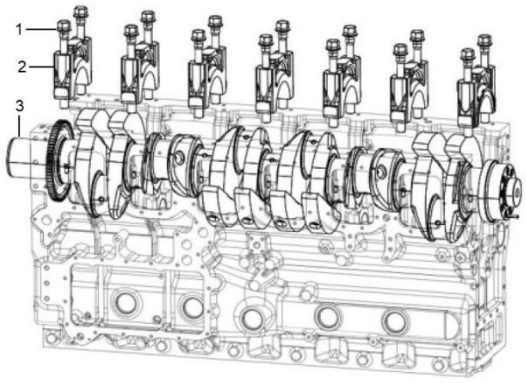


Figure 111.

NO.	Name
1	Main Bearing Cap Bolt
2	Main Bearing Cap
3	Crankshaft

7. Reinstall the main bearing caps (Figure 111, Item 2).
8. Apply a light coat of clean engine oil to the bearing cap main bolts (Figure 111, Item 1).
9. Tighten the main bearing bolts in the following sequence:
    i. Tighten the main bearing bolts (Figure 112) in alphabetic order (A – N) to 59 lb-ft.
    ii. Tighten the main bearing bolts (Figure 112) in alphabetic order (A – N) to an angle of 60°.
    iii. Tighten the main bearing bolts (Figure 112) in alphabetic order (A – N) to an angle of 199 ± 15 lb-ft.
10. Rotate the crankshaft to assure it turns freely.

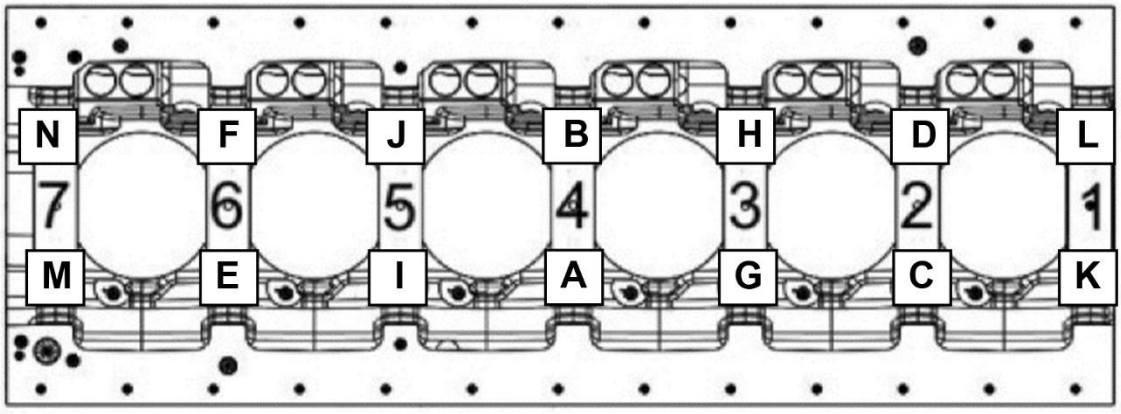


Figure 112.

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.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

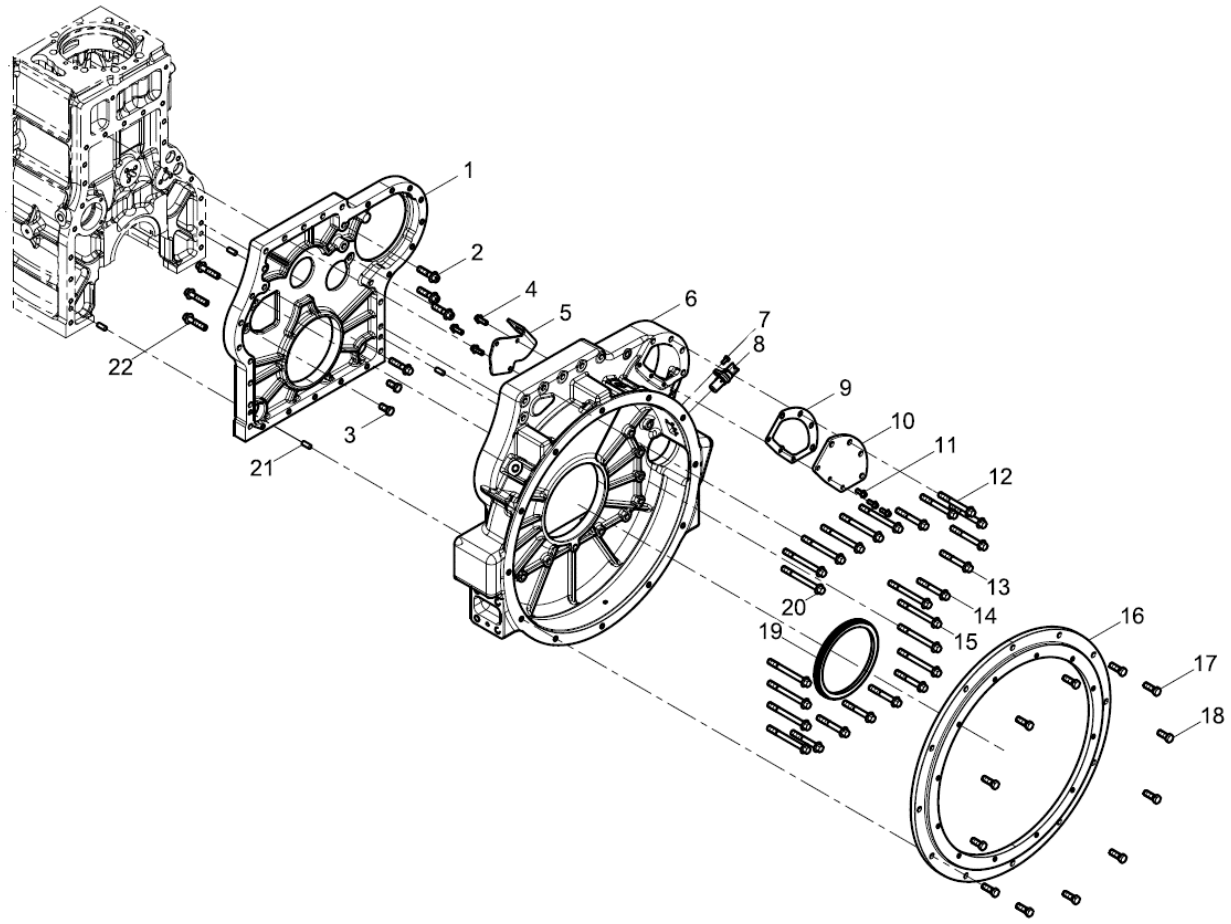


Figure 113. Flywheel Housing Assembly

NO.	Name	NO.	Name	NO.	Name
1	Timing Gear Chamber	10	Cover	19	Rear Oil Seal
2	Bolt	11	Bolt	20	Bolt
3	Bolt	12	Bolt	21	Pin
4	Bolt	13	Bolt	22	Bolt
5	Bracket	14	Bolt		
6	Flywheel Housing	15	Bolt		
7	Bolt	16	Coupling Ring		
8	Sensor	17	Bolt		
9	Gasket	18	Bolt		

1. If removed, install the camshaft first.
2. Install the rear oil seal group on the flywheel housing (Figure 114).

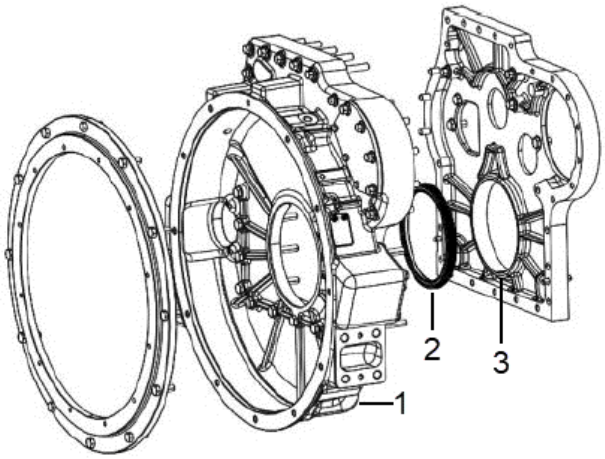


Figure 114.

NO.	Name
1	Flywheel Housing
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 114, Item 2) to the rear end of engine block by using the guide rods.

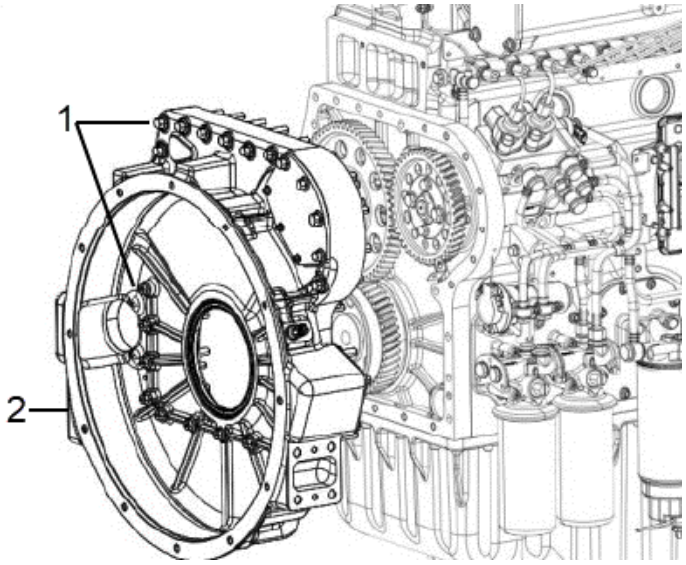


Figure 115.

NO.	Name
1	Flywheel Housing Bolts
2	Flywheel Housing

6. Apply Loctite 242 sealant coated at the threads of the flywheel housing bolts (Figure 115, Item 1).
7. Hand-tighten the top flywheel housing bolts first (bolts above the gears on the flywheel housing).
8. Tighten the bolts in two steps in the following sequence (Figure 115):
    i. Tighten the bolts (1-14) to 59 lb-ft.
    ii. Tighten the bolts (1-14) to 133 lb-ft.
    iii. Finished by tightening the top flywheel bolts to 133 lb-ft.

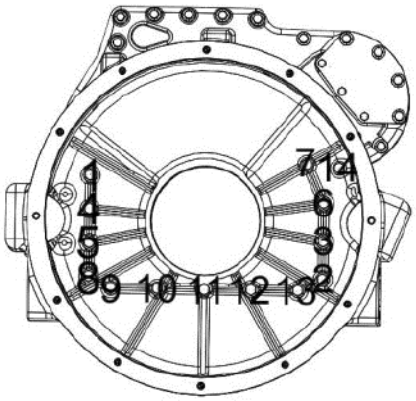


Figure 116.

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 117).

Figure 117.

9. Assemble the flywheel ring to the flywheel if removed.
10. Fit the flywheel guide rods on the crankshaft.
11. Apply a film of oil to the threads and under the head of the flywheel fixing bolts (Figure 118, Item 1).
12. Using suitable handling, install the flywheel (Figure 118, Item 2) on the crankshaft.
13. Remove the guide rods.

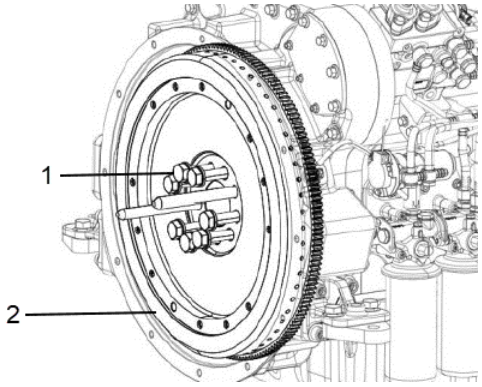


Figure 118.

NO.	Name
1	Bolt
2	Flywheel

14. Tighten the bolts in two steps in the following sequence (Figure 119):
    i. Tighten the bolts (1-10) to 66 lb-ft.
    ii. Tighten the bolts (1-10) to 133 lb-ft.

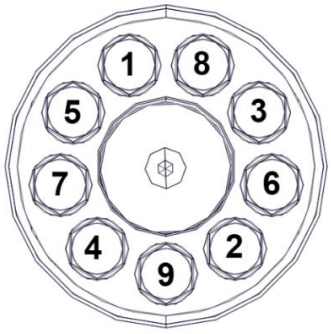


Figure 119.

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 120).
- The manufacturing marking on the top of the piston will be oriented towards the flywheel side.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

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.

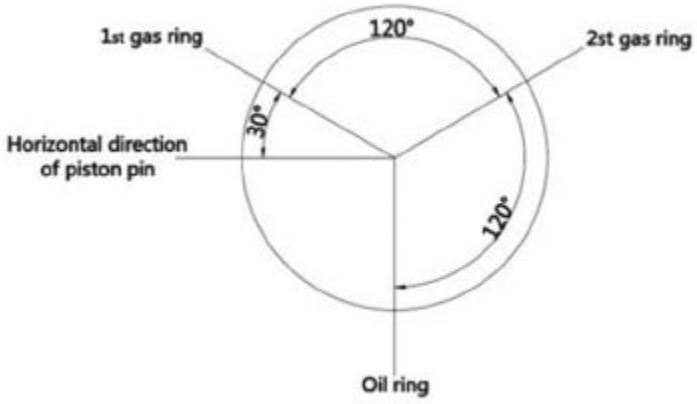


Figure 120.

3. Using a piston ring compressor 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 connecting rod and piston (Figure 121, Item 1) until the connecting rod big end and its half bearing are in place on the crank pin.
6. Reinstall the connecting rod cap (Figure 121, Item 2). Fit the connecting rod bolts (Figure 121, Item 3) and fully engage the cap (turn the crankshaft to facilitate fitting of bolts).
7. Tighten the connecting rod bolts (Figure 121, Item 3) in following sequence:
    i. Pre-tighten bolts to 74 lb-ft.
    ii. Tighten the bolts to 147 lb-ft.
    iii. Tighten to an angle of 60°.
    iv. Tighten to an angle of 45°.

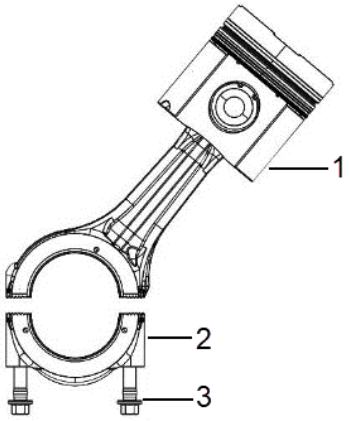


Figure 121.

NO.	Name
1	Connecting Rod and Piston
2	Rod Cap
3	Bolt

8. Check the side 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 122, Item 1) if necessary.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

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 122, Item 2), gradually rotating it as you insert it.
6. Apply a film of oil to the bearing bore. Fit the bearing (Figure 122, 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 fasten bolts (Figure 122, Item 4) and tighten to a torque of 29 lb-ft.

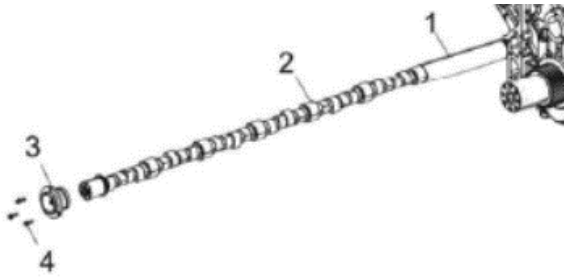


Figure 122.

NO.	Name	NO.	Name
1	Camshaft 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 120).
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

1. Ensure all timing gears are free from debris and have no physical damage.
2. Oil the idler gear (Figure 123) and install onto the engine block, insert the spacers with the bolts and torque the bolts to 52±5 lb-ft.

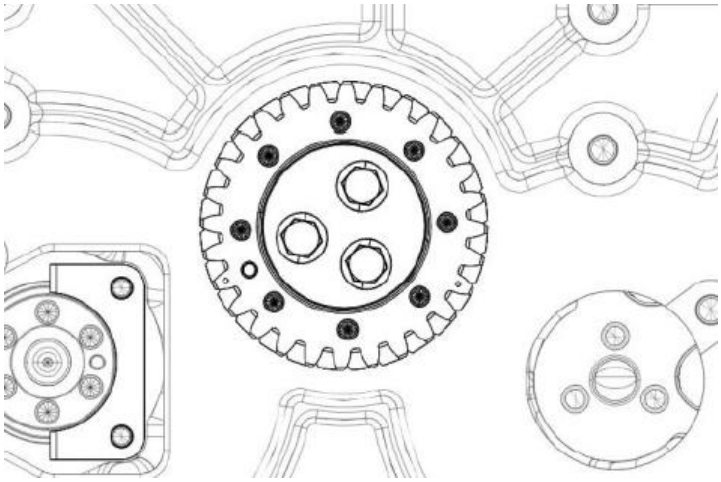


Figure 123.

3. Manually rotate the idler gear to ensure it can rotate smoothly.
4. Oil the idler gear (Figure 124) and install onto the engine block, ensure to install the two-timing marks between the single (already installed) smaller timing mark (Figure 124).

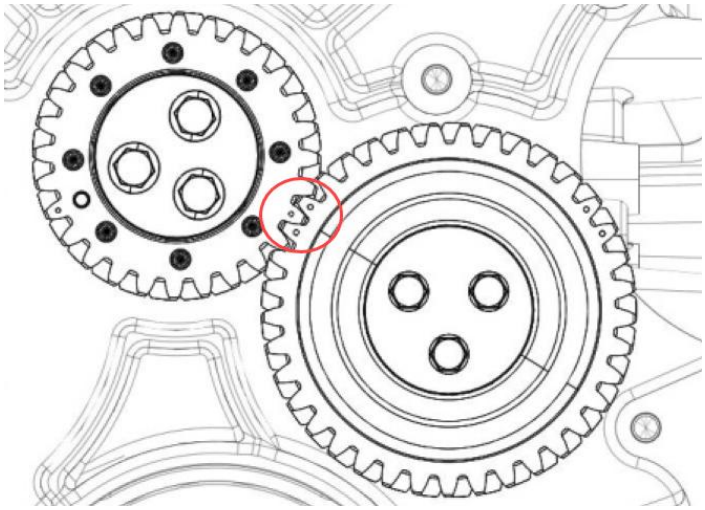


Figure 124.

5. Install the spacers and bolts and torque the bolts to 70±5 lb-ft. Rotate the two gears to ensure they rotate smoothly.
6. Install the camshaft using the dowel pin and ensure the two-timing marks on the camshaft gear lie in the middle of the idler gear timing mark (Figure 125).

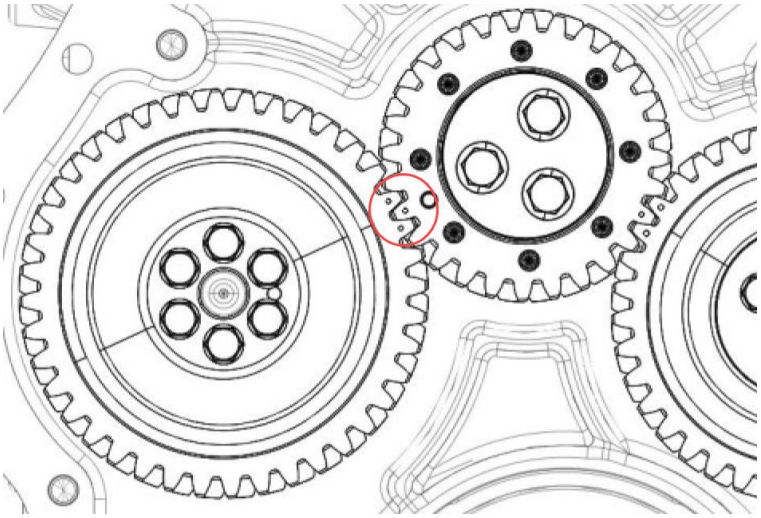


Figure 125.

7. Torque the camshaft gear bolts to 48±5 lb-ft.
8. Install the fuel injection drive gear with the pressure plate, ensure to align the single timing mark between the two-timing marks of the idler gear (Figure 126).

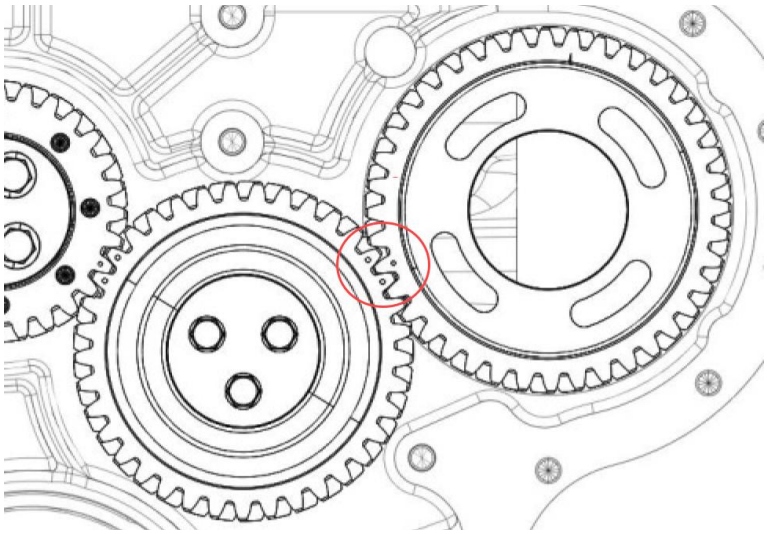


Figure 126.

9. Torque fuel injection drive bolts to 94 lb-ft.
10. Manually rotate the flywheel until cylinder 1 piston reach TDC.

11. Install the crankshaft timing gear and ensure the dowel pin and both timing marks are at the 12 o'clock position (Figure 127).

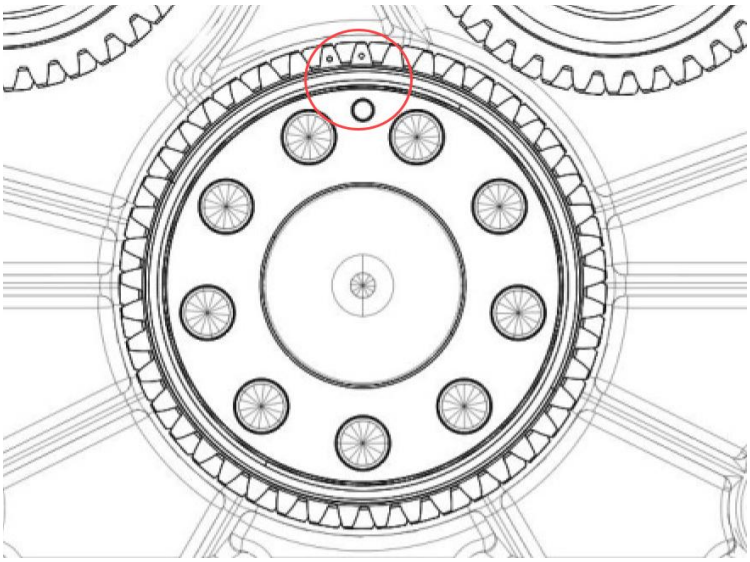


Figure 127.

12. Install the dowel pin (Figure 128) to the idler gear that was previously installed.

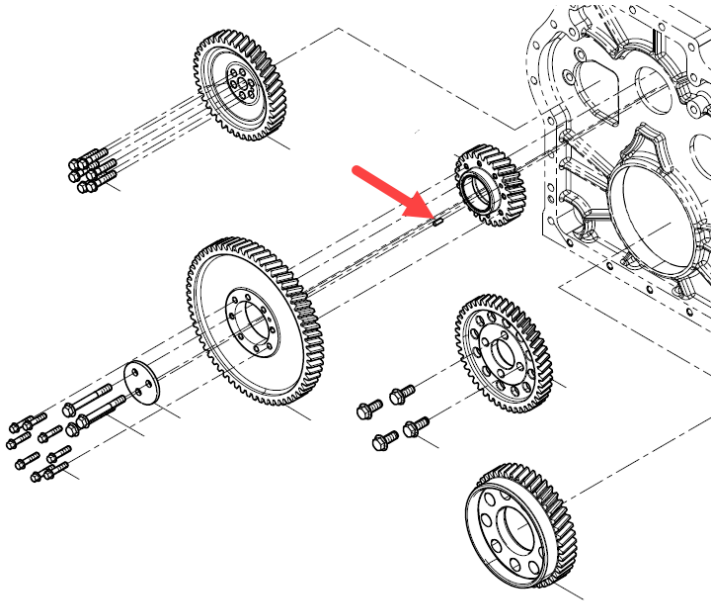


Figure 128.

13. Insert the big idler gear onto the dowel pin on the previously installed smaller idler gear (Figure 129). Ensure to place the timing mark of the big idler gear between the two-timing marks of the crankshaft timing gear (Figure 124).

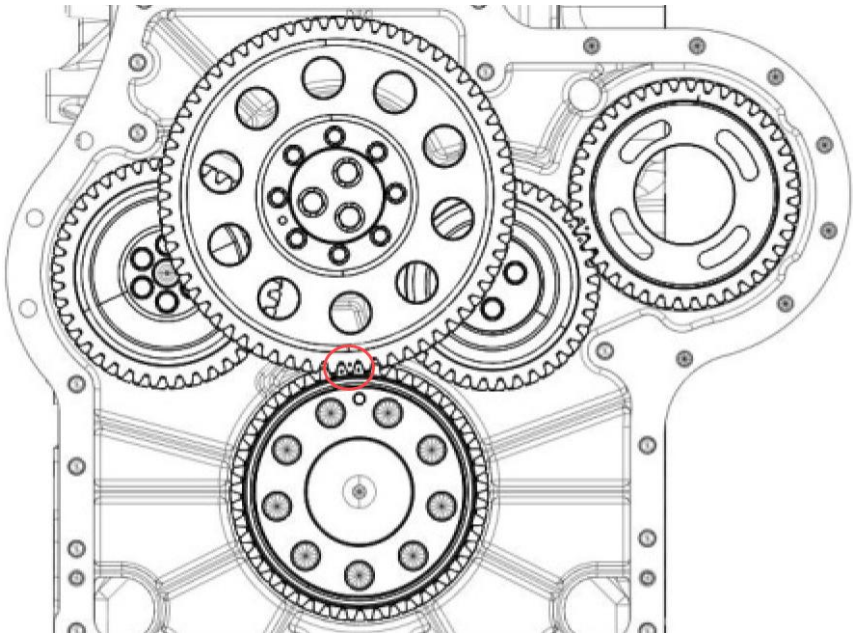


Figure 129.

INSTALLATION OF OIL PAN

NOTE:

- Replace all O-rings once removed.
- Oil pan weighs 313 lbs (142 kg), use suitable lifting means when installing oil pan.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

1. Install the oil strainer by tightening both bolts (Figure 130, Items 1 & 2).

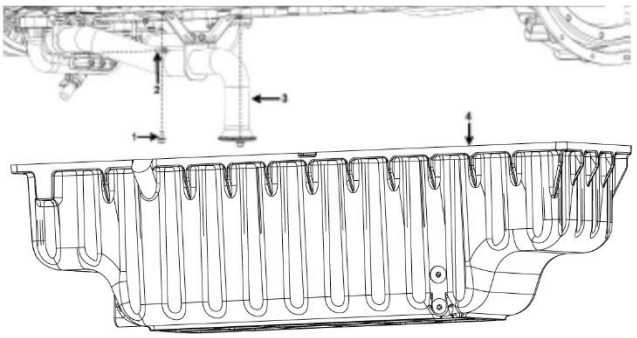


Figure 130.

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 oil dipstick.

OIL TEMPERATURE/PRESSURE SENSOR

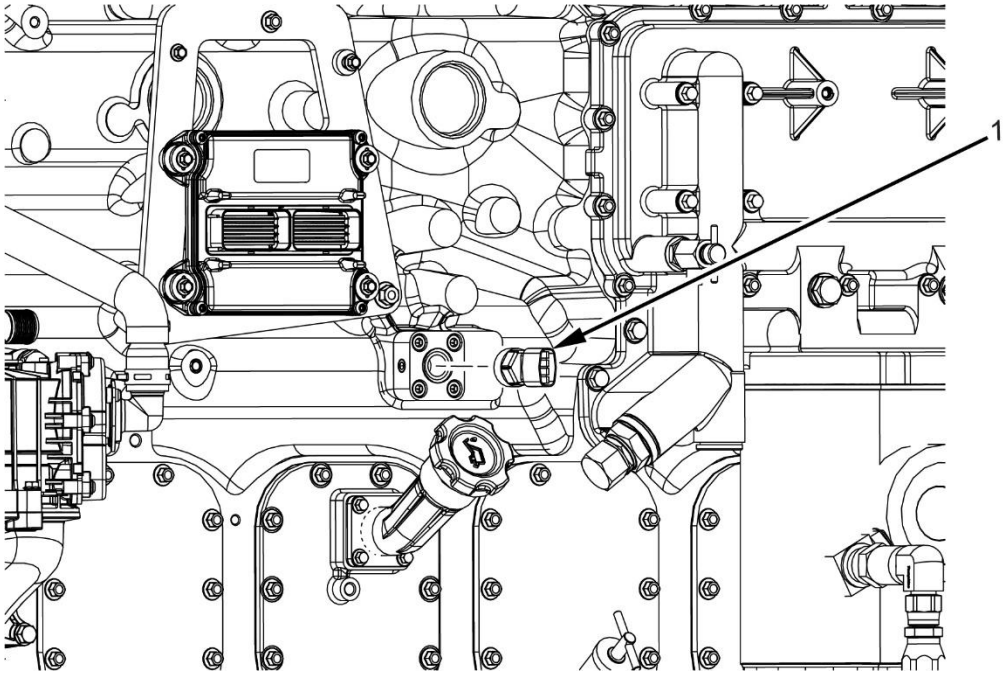


Figure 131. Oil Temperature/Pressure Sensor Assembly

NO.	Name
1	Oil Temp/Pressure Sensor

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

COOLING SYSTEM DIAGRAM

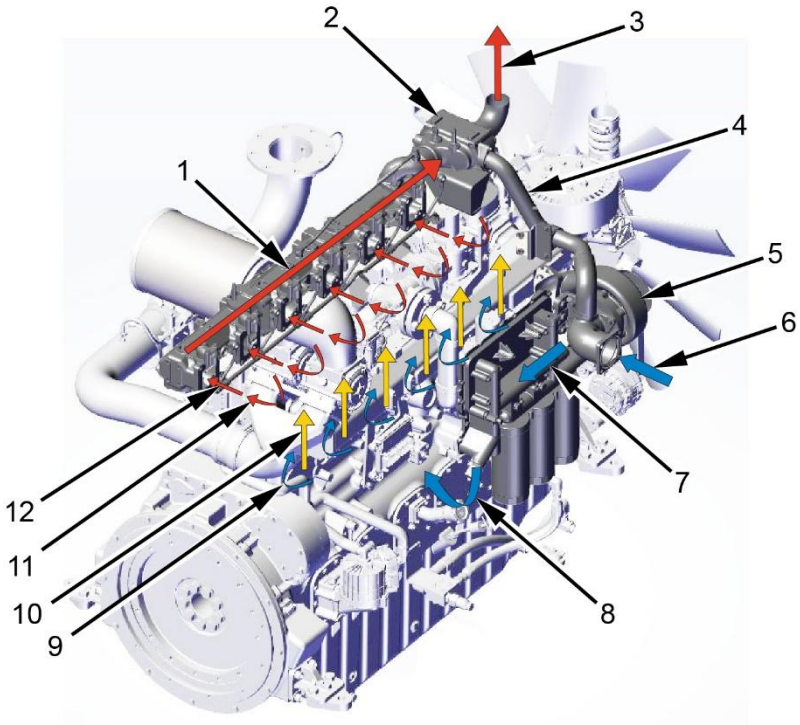


Figure 132. Cooling System Circuit Diagram

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Water cooled exhaust manifold	4	Coolant from thermostat (closed status) to pump	7	Coolant flowing through lube oil cooler	10	Coolant flowing from liner to cylinder head
2	Thermostat	5	Coolant pump	8	Coolant flowing to block from lube oil cooler	11	Coolant flowing through cylinder head
3	High temp. coolant from thermostat to radiator	6	Coolant from radiator to pump	9	Coolant flowing around liner		Coolant flowing out of cylinder head

WATER OUTLET PIPE

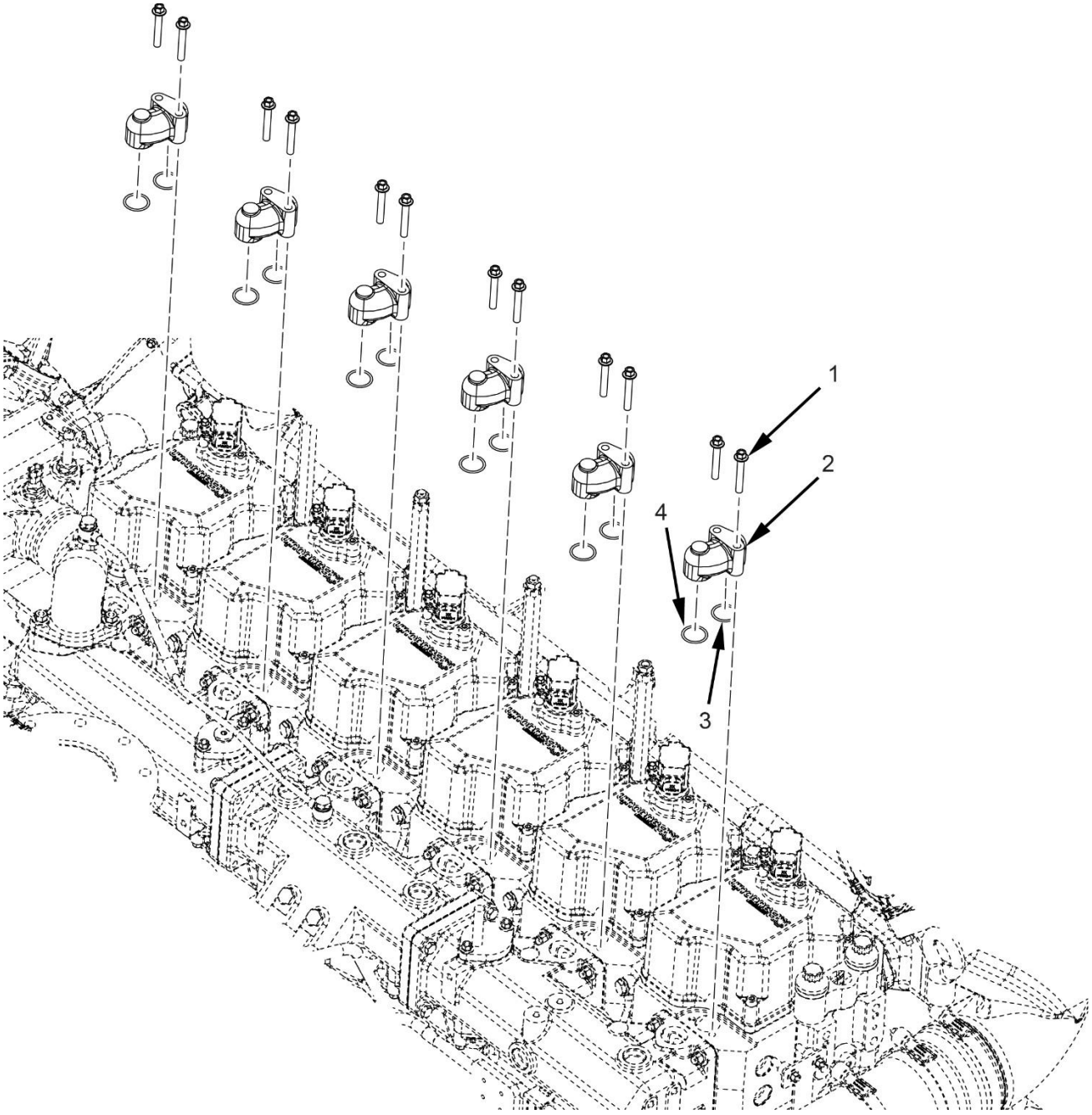


Figure 133. Water Outlet Pipe Assembly

NO.	Name	NO.	Name
1	Bolt	3	O-Ring
2	Pipe	4	O-Ring

REMOVAL

1. Drain coolant into suitable container.
2. Remove all bolts (Figure 133, Item 1).
3. Remove the pipes (Figure 133, Item 2).
4. Remove all O-rings (Figure 133, Items 3 & 4).

NOTE:

- Inspect O-Rings and pipes for any damage.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

INSTALLATION

1. Clean all mating surfaces on top of the cylinder heads and on the back of the thermostat housing from any debris.
2. Insert the O-rings (Figure 133, Items 3 & 4) on top of the cylinders.
3. Insert the pipes (Figure 133, Item 2).
4. Insert and torque the bolts (Figure 133, Item 1).

THERMOSTAT

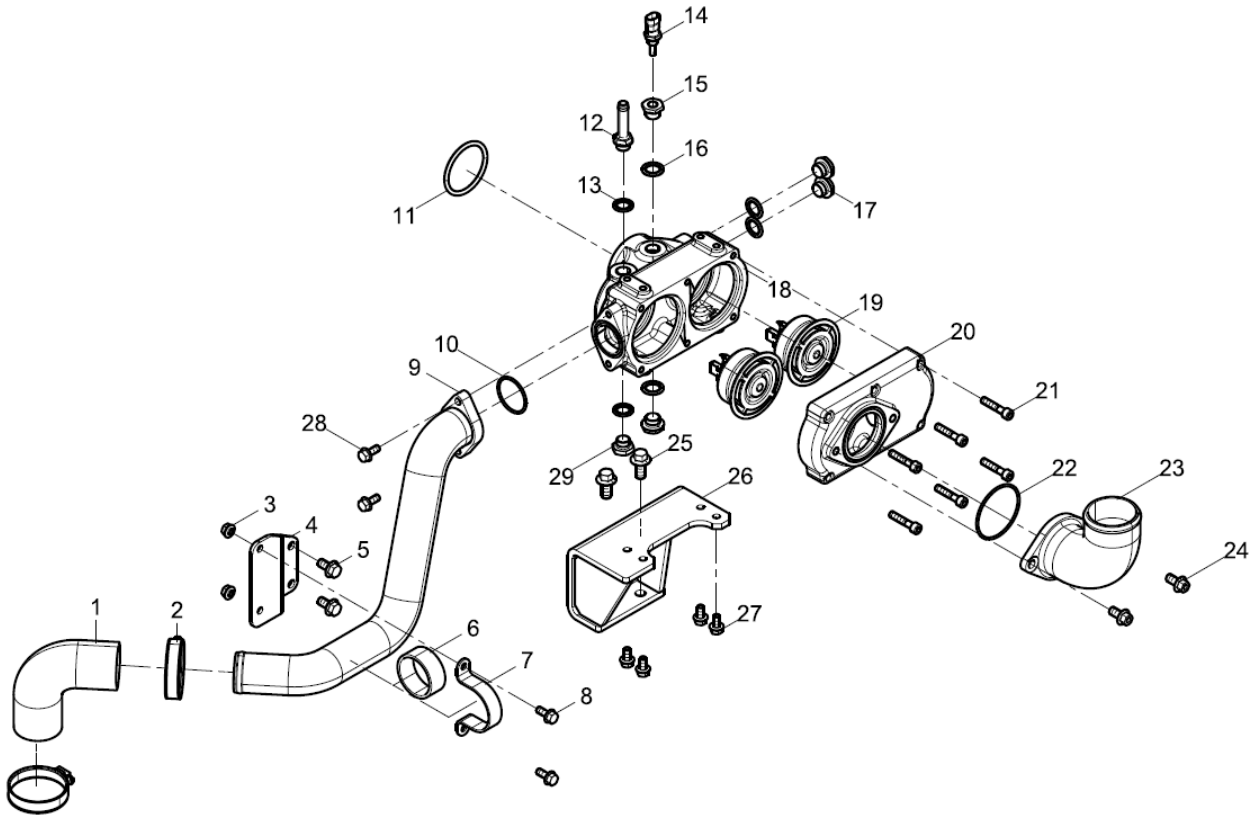


Figure 134. Thermostat Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Rubber Pipe	10	O-Ring	19	Thermostat	28	Bolt
2	Clamp	11	O-Ring	20	Cover	29	Plug
3	Nut	12	Pipe Joint	21	Bolt		
4	Bracket	13	Washer	22	O-Ring		
5	Bolt	14	Temp Sensor	23	Pipe		
6	Sleeve	15	Adapter	24	Bolt		
7	Clamp	16	Washer	25	Bolt		
8	Bolt	17	Plug	26	Bracket		
9	Water Pump Pipe	18	Thermostat Body	27	Bolt		

NOTE:

- Inspect O-Rings and pipes for any damages.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*
- Thermostat initial opening temperature is 176°F.
- Thermostat full opening temperature 198°F.

REMOVAL

1. Drain coolant into suitable container.
2. Remove the bolts (Figure 134, Item 21) and remove the thermostat cover (Figure 134, Item 20).
3. Carefully remove the thermostats (Figure 134, Item 19).

INSTALLATION

1. Install the new thermostats (Figure 134, Item 19) into the thermostat body (Figure 134, Item 18).
2. Install the thermostat cover (Figure 134, Item 20) and insert and torque the bolts (Figure 134, Item 21).
3. Reconnect all water pipes (If removed).

OIL COOLER

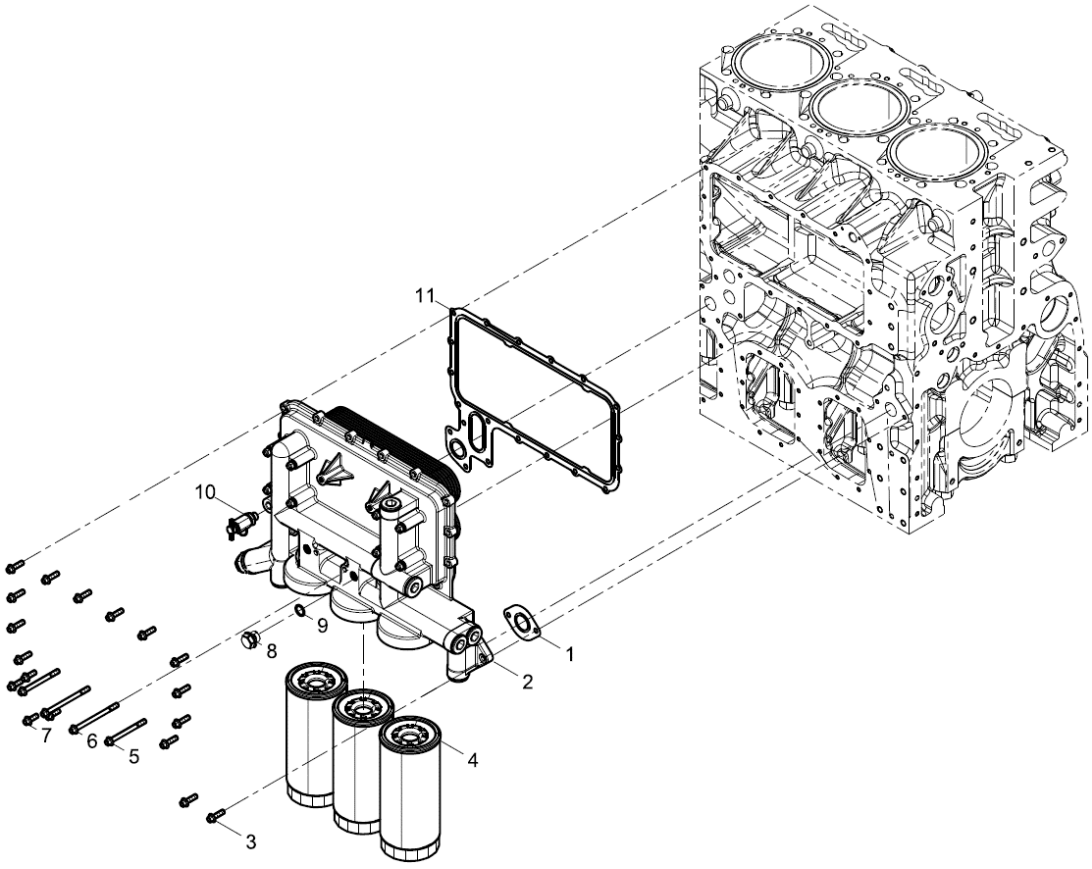


Figure 135. Oil Cooler Assembly

NO.	Name	NO.	Name	NO.	Name	NO.	Name
1	Gasket	4	Oil Filter	7	Bolt	10	Valve
2	Oil Cooler	5	Bolt	8	Plug	11	Gasket
3	Bolt	6	Bolt	9	Washer		

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 BOLTS AND NUTS CHART.*

REMOVAL

1. Drain the cooling system.
2. Remove the oil filter assembly (Figure 135, Item 4) if necessary.
3. Remove the bolts (Figure 135, Items 5, 6 & 7) and remove the oil cooler assembly (Figure 135, Item 2).
4. Remove the oil cooler gaskets (Figure 135, Item 1 & 11).

NOTE:

Replace all O-rings, seals, and gaskets.

INSTALLATION

1. Clean all debris from the cylinder block and oil cooler.
2. Place new gaskets (Figure 135, Items 1 & 11) and install the oil cooler assembly (Figure 135, Item 2) onto the cylinder block.
3. Apply Loctite 242 to all bolts (Figure 135, Items 5, 6 & 7).
4. Insert and torque the bolts (Figure 135, Items 5, 6 & 7) to 26 lb-ft.
5. Install the oil filters (If removed).

OIL RECOMMENDATION

When the 20L engine is being filled for the first time, oil should be filled to the max scale of 62 liters.

20L engine oil should be determined according to the temperature (Figure 136).

SAE No.	Sulfated Ash Content by Weight	Engine Oil Capacity (min/max)	Recommended Oil
15w-40	0.25 - 0.5% by wt. API CD/CF or higher	51 qts / 65.5 qts	Chevron HDAX 5200 Low Ash Gas Engine Oil

Figure 136. Oil Recommendation Chart

ENGINE OIL FILTER AND OIL REPLACEMENT

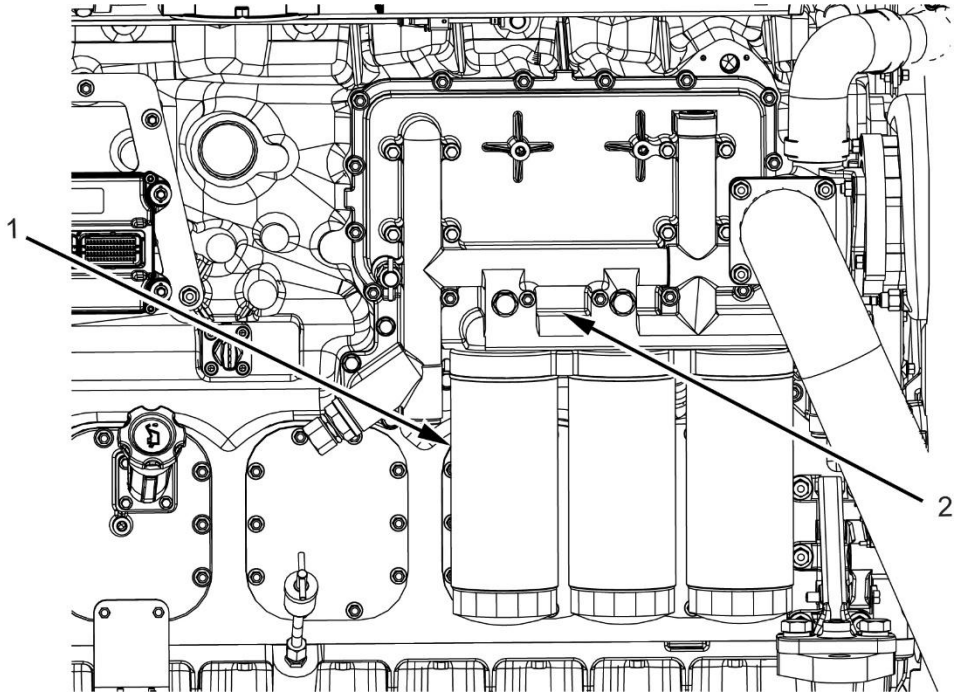


Figure 137. Engine Oil Filter Assembly

NO.	Name
1	Oil Filters
2	Oil Filter Seat

REMOVAL

1. Separate the oil filters (Figure 137, Item 1) from the oil filter seat (Figure 137, Item 2).

INSTALLATION

1. Apply clean oil on all filter rings (Figure 138).

Figure 138.

2. Hand tighten all oil filters (Figure 138, Item 1) onto the oil filter seat (Figure 138, Item 2).
3. Tighten all oil filters (Figure 138, Item 1) a 1/2 turn past hand tighten.

STARTER MOTOR

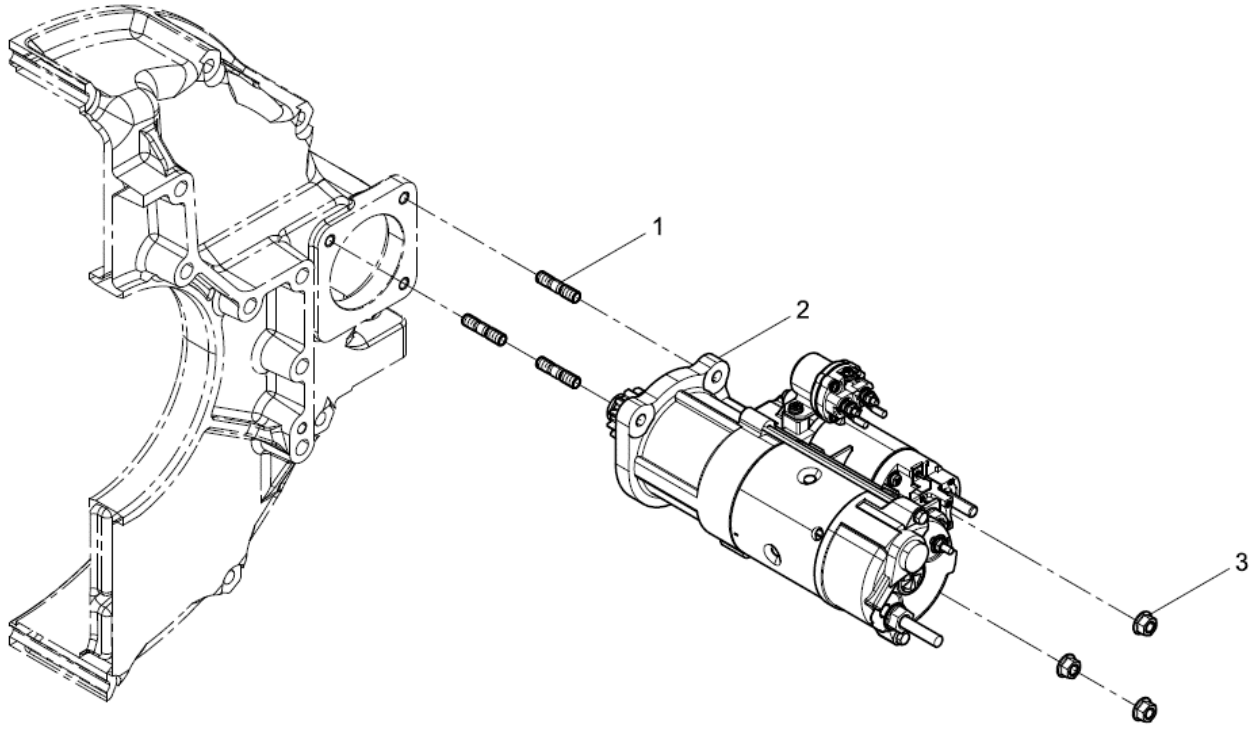


Figure 139. Starter Motor Assembly

NO.	Name
1	Stud
2	Starter Motor
3	Nut

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.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

REMOVAL

1. Loosen and remove the starter wires.
2. With a 16mm wrench remove the starter nuts (Figure 139, Item 3)
3. Remove the starter (Figure 139, Item 2).

INSTALLATION

1. Apply Grease to the gear of the starters.
2. Place the starter motor (Figure 139, Item 2) into the flywheel cover and ensure it is engaged correctly.
3. Insert and torque the starter nuts (Figure 139, Item 3).
4. Reconnect all starter wires.

OIL/GAS SEPARATOR & BREATHER

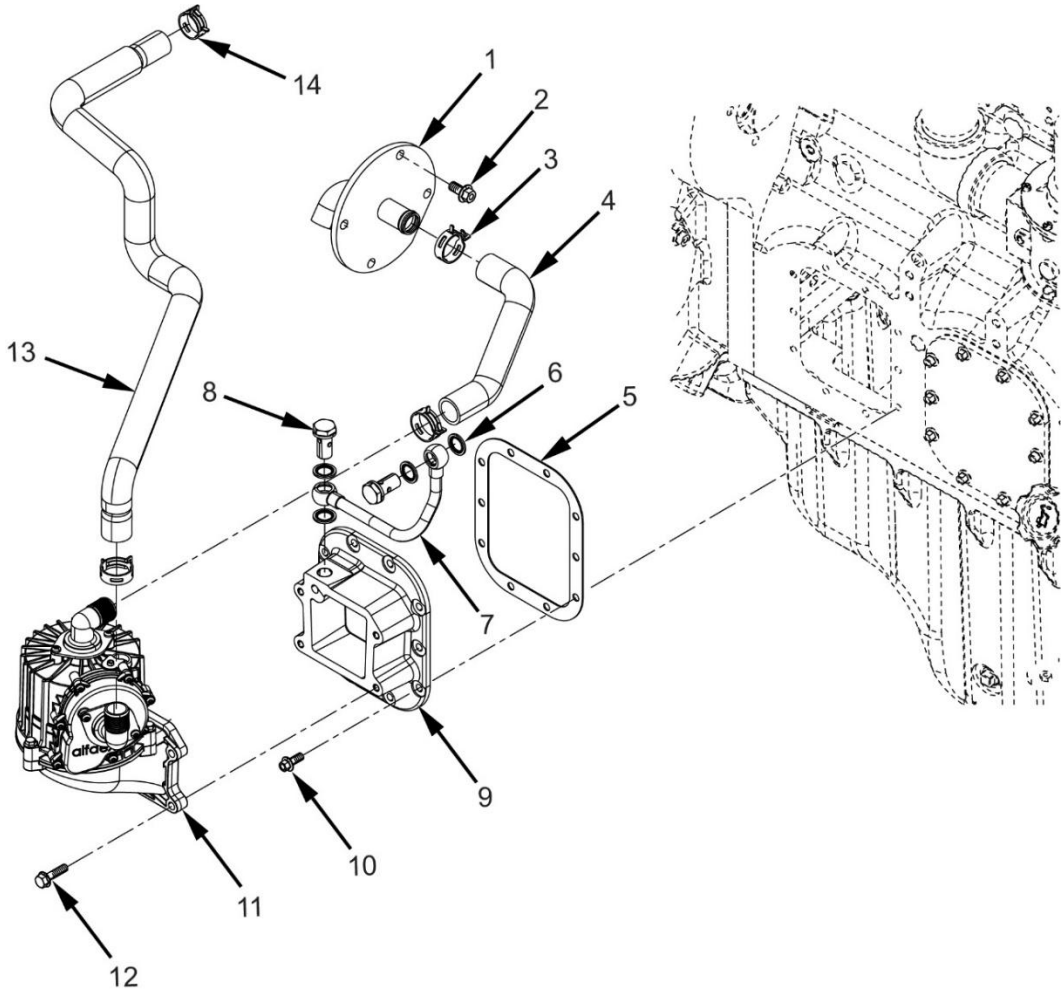


Figure 140. Breather Assembly

NO.	Name	NO.	Name	NO.	Name
1	Cover	6	Assembled Sealing Washer	11	Oil-Gas Separator
2	Bolt	7	Pipe	12	Bolt
3	Hose Clamp	8	Hollow Screw	13	Oil-gas Separator Air-outlet Pipe Assembly
4	Oil-gas Separator Air-inlet Pipe	9	Handhole Cover	14	Clamp
5	Gasket	10	Bolt		

NOTE:

- Ensure breather is not clogged and removed from all debris.
- Ensure breather hose has no cracks or damages.
- Ensure breather holds air using an air compressor (0.5 psi max), If any air leaks from the breather ensure to replace breather assembly.
- The breather gasket can be reused only once.
- All fasteners and bolts should be tightened to a given torque. If a special torque is not provided, see the *TIGHTENING TORQUES FOR STANDARD BOLTS AND NUTS CHART.*

REMOVAL

1. Loosen the clamps (Figure 140, Item 3).
2. Remove the hose (Figure 140, Item 4).
3. Remove the bolts (Figure 140, Item 2).
4. Remove the cover (Figure 140, Item 1).
5. Loosen the clamps (Figure 140, Item 14).
6. Remove the hose (Figure 140, Item 13).
7. Remove the bolts (Figure 140, Item 12) and remove the oil/gas separator (Figure 140, Item 11).
8. Remove the hollow screws (Figure 140, Item 8), assembled sealing washers (Figure 140, Item 6) and pipe (Figure 140, Item 7).
9. Remove the bolts (Figure 140, Item 10).
10. Remove the handhole cover (Figure 140, Item 9) and gasket (Figure 140, Item 5).

INSTALLATION

1. Place the handhole cover (Figure 140, Item 9) and gasket (Figure 140, Item 5) on the engine and secure with bolts (Figure 140, Item 10).
2. Install pipe (Figure 140, Item 7) with hollow screws (Figure 140, Item 8) and assembled sealing washers (Figure 140, Item 6).
3. Install the oil/gas separator (Figure 140, Item 11) with bolts (Figure 140, Item 12).
4. Install hose (Figure 140, Item 13).
5. Tighten the clamps (Figure 140, Item 14).
6. Install the cover (Figure 140, Item 1) and secure with bolts (Figure 140, Item 2).
7. Install the hose (Figure 140, Item 4).
8. Tighten the clamps (Figure 140, Item 3).

APPENDIX

APPENDIX A: RECOMMENDED TORQUES FOR HOLLOW BOLTS

Specification	Head type	Material	Torque （N·m）
Hex head hollow bolt torque	M10×1	Copper bolts	13±2
	M6×1	Steel bolts	6±1
	M10×1		21±3
	M14×1.5		27±3
	M16×1.5		40±5
Flange face hollow bolt	M10	Steel bolts	20±3
	M12		28±3
	M14		32±3
	M16		36±3
	M10×1	Copper bolts	15±2

APPENDIX B: RECOMMENDED TORQUES FOR STANDARD BOLTS

Specification（coarse thread）	Grade	Hexagon head bolts, hexagon nuts and hexagon socket cylindrical head screws（N•m）		Hexagon flange face bolts and hexagon flange face nuts（N•m）	
		Phosphating, oxidizing bolts	Galvanized bolts	Phosphating, oxidizing bolts	Galvanized bolts
M4	8.8	2.8	3.1	-	-
	10.9	4.1	4.6	-	-
	12.9	4.8	5.3	-	-
M5	8.8	5.5	6.1	6.2	6.9
	10.9	8.1	9.0	9.1	10
	12.9	9.5	11	11	12
M6	8.8	10	11	11	12
	10.9	14	16	15	17
	12.9	17	18	18	20
M8	8.8	23	26	25	28
	10.9	34	38	37	41
	12.9	40	44	43	48
M10	8.8	46	51	50	55
	10.9	67	75	73	81
	12.9	79	88	85	95
M12	8.8	79	88	87	97
	10.9	115	130	130	140
	12.9	135	150	150	165
M14	8.8	125	140	140	155
	10.9	185	205	205	230
	12.9	215	240	240	265
M16	8.8	195	215	215	240
	10.9	285	320	320	350
	12.9	330	370	370	410
M18	8.8	280	310	-	-
	10.9	400	440	-	-
	12.9	470	520	-	-
M20	8.8	390	440	-	-
	10.9	560	620	-	-
	12.9	650	730	-	-
M22	8.8	540	600	-	-
	10.9	760	860	-	-
	12.9	890	1000	-	-
M24	8.8	680	750	-	-
	10.9	960	1070	-	-
	12.9	1130	1260	-	-

APPENDIX B: RECOMMENDED TORQUES FOR STANDARD BOLTS

Specification（fin thread）	Grade	Hexagon head bolts, hexagon nuts and hexagon socket cylindrical head screws（N•m）		Hexagon flange face bolts and hexagon flange face nuts（N•m）	
		Phosphating, oxidizing bolts	Galvanized bolts	Phosphating, oxidizing bolts	Galvanized bolts
M8×1	8.8	25	28	27	30
	10.9	36	40	39	44
	12.9	42	47	46	51
M10×1	8.8	50	56	55	61
	10.9	74	83	80	90
	12.9	87	97	94	105
M10×1.25	8.8	48	54	52	58
	10.9	71	79	77	86
	12.9	83	92	90	100
M12×1.25	8.8	85	96	94	105
	10.9	125	140	140	155
	12.9	150	165	160	180
M12×1.5	8.8	82	92	91	100
	10.9	120	135	135	150
	12.9	140	160	155	175
M14×1.5	8.8	135	150	150	170
	10.9	200	220	220	245
	12.9	230	260	255	285
M16×1.5	8.8	205	230	230	255
	10.9	300	340	340	380
	12.9	350	400	390	440
M18×1.5	8.8	310	350	-	-
	10.9	440	500	-	-
	12.9	520	580	-	-
M20×1.5	8.8	430	480	-	-
	10.9	610	690	-	-
	12.9	720	810	-	-
M20×2	8.8	410	460	-	-
	10.9	590	660	-	-
	12.9	690	770	-	-
M22×1.5	8.8	580	660	-	-
	10.9	830	930	-	-
	12.9	970	1090	-	-
M24×2	8.8	730	820	-	-
	10.9	1040	1170	-	-
	12.9	1210	1360	-	-

APPENDIX C: DATA FOR SPECIAL TIGHTENING TORQUE

Name of bolt	Type	Assembly	Tightening technical requirements
Main bearing bolt	M24x2	Lub. oil	Tighten the screws to a torque of **(-140±10) N•m**
			Tighten the screws to an angle of (90±2)°
			Tighten the screws to an angle of (90±2)°
Auxiliary bolt for main bearing cover	M14×1.5-10.9	Lub. oil	Tighten the screws to a torque of (60±5) N•m
			Tighten the screws to an angle of (90±2)°
			Tighten the screws to an angle of (60±2)°
Cylinder head main bolt	M16x2 (Main Bolt M20x2 (Secondary Bolt)	Lub. oil	Tighten the M16 screws to a torque of 80 N·m ; Tighten the M20 screws to a torque of 80 Nm
			Tighten the M16 screws to an angle of 60°±5°; Tighten the M20 screws to an angle of 60°±5° °
			Tighten the M16 screws to an angle of 60°±5°; Tighten the M20 screws to an angle of 60°±5°
			Tighten the M20 screws to an angle of 60°±5°; Tighten the M20 screws 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.
Cylinder head pair bolt	M12×1.5-10.9	Lub. oil	Tighten the screws to a torque of (40±3) N•m
			Tighten the screws to an angle of(120±5)°
			Tighten the screws to an angle of(120±5)°
Crankshaft pulley bolt	M12×1.5-10.9	Loctite 242	Tighten the screws to a torque of (45±3) N•m
			Tighten the screws to an angle of (90±2)°
			Tighten the screws to an angle of (45±2)°
Torsional shock absorber bolt	M10×1.5-12.9	Lub. oil	tightening torque： (100±10) N•m
Flywheel bolt	M20x2.0	Loctite 242	Tighten the bolts to a torque of 190±10 N•m
			Tighten the bolts to an angle of 90±5 °

APPENDIX C: DATA FOR SPECIAL TIGHTENING TORQUE - CONTINUED

Connecting rod bolt	M16x1.5	Lub. oil	Tighten the screws to a torque of 200 N·m
			Tighten the screws to an angle of 60°
			Tighten the screws to an angle of 45°

APPENDIX D: TABLE OF AUXILIARY MATERIAL

SN.	Name	Color	Purpose and location
1	Molykote Pulver	Black	Applied on flat and smooth metal surfaces to prevent seize For example, applied onto outer surfaces of cylinder liners
2	Molykote G-N-U plus	Dark grey	Lubrication before the lubricating oil pressure builds up. For example, applied onto the intake valve stem

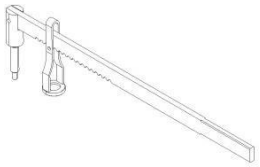
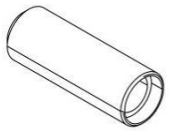
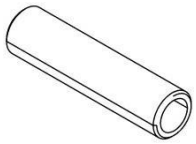
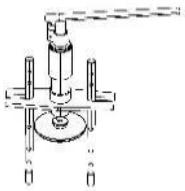
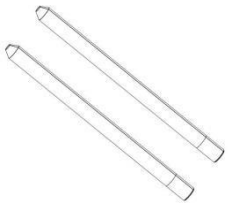
APPENDIX E: TABLE FOR SEALANT APPLICATION

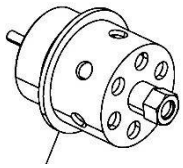
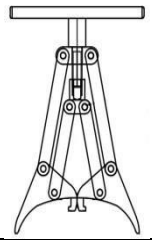
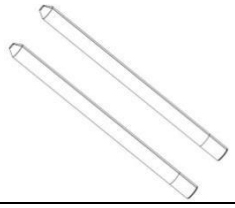
Mark	Main use	List of locations for application of sealant	Supplement
Loctite 242	It's applied onto the threads to prevent being vibrated to looseness, with moderate strength.	Screw plug	Alternatively, the thread preapplication sealant DriLoc 204 can be preapplied.
		Control valve	
		Oil cooler bolt	
		Engine oil cooler	
		Flywheel cover bolt	
		Front end cover bolt	
		Engine oil filter base	
		Intermediate idler bolt	
		Camshaft thrust plate bolt	
		Camshaft timing gear bolt	
		Bolt, fuel return pipe fixing device, fuel pump	
		Air compressor shaft end thread Strainer bolt	
		Bolts of sensor and harness fixing device	
Loctite 271	Preventing looseness, fixing	Cup plug, oil drain hole	N/A
Loctite 277	For sealing between element and bore	Other cup plugs	N/A
Loctite 270	Sealing cylinder head top	Cylinder head	N/A
Loctite 510	It's applied onto shining metal surfaces for sealing purpose.	Crankshaft rear end bonding surface	N/A
Loctite 5910	It's applied onto shining metal surfaces for sealing purpose.	Front- and front-end cover	N/A
		Rear end face and flywheel housing bonding surface	

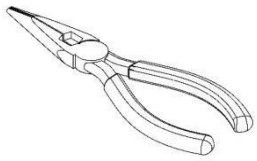
APPENDIX F: FIT CLEARANCES FOR MAIN PARTS OF ENGINE

S/N	Items		Theoretical value (mm)
1	Main bearing clearance		0.09～0.164
2	Connecting rod bearing clearance		0.06～0.129
3	Crankshaft axial clearance		0.102～0.305
4	Connecting rod axial clearance		0.2~0.4
5	Clearance between connecting rod small end bush and piston pin		0.04～0.061
6	Idle gear bearing		0.05~0.094
7	Piston ring gap working clearance at cold state		
	The triple ring group piston ring	First ring	0.35 ~ 0.5
		Second ring	0.50～0.70
		Oil control ring	0.3~0.65
8	Piston and cylinder liner clearance		0.121~0.164
9	Clearance between piston and cylinder head (TOP dead center)		1.15（scope：0.83~1.66）
10	Intake valve bottom concave cylinder head flat face		±0.2
11	Exhaust valve bottom concave cylinder head flat face		±0.2
12	Air valve bottom concave cylinder head flat face exhaust/intake		±0.2/±0.2
13	The top of the cylinder liner is above the cylinder block		0.05～0.10
14	Camshaft axial clearance		0.1～0.4
15	Camshaft bearing clearance		0.04～0.12
16	Clearance between tappet and hole		0.025 ~ 0.089
17	Clearance between the outer diameter of cylinder liner and the cylinder hole of engine body		－0.02～0.023
18	Clearance between rocker arm and rocker arm shaft		0.022-0.082
19	Intake valve gap (cold state)		0.021 (0.533mm)
20	Exhaust valve gap (cold state)		0.039 (0.990mm)
21	Clearance between crankshaft speed sensor and flywheel		2.8±0.4
22	Camshaft speed sensor and signal disc clearance		1.0±0.5
23	Intermediate pinion - camshaft timing gear		0.07-0.26
	Crankshaft timing gear - large middle gear		0.1-0.28
	Middle big gear - air compressor gear		0.07-0.28
	Middle big gear - hydraulic pump gear		0.07-0.28
	Middle big gear - fuel pump gear		0.07-0.3
	Middle big gear - rear drive gear		0.07-0.3
	Oil pump intermediate gear - oil pump gear		0.1-0.3

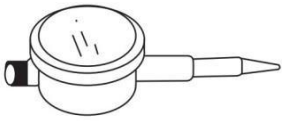
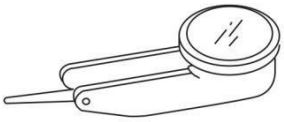
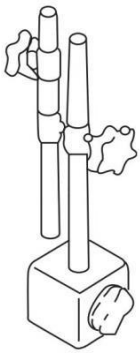
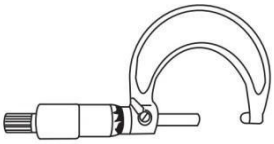
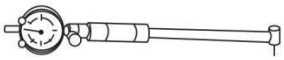
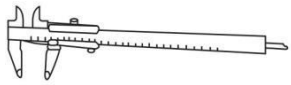
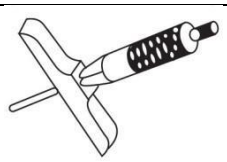
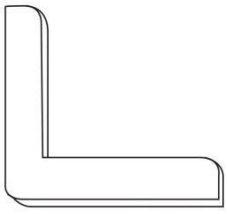
SPECIAL TOOLS

No.	Tool Name	Application	Illustration
1	Valve spring tool	Remove valve spring	
2	Tappet Tool	Remove/Install the tappet	
3	Intake valve seal tool	Remove/Install Intake valve seal	
4	Exhaust valve seal tool	Remove/Install Exhaust valve seal	
5	Liner remover	Remove cylinder liner	
6	Liner installer	Install cylinder liner	
7	Flywheel guide rods	Remove/Install the flywheel	

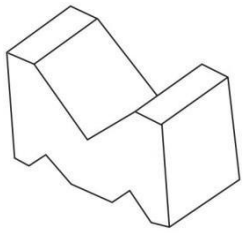
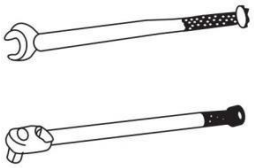
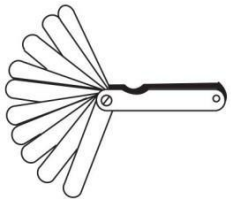
No.	Tool Name	Application	Illustration
8	Rear seal installer	Install the rear seal	
9	Front oil seal installer	Install the front seal	
10	Piston mounting cone sleeve	Install the piston	
11	Piston ring clamp	Remove and install piston rings	
12	The flywheel guide rod	Remove/install flywheel	

No.	Tool Name	Application	Illustration
16	Body brace tool	Open the body and remove the main bearing cover	
17	Nipper	Install piston pin retainer	

MEASURING INSTRUMENTS

No.	Instrument Name	Application	Illustration
1	Dial Indicator	Measure shaft bend and end play	
2	Test Indicator	Measurements of narrow or deep portions that cannot be measured by dial gauge	
3	Magnetic Stand	For holding the dial gauge when measuring	
4	Micrometer	For measuring the outside diameters of crankshaft, pistons, piston pins, etc.	
5	Cylinder Bore Gauge	For measuring the inside diameters of cylinder liners, bearing bores, etc.	
6	Calipers	For measuring outside diameters, depth, thickness and width	
7	Depth Micrometer	For measuring of valve recession	
8	Square	For measuring valve spring inclination and straightness of parts	

MEASURING INSTRUMENTS - CONTINUED

No.	Instrument Name	Application	Illustration
9	V-Block	For measuring shaft bend	
10	Torque Wrench	For tightening nuts and bolts to the specified torque	
11	Feeler Gauge	For measuring piston ring gaps, piston ring clearance, and valve adjustment clearance	
12	Beaker	Heating coolant	
13	Thermometer	Measure the temperature of the coolant	
14	Multimeter	Measure the resistance of the water temperature sensor	

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